

# PREMUS2016 TORONTO

Preventing work-related musculoskeletal disorders in a global economy

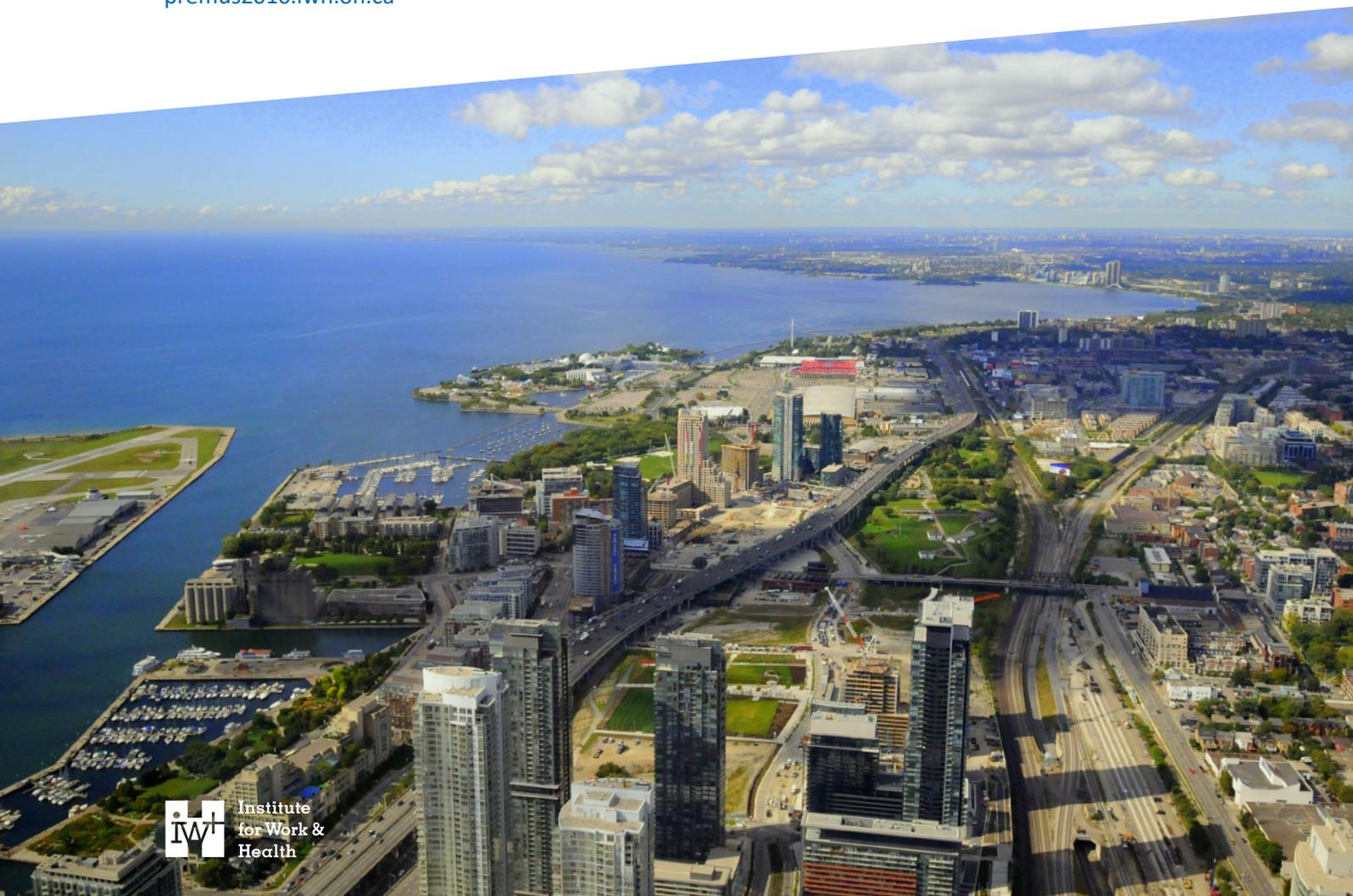
## BOOK OF ABSTRACTS

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SYMPOSIUM 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, BALLROOM B

## When do scientific reviews have an impact on enterprise or public policy?

**Chair: David Rempel, Professor Emeritus of Medicine, Division of Occupational and Environmental Medicine, University of California at San Francisco, Richmond, Calif., U.S.A.**

Reviews of the scientific evidence regarding the prevention or treatment of work-related musculoskeletal injuries or disorders have been conducted in order to guide enterprise and public institution policies and actions. They often follow a systematic review or a consensus-based process. Reviews may lead to voluntary guidelines or regulations. The purpose of this symposium is to discuss the impact of these reviews from the perspective of different countries, regions and organizations. The presentations use a case-study approach to reflect on reasons why reviews have or have not had an impact on public or enterprise policies and actions.

## Impact of OHS systematic reviews: a Canadian perspective

Emma Irvin (presenter), Dwayne Van Eerd

**Background.** Busy occupational health and safety (OHS) practitioners are challenged to keep pace with emerging research evidence. Systematic reviews provide a synthesis of the evidence on specific topics and provide an unbiased overview of the literature. IWH has been conducting systematic reviews for over 20 years. IWH's approach to systematic reviews is unique; in addition to a rigorous methodological approach, IWH includes opportunities to directly engage with stakeholders during the review process (Irvin, 2009; Keown, 2008). Stakeholder audiences include clinicians, practitioners, researchers, workplace parties and policy-makers. The objective of this presentation is to discuss the impact of IWH reviews from a Canadian perspective.

**Methods.** Using a case-study approach, we focus on the benefits, challenges and impacts that the IWH has had in engaging stakeholders. Our integrated approach includes gathering feedback directly from stakeholders about impact of our evidence syntheses. In addition, we track the impact of our reviews through surveys and case studies.

**Results.** Feedback from stakeholders suggests that being involved in the systematic review process has been positive for decision-making. Stakeholders report that, over time, they have increased their capacity to appraise research findings and understand levels of evidence. They report that involvement in the review process ensures there is interest in, and uptake of, the messages and recommendations of a review. In addition, formal case studies reveal the impacts of reviews on policy and workplace practice; e.g. "(IWH) played a pivotal role in supplying evidence" for a New Service Delivery Model for a compensation provider.

**Discussion.** The many potential benefits to including stakeholders in the process of a systematic review include increased accessibility, dissemination and uptake of systematic review findings. A challenge that researchers face is that stakeholder interactions can be time and resource intensive. Policy and practice impacts result from systematic review recommendations in a Canadian province.

## Knowledge translation at the Liberty Mutual Research Institute for Safety

Ian Noy (presenter)

**Background.** At Liberty Mutual, emphasis is placed on providing superior, evidence-based services to customers aimed at the prevention of injuries and disability. The Liberty Mutual Research Institute for Safety in Hopkinton, U.S.A., was established over 60 years ago to support this goal through the conduct of original, peer-reviewed research as well as state-of-the-science reviews. Recently, the formalization of a knowledge translation function was instituted to further synergize collaboration with business partners who have a key role in knowledge implementation and impact. The presentation will highlight the key elements of this program.

## The impact of a scientific review on return to work: the Danish experience

Ole Mortensen (presenter)

**Background.** In Denmark, an agreement was made between the government, unions and employers' organization that the literature should be reviewed to determine which return-to-work interventions are the most effective.

**Methods.** The literature review was published by the National Research Center for the Working Environment. Before the review was released, meetings were held with the unions and employers. The meetings gave rise to many discussions; however, they resulted in a common agreement on the recommendations of the review. When the review was published, a large public meeting was held with presentations from recognized international researchers discussing the recommendations from the review.

**Results / Discussion.** The impact of the review was large. The reasons for the impact and the plan for implementation that followed the review will be presented and discussed at the symposium.

## The impact of reviews summarizing the state-of-the-art regarding the relationship between occupational hazards and musculoskeletal disorders on national policy in the Netherlands

Allard van der Beek (presenter)

**Background.** This paper aims to describe the impact of recent reviews summarizing the scientific state-of-the-art regarding the relationship between occupational hazards and musculoskeletal disorders (MSDs) on national Dutch policy.

**Methods.** The Health Council of the Netherlands is an influential, independent advisory body for Dutch government and parliament. The Minister of Social Affairs and Employment asked the Health Council to alert him to new scientific insights concerning health- and safety-based limits for various occupational hazards. For this reason, a Health Council committee of scientific experts was formed. This committee performed reviews to support an evidence-based guidance to the Minister about the health effects of several occupational hazards. These reviews should result in advisory reports or letters on heat stress, falls from height, biological agents, work stress and five hazards relevant for work-related MSDs.

**Results.** Five advisory reports relevant to work-related MSDs were published between 2011 and 2013: repetitive movements at work; computer use at work; pushing, pulling and applying force in work situations; manual lifting at work; and working while standing, kneeling or squatting ([www.gezondheidsraad.nl/en/publications/advisory-reports](http://www.gezondheidsraad.nl/en/publications/advisory-reports)). The manual lifting review was also “translated” into a scientific article (Coenen et al, 2014).

**Discussion.** So far, the reviews of the Health Council have had no observable impact. It seems the Minister’s request was prompted by questions in Dutch parliament rather than by his ambition to change policies. National policies aiming at prevention of work-related MSDs still largely rely on covenants between organizations representing employers and employees, either at the enterprise or sector level.

## Case studies: reports from the U.S. National Academy of Sciences

David Rempel (presenter)

**Background.** The U.S. National Academy of Sciences (NAS) was established in 1863 to advise the nation on issues related to science and technology. Advice to government agencies is usually delivered in the form of published scientific reviews.

**Methods.** A review is typically written by a committee of 19 appointed scientists who meet for up to 24 months to review the scientific literature, interview experts and write the report.

**Results.** This presentation will review the impact of two reports prepared by the NAS. One was a Congressional requested review that led to the publication of *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities* (National Academy Press, 2001). The other was requested by a Federal Agency and led to the publication of *Improving Self-Escape from Underground Coal Mines* (National Academy Press, 2013).

**Discussion.** The impact of the two reports on government agencies and society will be discussed.

SYMPOSIUM 2, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 203A

## Evaluation of MSD biomechanical risk factors: the use of inertial sensors

**Chair: Adriana Savescu, Researcher, Human Life Department, French National Institute on Security and Occupational Health (INRS), Vandoeuvre, France**

In order to propose consistent solutions for the prevention of musculoskeletal disorders (MSDs), the evaluation of biomechanical risk factors is necessary. Different measurement systems are available at this time. These include optoelectronic systems and/or electrogoniometers. However, when the evaluation of biomechanical risk factors is required in the field, the use of these types of systems is not always possible because of their complex requirements or their lack of accuracy. In recent years, some researchers have pointed out the potential use of inertial sensors. This technology is referred to variously in the literature as IMU (inertial measurement unit), I(M)MU (inertial [and magnetic] measurement unit), MIMU (magnetic and inertial measurement unit) and IMMS (inertial and magnetic measurement system). The inertial sensor is based on three different basic sensors: 3D accelerometer, 3D gyroscope and 3D magnetometer. These sensors are small and easy to use for full-body human motion capture. The recorded data can be used to estimate 3D orientations, angular speeds and accelerations. This symposium looks at the different uses of this technology from the perspective of MSD prevention, and its possibilities, advantages and limitations.

## Using inertial sensors to monitor workers' trunk posture: the case of daycare workers

Genevieve Dumas (presenter), André Plamondon, Tara Diesbourg

**Background.** Inertial sensors are being used more frequently to monitor workers' posture. The objective of this presentation is to highlight the advantages and limitations of using inertial sensors to monitor workers' trunk posture, with examples from a recent study of daycare workers.

**Methods.** 24 workers from five daycare centres were instrumented over their clothes and continuously monitored for 3.3 hours on average with a dosimeter developed at IRSST. The dosimeter consists of two Xsens inertial sensors attached at the level of T1 and S1 and connected by a torsion rod. The data collected allowed monitoring the trunk and the pelvis flexion/extension and lateral bending (relative to vertical) as well as rotation of the trunk relative to the pelvis in three directions. The amount of time spent in each posture was represented in two ways, APDF and exposure variation analysis (EVA), for the five absolute and relative angles of the trunk. In addition, the workers were recorded with a video camera to identify the different tasks performed during the monitoring time.

**Results.** The inertial sensors allowed us to obtain continuous monitoring of 3D trunk posture while the workers performed their tasks with minimal disturbance to them. The results were reliable and reasonably precise (within a few degrees) compared to alternative field methods. APDF and EVA analyses allowed us to compare postural demands and discriminate between tasks and children age groups for each individual angle. However, the methods of analysis did not allow us to exploit the information collected by the sensors to its full potential. That's because the sensors can only consider one angle at a time while it is known that combined flexion and lateral bending or torsion are more demanding than deviating from the neutral zone in a single direction at a time.

**Discussion.** Research is needed to develop a more comprehensive approach.

## Orientation drift compensation of inertial sensors in magnetically distorted field applications

Christoph Schiefer, Rolf P. Ellegast, Ingo Hermanns (presenter), Thomas Kraus, Elke Ochsmann, Christian Larue, André Plamondon

**Background.** Inertial measurement units (IMU) provide a wide range of applications in mobile human motion tracking. IMUs measure angular rate, acceleration and magnetic field information, allowing 3D orientation estimation. In scenarios with a permanently distorted magnetic field, for example at workplaces, orientation estimation algorithms revert to using only angular rate and acceleration information. The result is an increasing drift error of the heading information that restricts the usability of IMUs to mainly magnetically undisturbed environments. To be more robust against disturbances, a method to compensate the orientation drift based on angular rate and acceleration has been developed and evaluated.

**Method.** At periodic points in time, zero points (ZP) were used to provide additional heading and gyroscope bias information that were combined with bidirectional orientation computation. In a laboratory environment, eight subjects were equipped with the CUELA system including IMUs at trunk, head and upper extremities. They performed a predefined course of box handling for 40 minutes at different motion speeds and ranges of motion. The orientation estimation was compared to an optical motion tracking system (Optotrak) using residual Euler angles as error function. Varying interval lengths between ZPs were analyzed to determine the necessary ZP-frequency at an acceptable error level.

**Results.** At a mean interval-length of 1.1 min between two ZPs without magnetometer usage, the resulting mean root mean squared error ranged from 1.7° to 7.6° (roll and pitch) and from 3.5° to 15.0° (heading) depending on the measured segment. The 95% limits of agreement ranged in best case from -2.9° to 3.6° at the hip roll angle and in worst case from -19.3° to 18.9° at the forearm heading angle.

**Discussion.** This study demonstrates that combining ZPs and bidirectional computation can reduce orientation error of IMUs in environments with magnetic field distortion.

## Effect of task complexity and duration when validating an inertial system with an optoelectronic system

Xavier Robert-Lachaine (presenter), Hakim Mecheri, Christian Larue, André Plamondon

**Background.** With the advancement of inertial measurement units (IMUs) over the last decade, *in situ* motion analysis appears promising. However, prior to testing directly in the field, validation against an established reference such as optoelectronic systems remains important. Previous IMUs validation studies have been incomplete regarding aspects of complexity of movements and duration of trials. These aspects are problematic for ergonomics applications where workers execute long, complex tasks. The objective of this study was to measure the error occurring from the IMUs technology in comparison to an optoelectronic system, and evaluate the effect of task complexity and duration.

**Methods.** Whole-body kinematics from 12 healthy participants were recorded simultaneously at 30 Hz with a full-body Xsens system where an Optotrak cluster was rigidly fixed on top of every IMU sensor. Simple short tasks for each joint and manual material handling tasks (duration of 32min) between four stations were performed. The coordinate systems were aligned between the two systems with angular velocities. Anatomical landmarks and coordinate systems were based on the International Society of Biomechanics recommendations. Joint angles were compared between the two systems with root mean square error (RMSE). Separate, one-way repeated measures ANOVA were applied on the eight joints and respective three rotations to contrast the factor task (simple short vs. long complex).

**Results.** Significant differences ( $p \leq .001$ ) between tasks were observed on all joints. RMSE was systematically higher for the long complex task with a mean on all joints of  $2.8^\circ$  compared to  $1.2^\circ$  during short simple tasks.

**Discussion.** IMUs' accuracy is affected by the complexity and duration of the tasks. Nevertheless, all joint rotations remained under an acceptable level of  $5^\circ$  RMSE during handling tasks with the exception of ankle eversion/inversion reaching  $7.8^\circ$ . IMUs show potential to track workers during their daily labour, which could help in the management of musculoskeletal diseases.

## Hand position estimation using inertial sensors

Brice Bouvier, Adriana Sevescu (presenter), Sonia Duprey, Raphael Dumas

**Background.** Magneto-inertial measurement units (MIMUs) are used more and more in various applications, including ergonomics, as they allow for ambulatory measurements. Despite much interest from the scientific community in this topic, several aspects of research deserve more investigation. Since MIMUs only deliver 3D orientation data, the determination of MIMU-based segment positions remains challenging. This work proposes the assessment of MIMU-based hand-positioning error.

**Methods.** 10 subjects participated in this study. They were equipped with four MIMUs, placed on the thorax, right upper arm, right forearm and right hand segments. Each subject repeated five experimental sessions, each consisting of four test conditions: two static poses (rest-pose, T-pose) and two series of movement (maximal shoulder flexion, circular multi-joint movement). The MIMU-based upper limb kinematic chain was obtained by associating information of: (1) 3D segment orientations, determined during a static pose calibration; and (2) segment lengths, estimated by regression rules based on the subject height. The hand-positioning error was calculated by using an optoelectronic system as reference (REF) and by aligning both MIMU and REF thorax segments together. The root mean square error (RMSE) was extracted for each experimental session and was then averaged over them (n=50).

**Results.** A global RMSE in the range of 7-15 cm confounding the four test conditions was observed. This range of error is consistent with values mentioned in other studies, performed on a robotic arm or without considering the wrist motion. 3D visualization of the upper limb represents a complementary source of information to joint angles data, especially for shoulder joint, in order to ease the interpretation of postures and movements in a general context of musculoskeletal disorder prevention.

**Discussion.** If more precision for upper limb positioning is required, the use of a more advanced kinematic chain and dedicated calibration steps represent interesting approaches to investigate.

## Inertial measurement units for assessment of the pattern of forward bending among blue-collar workers from the DPhacto cohort

Pascal Madeleine (presenter), M. Villumsen, M.B., Jorgensen, A. Holtermann, A. Samani

**Background.** New developments in electronics have enabled the use of Inertial Measurement Units (IMUs) to record physical activity in a minimally obstructive manner over several days. Individual, physical and psychosocial risk factors are known to play a role in the development of work-related musculoskeletal disorders. This presentation focuses on the results obtained from diurnal assessments of forward bending among blue-collar workers in Denmark.

**Methods.** In total, 681 blue-collar workers were monitored diurnally for four days and nights, on average. The duration and pattern of forward bending of the trunk were extracted from all-day IMU recordings, both at work and during leisure time. Exposure variation analysis was applied on forward bending during both work and leisure time. Low-back pain intensity was measured on a 0–10 scale and divided into low and high pain. Individual factors (age, gender, smoking) as well as psychosocial factors (social support) were adjusted for.

**Results.** The duration of forward bending was not significantly associated with the intensity of pain, but was modified by the level of social support during all day, work and leisure time ( $p < 0.05$ ). A more variable pattern of forward bending was found during leisure compared to work ( $p < 0.05$ ). Further, the pattern of forward bending was modified by individual factors like age and gender ( $p < 0.05$ ).

**Discussion.** The findings underline the complex interactions between individual, physical and psychosocial risk factors leading to low-back pain among blue-collar workers.

## Estimating 3D low-back moments during trunk bending using an inertial motion capture suit

Gert Faber (presenter)

**Background.** Inertial motion capture (IMC) systems have become increasingly popular for ambulatory movement analysis. However, few studies have attempted to use these measurement techniques to estimate kinetic variables, such as joint moments. Therefore, this study evaluated the performance of a wearable IMC system (MVN, Xsens) in the estimation of 3D low-back (L5/S1) moments during trunk bending tasks.

**Methods.** Nine healthy male subjects performed three tasks: (1) symmetric forward trunk bending; (2) 45° asymmetric trunk bending; and (3) fast forward trunk bending. Using the ambulatory IMC system, L5/S1 moments were estimated based on the upper-body kinematics using a top-down inverse dynamics analysis. As a gold standard reference, L5/S1 moments were calculated using a bottom-up inverse dynamics model based on force plate (Kistler) data and lower-body kinematics measured with an optical motion capture system (Optotrak).

**Results.** Averaged over subjects, L5/S1 moment RMS errors remained below 10Nm for all tasks ( $\pm 5\%$  of the peak extension moment). This is an encouraging result considering that these L5/S1 moment errors are in the range of the accuracy of the gold standard inverse dynamics methods. Only for the lateral flexion component were the errors somewhat larger.

**Discussion.** L5/S1 moments due to upper body posture/motion are captured quite well using the IMC system, which makes it a promising candidate for low-back load monitoring at the workplace.

SYMPOSIUM 3, MONDAY, JUNE 20, 1:30AM – 3:00PM, BALLROOM B

## Using job exposure matrices to determine the impact of physical workload on workers' musculoskeletal health: challenges and opportunities (Part I)

**Chair: Nils Fallentin, Research Director, National Research Center for the Working Environment, Copenhagen, Denmark**

Job exposure matrices have historically been used in epidemiological studies to assign cumulative exposure to workers. The job exposure matrix (JEM) is a cross-classification of industry-specific job titles with agents to which persons in the jobs are exposed, allowing researchers to translate job and industry data into exposure data. This approach has proved to be a valuable method in studies addressing a variety of occupational risks. It is, however, only in recent years that the JEM approach has been used to study exposure-response relationships between physical workload and musculoskeletal disorders.

Construction of JEMs for physical workload faces a number of problems related to the quality of the exposure assessment (self-reported, expert-based or measured), the uncertainty in underlying exposure-dose assumptions, and the potential misclassification introduced due to the inherent variability in exposure within a job group or job title.

This symposium (the first of two on this subject) presents and discusses the challenges and opportunities of using JEMs to determine the impact of physical workload on workers' musculoskeletal health. The results and experience gained from recent studies are presented together with methodological discussions.

## Development and evaluation of a job exposure matrix for general population studies of musculoskeletal disorders

Bradley Evanoff (presenter), Ann Marie Dale, Skye Buckner-Petty, Gaelle Santin, Marcel Goldberg, Marie Zins, Alexis Descatha

**Background.** Exposure estimates based on workers' self-report may result in inaccurate or biased estimates. Using a JEM to group self-reported physical exposures at the level of job titles can create unbiased homogenous exposure groups appropriate for epidemiological studies. This preliminary study tested several attributes of a JEM based on self-reported physical exposures, including variance between and within groups, agreement of individual and job-title level estimates and exposure-symptom association.

**Methods.** Data were obtained from CONSTANCES, a large French general population study. Self-reported values for physical exposures were grouped by job, defined by the French PCS code. We analyzed within- and between-job variance of 18 hand/wrist physical exposures (including force, hand vibration, repetition), and examined agreement between individual and group level exposures. We tested the validity of the JEM by examining its ability to demonstrate exposure-response relationships with the outcome of hand/wrist pain.

**Results.** Our preliminary dataset contained 30,895 workers in 1,201 job titles. After restricting for jobs with 10 or more workers, we analyzed exposures in 28,544 workers representing 335 unique jobs. Between-group variance in exposure estimates exceeded within-group variance. We compared job-title based to self-reported exposures defined by workers in each job who exceed the dichotomous exposure cutpoint defined by the SALTSA criteria. The proportion of agreement for 18 exposures ranged from 0.6-0.82; kappa values ranged from 0.11-0.62. In multivariate models controlling for age, gender, and co-morbidities, job-title based exposures for force and repetition were significant and dose-dependent predictors of hand/wrist pain. Analyses are proceeding to extend the range of exposures and health outcomes.

**Discussion.** This pilot study showed the feasibility of creating a general population JEM based on individual self-reported data. JEM may be useful to enable assignment of workplace physical exposures in large-scale epidemiology studies that would otherwise lack exposure data.

## Comparison between two Danish expert-based JEMs and exposure estimates derived from ISCO-linked U.S. O\*NET job groups

Johan Hviid Andersen (presenter), Nils Fallentin, Poul Frost, Tine Rubak, Annett Dalboge, Jane F. Thomsen, Ann Marie Dale, Susanne W. Svendsen, Bradley Evanoff

**Background.** Recent studies in several countries have used job exposure matrices to estimate workplace physical or biomechanical exposures in studies of musculoskeletal disorders. The validity of exposure estimates derived from JEMs remains uncertain, and the potential difference in exposure estimates assigned to specific job groups by JEMs using different methods or created in different countries has rarely been analyzed.

**Methods.** The study compares exposure estimates assigned to specific jobs in one U.S. and two Danish JEMs quantifying shoulder and lower body biomechanical exposures. Jobs or job groups will be identified by transferring Danish and U.S. national job title coding schemes (D-ISCO and SOC) to the international ISCO system to allow direct matching of job codes. Measures of force, repetition, and posture from the existing Danish JEMs — used in general population studies of MSDs — will be compared to job exposure values available in the American O\*NET job database. O\*NET data has previously been used in a number of JEMs and the database provides estimates of job-related physical exposure variables categorized as, for example, strength requirements or time spent making repetitive movements.

**Results.** Results are not yet available from this ongoing study, but at the symposium, challenges in mapping job codes between different countries will be presented and the level of agreement between exposure estimates at the job level in the Danish and U.S. JEMs will be reported.

**Conclusions.** JEMs are increasingly used to estimate occupational physical or biomechanical exposures. Comparing agreement of exposure estimates between exposure matrices developed in different countries will aid in the interpretation of study findings and advance the methodology of this exposure assessment technique for further studies.

## Job exposure matrices for estimating workplace physical exposures

Bradley Evanoff (presenter), Alexis Descatha, Ann Marie Dale

**Background.** While workplace physical exposures are associated with musculoskeletal disease and other health outcomes, current methods of exposure assessment have significant limitations. A job exposure matrix provides an efficient option for estimating physical exposures, particularly in large cohorts and for retrospective exposures.

**Methods.** Methods used in recent and ongoing studies, and discussion from a recent symposium at the Danish Ramazzini Center, are summarized.

**Results.** Use of JEMs to estimate physical exposures is increasingly common; JEMs have been recently applied to diverse outcomes including carpal tunnel syndrome, osteoarthritis of the back and lower extremities, shoulder disorders, vascular diseases, pregnancy and work disability. JEMs for chemical exposures typically rely on data from direct workplace measures; most JEMs for physical exposures have relied on expert ratings of exposure or on pooling of self-reported exposure at the job level. O\*NET, a national database of requirements for different jobs, uses both self-reported and expert-rating data, and has been used to estimate physical exposures in several studies. These different strategies will be presented and compared, including examples from ongoing studies. Advantages of JEM include lack of individual level information biases, and the ability to assign exposures retrospectively based on job titles. A disadvantage is the inability to account for exposure variation between workers in the same job.

**Discussion.** JEMs are increasingly used to estimate workplace physical exposures, and can assign valid and unbiased work exposure estimates to large population datasets containing no exposure data beyond job titles. These JEM methods should be more widely recognized to advance occupational disease epidemiology.

## A general population job exposure matrix based on expert ratings and technical measurements: upper arm elevation and repetitive shoulder movements

Annett Dalbøge (presenter), Gert-Åke Hansson, Poul Frost, Johan Hviid Andersen, Thomas Heilskov-Hansen, Susanne Wulff Svendsen

**Background.** Job exposure matrices (JEMs) should preferably include exposure estimates using a common metric. The aim of this study was to convert our recently constructed general population JEM (The Shoulder JEM) based on expert ratings into measurement scales for upper arm elevation and repetitive shoulder movements.

**Methods.** The Shoulder JEM covers all Danish occupational titles, divided into 172 job groups with expected homogenous shoulder exposures. Expert ratings were performed for all job groups by five occupational health physicians using benchmark groups as a calibration tool. For 36 of these job groups, we obtained technical measurements (inclino-metry) of upper arm postures (% time with elevation  $>90^\circ$ ) and movements (median angular velocity [ $^\circ/s$ ]). Expert ratings and technical measurements were compared using Pearson's correlation analysis. We used linear regression analyses to calculate calibration equations, which we used to convert the expert ratings for all 172 job groups to predicted measured job exposure estimates. Bland-Altman analyses were used to assess the agreement between the predicted and measured estimates.

**Results.** The correlation coefficient between the expert ratings and technical measurements was 0.80 for %time with upper arm elevation  $>90^\circ$  and 0.67 for repetitive shoulder movements. The corresponding calibration equations were  $y=0.5 \text{ \% time}+0.16* \text{ expert rating}$  and  $y=27 \text{ }^\circ/s+0.49* \text{ expert rating}$ . For upper arm elevation  $>90^\circ$ , the 95% limits of agreement were  $\pm 2.9 \text{ \%time}$ ; for repetitive shoulder movements, the limits were  $\pm 35 \text{ }^\circ/s$ .

**Discussion.** We transformed exposure estimates based on expert ratings into estimates on measurement scales for all occupations in Denmark.

SYMPOSIUM 4, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 202B

## Musculoskeletal and venous disorders in standing work: risk factors and perspectives for future prevention (Part 1)

**Chair: Benjamin Steinhilber, Scientific Co-worker, Institute of Occupational Medicine, Social Medicine and Health Services Research, University Hospital Tübingen, Tübingen, Germany**

Prolonged standing at work is associated with several musculoskeletal and venous disorders. Prevention strategies consider footwear and flooring, exposure reduction, modification of physical activity level during standing, tools like standing aids and more. However, only few recommendations on standing work exist that mainly advise a reduction in the overall exposure time. Consequently, criteria for developing concepts of preventive workplace designs in different occupational settings are missing.

This symposium (the first of two on this subject) will give an overview of epidemiological data on standing exposure in different occupations and associated disorders. Additionally, presentations on experimental data will provide insight into aspects of standing physiology as a basis for developing and evaluating prevention strategies. Further, musculoskeletal strain during standing work will be contrasted with data assessed during seated work. This symposium aims to encourage the scientific discourse on standing work, which has a significant impact of work-related diseases.

## Performance, muscle activity and discomfort while standing, sitting or using standing aids with different seat slopes

Corinne Nicoletti (presenter), Jacqueline Gasser, Thomas Läubli

**Background.** At many workplaces, employees are required to remain in a standing or a sitting position during the whole day. Prolonged standing, as well as prolonged sitting, is known to lead to health problems such as musculoskeletal or cardiovascular disorders. Furthermore, day-long sitting has been linked to increased mortality by several studies. A possible solution to alleviate the strain of standing — as well as to reduce sitting time — could be a standing aid. The aim of this study was to compare leg and lower back muscle activity, heart rate, work performance and subjects' discomfort while working with a standing aid, standing and sitting.

**Methods.** 20 subjects participated in this study. They were asked to perform computer work — a work task using fine motor skills, and a work task using gross motor skills for five minutes in different positions. The positions assessed were standing using a standing aid with four different seat slopes, standing and sitting. During the work tasks, the activity of the m. gastrocnemius, m. vastus lateralis and m. erector spinae was measured using surface electromyography (EMG). Furthermore, the heart rate, the performance and the discomfort of the positions were assessed.

**Results.** First results from 12 subjects showed that a standing aid with a seat slope of 25° against the horizontal axis could reduce the activity in the lower back compared to sitting and standing, and reduce the activity in the lower legs compared to standing.

**Discussion.** After completion of the measurements, we will describe the static and dynamic load of the muscles. The heart rate will give a measure of the effort needed to work in the tested positions. Including the measure of performance and the index of discomfort, we expect to derive optimal seat angles and seat heights for the design of standing helps.

## Discomfort and standing work in Europe

**Thomas Laeubli (presenter), Maria Gabriela Garcia Rodriguez, Maggie Graf**

**Background.** Although it is generally known that long periods of standing produce discomfort, the emphasis in health promotion tends towards recommending people to sit less, and little attention is paid to the problem of standing at work. This is surprising, as standing at work is the most common physical risk in European workplaces according to the results of the European Working Conditions Survey (EWCS).

**Methods.** The data for 30,000 full-time workers in the European Working Conditions Survey was analyzed.

**Results.** The analysis showed that almost half of the workers in Europe stand at work for more than three quarters of their working time. It revealed strong and highly significant correlations between the amount of time spent standing at work, back pain and pain in the legs. Additionally, long periods of standing at work were found to be associated with reports of working in tiring or painful postures. A significant interaction was found between age and both backache and muscular pains in the lower limbs. Older workers were found to more frequently report both types of pain than younger workers, and this was greater in the groups that stand for longer periods of time.

**Discussion.** As prolonged sitting has been linked to an increased risk of cardiovascular diseases and cancer, the question of an appropriate balance between sitting, walking and standing is essential for the work of practitioners working on the prevention of musculoskeletal disorders.

## Body posture and movement among 19,000 employees in the industrial sector

Andre Klussmann (presenter), Christoph Muehlemeyer, Patrick Serafin, Klaus-Dieter Wendt, Peter Dolfen

**Background.** Prolonged sitting and standing may lead to discomfort, symptoms and disorders, especially in the musculoskeletal system. However, too much physical activity may also be harmful for employees, if they are not adequately trained (Holtermann et al, 2010) or if fatigue accumulates. A combination of sitting, standing and moving may be ideal. This issue is particularly relevant in the industrial sector. Risk assessment data of workplaces at 50 different plants in the industrial sector in Germany were analyzed to quantify the distribution of body postures and movement.

**Methods.** All workplaces with employees in the production areas (excluding administration workplaces) in the 50 plants were analyzed using the exposure-documentation system (BDS, Klussmann et al, 2013). This data set was analyzed according to body posture and movement during the 8-hour shifts and allowed for the possibility of changing working postures.

**Results.** Among 18,818 employees in the production areas, 7,027 (37.3%) stand for more than 50% of the time (> 4 hours) and of these, 625 (3.3%) stand for more than 85% of their working time in an average eight-hour shift (> 7 hours). 1,106 employees (5.9%) walk for more than 85% of their working time (e.g. on U-shaped production lines). At workplaces where employees stand for more than four hours, a change of working posture is (nearly) always possible for 88.5%, but strongly limited, or not possible, for approximately 3% of the employees.

**Discussion.** Many employees in the industrial sector are exposed to prolonged standing, with and without the ability to walk about. To provide companies with validated recommendations on work design, further research is needed to develop an evidence-based model for the optimal distribution of sitting, standing and walking during the shift.

SYMPOSIUM 5, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 203A

## Efficient assessment of physical workload (Part 1)

**Chair: Marina Heiden, Senior Lecturer, Centre for Musculoskeletal Research, University of Gävle, Gävle, Sweden**

Physical loads at work are important determinants of musculoskeletal disorders and work performance. Thus, interventions targeting physical workloads have the potential to reduce the occurrence of disorders, and even improve well-being and performance. However, in order to reliably document workloads, or to design effective interventions and establish their effects, efficient strategies for assessing workloads in various occupations must be developed. Such strategies should be feasible to use for large samples, and lead to accurate and precise exposure estimates. Preferably, they should also be cost-efficient, thus providing exposure information with good quality at a low cost. This symposium, the first of two on this subject, will give you an overview of, and an opportunity to discuss, current research findings on the performance of different exposure assessment strategies. It includes presentations on ongoing research on the validity and reliability of strategies for assessing physical exposure in different occupations.

## Cost-efficient assessment of variation in arm posture during paper mill work

Marina Heiden (presenter), Jennifer Garza, Catherine Trask, Svend Erik Mathiassen

**Background.** Arm posture is a recognized risk factor for occupational upper extremity musculoskeletal disorders and thus often assessed in research and practice. Posture assessment methods differ in cost, feasibility and, perhaps, bias. An attractive approach could be to build statistical models for predicting results of expensive direct measurements of arm posture from cheaper or more accessible data, and apply them to large samples in which only the latter data are available. We aimed to build and assess the performance of such prediction models in a random sample of paper mill workers.

**Methods.** 28 workers were recruited to the study, and their upper arm postures were measured during three full work shifts using inclinometers. Simultaneously, the workers were video filmed, and their arm posture and gross body posture were assessed by observing the video afterwards. Models for predicting the inclinometer-assessed duration (proportion of time) and frequency (number/min) of periods spent in neutral right arm posture ( $<20^\circ$ ) were fitted using subject and observer as random factors, measured shift (1, 2 or 3) as fixed factor, and either observed time in neutral right arm angle or observed gross body posture as predictor.

**Results.** For the proportion of time spent in neutral arm posture, the best performance was achieved by using observed gross body posture as predictor (explained variance:  $R^2=26\%$ ; standard error:  $SE=9.8$ ). For the frequency of periods spent in neutral arm posture, the corresponding model fit was  $R^2=60\%$  and  $SE=5.6$ . Bootstrap resample validation of the latter model showed an expected performance in other samples of  $R^2=59-60\%$  and  $SE=5.5-5.6$  (5th-95th percentile).

**Discussion.** Surprisingly, we found that observed gross body posture was a better predictor of variation in arm posture than observed arm angles. The findings suggest that arm posture during paper mill work can be cost-efficiently assessed using simple observations.

## Variance components of observed postural exposure: the effect of partly visible periods

Catherine Trask (presenter), Svend Erik Mathiassen, Mehdi Rostami, Marina Heiden

**Background.** Previous studies have shown that video-based observation of postures that are only partly visible leads to different daily summary values than when postures are fully visible. However, the source of these differences is unclear. The purpose of this study was to estimate the between-observer variance of trunk and arm posture estimates (relative to within- and between-worker variance), and to investigate the effect of visibility on this observer variability of trunk and arm postural exposure estimates.

**Methods.** Video recordings were made of 28 pulp mill workers for three full shifts each. Trunk and arm postures were then estimated by trained observers using a work sampling approach; posture images were also assessed as being “fully” or “partly” visible. REML techniques were used to estimate the between-worker, between-day and between-observer components of variance at different visibility levels; Wald-based confidence intervals and p-values were used to determine sources of variation.

**Results.** Estimates of partly visible postures (as agreed upon by all observers) were lower than fully visible postures. However, more than 90% of trunk observations and 85% of arm observations did not have full agreement on visibility between observers. Right upper arm posture showed smaller between-observer variance when all observers rated a posture to be fully visible, as compared to all observers agreeing it was only partly visible. This suggests partly visible data introduces more methodological (i.e. between-observer) variability when compared to fully visible data. However, no significant differences in between-observer variability were found for the trunk, suggesting that other factors explain the reported differences in estimated postures between fully and partly visible data in this case.

**Discussion.** Future studies involving concurrent direct measurement would determine whether there is a true difference in posture between partly visible and fully visible periods, or whether the difference between fully and partly visible periods are related to observer performance.

## Reliability of using observations when assessing different posture variables

Jennifer Garza (presenter), Svend Erik Mathiassen, Marina Heiden

**Background.** Working in extreme postures has been identified as a risk factor for musculoskeletal symptoms. Directly measuring work postures is considered to be the most accurate approach for assessing these exposures, but it is often not feasible to directly measure posture due to time or budget constraints. Alternatively, direct measurements of postures can be predicted based on observations of workers' postures. Since observers are known to differ in posture ratings, it may, however, be necessary to develop calibration procedures for each specific observer.

**Methods.** Arm and back postures of a random sample of 28 paper mill workers were measured via inclinometry and also were assessed by three observers from videos. Linear models with participant number and observer as random effects were resolved to assess whether or not observed postures were associated with the corresponding inclinometer values and if the effect of observer on slope and intercept was significant ( $p < 0.05$ ). The variance explained by these models was compared to the variance explained by corresponding linear models yet with observer entered as a fixed effect (i.e. allowing different slopes and intercepts for different observers).

**Results.** For all postures, the variance explained was similar when using observer as a fixed compared to a random effect (R-squared ranging from 0.41 to 0.56 for observer as fixed or random effect). Throughout, participant was the major source of variance.

**Discussion.** Our findings of similar amounts of variance explained when using observer as a fixed compared to a random effect for all postures indicates that calibration models developed for each individual observer may not necessarily perform better than a general calibration applying to any observer. Since posture observations explained only a small proportion of directly measured posture variance, observation may not be very useful in this setting.

## Influence of task proportion errors on the effectiveness of task-based job exposure modeling

Svend Erik Mathiassen (presenter)

**Background.** Job-based exposure estimation using the occupational mean (JBM) is associated with substantial error. Many studies have therefore estimated job exposures from workers' tasks, i.e. task-based modeling (TBM), typically by combining individual workers' task proportions (TP) in the job with a general task exposure matrix. Studies of postures and muscle activity have, however, shown that TBM may be ineffective; one possible reason being that TPs are not correct. The present simulation study investigated the influence of random and systematic TP error on TBM performance.

**Methods.** We constructed two virtual two-task jobs with task exposure contrasts of 0.2 and 0.8. In both, TPs and task exposures mimicked likely occupational scenarios. We then simulated four cases of TP error: no error, random error, bias, and bias *and* random error. For each case, we varied the TP error size, and compared the absolute errors of TBM- and JBM-based job exposures for 10,000 virtual workers.

**Results.** For the low-contrast job, TBM with error-free TPs was, on average, only 6% more efficient than JBM, and the probability of TBM leading to a more correct job exposure than JBM was 56%. TP errors had negligible effects on effectiveness. With error-free TPs in the high-contrast job, TBM was 75% more efficient than JBM, and led to more correct job exposures for 71% of all workers. TP errors decreased TBM performance, down to being 34% better than JBM when both random and systematic errors were "large"; 62% of all individuals being more correctly assessed by TBM.

**Discussion.** For jobs with limited task exposure contrast, TBM was essentially equivalent to JBM, while TP errors had marginal impact. In high-contrast jobs, TBM was more effective, but was also more sensitive to both random and systematic TP errors. This may feed further discussion of the cost-efficiency of TBM in occupational settings.

SYMPOSIUM 6, MONDAY, JUNE 20, 3:30PM – 5:00PM, BALLROOM B

## Using job exposure matrices to determine the impact of physical workload on workers musculoskeletal health: challenges and opportunities (Part 2)

**Chair: Nils Fallentin, Research Director, National Research Center for the Working Environment, Copenhagen, Denmark**

Job exposure matrices have historically been used in epidemiological studies to assign cumulative exposure to workers. The job exposure matrix (JEM) is a cross-classification of industry-specific job titles with agents to which persons in the jobs are exposed, allowing researchers to translate job and industry data into exposure data. This approach has proved to be a valuable method in studies addressing a variety of occupational risks. It is, however, only in recent years that the JEM approach has been used to study exposure-response relationships between physical workload and musculoskeletal disorders.

Construction of JEMs for physical workload faces a number of problems related to the quality of the exposure assessment (self-reported, expert-based or measured), the uncertainty in underlying exposure-dose assumptions, and the potential misclassification introduced due to the inherent variability in exposure within a job group or job title.

This symposium (the second of two on this subject) presents and discusses the challenges and opportunities of using JEMs to determine the impact of physical workload on workers' musculoskeletal health. The results and experience gained from recent studies are presented together with methodological discussions.

## Occupational mechanical exposures and risk of inguinal hernia, varicose veins, osteoarthritis of the hip and combined pain in the lower and upper body: experiences from using the Lower Body JEM in large-scale epidemiologic studies

Paul Frost (presenter), Tine Steen Rubak, Vad Marie, Sorosh Tabatabaeifar, Tine Gjedde Sommer, Johan Hviid Andersen, Susanne Wulff Svendsen

**Background.** The Lower Body JEM, an expert-based job exposure matrix (JEM) quantifying occupational mechanical exposures, was applied for independent exposure assessment in epidemiologic studies of inguinal hernia, varicose veins, osteoarthritis (OA) of the hip and combined pain in the upper and lower body. The aim of this presentation is to evaluate the performance of the Lower Body JEM as an exposure assessment tool in studies of the impact of occupational mechanical exposures on risk of different common musculoskeletal disorders.

**Methods.** One study of inguinal hernia and one of varicose veins, both longitudinal, and one nested case-control study of hip OA all used national register-based outcome assessment. One cross sectional study of combined pain in the upper and lower body used questionnaire for outcome assessment. In all studies, individual exposure estimates of standing/walking (hours/day), total load lifted (kg/day), and frequency of lifting loads weighing  $\geq 20$  kg (times/day) were assessed using the Lower Body JEM, which covers all job titles in the Danish version of the International Standard Classification of Occupations DISCO88.

**Results.** Risk of lateral inguinal hernia, varicose veins and hip OA was related to standing/walking and lifting. Risk of combined pain was related to combined exposures to the upper and lower body.

**Discussion.** Exposure assessments using the Lower Body JEM demonstrated validity in prediction of different common lower body disorders and combined pain in the upper and lower body. Combining job histories with the Lower Body JEM allows assessment of cumulative exposure estimates. Validation and calibration of the expert-based exposure estimates using appropriate technical and/or observational measurement methods and refined exposure variables would be important next steps.

## Incident carpal tunnel syndrome in a large pooled cohort study: results obtained by JEM versus results obtained from observed exposures

Ann Marie Dale (presenter), Skye Buckner-Petty, Bethany T. Gardner, Carisa Harris-Adamson, Jay Kapellusch, Kurt T. Hegmann, Matthew S. Thiese, Stephen Bao, Linda Merlino, David Rempel, Christine Ekenga, Bradley A. Evanoff

**Background.** Many population-based datasets contain information on musculoskeletal disorder health outcomes, but lack measured work exposure data. A job exposure matrix (JEM) offers a cost-effective solution for estimating occupational exposures; however, the validity of such estimates has been little studied. This study will test exposure associations for incident carpal tunnel syndrome (CTS) in a large pooled cohort of U.S. workers, and compare associations from using a JEM to associations using observed individual exposures.

**Methods.** We used pooled data from the prospective NIOSH Upper Extremity Consortium and standardized job-title assignments. All studies collected personal, health and employment information and video observations of individual work tasks. Incident CTS required positive hand symptoms and abnormal median neuropathy. JEM exposures came from the U.S. Occupational Network (O\*NET) for hand force (static, dynamic) and repetitive motion. We combined two JEM exposures into categories by levels (high/high, high/low mixed, low/low) and ran Cox proportional hazards regression models to incident CTS. Results were compared to previously published results from the same cohort using directly measured exposures.

**Results.** Among 2,424 workers with 192 incident cases of CTS, crude models with time varying predictors showed significant associations for each force exposure combined with repetitive motion (static force HR=1.99; dynamic force HR=2.08). Published results using observed exposures showed similar significant associations for peak hand force (HR=2.07), forceful repetition rate (HR=1.84) and per cent time spent (duty cycle) in forceful hand exertions (HR=2.05). These HRs are similar to those seen using individual level exposures in this same cohort, though confidence intervals are wider.

**Discussion.** Significant relationships between force and repetitive motion exposures were shown using job-title based exposure estimates. Comparisons of risk estimates from JEM versus observed methods were similar, supporting the use of JEMs to evaluate relationships within large cohorts that otherwise lack individual exposure data.

## Example of using JEM: Carpal tunnel syndrome and computer exposure at work in two large complementary cohorts

Alexis Descatha (presenter), Zakia Mediouni, Julie Bodin, Ann Marie Dale, Matthieu Carton, Annette Leclerc, Natacha Fouquet, Christian Dumontier, Yves Roquelaure, Bradley Evanoff

**Background.** The boom in computer use and concurrent high rates in musculoskeletal complaints and carpal tunnel syndrome (CTS) among users have led to a controversy about a possible link. The present study used longitudinal data from two large complementary cohorts to evaluate a possible relationship between CTS and the performance of computer work, assessed by questionnaire in one and by a job exposure matrix in the other one.

**Methods.** The Cosali cohort is a representative sample of a French working population that evaluated CTS using standardized clinical examinations and assessed self-reported computer use. The PrediCTS cohort study enrolled newly hired clerical, service, and construction workers in several industries in the United States, evaluated CTS using symptoms and nerve conduction studies (NCS), and estimated exposures to computer work using a job exposure matrix. During a follow-up of three to five years, the association between new cases of CTS and computer work was calculated using logistic regression models adjusting for sex, age, obesity, and relevant associated disorders.

**Results.** In the Cosali study, 1,551 workers (41.8%) completed follow-up physical examinations; 36 (2.3%) subjects were diagnosed with CTS. In the PrediCTS study, 711 workers (64.2%) completed follow-up evaluations; 31 (4.3%) had new cases of CTS. The adjusted odds ratio for the group with the highest exposure to computer use was 0.39 [0.17; 0.89] in the Cosali cohort and 0.16 [0.05; 0.59] in the PrediCTS cohort.

**Discussion.** Data from two large cohorts in two different countries showed no association between computer work and new cases of CTS among workers in diverse jobs with varying job exposures. Job exposure matrix might be used in such purposes.

## Occupational mechanical exposures and risk of shoulder surgery: modelling cumulative exposures, duration and intensity

Annett Dalbøge (presenter), Poul Frost, Gert-Åke Hansson, Johan Hviid Andersen, Susanne Wulff Svendsen

**Background.** We have recently reported that occupational cumulative mechanical exposures of the shoulder increased the risk of surgery for subacromial impingement syndrome (SIS). To guide preventive strategies, it would be important to clarify the separate effects of the two components of cumulative exposure, i.e. exposure intensity and exposure duration on the risk of surgery for SIS. The aim of this study was to evaluate the associations between exposure intensity and exposure duration and risk of surgery for SIS.

**Methods.** We conducted a register-based cohort study. The cohort included the entire Danish working population (n=2,374,403 persons). During follow up from 2003 to 2008, 14,811 first-time events of surgery for SIS occurred. For each cohort member, register-based occupational codes were linked to a general population job exposure matrix (the Shoulder JEM) to allocate year-by-year exposure intensity of upper arm elevation >90° (%time), repetitive shoulder movements and forceful shoulder exertions (scaled from 0-4). For a 10-year time window, with a one-year lag-time, we calculated number of years (duration) with exposures in different exposure intensities (three categories). We applied logistic regression analysis with mutual adjustment for potential confounders (age, sex, region of residence and mechanical exposures).

**Results.** Preliminary results showed an exposure-response relationship for both intensity and duration of working with forceful shoulder exertions reaching a maximum ORadj of 1.9 (10 years in the highest exposure category). For working with upper arm elevation >90°, an exposure-response relationship was found for exposure intensity and duration reaching a maximum ORadj of 1.5 (10 years in the highest exposure category). For repetitive shoulder movements, a small gradual increase in ORadj to 1.3 was found (10 years in the highest exposure category).

**Discussion.** In general, the risk of surgery for SIS increased gradually with increasing exposure intensity as well as with increasing exposure duration.

SYMPOSIUM 7, MONDAY JUNE 20, 3:30PM – 5:00PM, BALLROOM B

## Musculoskeletal and venous disorders in standing work: risk factors and perspectives for future prevention (Part 2)

**Chair: Benjamin Steinhilber, Scientific Co-worker, Institute of Occupational Medicine, Social Medicine and Health Services Research, University Hospital Tübingen, Tübingen, Germany**

Prolonged standing at work is associated with several musculoskeletal and venous disorders. Prevention strategies consider footwear and flooring, exposure reduction, modification of physical activity level during standing, tools like standing aids and more. However, only few recommendations on standing work exist that mainly advise a reduction in the overall exposure time. Consequently, criteria for developing concepts of preventive workplace designs in different occupational settings are missing.

This symposium (the second of two on this subject) will give an overview of epidemiological data on standing exposure in different occupations and associated disorders. Additionally, presentations on experimental data will provide insight into aspects of standing physiology as a basis for developing and evaluating prevention strategies. Further, musculoskeletal strain during standing work will be contrasted with data assessed during seated work. This symposium aims to encourage the scientific discourse on

## Determining lower leg edema in standing work: reliability of a modified water plethysmograph and effects of prolonged standing exposure

Rudolf Wall (presenter), Robert Seibt, Gabriela Garcia-Rodriguez, Andre Klusmann, Thomas Läubli, Bernard Martin, Monika A. Rieger, Benjamin Steinhilber

**Background.** Persistent edema of the lower extremities in standing work increases the risk of venous diseases. Knowledge of the time course of edema development could help optimize ergonomic workplace design. The modified water plethysmograph (WPmod) used here to determine edema, limits measurement time to 5min. The aim of the study was to determine test-retest and interrater reliability of WPmod and to investigate effects of prolonged standing on lower leg edema.

**Methods.** First, test-retest and interrater reliability of WPmod were examined (n=20, 9♀). During measurements, lower leg was positioned in a water basin (25-30°C) in a standardized manner. Subsequently, the displaced water was drained for 5min and then weighed. Lower leg volume (LLV) was measured six times in total. Each of two investigators (I) conducted three measurements at 30-minute intervals with every subject on separate days. To evaluate reliability intraclass-correlation coefficient (ICC), standard error of measurement (SEM) and smallest real difference (SRD) were calculated separately for measurement one to three on both days. WPmod was then applied in a study involving 30 healthy subjects (15♀). They spent 275 minutes (including two breaks) standing or walking in randomized order on two separate days. LLV was determined before and after exposure.

**Results.** The ICC of interrater reliability and test-retest reliability within each investigator was 0.99. In I1 and I2, SEM was 27 and 23 ml respectively. SRD was calculated as 75 ml for I1 and 64 ml for I2. LLV of the subjects increased during standing on average by 109±63 ml. Walking exposure changed LLV by 9±41 ml. This difference was statistically significant (p<0.0001).

**Discussion.** The WPmod presented here was proved suitable for detecting LLV because of its high test-retest and interrater reliability. Measured volume changes can thus be attributed to walking and standing exposure.

## Long-term leg muscle fatigue in standing work: effects of two ergonomic interventions

Maria-Gabriela Garcia (presenter), Rudolf Wall, Benjamin Steinhilber, Thomas Läubli, Bernard Martin

**Background.** Musculoskeletal disorders have been associated with accumulation of muscle fatigue. Prolonged standing work leads to long-term leg muscle fatigue. The effectiveness of ergonomics interventions to reduce the muscle fatigue induced by prolonged standing work is still controversial. Thus, the goal of this study was to investigate and compare the effects of long-term muscle fatigue after standing on a hard floor or an anti-fatigue mat and slow-pace walking.

**Methods.** Using a repeated measures design, 10 males and eight females were tested in three conditions while simulating standing work. The work tasks were standardized for all subjects and performed over five hours of the work day and included one seated rest break and a lunch break. Lower leg muscle fatigue was quantified by the decrease in muscle twitch force and the increase in twitch duration in responses to electrical stimulation. Fatigue was assessed before the work task, at midday, immediately at the end, and at 30 minutes and one hour after a seated post-work recovery period.

**Results.** A significant decrease of muscle twitch force (MTF) and an increase of twitch duration (TD) was observed after five hours of standing on the concrete floor, or on the floor mat. The long-term fatigue effects persisted at least one hour post work in both conditions. Muscle fatigue effects were less pronounced, but still significant, at the end of the walking work. None of the three conditions led to fatigue effects after 110 minutes of standing or walking.

**Discussion.** These results indicate that prolonged standing on a floor mat has similar long-term muscle fatigue effects on the lower limbs as standing on a hard floor. Thus, the use of an anti-fatigue mat may not alleviate these effects during prolonged standing. This type of fatigue may be attenuated by walking. However, walking should not be considered as an ultimate solution.

## Relationship between lower limb vascular and muscular outcomes in standing and sit-standing work postures

David Antle (presenter), Julie Côté

**Background.** Vascular and muscular outcomes are reported to have an impact on lower limb discomfort during standing work. Previously, we demonstrated that sit-stand stools can reduce indicators of blood pooling and discomfort in the lower limbs when compared to standing. In this project, we aim to determine whether or not lower limb muscle activity differs between standing and sit-stand postures, and to determine if activity changes relate to vascular/discomfort outcomes.

**Methods.** 16 participants were outfitted with laser Doppler flow (LDF) electrodes to measure blood flow in the lower limb, a sphygmomanometer to measure lower limb blood pressure, and electromyography electrodes on the soleus, gastrocnemius and tibialis anterior. Participants completed a simulated industrial task over 34 minutes in a standing condition and in a sit-standing condition. Vascular and muscular outcomes, as well as reported discomfort, were tracked during sessions. Repeated measures ANOVAs (posture x time) were used to assess differences.

**Results.** During standing, there were significant increases in tibialis anterior and gastrocnemius activity over time ( $p < 0.00052$ ). Early analysis showed higher muscle activity levels across the sit-standing condition. There were significant increases in lower limb blood flow ( $p = 0.011$ ) over time, and significantly higher blood flow ( $p = 0.011$ ), lower limb blood pressure ( $p = 0.001$ ), and discomfort ( $p < 0.0001$ ) while standing. Data also showed that the timing of the increases of muscle activity occurred after an increase in blood pressure and blood pooling onset during standing. Early results suggest earlier onset of increased lower limb musculature activity in the sit-standing posture.

**Discussion.** Taken together, these results suggest that earlier onset of increased activity in the lower limb during sit-standing posture may allow greater dynamic action to prevent as drastic an increase in blood pooling, pressure and discomfort when compared to standing. These results provide further insights into the potential applicability of sit-stand stools and movement patterns that might explain their benefits.

SYMPOSIUM 8, MONDAY, JUNE 20, 3:30PM – 5:00PM, ROOM 203A

## Efficient assessment of physical workload (Part 2)

**Chair: Marina Heiden, Senior Lecturer, Centre for Musculoskeletal Research, University of Gävle, Gävle, Sweden**

Physical loads at work are important determinants of musculoskeletal disorders and work performance. Thus, interventions targeting physical workloads have the potential to reduce the occurrence of disorders, and even improve well-being and performance. However, in order to reliably document workloads, or to design effective interventions and establish their effects, efficient strategies for assessing workloads in various occupations must be developed. Such strategies should be feasible to use for large samples, and lead to accurate and precise exposure estimates. Preferably, they should also be cost-efficient, thus providing exposure information with good quality at a low cost. This symposium, the second of two on this subject, will give you an overview of, and an opportunity to discuss, current research findings on the performance of different exposure assessment strategies. It includes presentations on ongoing research on the validity and reliability of strategies for assessing physical exposure in different occupations.

## Improving questionnaire-based estimates of occupational physical activity of blue-collar workers by individual and work-related information

Nidha Gupta, Marina Heiden (presenter), Svend Erik Mathiassen, Andreas Holtermann

**Background.** Questionnaire-based information of occupational physical activities is extensively used, but susceptible to systematic errors. Calibration modeling may reduce errors and improve precision of questionnaire-based information by transforming the self-reported data into more correct estimates of “true” exposure. We aimed (1) to determine the ability of unadjusted ratings of Saltin and Grimby’s Occupational Physical Activity (SGOPA) question to estimate objectively measured sedentary behaviour, physical activity and cardiovascular load, and (2) to develop and evaluate statistical models calibrating SGOPA ratings into expected values of objectively measured exposures.

**Methods.** 214 blue-collar workers responded to a questionnaire comprising the SGOPA question and questions on several individual and work-related factors. They wore two accelerometers measuring time spent in sedentary and in physical activities, and one Actiheart monitoring cardiovascular load (eventually expressed as %Heart Rate Reserve) for one to four days. Least-squares linear regression models were developed to predict each objectively measured exposure from SGOPA and additional self-reported individual and work-related predictors.

**Results.** SGOPA alone explained 22% ( $R^2$  adjusted=21%) of the variance between individuals in sedentary behaviour and physical activities, and 8% ( $R^2$  adjusted =7%) of the variance in high cardiorespiratory load. When adding predictors related to individual and work to the regression model, explained variance increased to 51% ( $R^2$  adjusted=46%) for both sedentary behaviour and physical activities, and to 27% ( $R^2$  adjusted=19%) for high cardiorespiratory load. Bootstrap validation suggested that explained variance would be reduced by 9-15% for the three exposures when using the model on other data sets.

**Discussion.** SGOPA itself shows only limited ability to predict objectively measured sedentary behaviour, physical activities and cardiovascular load at work, but the performance of a calibration model can be considerably improved by adding further self-reported predictors.

## Predicting physical exposures during computer use as a means to investigate the relation between physical exposures and symptoms in a large cohort of office workers

Maaïke Huysmans (presenter), Belinda Eijkelhof Jennifer Garza Birgitte Blatter, Peter Johnson, Jaap Van Dieen Allard van der Beek, Jack Dennerlein

**Background.** Since measuring physical exposures directly is time consuming and costly, only a limited number of prospective studies have examined the relationship between computer-related physical exposures and musculoskeletal symptoms. We aimed to examine the relationship between physical exposures and neck and upper extremity symptoms by building prediction models for physical exposures and applying these models to data of a large prospective cohort (PROMO).

**Methods.** Step 1: We built prediction models for 14 neck-shoulder and 16 arm-wrist-hand physical exposures using data from the PROOF study, an observational field study (n=117) using self-reported factors and direct measurements of office workers' physical exposures during two hours of computer use. Physical exposures that had >50% classification agreement between predicted and observed exposures were taken to Step 2.

Step 2: We applied the prediction models to the PROMO cohort and examined the relationship between predicted physical exposures and the development of neck-shoulder and arm-wrist-hand symptoms in the first year of follow-up by using logistic regression analyses. We used data of 1,220 and 1,379 office workers who were free of neck-shoulder and arm-wrist-hand symptoms at baseline, respectively.

**Results.** Five neck-shoulder exposures and seven arm-wrist-hand exposures were successfully predicted and proceeded to Step 2. Workers with high predicted trapezius muscle activity (right side) and high values of predicted lateral torso tilt had a higher risk of developing neck-shoulder symptoms than those with low values, while high predicted shoulder flexion was protective for developing future symptoms. Workers with high predicted wrist velocities were found to be at higher risk for developing arm-wrist-hand symptoms.

**Discussion.** Prediction models were shown to be useful to predict physical exposures in a large cohort of office workers. Predicted physical exposures were related to the development of neck-shoulder and arm-wrist-hand symptoms.

## A web-based survey to document workers' mechanical exposures at a workplace level

Richard Wells (presenter), Niki Carlan, Amin Yazdani, Philip Bigelow

**Background.** Despite many biomechanical risk factors being linked to the development of musculoskeletal disorders (MSDs), little measurement of the prevalence of physical loads in workplaces is conducted. Such data as exists typically comes from questionnaires completed by large numbers of workers. Through a collaborative partnership with unions and a health and safety organization, we developed and tested a pen-and-paper survey to document exposures at a workplace level.

**Methods.** Loading types related to the development of MSDs were emphasized. 26 types of physical loads in workplaces were identified, including pushing, using pinch grips, driving and using a computer. Surveys were first completed independently by two members of each organization's joint health and safety committee (JHSC). The same survey was later completed collectively to arrive at a consensus between the two members. Results of the surveys were then compared to findings from a walk-through conducted by an ergonomist.

**Results.** Substantial to excellent agreement was found between the identification and assessment of exposure levels by the ergonomist and workplace (Yazdani et al, 2016). The survey is therefore an efficient technique (~30 mins) to characterize the loads to which workers are exposed. Based upon user feedback a number of modifications were requested. These included using both imperial and metric measures, adding loading types, adding "occasionally" as a loading duration, including better instructions and examples, and making the survey available electronically versus using a pencil and paper. Climbing was added as a loading type. We explored a number of platforms to house the on-line survey and ultimately decided on REDCap™. Animated GIFs were added to illustrate each loading type. The system also provided a summary report of the physical loads to the workplace. The report was made available immediately after the workplace completed the survey.

**Discussion.** The survey was developed as a surveillance tool, but workplaces told us that they found it useful in planning their health and safety and MSD prevention activities.

**Reference.** Yazdani, A., Bigelow, P., Carlan, N., Naqvi, S., Robson, L. S., Steenstra, I & Wells, R. (2016). Development and Evaluation of a Questionnaire to Document Worker Exposures to Mechanical Loading at a Workplace Level. IIE Transactions on Occupational Ergonomics and Human Factors.

## Quick reference tables to estimate female manual arm strength

Jim Potvin (presenter), Nicholas J. La Delfa

**Background.** This presentation will provide a subset of manual arm strength (MAS) data collected in a laboratory setting in quick reference tables, which can be used to quickly approximate average female MAS values, and correct for selected percentiles.

**Methods.** Over the past 12 years, our lab collected MAS data from a total of 95 female participants (age =  $35.5 \pm 12.3$  yrs; range = 20-62 yrs). Participants stood upright and exerted maximum forces with the hand in a wide variety of hand locations relative to the shoulder (n = 36). Every hand location had MAS trials in directions superior, inferior, anterior, posterior, lateral and medial to the shoulder, and many had other combinations of two and three of these directions (~15 directions per hand location). There were a total of 536 tested combinations of hand location and force direction, with an average of 25.1 participants per condition, for a total of 13,460 MAS trials.

**Results.** An artificial neural network (ANN) was developed with 85% (n = 456) of these conditions: it used hand location and force direction, relative to the shoulder, and predicted the MAS values very well ( $r^2 = 0.97$ , RMS error = 5.2 N). The ANN also performed well with an independent test data set of 15% of the conditions ( $r^2 = 0.842$ , RMSD = 13.1 N, n = 80).

**Discussion.** We call this the “arm force field” method, and it is currently being integrated into various digital human model software (DHM) packages.

SYMPOSIUM 9, TUESDAY, JUNE 21, 10:30AM – 12:00PM, BALLROOM B

## Biomechanics of the upper extremities during mobile IT work (Part 1): smartphone use I

**Chair: Pascal Madeleine, Professor, Department of Health Science and Technology, Aalborg University, Aalborg, Denmark**

Information technology (IT) work is nowadays often performed in mobile environments. One key reason for this is the increasing use of multi-touch, hand-held devices (smartphones). However, prolonged use of smartphones in our daily lives is associated with physical risk factors that may lead to the development of musculoskeletal disorders in the upper extremities. This symposium, the first of four on the subject of mobile IT work, gathers a group of international experts to share their latest research findings on the effects of smartphone use on the biomechanics of the upper extremities. A round table will take place at the end of the symposium.

## Effects of mobile input device type and texting style on upper extremity and upper trapezius muscle activity and cervical posture during texting

Jonathan Dropkin (presenter), Judith Gold

**Background.** The estimated annual frequency of worldwide text messaging is expected to increase from nearly six trillion in 2011 to over nine trillion in 2016. Based on the number of individuals who may use mobile input devices, and the potential adverse health effects from text messaging, it is important to characterize muscle activity and postures on familiar handheld devices and during common texting styles. The objective of the study was to examine the influence of input device type (touchscreen versus physical keypad) and texting style on upper extremity and upper trapezius muscle activity and cervical posture during a texting task.

**Methods.** College students performed a brief texting task under random experimental conditions. The students used 3.5-inch touchscreen and physical keypad devices with two texting styles — right hand holding device/right thumb typing, and both hands holding device/both thumbs typing. Outcome measures, captured by video camera, included the degree of cervical spine flexion for a given texting condition and muscle activity of the upper trapezius, extensor carpi radialis, flexor digitorum superficialis, and the abductor pollicis brevis, captured by surface electromyography.

**Results.** Physical keyboard texting resulted in greater thumb, finger flexor and wrist extensor muscle activity than on a touchscreen of similar dimensions. Texting on either device produced greater wrist extensor muscle activity during one-hand/thumb texting than with both hands/thumbs. Texting with both hands/thumbs resulted in a small increase in cervical flexion ( $p < 0.05$ ).

**Discussion.** Results suggest that virtual keyboard mobile devices used with both hands may reduce biomechanical loading in the distal upper extremity and upper trapezius. Findings may serve to inform designers and ergonomists about the relationship between device design features, texting styles, exposures and musculoskeletal disorders.

## Young children's movements while using mobile touchscreen devices

Leon Straker (presenter), Pieter Coenen, Amity Campbell, Sonia Ranelli, Erin Howie

**Background.** Mobile, touchscreen devices such as tablet computers are increasingly used for a wide range of tasks across the population, including by young children. There is concern that substantial exposure to the use of these devices by young children will result in lack of movement variety and thus increase the risk of musculoskeletal disorders across lifespan. Therefore, the aim of this study was to evaluate the amount of upper limb and whole-body movement during use of tablet computers.

**Methods.** In a within-subjects laboratory study, the upper limb and whole-body movement of young children was measured as they engaged in three separate activities for 15 minutes each: using a tablet computer; viewing a movie on a large TV screen; and, playing with toys. Movement was measured using Actigraph GT3x accelerometers worn on the dominant side wrist and anterior superior iliac spine. Movement was characterised as the one minute epoch count in X, Y and Z axes. Differences between activities in movement performed were examined using one-way repeated measures analyses of variance.

**Results.** 10 (7 female) children age 3.8±0.8 years participated. Mean (±SD) movement was significantly different between activities, with movement during tablet play typically greater than during TV viewing and less than during toy play for both upper limb and whole body in each plane (except for upper limb Y movement). For example, Z axis counts were 71.3 (hip) and 237.4 (wrist) during tablet play compared with 47.2 (hip) and 114.6 (wrist) during TV viewing and 178.1 (hip) and 766.9 (wrist) during toy play.

**Discussion.** These findings show that the amount of movement of the upper limb and whole body is different for young children using tablet computers. A better understanding of the physical impact of the use of these devices will help inform guidelines for appropriate use by children.

## Is motor variability influenced in a smart way by smartphone use?

Pascal Madeleine (presenter)

**Background.** The structure (i.e. sample entropy, SaEn) of variability is an important feature of movement variability. To date there is no available information on the effects of smartphone use on SaEn. This presentation will address the effects of smartphone use on the SaEn of surface electromyography (SEMG) signals during text entry.

**Methods.** 20 young adults with and without chronic neck-shoulder pain participated in the study. Text entry consisted of: (1) bilateral texting with both thumbs, (2) unilateral texting with the right thumb on a smart-phone, and (3) bimanual texting on a PC for 10 minutes. The SEMGs of left and right cervical erector spinae (CES), upper trapezius (UT) and lower trapezius (LT) muscles were recorded. SaEn were computer over 1s epoch with  $m=2$  and  $r=0.20SD$  of the time series. A mixed model repeated measures analysis of variance was used to evaluate the effect of group as between-subject factor, and task and time as within-subject factor.

**Results.** SaEn of CES tended to be lower for cases compared with controls ( $p=0.07$ ). SaEn were in general lower during PC texting compared with bilateral/unilateral texting ( $p<0.05$ ). SaEn decreased over time ( $p<0.05$ ).

**Discussion.** The results revealed that the structure of SEMG variability changed in relation to time and to the type of text entry.

## Is texting on mobile phones a risk factor for musculoskeletal disorders in neck and upper extremities?

Ewa Gustafsson (presenter), Sara Thomée, Anna Grimby-Ekman, Mats Hagberg

**Background.** The use of mobile phones for text messaging is a common part of life for most young adults today. However, there is a lack of knowledge about how this immense amount of texting may affect their musculoskeletal health over time. The aim of this study was to examine whether or not texting on mobile phones is a risk factor for musculoskeletal symptoms in neck and upper extremities among young adults.

**Methods.** The study was a longitudinal, population-based cohort study with young adults (20-24 years). Data was collected via a web-questionnaire at baseline (n=7,092) and two follow ups (at one and five years). The exposure variable was the amount of reported text messages per day in the past 30 days and the health outcomes that reported ongoing pain in neck and upper extremities and numbness/tingling in hand/fingers. Two types of logistic models were used: (1) cross-sectional analysis with baseline values and (2) prospective incidence analyses among those symptom-free at baseline with outcomes (new cases) at the one- and five-year follow ups.

**Results.** After adjustments for confounders (sex, age, stress, general health, education, occupation, physical activity and computer use), cross-sectional associations were found between text messaging and reported symptoms in neck and upper extremities for both men and women (ORs 1.3-2.0). Among those symptom-free at baseline, prospective associations were found in the one-year analyses between text messaging and reported symptoms in the hand/fingers (OR 2.0). No clear associations were found between text messaging and reported symptoms at the five-year follow up.

**Discussion.** In this study, cross-sectional associations were found between text messaging and reported musculoskeletal symptoms in neck and upper extremities for both men and women. In addition, text messaging was a prospective risk factor for reported symptoms in the hand/fingers in the one-year analysis.

SYMPOSIUM 10, TUESDAY, JUNE 21, 10:30AM – 12:00PM, ROOM 201A

## Implementing ergonomic change

**Chair: Dwayne Van Eerd, Associate Scientist, Institute for Work & Health, Toronto, Canada**

Implementing ergonomic change in workplaces is challenging. Participatory ergonomics (PE) programs are a popular approach for reducing occupational hazards and improving workers' health (Rivlis, 2008). PE can improve workplace conditions through participation, communication and group problem-solving. However, research findings with respect to program effectiveness are mixed (Pehkonen et al, 2009). Mixed effectiveness findings may be associated with intervention intensity (Wells et al, 2009; Cole et al, 2009) and implementation processes. Traditional or consultant-based approaches to implementing ergonomic change also face similar challenges.

Numerous implementation models (or frameworks) geared to health care, community and public health settings and business management programs have been proposed (Linnan and Steckler, 2002; Fixsen et al, 2005; Tabak et al, 2012; Datta & Pettigrew, 2013; Proctor et al, 2011). However, occupational health and safety program implementation has not been featured as part of the discussion on implementation approaches.

Inconsistent findings on the effectiveness of implementing ergonomic change — and in establishing links to the reduction of occupational hazards such as musculoskeletal disorders (MSDs) — indicate that an examination of the implementation processes is necessary. This symposium will present on the implementation of ergonomic change in workplaces in Denmark, the Netherlands, Australia and Hong Kong, providing an international perspective.

## The implementation of ergonomics advice and the “stage of change” approach

Paul Rothmore (presenter), Paul Aylward, Jonathan Karnon

**Background.** Various methods have been proposed to improve the implementation and effectiveness of injury prevention advice according to behaviour change principles. The most frequently applied of the behaviour change methods in workplace settings has been Prochaska and DiClemente’s stage-of-change (SOC) framework. This paper investigates the implementation of injury prevention advice tailored according to the SOC approach.

**Methods.** Purposive sampling was used to select medium-large organizations from industry groups in South Australia known to be at high risk of musculoskeletal injury. Each organization was asked to recruit 10-20 employees who performed substantially similar tasks (a workgroup). All members of the workgroups completed a questionnaire to identify their SOC and, in a participatory approach, were asked to identify any changes they had made, or that should be made, to reduce the risk of injury. Each company was subsequently visited by an ergonomist in a two- to three-hour site visit. Based on direct observation and further informal discussions with the employees, a report was prepared for company managers detailing the observations made and suggested changes. Approximately equal numbers of organizations were then randomly assigned to receive either a “standard” report or a report that had been “tailored” according to the SOC profile of the workgroup. 12 months later, semi-structured interviews were conducted with each manager

**Results.** In a multivariate model, managers who had received “tailored” advice were found to have implemented significantly more of the recommended changes (IRR=1.68, 95% CI 1.07-2.63) and more “additional” changes (IRR=1.90, 95% CI 1.12-3.20).

**Conclusion.** The findings from this study suggest that the implementation of injury prevention recommendations, incorporating expert observation and worker participation, may be improved by the tailoring of recommendations according to SOC principles.

## Participatory ergonomics for preventing work-related musculoskeletal disorders of aircraft cabin cleaners in Hong Kong

Billy So (presenter), Leung Kim Hung

**Background.** Musculoskeletal disorders (MSDs) are the leading cause of work disability. Aircraft cabin cleaning is a unique type of cleaning work that is characterized by highly concentrated physical activity conducted in compressed time, during shift work and in limited working space. Aircraft cabin cleaning is associated with multiple ergonomic, physical and psychosocial hazards for work-related MSDs. Prevention strategies for aircraft cabin cleaners need to be specially designed to address these issues. The purpose of this research was to investigate the effectiveness of a participatory ergonomics (PE) approach in preventing of work-related MSDs among aircraft cabin cleaners.

**Methods.** A controlled trial was conducted on 100 cleaners recruited from two aircraft cabin service companies in Hong Kong. The aircraft service companies were assigned into intervention and control groups. The intervention group (n=50) participated in a four-week PE program that included workplace training, equipment skill enhancement and an exercise program based on the findings from our previous studies. The control group (n=50) received a general education on manual handling. Both groups had baseline and follow-up assessments, which included health outcome evaluation and exposure change evaluation. Health outcome evaluation focused on the prevalence of musculoskeletal disorders and reported sick leave. Exposure change evaluation included the perceived physical workload, job satisfaction, psychological stressor and reported occurrences of awkward postures.

**Results.** The intervention group showed a statistically significant decrease in prevalence of lower back ( $p=0.039$ ), knee ( $p=0.039$ ), and ankle and feet ( $p<0.005$ ) disorders after the intervention. The intervention group exhibited a decrease in perceived physical demand, psychological stressor, reported awkward postures and reported sick leave. The control group showed no change in prevalence of musculoskeletal disorders and other outcomes.

**Discussion.** This study showed that a PE approach can help to decrease work-related MSDs among aircraft cabin cleaners and reduce exposures to work-related risk factors.

## Implementing a participatory change program in health care

Dwayne Van Eerd (presenter), Era Mae Ferron, Teresa D'Elia, Benjamin Amick

**Background.** Musculoskeletal disorders (MSDs) and slips, trips and falls (STFs) are a major source of work disability and a substantial proportion of injuries in health care. Participatory ergonomics (PE) programs are popular approaches to reduce workplace injuries. An Ontario health and safety association developed a unique and comprehensive PE program called Employees Participating in Change (EPIC) to reduce the incidence of MSDs and STFs in long-term care (LTC). EPIC seeks to build management systems and accountability structures to support program success and sustainability. Our objective is to describe a process evaluation in a field study of EPIC.

**Methods.** The field study was conducted in six LTC facilities (3 intervention, 3 control). Two participating intervention sites focused on reducing MSDs and the other on STFs. One MSD site focused on two nursing units and the dietary department (n=96) and the other MSD site selected the environmental department (n=26). The STF intervention site focused on four nursing units and all dietary staff (n=269). A process evaluation, developed by Linnan and Strickler (2002), was adapted employing a qualitative approach. Structured interviews allowed us to capture details about EPIC implementation directly from those involved. Interviews were conducted with program participants and frontline staff at three time points (early, mid and late in program implementation).

**Results.** Staff reported improvements in working relationships and communication with supervisors regarding health and safety issues. EPIC participants identified injury prevention efforts as a “win-win” for management and frontline staff, high levels of staff “buy-in,” and increased regular communication among staff about identifying and managing hazards. Additionally, EPIC activities extended facility-wide. Program sustainability was evident, as sites incorporated MSD and STF identification and management in new-worker orientation.

**Conclusion.** EPIC implementation led to changes and hazard reduction. Implementation of participatory approaches are challenging; however, the impacts are positive and sustainable.

## Processes, barriers and facilitators to implementation of a participatory ergonomics program among nurses' aides

Charlotte Rasmussen (presenter), Naja Mikkelsen, Marie Ravn, Karen Søgaard, Marie Jørgensen, Andreas Holtermann

**Background.** Effectiveness of ergonomics interventions in preventing low-back pain is not convincing. This could either be due to failure of the intervention concept or to the interventions being poorly implemented. The aim of this study was to gain insight into the processes of a participatory ergonomics program with an emphasis on identifying strain-inducing work tasks, suggested solutions and evaluation of implementation barriers and facilitators.

**Methods.** As part of a multi-faceted intervention for prevention of low-back pain among nurses' aides, a participatory ergonomics program was developed. The program consisted of a kick-off meeting, two workshops and two follow-up meetings (9 hours in total). Data were collected from action plans containing information about three to four prioritized work tasks identified as physically demanding or strenuous, and the suggested solutions to these tasks. Barriers and facilitators were derived from the final evaluation sheet.

**Results.** A total of 142 strenuous work tasks were prioritized. Of these, 69% were categorized as physical, 24% as organizational and 7% as psychosocial. A total of 149 solutions were suggested. Most of the solutions (55%) were categorized as organizational, 43% as physical and 2% as psychosocial.

A total of 88 barriers and 75 facilitators to implementation were identified. The barriers were divided into 47% relating to internal factors such as the team or management, and 53% relating to external factors such as time, insufficient financial resources and collaboration with citizens or relatives. The facilitators were similarly divided into 73% relating to the internal factors and 27% relating to the external factors.

**Discussion.** In this participatory approach, the majority of the suggested solutions were organizational. This indicates that future participatory ergonomics programs should be directed at solving problems on an organizational level.

## Development and implementation of a guideline on a participatory approach in workplaces in the Netherlands

Maaïke Huysmans (presenter), Frederieke Schaafsma, Han Anema

**Background.** In the Netherlands, we developed a multidisciplinary guideline on a participatory approach (PA) in workplaces, in collaboration with insurance physicians, work experts, occupational health physicians, occupational health nurses, occupational hygienists and occupational therapists. PA is a systematic approach with pre-defined steps to find consensus between worker(s) and relevant stakeholders (e.g. supervisors or employer) on the main problems and solutions for workers' health problems and work participation under the guidance of a professional, as stated above. This results in an action plan that defines what is done, by whom and when. The guideline was divided to accommodate two different settings: the organizational approach and the individual approach. The organizational approach is mainly performed in primary prevention and targets multiple workers. The individual approach is mostly used in secondary and tertiary prevention and is used for treatment or reintegration of the individual worker.

**Methods.** A working group was formed with representatives from all seven participating professions and came together four times. The working group defined the topics that needed to be addressed by the guideline. Where possible, the guideline was based on scientific literature. In case of no (or insufficient) scientific evidence, an expert opinion was formulated by the working group. The concept guideline was reviewed by experts in the field and adjusted to their comments, which resulted in the final guideline. This whole process was supervised by a steering committee.

For the implementation of the guideline, authorization will be arranged by the participating professional associations. Furthermore, training, tailored to the specific professions, will be developed and piloted in the field and offered to professionals through existing educational structures.

**Results.** We successfully developed a multidisciplinary guideline on a participatory approach at in the workplace.

**Discussion.** Currently, this guideline has been implemented in practice by arranging authorization and training in the field.

SYMPOSIUM 11, TUESDAY, JUNE 21, 10:30AM TO 12:00 PM, ROOM 202A

## Technical field measurements of sedentary work and occupational physical demands: a PEROSH-initiative (Part 1)

**Chair: Andreas Holtermann, Professor, Physical Workload and Musculoskeletal Disorders, National Research Centre for the Working Environment, Copenhagen, Denmark**

Sedentary work and physical work demands are generally acknowledged to be primary risk factors for musculoskeletal disorders (MSDs). Exposure assessments in this area have, to a large extent, been based on self-reported information or observations that may be imprecise and potentially biased. This means that the existing knowledge, recommendations and legislation for preventing MSDs may not be optimal or, in the worst case, incorrect. Therefore, there is a great need for technical field measurements that are capable of providing valid information about sedentary work and occupational physical demands.

However, extensive knowledge exchange, discussions and research are required before consensus on technical field measurements of sedentary work and occupational physical demands can be accomplished. The aim of this symposium (the first of two on this subject) is to present and discuss aspects like validity, feasibility, analyses and the future use of various technical field measurements of sedentary work and occupational physical demands. This symposium, the first of two on the subject, is based on a PEROSH-initiative of 11 work-environment research institutes to develop recommendations for procedures on technical field measurements of sedentary work and occupational physical demands.

## Validation and calibration of questionnaire-based sitting time: an accelerometer-based study among blue collar workers

Nidhi Gupta, Caroline Stordal Christiansen, Christiana Hanisch, Hans Bay, Hermann Burr, Andreas Holtermann (presenter)

**Background.** Questionnaire-based sitting time may be susceptible to systematic errors, and methods for improving them are requested. Thus, we aimed to (1) investigate the differences between questionnaire and accelerometer-based sitting time, and (2) develop and evaluate a prediction model for improving the accuracy of questionnaire-based sitting time.

**Methods.** 183 blue-collar workers reported sitting time per day by questionnaire and wore two accelerometers for one to four days to determine their sitting time per day. Least squares linear regression models were developed to predict accelerometer-based sitting time from questionnaire-based sitting time and other self-reported individual and work-related predictors.

**Results.** Questionnaire and accelerometer-based average sitting time were ~272 and ~476 minutes/day, respectively. A low Person correlation ( $r=0.32$ ), high mean bias (204.1min) and wide limits of agreement (549.8 to -139.7min) between questionnaire and accelerometer measured sitting time were found. The prediction model based on questionnaire-based sitting only explained 10% of the variance in accelerometer-based sitting time. Inclusion of body mass index, smoking status, gender, rating of perceived exertion, influence at work, slow and fast walking duration, low-back pain and dietary patterns in the model increased the explained variance to 41%, with 10% optimism using a resampling bootstrap validation. Based on a split validation analysis, the developed prediction model on ~75% of the workers ( $n=132$ ) reduced the mean and the standard deviation of the difference between questionnaire and accelerometer-based sitting time by 64% and 42%, respectively, in the remaining 25% of the workers.

**Discussion.** This study indicates that questionnaire-based sitting time is inaccurate and that a prediction model can materially improve its precision.

## Classification of wearables for occupational physical activity measurements

Britta Weber (presenter), Rolf Ellegast, Anika Weber, Vera Schellewald, Ulrich Hartmann

**Background.** Various studies show an adverse relationship between long-lasting physical inactivity and musculoskeletal disorders and cardiovascular diseases. To evaluate potential risks, the knowledge of physical activity (PA) parameters such as sitting time, physical activity intensity (PAI), heart rate, steps etc. is required. Over the last several years, the number of commercially available wearables has increased. The aim of this study was to identify wearables that may be suitable for quantifying PA at workplaces and to develop a level scheme for classifying wearables.

**Methods.** An internet-based search on available wearables was carried out and the result was stepwise selected. In the first step, all wearables were excluded that didn't meet the criteria "available for order," "wearable in work environments" and "continuous PA parameter output with time resolution  $\geq$  min-1." In the second step, selection was refined according to the criteria: "autonomous application for several days," "wearing comfort," "data accessibility" and "cost-benefit ratio." Afterwards, a level scheme for classifying wearables in terms of effort, complexity and accuracy was developed. Finally the scheme was completed by accurate scientific PA measurement systems as reference systems.

**Results.** A total of 250 wearables were found; 10/five of them remained after the first/second selection. The selected wearables were classified into two levels. Level 1 included small commercial systems that are easy to mount at one body part (e.g. wrist, hip, ankle) with very high wearing comfort. Level 2 comprises commercial functional wear that operates with more complex sensors but with high wearing comfort. The added level 3 contained scientific systems to provide accurate PA measurements with sensors covering several body parts.

**Discussion.** The level scheme provides a good assignment of wearables to quantify PA depending on the respective application. Since studies on validity of level 1 and level 2 wearables are needed, accuracy testing against level 3 systems is planned.

## Practical objective measurements for sedentary time and body postures using Excel and iOS

Mikael Forsman (presenter), Liyun Yang, Carl Lind

**Background.** Work environment authorities and occupational health services request cost-effective, objective and scientifically based methods for risk assessments. Until now, technical measurements have been considered to be too time-consuming. The purpose of the study was to develop and test new user-friendly methods for technical measurements of postures and movements during work — specifically percentage of sedentary time and postures of trunk and upper arms.

**Methods.** This effort resulted in three methods. Two easy-to-use methods were developed with a small inexpensive accelerometer (with an integrated USB-memory) and new programs in Excel. In the first, the accelerometer is attached to the thigh. After one-workday measurement, and after clicking on the recorded file on the USB-memory, the result (e.g. the time percentage of the work-day in sedentary posture) is directly shown in Excel. Similarly, in the second, the accelerometer is attached to the upper arm at the insertion of deltoid. A measurement is started with the arm by hanging down in a zero-degree inclination. After the measurement, parameters of angles are shown in Excel. For the third method, an “even easier” iPhone/iPod Touch app was developed (App Store: ErgoArmMeter). The iPhone is attached to the upper arm with a training armband. The arm is first allowed to hang straight down while the app is calibrated for zero degrees, then the user is able to start and stop a measurement. After the measurement, the app shows parameters of angles and angular velocities.

**Results.** The methods were validated by comparison to an optical measurement method. The methods proved to be comparable with research methods, and are easier to use and easier for the participants to carry compared to previous research methods.

**Discussion.** In view of their usability and low cost, these methods are expected to become attractive for risk assessments of tasks and the prioritization of interventions. As well, these methods may be useful for evaluating implemented changes and reducing high exposures to sedentary work, and assessing postures and movements of upper arms.

SYMPOSIUM 12, TUESDAY, JUNE 21, 1:30PM – 3:00PM, BALLROOM B

## Biomechanics of the upper extremities during mobile IT work (Part 2): smartphone use II

**Chair: Pascal Madeleine, Professor, Department of Health Science and Technology, Aalborg University, Aalborg, Denmark**

Information technology (IT) work is nowadays often performed in mobile environments. One key reason for this is the increasing use of multi-touch, hand-held devices (smartphones). However, prolonged use of smartphones in our daily lives is associated with physical risk factors that may lead to the development of musculoskeletal disorders in the upper extremities. This symposium, the second of four on the subject of mobile IT work, gathers a group of international experts to share their latest research findings on the effects of smartphone use on the biomechanics of the upper extremities. A round table will take place at the end of the symposium.

## Smartphone usage pattern and its biomechanical impact on the cervical spine and shoulder

Gwanseob Shin (presenter), Sojeong Lee

**Background.** The rapid growth of smartphone use has also produced growing ergonomic concerns about “text neck” syndrome. Text neck refers to pain symptoms on the neck and neighbouring body regions caused by the prolonged or frequent looking-down posture of mobile device users. Although the association between smartphone use and the occurrence of text neck syndrome has been generally accepted, sufficient scientific evidence that implies a dose-response relationship between them is lacking. The main objective of this study, therefore, was to quantitatively determine the nature of this relationship by evaluating changes in tissue properties of the neck and shoulder musculature associated with the pattern of smartphone use.

**Methods.** Smartphone usage pattern (time and duration of each app) and head flexion angle data were simultaneously collected using a usage tracking app and a wearable inertial sensor during an eight-hour period of a typical work day. In addition, increments in the stiffness of shoulder and neck muscles and the amount of anterior shift of natural head posture after the eight-hour period were quantified.

**Results.** Data from 30 asymptomatic smartphone users showed that those who used their smartphone for longer intervals during the eight-hour period maintained a looking-down posture more often and longer, and they also showed greater increase in stiffness of neck and shoulder muscles after the eight-hour period.

**Discussion.** Results of this study suggest positive association between the intensity of smartphone use and the risk of text neck syndrome, and imply the importance of proper ergonomic interventions for preventing “text neck” in smartphone users.

## Mechanisms of motor control during smartphone texting contributing to neck pain

Grace Szeto (presenter), Yanfei Xie

**Background.** Multi-touch smartphones have rapidly become a powerful communication tool common in our daily lives. This study aimed to examine the muscle activity and neck kinematics comparing one-handed versus two-handed texting tasks in those with chronic neck pain compared with healthy controls.

**Method.** Participants were assigned to case or control groups (mean age=23.9±3.2, n=20 each). Surface electromyography (sEMG) and 3D motion were recorded in the cervical and shoulder areas during 10 minutes of texting using the same smartphone device (iPhone 4). The order of texting with one or both hands was randomized.

**Results.** Median muscle activity in the upper trapezius (UT) and cervical erector spinae bilaterally were consistently increased during both texting tasks in the case group compared to the control group. In terms of spinal posture, there was no apparent difference in cervical spine flexion angle between the two groups, but the case group showed increased rotation range during texting with both hands. There was a trend of group difference in thoracic flexion in bilateral texting. In texting with one hand, there was no apparent difference in cervical and thoracic spine posture between groups.

**Discussion.** Our previous research on office workers using desktop computers demonstrated increased activity in cervical postural muscles and increased forward head postural angles as part of the mal-adaptive motor control mechanisms that contribute to musculoskeletal disorders. People who use computers at work and then continue to use mobile devices after work would be most susceptible to developing such motor control malfunctions and aggravating their symptoms.

## Biomechanical exposures, typing productivity, subjective comfort and usability during touchscreen, virtual keyboard use

Jeong Ho Kim, Peter Johnson (presenter)

**Background.** Despite the influx of the touchscreen virtual keyboard on tablets, little information is available on biomechanical exposures associated with different sized, virtual keyboard interfaces. Therefore, we investigated whether or not there were differences in typing biomechanics and usability between conventional physical keyboards and touchscreen virtual keyboards and if different virtual keyboard key sizes affected biomechanical exposures, comfort and productivity.

**Methods.** In a repeated-measured design with 19 subjects, typing force, finger/shoulder electromyography (EMG), subjective comfort and typing productivity were collected during typing on a virtual, notebook and desktop keyboard. In a separate study with 21 subjects, typing force, finger/shoulder muscle activity, wrist posture, subjective comfort and typing performance were compared across four different virtual keyboard key sizes (13, 16, 19, 22mm square keys with 2mm between-key spacing).

**Results.** The virtual keyboard had lower typing force ( $p < 0.0001$ ) and finger muscle EMG ( $p < 0.05$ ) as compared to the conventional, tactile notebook and desktop keyboards. However, typing on the virtual keyboard resulted in a significant reduction in typing speed and subjective comfort ( $p < 0.0001$ ) and slightly increased shoulder muscle EMG. While the virtual keyboard key sizes did not affect typing force, finger muscle EMG and ulnar deviation, the smallest (13mm) keys reduced typing speed ( $p < 0.0001$ ) and subjective comfort ( $p < 0.0001$ ) and increased shoulder muscle EMG ( $p < 0.10$ ).

**Discussion.** The study findings indicated that conventional keyboards may be more suitable when engaging in long typing sessions where higher typing productivity is required; however, when typing productivity is not at a premium, the virtual keyboard with 16mm (or larger) keys is a suitable interface. Furthermore, a virtual keyboard with key sizes less than 13mm may be less suitable for touch typing due to the lower productivity, reduced comfort, and higher static loading in the shoulder muscles.

SYMPOSIUM 13, TUESDAY, JUNE 21, 1:30PM – 3:00PM, ROOM 201A

## The design, development and use of digital tools for MSD Prevention

**Chair: Dwayne Van Eerd, Associate Scientist, Institute for Work & Health, Toronto, Canada**

Workplaces and practitioners alike are faced with the challenge of prioritizing limited resources for interventions and making investments that will have the highest impact on preventing musculoskeletal disorders (MSDs). Digital tools are showing promise as a means of providing strategic guidance to workplace stakeholders and of building internal capacity “on the ground” without direct involvement. These types of tools are appealing because they not only have the potential for a global reach — and, therefore, a very high impact — but may also become an invaluable source of real-time data for organizations, practitioners, governments and researchers. Symposium presenters will highlight challenges and successes and discuss future directions for work in the development of digital health and safety tools.

## eOffice Ergo: development of an e-learning course

Dwayne Van Eerd (presenter), Benjamin Amick, Trevor King, Mathew Kennedy

**Background.** Office workers may be at risk for MSDs and reduced productivity due to sub-optimal computer workstation set up. Often, the changes required to achieve optimal workstations are relatively straightforward and can be made by workers with appropriate training. In-person training (IPT) is considered time and cost intensive. E-learning can be delivered quickly with minimal cost. It is important for training to be as up-to-date as possible with science and standards (CSA, ANSI). The presentation objective is to describe the development and testing of an eLearning for office ergonomics.

**Methods.** The e-learning was developed using instructional design theory. A pilot evaluation of the Beta version of the e-learning included focus group testing among two sets of office workers (6-8 participants per group) and usability testing. A more in-depth evaluation of effectiveness was undertaken in a controlled field trial in a variety of workplaces from various sectors in Ontario. Data from pilot and field trials were used in subsequent development steps.

**Results.** Beta version 1.0 focus group feedback identified navigation changes, the need for a glossary and content limits. Usability testing identified timing issues, user evaluation challenges, and screen resolution improvements. The pilot evaluation revealed statistically significant changes in knowledge, self-efficacy, work postures, workstation configuration and adjustments and symptoms. Beta version 2.0 was created based on an expert advisory panel's recommendations and feedback from study participants. Results from a large field trial revealed that IPT and E-learning performed similarly on all outcomes measured. The final version is available and has been downloaded 4,800 times to date.

**Discussion.** We describe the development steps, testing and characteristics of an E-learning for computer workers. The E-learning shows promise as an effective and cost-effective method of reducing the common hazards of computer work. Future research will explore the effectiveness of "enhancing" the E-learning with short IPT modules.

## Can we flip the classroom in occupational health? A case study related to workforce aging

Ken Scott (presenter)

**Background.** The world of education, like other sectors, is being disrupted by technology. In a “flipped classroom,” students view online lectures outside of the classroom and later apply concepts during classroom exercises under the guidance of an instructor. Whether this approach can be applied in the context of an occupational health training program is yet to be determined. Despite widespread awareness that workforce aging will impact business practices in the near future, very few organizations are currently taking meaningful steps to prepare for the aging of the workforce.

**Methods.** A two-day workshop titled “Designing the Age Friendly Workplace” was developed at the University of Washington to help organizations design age-friendly workplaces, focusing on three domains: ergonomics and the physical work environment, health promotion and work-life balance. The workshop was designed to educate organizations on the underlying issues, identify strategies to prepare and plan ahead by developing a tailored action plan. This presentation will describe the process whereby the original two-day workshop was adapted to an online format, as well as the ongoing evaluation of our efforts.

**Results.** As of November 2015, the online materials have registered 1,881 YouTube views in 25 countries, equating to approximately 65 hours of watch time. With 710 views, the most popular module, titled “Universal Design Principles,” offers a description of seven principles designers can follow to prevent disability associated with musculoskeletal disorders.

**Discussion.** Whether or not the occupational health classroom can (or should) be flipped is something occupational health practitioners and researchers will need to carefully consider as the educational environment is increasingly broadcast online. The capacity to reach far beyond geographic and political borders offers profound promise. That same distance, however, raises important questions about evaluation and impact.

## Evaluation of Oculus Rift as a tool for ergonomics assessments within Siemens Jack

Michael Sonne (presenter), Michael Rizzuto, Nicolas Vignais, Peter Keir

**Background.** A rapidly updated view of a virtual workspace from the perspective of a digital human model can be streamed to a head-mounted display to immerse a worker in the virtual workspace. However, virtual reality systems are expensive and operate under the assumption that movements in the virtual workspace represent real-world actions. The purpose of this study was to assess the efficacy and feasibility of using the Oculus Rift with commonly used motion capture, and virtual ergonomic tools (Siemens Jack), to simulate real-world occupational tasks.

**Methods.** Participants performed a simple pointing task under three conditions: (1) real environment with auditory point stimulus (REA); (2) virtual environment with auditory stimulus (VEA); and, (3) virtual environment with visual stimulus (VEV). End-point error, movement time and peak fingertip velocity were calculated for each discrete point event. Wrist, elbow and shoulder joint angles were calculated at peak acceleration, peak velocity, peak deceleration and end-state for each point.

**Discussion.** There was significantly greater end-state pointing error in both virtual conditions. Peak pointing velocity was significantly slower and movement time was significantly longer during virtual conditions. Joint angles did not significantly differ between real and virtual conditions at all phases of each pointing motion. While there was more error in the pointing task in both virtual environment tasks, joint angles did not differ significantly from the real environment. Thus, Oculus Rift, or other low-cost virtual reality systems, may be useful for examining hand clearances or postural assessments within Siemens Jack. The visual pointing stimulus did not appear to influence strategies or performance. These data support the concept of posture-based ergonomic assessments using virtual reality task simulations with products like Oculus Rift and Siemens Jack.

## Designing mobile apps for the workplace: building capacity and big data

Curtis Vandergriendt, Michael Sonne (presenter)

**Background.** The Occupational Health Clinics for Ontario Workers (OHCOW) has recently increased its focus on creating digital tools and products, particularly mobile apps, to maximize its impact on promoting ergonomics and MSD prevention with resource constraints. One initiative was the design of a work-related pain mobile app to engage workplaces at the worker level to initiate ergonomic improvements. It was important to have a user-centred design.

**Methods.** OHCOW partnered with the Canadian Centre for Occupational Health & Safety (CCOHS) to provide software development and graphic design resources. There was a tight timeline for up-front design work in order to meet scheduling and funding requirements. A process was used to quickly generate ideas, test hypotheses and make iterative improvements to the design before investing expensive software development time. The user-testing process that was used in this project was able to quickly identify usability problems and opportunities for iterative improvements.

**Results.** PainPoint was released in October as part of Global Ergonomics Month. The app has been well received and promoted by the Ministry of Labour in Ontario. Over 400 users were recorded in the first month of release, including over 37,000 individual screen views and an average time in-app of two minutes. Current downloads and other user engagement analytics will be shared.

**Conclusion.** The use of a mobile app is showing promise as a means to engage workplaces on ergonomic efforts on a large scale. Further effort is needed to evaluate the effectiveness and impact of the app itself based on workplace outcomes. Further work is in progress to expand the capabilities and scope of PainPoint use to include aggregate data analytics. The collection and use of this type of data provides unique opportunities for real-time reporting of discomfort and exposure trends that could be used as leading indicators for organizations, practitioners, governments and researchers.

SYMPOSIUM 14, TUESDAY, JUNE 21, 1:30PM – 3:00PM, ROOM 202A

## Technical field measurements of sedentary work and occupational physical demands: a PEROSH-initiative (Part 2)

**Chair: Andreas Holtermann, Professor, Physical Workload and Musculoskeletal Disorders, National Research Centre for the Working Environment, Copenhagen, Denmark**

Sedentary work and physical work demands are generally acknowledged to be primary risk factors for musculoskeletal disorders (MSDs). Exposure assessments in this area have, to a large extent, been based on self-reported information or observations that may be imprecise and potentially biased. This means that the existing knowledge, recommendations and legislation for preventing MSDs may not be optimal or, in the worst case, incorrect. Therefore, there is a great need for technical field measurements that are capable of providing valid information about sedentary work and occupational physical demands.

However, extensive knowledge exchange, discussions and research are required before consensus on technical field measurements of sedentary work and occupational physical demands can be accomplished. The aim of this symposium (the second of two on this subject) is to present and discuss aspects like validity, feasibility, analyses and the future use of various technical field measurements of sedentary work and occupational physical demands. This symposium, the first of two on the subject, is based on a PEROSH-initiative of 11 work-environment research institutes to develop recommendations for procedures on technical field measurements of sedentary work and occupational physical demands.

## How to objectively measure lifting burden in the field on many participants: results and experience from use of pressure-measurement insoles in a field study

Markus Koch (presenter), Lars-Kristian Lunde, Mikael Forsman, Stein Knardahl, Kaj Bo Veiersted

**Background.** High mechanical exposures at work have been associated with musculoskeletal disorders (MSDs). In the construction and health-care sectors, these exposures are common. Thus, it is of significant interest to investigate the extent to which aspects and levels of mechanical exposures are associated with the development of MSDs. However, self-reported work exposures may be inadequate to the task of providing precise measures. Therefore, studies using valid objective measurements of mechanical exposures should be included in this investigation.

**Methods.** Vertical ground reaction forces were assessed in 65 construction and 62 health-care workers by using pressure-measurement insoles in the shoes of the participants over a complete working day. Additionally, the participants were followed by a researcher, observing various mechanical exposures (manual material handling, postures and movements). Vertical ground reaction forces were calculated using the raw data from the insoles and custom calculation algorithms.

**Results.** The pressure-measurement insoles were tested for validity and reliability in field measurements. Average root mean square errors compared to real forces ranged from 6.6% to 17.7%. Larger errors occurred in situations with strongly bended insoles, and a creeping of forces could be observed during static exposures and long time measurements. With custom calculation algorithms, these errors were rectified. It was found that the insoles during the 127 measurements were applicable, durable and damage free. Participants reported no restrictions due the use of the insoles. Data are currently being analyzed and results will be ready spring 2016.

**Discussion.** The validity and reliability of the pressure-measurement insoles for field use were assessed as acceptable. The insoles are a cost-effective method for measuring vertical forces at a work site. Objectively measured ground reaction forces at work will increase the knowledge about the association of exerted forces and MSDs.

## Development of a CTS risk-assessment method for manual working processes based on technical measurements

Ulrike Hoehne-Hueckstaedt (presenter), Ulrich Glitsch, Dirk Marcel Ditchen, Rolf Peter Ellegast

**Background.** Manual working processes involving repetition and significant grip forces constitute risk for musculoskeletal disorders (MSDs) of the upper limb, e.g. carpal tunnel syndrome (CTS). Although there are several observational methods for risk assessment, objective and quantitative information on overall exposure is scarce. However, this information is needed to define thresholds both for single and combined risk factors. Therefore, this study was launched to develop an assessment method based on kinematic and physiological field measurements.

**Methods.** Relevant measurement parameters for awkward postures of the upper extremities, repetitiveness and level of grip forces — as well as suitable assessment methods — were identified from the literature. From these, a measurement setup combining kinematics and electrical muscular activity by using accelerometers, gyroscopes and potentiometers (CUELA) and surface electromyography was developed, tested and applied in field measurements including 73 different occupational tasks. A new assessment method was developed by merging different methods from the literature to combine the comprehensive measured risk parameters.

**Results.** The approach consists of a traffic-light orientated assessment for awkward postures (angle categories), grip forces (percentage maximum voluntary contraction) and repetitiveness (angular velocity, frequency and micropauses). For the latter, we developed a “conversion method” to make these results comparable to those from observational methods like hand activity level (HAL, ACGIH, 2001). The objective and quantitative measurements of workload factors are used to build up a data base for exposure on task level (task exposure matrix).

**Conclusion.** Technical measurement and the combined assessment of various risk factors contribute to a better understanding of the impact of manual working processes, to the improvement of risk assessment and to the ability to effectively tackle work-related musculoskeletal upper limb disorders, such as CTS.

## Sample size and statistical performance in studies of sedentary behaviour: a novel approach based on compositional data analysis

Svend Erik Mathiassen (presenter)

**Background.** Sedentary behaviour studies often describe the extent of sitting by a time proportion; typically per cent time spent sitting. Proportions are examples of so-called “compositional data,” since they add up to a constrained sum (i.e. 100%). Compositional data differ from non-compositional data in aspects of essential importance to their analysis and interpretation, including how to address variability. Compositional data analysis (CDA) acts in a space of logarithmically transformed ratios of proportions, rather than on the proportions *per se*. We compared the statistical properties of confidence intervals (CI) of group mean values of sitting-time proportions obtained using standard procedures and CDA, exemplified by sample sizes required to obtain a specified precision.

**Methods.** Sitting and non-sitting time proportions calculated from whole-day accelerometer recordings in 25 office workers were used as a heuristic example. Variability between subjects was assessed using standard statistics and CDA. In both cases, the size and shape of a 95% CI on the estimated mean sitting-time proportion of  $n$  subjects was assessed for different sizes of the mean and values of  $n$ .

**Results.** While standard CIs at a specific  $n$  are independent of the mean value and symmetric, CDA-derived CIs are asymmetric, except at a mean of 50%, and wider at “medium” than at “extreme” mean values. In the example, a 95% CI of  $\pm 5\%$  around the mean was obtained using  $n=26$  subjects according to standard procedures. However, using CDA, upper 95% CI limits of  $+5\%$  were obtained with  $n=5$  for a mean value of 90%, but required  $n=58$  when the mean value was 60%. Similar-sized lower 95% CI limits of  $-5\%$  were obtained with  $n=13$  and  $n=63$  at 90% and 60% means, respectively.

**Discussion.** CDA-based estimates of sample sizes differed markedly from estimates based on standard statistics. Properties and implications of CDA in sedentary behaviour research deserve further consideration.

SYMPOSIUM 15, TUESDAY, JUNE 21, 1:30PM – 3:00PM, ROOM 202B

## Workplace interventions for sedentary work (Part 1)

**Chair: Veerle Hermans, Professor and Department Head of Ergonomics at IDEWE, Vrije Universiteit Brussel, Brussels, Belgium**

Recent research mentions the relationship between increased sitting time at work and increased risks of cardiovascular disease, obesity, diabetes and even mortality. Therefore, employees are encouraged to change their sitting behavior. A lot of new devices or workstation alternatives are coming into the market: sit-stand tables, desk bikes, walking stations, etc. This symposium, the first of two on this subject, addresses the effectiveness and feasibility of these interventions with respect to several aspects: sitting time, postural and physiological effects, musculoskeletal health, physical fitness and productivity.

## Are workplace interventions for reducing sitting at work effective?

Nipun Shrestha, Veerle Hermans (presenter), Katriina Kukkonen Harjula, Sharee Ijaz, Soumyadeep Bhaumik

**Background.** The number of people working while seated at a desk keeps increasing worldwide. This has contributed to increased cardiovascular disease, obesity and diabetes. Therefore, reducing and breaking up time that people spend sitting while at work is important for health. This study was conducted to evaluate the effects of workplace interventions to reduce sitting at work compared to no intervention or alternative interventions.

**Methods.** We conducted electronic searches of MEDLINE, CENTRAL, CINAHL, OSH UPDATE, Embase, PsycINFO, Clinical trials.gov and WHO search trial portal. We included RCTs, cluster-RCTs, quasi-RCTs and controlled before-and-after studies. Two review authors independently screened studies for eligibility and completed data extraction and risk of bias assessment.

**Results.** We found very low quality evidence (based on three studies) that the introduction of sit-stand desks reduced workplace sitting. When combined with information and counselling, sit-stand desks decreased sitting at work on average by 113 minutes per eight-hour workday. Introducing walking strategies had no considerable effect.

One study found that guideline-based counselling by occupational physicians reduced sitting time at work by 28 minutes. However, reduction in total sitting time was non-significant.

There was an inconsistent effect of computer prompting on workplace sitting. One study reported a non-significant decrease of 18 minutes per work day at 10 days' follow up, and another study reported a significant reduction of 55 minutes per day at three months' follow up. Mindfulness training induced a non-significant reduction in workplace sitting time at both six and 12 months' follow up.

We are currently updating this review and results will be ready before conference date. We have found an additional nine RCTs.

**Discussion.** There is very low quality evidence that sit-stand desks can reduce sitting time at work, but the effects of policy changes and information and counselling are inconsistent. There are many ongoing trials, and this might change these conclusions in near future.

## Office work: the ergonomic pitfalls of today's "trendy" offices

Veerle Hermans (presenter), Liesbeth Daenen

**Background.** The introduction of the symposium "workplace interventions for sedentary work" focuses on the new world of working in offices nowadays. Offices look very attractive: design furniture, trendy colours, fancy lighting, integration of art and some ecologic details. In addition, offices are linked to the new way of working: flex work, shared offices, etc. Do these trendy offices really increase wellbeing at work? Some ergonomic pitfalls:

### 1/ Goodbye to classic ergonomics?

New office environments are likely to forget the classic rules of ergonomics. A trendy chair fits at a reception, a coffee corner or a short brainstorming meeting place, rather than at an office desk. To avoid even more physical complaints in office workers, the basic ergonomic rules need to be considered.

### 2/ Technology nerds

Since 1995, the number of laptops in companies increased tremendously. Studies examining awkward postures followed soon. After that, tablets and smartphones came and so, too, did posture problems.

### 3/Paradox of the two Cs: concentration and communication

Communication has increased a lot due to the arrival of the shared office, which is positive for team work. However, communication can disturb office workers when concentration tasks have to be performed.

### 4/ And last but not least ... sedentarism

Extended sitting time at work increases the risk of cardiovascular disease, obesity and diabetes. Therefore, employees should be encouraged to change their sitting behaviour. Workers are advised to replace sitting by performing light to moderate physical activities. Possibilities include adjustments in the workplace environment and design, or changes in the office desk design (e.g. sit-stand tables, ergobikes, treadmill desks). A lot of new devices have come into the market. This presentation will focus on the effectiveness of alternative workstations.

## Effects of occupational standing on musculoskeletal outcomes: a systematic review

Pieter Coenen (presenter), Lisa Willenberg, Joyce Shi, Genevieve Healy, David Dunstan, Leon Straker

**Background.** Exposure to high volumes of workplace standing time has typically been observed in specific occupational groups, such as retail, food service, health care, education and manufacturing. Moreover, the growing awareness of the potential health implications of too much sitting is leading to various initiatives to reduce workplace sitting. Exposure to occupational standing is, therefore, common across occupations and is likely to increase amongst traditionally sedentary occupational groups (e.g. office workers). Although musculoskeletal symptoms, lower limb venous disorders and adverse pre-natal outcomes, have previously been identified as health outcomes of occupational standing, a more rigorous, up-to-date and systematic review of the evidence is needed in light of the changing landscape of workplace environments. The aim of this study was, therefore, to systematically describe the evidence concerning dose-response association of occupational standing and musculoskeletal outcomes.

**Methods.** A systematic search for literature was conducted in several online databases using search terms in relation to “standing” and “work-related.” Two reviewers independently screened identified records and selected original research papers written in English that addressed general health effects of occupational standing.

**Results.** The search for literature yielded a total of 11,750 individual records. A total of 218 research papers were selected that met the inclusion criteria, with 122 of them having musculoskeletal disorders as the primary outcome. Among other outcomes, these studies described the effects of occupational standing on low-back pain, lower limb pain, neck/shoulder pain and specific musculoskeletal disorders such as osteoarthritis and reduced bone mineral density.

**Discussion.** The current systematic review describes the association of occupational standing with musculoskeletal outcomes. This information will inform the growing need for quality data on health outcomes of occupational standing that can be used to guide occupational safety and health research and practice.

## Objectively measured total and occupational sedentary time in three work settings

Allard van der Beek (presenter), Paula van Dommelen, Jennifer Coffeng, Hidde van der Ploeg, Cécile Boot, Ingrid Hendriksen

**Background.** Sedentary behaviour increases the risk for morbidity. Our primary aim was to determine the proportion and factors associated with objectively measured total and occupational sedentary time in three work settings. Secondary aim was to study the proportion of physical activity and prolonged sedentary bouts.

**Methods.** Data were obtained using ActiGraph accelerometers from employees of: (1) a financial service provider (n=49 men, 31 women), (2) two research institutes (n=30 men, 57 women) and (3) a construction company (n=38 men). Total sedentary time over the whole day and occupational sedentary time, physical activity and prolonged sedentary bouts (lasting  $\geq 30$  minutes) were calculated by work setting. Linear regression analyses were performed to examine general, health and work-related factors associated with sedentary time.

**Results.** Employees of the financial service provider and the research institutes spent 76-80% of their occupational time in sedentary behavior, 18-20% in light intensity physical activity, and 3-5% in moderate-to-vigorous intensity physical activity. Occupational time in prolonged sedentary bouts was 27-30%. Total time over the whole day was less sedentary (64-70%), and had more light intensity physical activity (26-33%). The employees of the construction company spent 44% of their occupational time in sedentary behavior, 49% in light, and 7% in moderate intensity physical activity, and spent 7% in sedentary bouts. Total time over the whole day spent in sedentary behavior was 56%, 40% in light, and 4% in moderate intensity physical behavior, and 12% in sedentary bouts. For women, low to intermediate education was the only factor that was negatively associated with occupational sedentary time.

**Discussion.** Sedentary behaviour is high among white-collar employees, especially in highly educated women. A relatively small proportion of sedentary time was accrued in sedentary bouts. It is recommended that worksite health promotion efforts should focus on reducing sedentary behavior through improving light intensity physical activity.

SYMPOSIUM 16, TUESDAY, JUNE 21, 1:30PM – 3:00 PM, ROOM 203A

## New methods for assessing risks for upper extremity MSDs (Part I)

**Chair: Carisa Harris Adamson, Director, Ergonomics Program, Center for Occupational and Environmental Health, University of California, Richmond, Calif., U.S.A.**

This symposium is the first of a two-part series on recent methods used to assess risk for occupational musculoskeletal disorders (MSDs) of the upper extremity. This symposium will begin with a presentation showing how the ACGIH TLV for Hand Activity Levels (TLV-HAL) is an effective tool for assessing risk for carpal tunnel syndrome (CTS) with reference to a large cohort study of Italian workers. Next, three different ways of calculating the TLV-HAL will be presented and variations in risk scores will be contrasted. Considerations on how to apply the various TLV-HAL methods will be discussed. Given the multifactorial nature of upper extremity MSDs, statistical techniques are often needed to fully understand how biomechanical, psychosocial and personal factors interact. The risk of shoulder disorders from psychosocial and biomechanical exposures will be presented using a structural equation models approach, followed by a discussion on how the associations between biomechanical and psychosocial risk factors for CTS are modified by personal and other physical factors. The symposium will end with a discussion on how job rotation is used to mitigate risk factors associated with upper extremity MSDs and, yet, how often attempts at mitigation fail because the risk does not change.

## Threshold limit value for biomechanical risk factors (ACGIH-TLV®): a cohort study on carpal tunnel syndrome in manual workers

Roberta Bonfiglioli (presenter), Stefano Mattioli, Andrea Farioli, Francesca Graziosi, Francesco Marinelli, Stefania Curti, Thomas J Armstrong, Francesco S Violante

**Background.** We applied the American Conference of Governmental Industrial Hygienists (ACGIH-TLV®) method to assess the role of repetition (hand activity level – HAL) and manual force (normalized peak force – PF) in the development of carpal tunnel syndrome (CTS).

**Methods.** Between 2000 and 2011, we followed a dynamic cohort of industrial workers and employees of nursery schools. CTS was diagnosed based on symptoms and nerve conduction studies. At first, we investigated the association between CTS and the values of HAL and PF categorized into tertiles. We then classified subjects with respect to action limit (AL) and threshold limit values (TLV). Cox regression models including age, gender, body mass index, and presence of predisposing pathologies were conducted to estimate hazard ratios of CTS. Population attributable fractions of CTS were estimated through maximum likelihood methods.

**Results.** We analyzed data from 3,131 workers (females=2032 [35.1%]; mean age at the baseline=37.9 years [SD 9.5]) with available information on at least two assessments. We observed 126 cases of CTS symptoms in 8,883 person-years (incidence rate 1.4, 95%CI 1.2–1.7). When modelling separately HAL and PF, both variables showed signs of association with CTS incidence (HAL: III tertile compared to I tertile, HR 1.77 [95%CI 1.04–3.01]; PF III tertile compared to I tertile, HR 1.70 [95%CI 1.09–2.69]). The ACGIH TLV® classification predicted the incidence of CTS (HR between AL and TLV 1.92 [95% CI 1.36–2.70]; above TLV 1.94 [95% CI 1.26–3.00]; p trend <0.001) and 28.0% of CTS cases in our study population were attributable to exposure levels above the AL.

**Discussion.** Biomechanical exposure is an important determinant of CTS risk. The ACGIH TLV® method predicted the risk of the disease, but the dose response was flat above the AL. Both HAL and PF levels were associated with the outcome.

## A comparison of three techniques for quantifying HAL and their impact on the ACGIH TLV for HAL risk predictions

Jay Kapellusch (presenter), Kimberly Dembinski, Callie O'Donnell

**Background.** This study proposed to examine differences between ACGIH TLV for HAL risk predictions using three different techniques to quantify HAL: (1) verbal anchor ratings; (2) table lookup based on frequency and duty cycle of exertion; and (3) Radwin et al (2015) computation using frequency and duty cycle of exertion.

**Methods.** Peak force, verbal anchor HAL, frequency of exertion and duty cycle ratings from 10,244 tasks performed by 1,784 predominantly manufacturing workers were evaluated. Data were obtained for left and right hands separately, and frequency and duty cycle of exertion were provided for all exertions and for “forceful” exertions. Each of the three methods was used to quantify HAL and classify tasks as below action limit (AL), between AL and threshold limit value (TLV) and above TLV.

**Results.** Table lookup and computational HAL ratings were highly correlated ( $r^2 = .852$  for all exertions, and  $.926$  for forceful exertions); verbal anchor HAL ratings were poorly correlated with tabular and computational HAL ratings regardless of whether all or only forceful exertions were used ( $r^2 \leq .647$ ). Across all methods, agreement on below AL classifications ranged from 80% to 99%. There was less agreement for above TLV (16% to 80%) and between AL and TLV (30% to 58%) classifications. In general, computational HAL classified more tasks as below AL (low risk), tabular HAL classified more tasks as between AL and TLV (moderate risk) and verbal anchor HAL resulted in more tasks classified as above TLV (high risk).

**Discussion.** The three techniques for quantifying HAL result in different risk predictions, but there is generally good agreement in identifying tasks that are below the AL. Due to its simplicity, verbal anchor HAL might be most useful if identification of likely low-risk tasks is itself valuable. For consistent classification across all three categories, time-study based computational HAL should be favoured.

## Associations between psychosocial and biomechanical factors and shoulder pain: A structural equation model

Julie Bodin (presenter), Ronan Garlandézec, Jean-François Viel, Nathalie Costet, Alexis Descatha, Natacha Fouquet, Yves Roquelaure

**Background.** The aim of this longitudinal study was to explore the direct and indirect relationships between psychosocial and biomechanical factors and shoulder pain (SP) in French workers.

**Methods.** Between 2002 and 2005, workers (58% men) were included in a French surveillance program. In 2007, they received a follow-up questionnaire. Workers completed questionnaires about musculoskeletal symptoms (Nordic questionnaire), personal factors and occupational factors, including the Job Content Questionnaire. Subjects free from SP at baseline (defined as workers without SP during the preceding seven days with intensity of pain  $\geq 2$  (0-10) and without SP for more than 30 days during the preceding 12 months) were studied (n=853 men and 581 women). The relationships between psychosocial and biomechanical factors at baseline and new onset of SP at follow up were analyzed using structural equation models (SEM) for each gender. Three latent variables were defined: decision latitude (decision authority and skill decision); biomechanical constraints (perceived exertion, arms above shoulder level and arms abducted); and SP (SP during the preceding seven days with intensity of pain  $\geq 2$  and SP for more than 30 days during the preceding 12 months).

**Results.** For men, SP was directly increased by biomechanical constraints (standardized coefficient=0.18,  $p=0.007$ ) and age (0.25,  $p<0.001$ ), job-stress dimensions did not influence SP. However, biomechanical constraints were increased by low decision latitude (0.19,  $p=0.001$ ) and low hierarchical social support (0.11,  $p=0.009$ ) and decreased by age (-0.17,  $p<0.001$ ).

For women, SP was increased by biomechanical factors (0.13,  $p=0.067$ ), age (0.26,  $p<0.001$ ) and BMI (0.16,  $p=0.003$ ). Biomechanical constraints were directly increased by low decision latitude (0.22,  $p=0.003$ ), high psychosocial job demand (0.14,  $p=0.026$ ) and decreased by age (-0.18,  $p<0.001$ ).

**Discussion.** This study showed that psychosocial factors (mainly decision latitude in both genders) influenced biomechanical factors, which in turn influenced SP.

## Effect modification of the association between biomechanical, work psychosocial exposure and carpal tunnel syndrome by personal and biomechanical factors

Carisa Harris Adamson (presenter), Ellen Eisen, Jay Kapellusch, Arun Garg, Kurt Hegmann, Matthew Thiese, Ann Marie Dale, Bradley Evanoff, Stephen Bao, Barbara Silverstein, Fred Gerr, David Rempel

**Background.** This analysis examined how personal factors modify the associations between biomechanical, workplace psychosocial factors and incident dominant-hand carpal tunnel syndrome(CTS).

**Methods.** 1,605 participants, without CTS at enrollment, were followed up to 6.5 years. Demographic information, medical history and workplace psychosocial stress was collected at baseline. Individual workplace biomechanical exposures were collected for each task and combined across the workweek using time-weighted-averaging (TWA) to estimate job-level exposures to the dominant hand. CTS case-criteria was based on median nerve symptoms and electrophysiological testing. Hazard ratios were estimated using Cox proportional hazard models. Stratification was used to assess differences in exposure-response relationships using median splits of the baseline exposure of interest.

**Results.** Women had a higher rate of CTS when exposed to a high Hand-Arm Activity Level (HRHAL= 2.22;95%CI: 1.28-3.85) or high % time forceful hand exertion (HR%time= 2.37;95%CI:1.30-4.31) versus men (HRHAL=1.42, 95%CI:0.77-2.60;HR%time=1.89;95%CI: 0.99-3.63). Workers over 40 years of age had increased rates of CTS when exposed to high peak forces (HR $\geq$ 40yrs=1.77;95%CI:1.04-3.03;HR<40yrs=0.86; 95%CI:0.45-1.67), but younger workers had a higher rate of CTS when exposed to a high per cent time in forceful hand exertion (HR<40yrs=2.75;95%CI:1.34-5.67;HR $\geq$ 40yrs=1.73;95%CI:0.98-3.03). Trends indicated that high psychological demand increased the rate of CTS among those with high biomechanical exposure (HRTLTV-HAL=1.58;95%CI:0.91-2.75) versus low biomechanical exposure (HRTLTV-HAL=1.09;95%CI:0.59-2.03), and that decision latitude was only protective among those with low biomechanical exposure (HRlow=0.65; 95%CI:0.37-1.13; HRhigh=1.21;95%CI: 0.62-2.37).

**Discussion.** The exposure-response relationship between biomechanical exposures and CTS differ by age and gender. Older individuals appear to have a higher rate of CTS when exposed to high peak force but a lower rate when exposed to high repetition. Trends indicate that high psychological demand further increased the rate of CTS among those with jobs having high biomechanical exposure, and decision latitude was only protective among those with low biomechanical exposure.

## Job rotation: a failed ergonomics intervention approach?

Stephen Bao (presenter), Jay Kapellusch, Andrew Merryweather, Matthew Thiese, Arun Garg, Kurt Hegmann, Barbara Silverstein

**Background.** Job rotation has been considered to be an administrative ergonomics intervention approach by many academic researchers, industrial practitioners and government entities. While both “successful” and “unsuccessful” reports have been published, many unknowns remain. For example: How is job rotation used in industries? Does job rotation lower biomechanical stressors? How do workers’ perceptions of their jobs change with rotation? We attempted to address these questions through the analysis of a pooled dataset of 1,834 participants from three study cohorts collected in a variety of U.S. workplaces.

**Methods.** Job rotation was defined as performing more than one task in a work shift. Biomechanical variables were quantified from sub-task data collected onsite or analyzed in a laboratory. They included: (1) forceful exertions, (2) repetitions, (3) duration of exertions, and (4) hand/wrist postures. These measures were used to quantify the sub-task biomechanical exposure data, and to quantify task and job-level exposures using several data reduction methods. Psychosocial data were measured based on responses to 10 questions, including job satisfaction and perceived physical and mental exhaustion.

**Results.** In the pooled dataset, 710 workers (or 38.7%) had job rotations. The results suggest that job rotation had significant effects on all biomechanical and most psychosocial measures. Even with job rotation, these workers generally had higher job biomechanical stressors and lower job satisfaction than those without job rotation.

**Discussion.** While job rotation has been widely implemented as an administrative ergonomics intervention to reduce job biomechanical stressors and to improve psychosocial factors, this study’s large dataset was unable to find evidence that job rotation reduced job biomechanical stressors associated with work-related musculoskeletal disorders. This suggests that it may be necessary for practitioners to more carefully plan job rotations so that rotation between jobs is accompanied by appropriately varied physical exposures in order to sufficiently reduce job physical exposures.

SYMPOSIUM 17, TUESDAY, JUNE 21, 3:30PM – 5:00 PM, BALLROOM B

## Biomechanics of the upper extremities during mobile IT work (Part 3): workstations and mobility I

**Chair: Pascal Madeleine, Professor, Department of Health Science and Technology, Aalborg University, Aalborg, Denmark**

Information technology (IT) work is nowadays performed in mobile environments. This mobility can be achieved by using sit-to-stand tables or by incorporating active pauses during IT work to induce more mobility for lower or upper limbs. However, the effects of this added mobility on upper extremity work is still not well described. This symposium, the third of four on the subject of mobile IT work, brings together international experts and speakers to share their latest research findings on the effects of workstations and mobile IT work on the biomechanics of the upper extremities. A round table will be organized at the end of the symposium.

## Modified computer workstations to increase mobility: how do they affect trunk, neck and upper limb patterns?

Julie Côté (presenter), Amanda Farias, Larissa Federowich

**Background.** Prolonged information technology (IT) work is increasingly prevalent in our society, both in work and leisure contexts. However, public health concerns related to health problems associated with a sedentary lifestyle justify efforts to incorporate more mobility in everyday life —including when using IT. Standing and, more recently, walking computer workstations are increasingly popular and have been associated with increased caloric expenditure and user satisfaction. In addition, computer workstation layouts with more than one screen, theoretically inducing more neck movements, are commonplace in both work and leisure settings, and have been associated with increased productivity and user satisfaction. However, little is known about how these more mobile IT workstations affect trunk and upper limb biomechanics.

**Methods.** In Study 1, 20 healthy adults performed a standardized, 90min computer task in three sessions in a seated, standing or walking posture. In Study 2, 27 healthy adults performed a similar computer task either with a laptop or with a dual-monitor setup. Computer work performance and trunk and/or upper limb electromyography (EMG), discomfort and blood flow were measured and analyzed for workstation and time effects.

**Results.** In Study 1, performance (words per minute) was not different for seated and walking work, and was better during standing, as was upper limb comfort. There were no differences in these parameters in Study 2. Generally, trunk and neck/shoulder muscle activity amplitude and functional connectivity were lower and electromyographical variability was higher in standing, walking and dual monitor work. However, none of the modified workstations had any effect on upper limb blood flow.

**Discussion.** Results suggest that in addition to the previously reported advantages of mobile computer workstations, they may also induce somewhat favourable muscle activity patterns, although these do not translate into increasing blood delivery to the upper limbs, at least during a 90min computer task.

## A comparison of upper limb muscle recruitment strategies during a manual task in seated and standing work postures

David Antle (presenter), Julie Côté

**Background.** People working in food processing, service and/or with a computer handle light loads repetitively. Performing these actions from a seated posture may influence upper-limb musculoskeletal disorders, whereas the standing posture may lead to improved upper limb outcomes. In this project, we evaluated standing/seated differences in muscle activity during a light, manual-handling task.

**Methods.** Participants (16) completed a 32-minute manual task in either a seated or a standing posture on separate days. Surface electromyography (EMG) was collected from right lower, middle and upper trapezius (LT, MT, UT) and anterior deltoid (AD). Discomfort data was also collected during the sessions. Differences were analyzed using repeated measures (ANOVAs) with two within-subject factors: posture and time. Changes in discomfort were assessed using Friedman ANOVAs, and a Spearman non-parametric correlation matrix was tabulated for variables showing significant posture and/or time changes.

**Results.** For the MT, UT and AD, there were significant “time x posture” interaction effects ( $p < 0.05$ ), with higher increases of EMG activity (RMS) with time in the seated position. There was also significant effect of posture on upper limb discomfort ( $p = 0.0016$ ), with seated postures having higher reported discomfort. While standing, there was a significant ( $p < 0.05$ ) negative correlation between LT activity and upper limb discomfort ( $r = -0.58$ ). In contrast, while seated, UT ( $r = 0.56$ ), MT ( $r = 0.57$ ) and AD ( $r = 0.61$ ) activity showed significant positive correlations with reported upper limb discomfort.

**Discussion.** These results show that upper limb muscle activity differs between seated and standing work, and that these differences may account for reported discomfort. Taken together, these results confirm the benefits of accomplishing a repetitive upper limb task in a standing position and supports the use of adaptable-height workstations in order to prevent various symptoms, such as upper limb discomfort.

## The impact of a low extra load during active pauses on variability in muscle activation

Nancy St-Onge (presenter), Afshin Samani, Pascal Madeleine

**Background.** Shoulder or neck pain in computer workers is a significant problem. Active pauses have been suggested as an alternative to relaxation during computer work as they may increase variability of muscle activation thereby allowing a change in motor unit recruitment pattern. The objective was to determine which type of active pause versus rest is more efficient in changing muscle activity pattern during a computer task in asymptomatic individuals.

**Methods.** 27 healthy, regular computer users performed a standardized 20-minute computer task consisting of highlighting a sentence using the mouse, clicking on a box and then typing the sentence in the box. The task was completed four times, integrating a different type of pause each time: sub-maximal isometric contraction, dynamic contraction, postural exercise and rest for upper limbs with hands on lap. Pauses occurred every five minutes, lasting eight seconds each time. Surface EMG activity was recorded bilaterally from cervical erector spinae, upper trapezius, middle trapezius, lower trapezius and deltoid anterior. Exposure variation analysis was computed on the computer work after the first pause. RMS was computed on each 5min-work period.

**Results.** Exposure variation analysis revealed more variability for muscles on the right side and less variability for the most superior muscles. However, pause type did not affect variability. RMS was, on the other hand, affected by pause type. In the neck muscles, RMS increased from the first five seconds to the last five seconds of the five-minute work period with rest, whereas it decreased with the isometric pause. Similar results were obtained in the upper and middle trapezius on the right side.

**Discussion.** Contrary to what we hypothesized, the variability of the activation pattern was not affected by pause type during computer work. However, RMS was decreased in response to sub-maximal isometric contraction underlining a lower muscular load.

SYMPOSIUM 18, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 202B

## Workplace interventions for sedentary work (Part 2)

**Chair: Veerle Hermans, Professor and Department Head of Ergonomics at IDEWE, Vrije Universiteit Brussel, Brussels, Belgium**

Recent research mentions the relationship between increased sitting time at work and increased risks of cardiovascular disease, obesity, diabetes and even mortality. Therefore, employees are encouraged to change their sitting behavior. A lot of new devices or workstation alternatives are coming into the market: sit-stand tables, desk bikes, walking stations, etc. This symposium, the second of two on this subject, addresses the effectiveness and feasibility of these interventions with respect to several aspects: sitting time, postural and physiological effects, musculoskeletal health, physical fitness and productivity.

## Feasibility of implementing a high intensity interval-training program within an office environment

Steven Fischer (presenter), Jugal Patel, Brittany Edgett, Trisha Scribbans, Joe Quadrilatero, Brendon Gurd

**Background.** Sedentary work poses a considerable health challenge. Exercise can combat the negative effects of sedentary work; however, time and access to exercise facilities can limit adherence. Whole body sprint interval training (WB-SIT), a sub category of high intensity interval training, is time-efficient, does not require access to exercise facilities and has been shown to improve fitness. The objective of this study was to investigate the feasibility of implementing a WB-SIT program within an office work environment.

**Methods.** Participants were recruited from a Manulife Financial office through e-mail. The office employed over 700 employees; however, only 31 participants were enrolled in the study. Anthropometrics, aerobic fitness, core and upper body strength, and lower body mobility were assessed before and after the WB-SIT exercise intervention. Two to four WB-SIT training sessions were held per week for 12 weeks. Within each supervised session, participants performed a three- to five-minute warm-up (e.g. walking up and down stairs) followed by eight- to 20-second exercise intervals completing whole body movements (i.e. jumping-jacks, squat-jumps, etc.), where each interval was separated by 10 seconds of rest. Overall, each training session lasted approximately 10 minutes and all sessions were held on site within bookable meeting spaces.

Participants completing the 12-week intervention (n=11) significantly improved their aerobic fitness, upper body strength and score on standardized functional movement tests. However, despite introducing a program that overcame traditional barriers of time and access, 65% of participants dropped out prior to week 12; a response rate of 35%. For those who engaged throughout the 12 weeks, compliance was 83±17%, meaning that participants attended five out of every six sessions on average. WB-SIT is capable of improving physical fitness in a workplace setting; however, a more integrative implementation approach is required (e.g. social engagement, incentives, goal setting, etc.) to improve response rates.

## Postural and physiological effects of dynamic office workstations

Rolf Ellegast (presenter), Juliane Botter, Eva-Maria Burford, Britta Weber, Reinier Könemann, Dianne Commissaris

**Background.** Prolonged sedentary work is increasingly discussed as a health risk factor for developing musculoskeletal disorders. To prevent physical inactivity at office workplaces, manufacturers are now offering dynamic workstations where desk-based computer work can be combined with light physical activity. The aim of this study was to investigate the differences in postural, muscular and physical activities resulting from two new dynamic workstations compared with a conventional sitting and standing workstation.

**Methods.** In a controlled laboratory setting, the biomechanical, physiological, subjective and performance effects of two dynamic workstations (treadmill desk and elliptical trainer) were compared with two conventional workstations (sitting, standing). 12 subjects performed standardized typing, reading, telephone, mouse dexterity and cognitive tasks. The order of tasks and workstations was randomized. Measures assessed included a comprehensive CUELA postural analysis, physical activity, heart rate, electromyography of m. trapezius and erector spinae and energy expenditure. Acceptability and rating of the workstations were quantified by questionnaires. The comparative statistical analysis was performed with a general linear model (GLM).

**Results.** No significant effect was found regarding postural differences and the muscular activity was only significantly higher for the trapezius muscle (50th percentile: 8.1 %MVC) at the dynamic workstations. On average, the dynamic workstations showed significantly increased physical activity intensities (0.4 to 1.5 mg), heart rate (14.3 to 27.5 %HRR) and energy expenditure (1.8 to 3.1 METs). The comparison of work performance led only for the mouse dexterity tasks to significantly worse results at the dynamic workstations. For all other tasks the work performance was equally good. Subjectively, work performance was rated worse at the dynamic workstations by the subjects.

**Discussion.** Dynamic workstations can be used to principally increase physical activity at office workstations, with comparable work performance. User acceptance has to be improved, e. g. by a better ergonomic design.

## Workstation alternatives to reduce sitting time at work

Allard van der Beek; Hidde van der Ploeg, Karin Proper, Erwin Speklé, Maaïke Huysmans, Lidewij Renaud (presenter)

**Background.** Too much sitting seems bad for health and it increases the risk for early death. The workplace has great potential to address the public health problem of too much sitting by introducing alternative workstations that allow desk work to be performed while standing, walking, stepping or biking and thereby replacing the traditional desk and office chair set up. Our aims were to (1) summarize effects of these alternative workstations on the total time spent sitting and health; and (2) give insight into the feasibility aspects of introducing these alternative workstations into the workplace.

**Methods.** We used information provided by four recent systematic reviews and by the individual studies included in these reviews.

**Results.** Workstation alternatives that allow desk work to be done while standing, walking, biking or stepping reduced the total time spent sitting without substantially affecting work performance. Reduction and breaking up prolonged sitting may, in theory, result in health benefits. Regarding musculoskeletal health, both negative side effects and musculoskeletal benefits have been reported. Benefits were, for instance, reduced musculoskeletal discomfort, low-back pain, shoulder tension, and wrist and elbow pain. In general, the alternative workstations were acceptable to users.

**Discussion.** It seems to be too early to abandon the traditional desk and chair from the office and recommend widespread use of alternative workstations. More high quality evidence is needed regarding the long-term (health) effects and generalizability of the results to different working populations. Negative musculoskeletal side effects may occur and should be prevented. Ergonomic research should play an important role in developing recommendations for set up and use of alternative workstations, as well as in improving their feasibility.

## Interventions to reduce sedentary behaviour and increase physical activity during productive work time: effects on work performance and metabolic and physiological outcomes

Maaïke Huysmans (presenter), Dianne Commissaris, Svend Erik Mathiassen, Divya Srinivasan, Lando Koppes, Ingrid Hendriksen

**Background.** In a systematic literature review, we investigated the effect on work performance and metabolic and physiological outcomes of interventions aimed at reducing sedentary behaviour (SB) and/or increasing physical activity (PA) during productive work time.

**Methods.** Scopus was searched for articles published from 1992 until March 12, 2015. We included studies: (1) addressing interventions aimed at reducing SB and/or increasing PA at the workplace, during productive work; (2) using a design including a control group or control condition; (3) being published as a full-length paper in a peer-reviewed journal in English; (4) reporting on work performance outcomes and metabolic and physiological outcomes (i.e. lipid and metabolic profiles, hemodynamic and cardiorespiratory measures and anthropometric measures). Relevant studies were evaluated using the Quality Assessment Tool for Quantitative Studies and summarized in a best evidence synthesis.

**Results.** 18 interventions were included and organized into two categories: (1) alternative workstation interventions (n=15), i.e. sit-stand workstations or “active” workstations; and (2) personalized behavioural interventions (n=3), i.e. interventions involving personalized goals and/or giving behavioural feedback using prompts or messages.

There was moderate evidence for alternative workstations *not* influencing hemodynamics and cardiorespiratory fitness as well as personalized behavioural interventions *not* influencing anthropometric measures. Evidence was insufficient (alternative workstations) or conflicting (personalized behavioral interventions) on lipid and metabolic profiles. For work performance, there was insufficient evidence for personalized behavioural interventions and conflicting evidence for alternative workstations. But for the latter, only one out of 11 studies showed a negative effect.

**Discussion.** Current evidence suggests that work performance is not negatively affected by alternative workstations. Furthermore, there is no strong case for introducing interventions aimed at reducing SB and/or increasing PA during productive work time in the hope of getting a positive effect on metabolic and physiological outcomes. However, large-scale, high quality studies with long-term follow-ups are needed before more definite conclusions on this topic can be drawn.

SYMPOSIUM 19, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 202B

## New methods for assessing risks for upper extremity MSDs (Part 2)

**Chair: Carisa Harris Adamson, Director, Ergonomics Program, Center for Occupational and Environmental Health, University of California, Richmond, Calif., U.S.A.**

This symposium is the second of a two-part series on recent methods used to assess risk for occupational musculoskeletal disorders (MSDs) of the upper extremity. The first symposium ended with a discussion on how job rotation often fails to alter biomechanical exposure levels. This symposium begins with a discussion of how the ACGIH TLV for Hand Activity Levels (TLV-HAL) and Strain Index can be used more effectively for workers with job rotation. Next, a different exposure assessment approach using a psychophysical research-based equation to determine the maximum acceptable effort will be presented as a way to account for cumulative effects of exposures over multiple tasks. The influence of repetitive loading characteristics on musculoskeletal tissues will be discussed, specifically on how characteristics like amplitude for repeated versus fluctuating stress can alter the fatigue life of tissues. The symposia will finish with a new and innovative method for quantifying repetitive motion using automated marker-less tracking computer vision to quantify frequency and duty cycle of exertions during hand intensive tasks.

## Using the TLV for HAL and the Strain Index to quantify risk of CTS for workers with job rotation

Jay Kapellusch (presenter), Barbara Silverstein, Arun Garg, Stephen Bao, Andrew Merryweather, Matthew Thiese, Kurt Hegmann  
Elizabeth Malloy

**Background.** The aim of the study was to compare risk classifications from the Strain Index (SI) and Threshold Limit Value for Hand Activity Level (TLV for HAL) using three different techniques for quantifying daily physical exposure for workers with job rotation. A large cross-sectional study of carpal tunnel syndrome (CTS) in manufacturing and service companies in the U.S. was used to compare how well these methods and techniques predict prevalence of CTS.

**Methods.** A total of 1,825 workers (706 with job rotation) had their task-level occupational physical exposures quantified using the SI and TLV for HAL. Daily physical exposures were estimated using time-weighted-average (TWA), typical and peak exposure techniques. CTS prevalence was determined from symptoms and abnormal nerve conduction studies. Odds Ratios (ORs) were calculated after adjusting for age, gender, BMI and research site.

**Results.** Dominant hand CTS prevalence was 16.3%. The TLV for HAL and SI disagreed on risk classifications for about 40% of workers. Nevertheless, both models showed statistically significant association with prevalence of CTS, and had comparable ORs. For daily exposure estimates, the TWA technique classified about 63% more workers' jobs as low risk as compared to the typical and peak techniques.

**Discussion.** Despite comparable statistical associations, disagreement between risk classifications using the TLV for HAL and SI creates uncertainty for job design, job analysis, risk assessments and developing intervention strategies. Better guidance for using these models — and perhaps revisions to one or both models — are needed to improve utility. For workers with job rotation, TWA, typical, and peak exposure techniques for assigning daily physical exposure have large disagreements and require dubious assumptions. An approach that integrates exposures from all tasks performed by a worker with job rotation, without diluting the effects of strenuous tasks, is needed.

## A time-weighted approximation of total demand to determine maximum acceptable efforts across a combination of different tasks

Jim Potvin (presenter)

**Background.** Based on a meta-analysis of existing psychophysical research on the upper limb, an equation was developed to estimate the maximum acceptable effort (MAE) based on the duty cycle (DC) for a single task repeated over an eight-hour day, such that  $MAE \sim 1 - DC^{0.24}$  (Potvin, 2012). However, most jobs are much more complex, requiring that different efforts be performed with different durations. This paper explains an application of the MAE equation, employed to account for the cumulative effects of multiple tasks. The equation can be rearranged to:  $DC \sim (1 - MAE)^{4.167}$ , such that the rest allowance appears to increase as a function of the effort to the  $\sim 4$ th power (quartic).

**Methods.** The proposed novel method (1) determines the full duration of multiple tasks to determine the total DC; (2) calculates a time-weighted average of [each task's total effort duration/min] x [that task's effort to the 4th power]; and (3) takes that average to the 0.25 power (i.e. the root mean quartic, or RMQ).

**Results.** In this way, it weights the higher efforts much more than the lower efforts. For example, if there is a job with two tasks, both being exerted for a total of 3s/min, with one requiring a 10% MVC effort and the other 60% MVC, the linearly time-weighted average would be 35.0% MVC, but the RMQ would be 50.8% MVC. Given a total duration of 6 s/min (DC = 0.10), the MAE would be 36.6% MVC, which acceptable with the linear weighting, but unacceptable with the RMQ method.

**Discussion.** This new method allows for complex tasks to be combined in an ergonomics analysis, which has not been possible to date. Currently, efforts are being made to validate the RMQ method against empirical data.

## The influence of repeated and fluctuating stress on fatigue life of musculoskeletal tissues

Sean Gallagher (presenter), Mark Schall

**Background.** Recent evidence suggests that musculoskeletal disorders (MSDs) may be the consequence of a fatigue failure process in musculoskeletal tissues. This paper will describe how certain characteristics of musculoskeletal tissue loading, particularly mean tissue stress, would influence estimates of cumulative tissue damage using fatigue failure theory.

**Methods.** An example is provided to demonstrate the effects of repeated stress, fluctuating stress and duty cycle on estimated cycles to failure for a tendon. The tendon is assumed to have an ultimate tensile strength (UTS) of 100 MPa and in all cases is loaded to 40% UTS. Duty cycles of 10%, 40%, and 70%, and repeated (0-40 MPa) and fluctuating (15-40 MPa) stresses are examined. Predicted cycles to failure are calculated using Goodman's equation.

**Results.** Table 1 presents results of the cycles to failure calculations.

Table 1. Stress amplitudes, mean stresses and estimated cycles to failure for repeated and fluctuating stresses and various duty cycles percentages.

	10% Duty Cycle	40% Duty Cycle	70% Duty Cycle
Repeated stress	$\sigma_a = 20$ MPa $\sigma_m = 2.0$ MPa	$\sigma_a = 20$ MPa $\sigma_m = 13.9$ MPa	$\sigma_a = 20$ MPa $\sigma_m = 25.9$ MPa
0-40 MPa	Fatigue Life: 19210 cycles	Fatigue Life: 5724 cycles	Fatigue Life: 1423 cycles
Fluctuating stress	$\sigma_a = 12.5$ MPa $\sigma_m = 16.2$ MPa	$\sigma_a = 12.5$ MPa $\sigma_m = 23.7$ MPa	$\sigma_a = 12.5$ MPa $\sigma_m = 31.2$ MPa
15-40 MPa	Fatigue Life: 2461 cycles	Fatigue Life: 1457 cycles	Fatigue Life: 818 cycles

**Discussion.** Musculoskeletal tissues typically do not experience fully reversed loading conditions (compression followed by tension), but instead experience either repetitive or fluctuating stresses. Each of the latter conditions result in a non-zero mean stress that will decrease the fatigue life of exposed tissues. Results of this analysis demonstrate the importance of minimizing the mean stress experienced by tissues, either by decreasing duty cycle, decreasing minimum/maximum stresses, or a combination.

## Automated computer vision exposure analysis for repetitive motion jobs

Robert Radwin (presenter), Oguz Akkas, Yu Hen Hu, Carisa Harris-Adamson, David Rempel

**Background.** Using laboratory simulations, we previously demonstrated that hand activity level (HAL) can be automatically measured directly from video — without the necessity for instruments or frame-by-frame analysis. Semi-automatic, marker-less tracking of the hand was used to measure frequency and duty cycle. We also demonstrated that hand speed and duty cycle (DC) measures were suited for automatically estimating HAL. Moreover, these measures demonstrated good agreement with independent observational ratings of videos for actual industry jobs where DC measures were obtained manually using frame-by-frame analysis. This research advances that work by employing fully automatic computer vision to measure HAL for actual industrial jobs.

**Methods.** 30 jobs were selected from the video database of industrial tasks from the prospective study of upper limb, work-related musculoskeletal disorders among U.S. production and service workers from a variety of industries. Video frames are first identified by the analyst for a representative cycle when an exertion is initiated (i.e. grasp) and terminated (i.e. release). This establishes thresholds for the decision tree algorithm to identify grasp and release element breakpoints for the remaining video using associated kinematic variables such as hand location, velocity, acceleration and spatiotemporal curvature to measure speed and DC.

**Results.** The manual frame-by-frame ground truth DC ranged from 0.46 to 0.85 while HAL ranged from 3.0 to 8.0. Average DC for automated analysis differed by .12 (SD=0.08) from manual frame-by-frame analysis ( $R=.52$ ,  $p<.01$ ). Average HAL differed by 0.6 (SD=0.39) from independent observer ratings ( $R=.97$ ,  $p>.5$ ).

**Discussion.** Automated exposure analysis offers a more objective, accurate, repeatable, accessible and efficient exposure assessment tool than observational analysis. Computer vision demands fewer resources than instruments or frame-by-frame analysis and has the potential for long-term, direct-reading exposure assessment. Computer vision can also conceivably be programmed on inexpensive, handheld devices such as smartphones or tablets, making it widely accessible.

SYMPOSIUM 20, WEDNESDAY, JUNE 22, 10:30AM – 12:00 PM,  
BALLROOM B

## Biomechanics of the upper extremities during mobile IT work (Part 4): workstations and mobility II

**Chair: Pascal Madeleine, Professor, Department of Health Science and Technology,  
Aalborg University, Aalborg, Denmark**

Information technology (IT) work is nowadays performed in mobile environments. This mobility can be achieved by using sit-to-stand tables or by incorporating active pauses during IT work to induce more mobility for lower or upper limbs. However, the effects of this added mobility on upper extremity work is still not well described. This symposium, the last of four on mobile IT work, brings together international experts and speakers will share their latest research findings on the effects of workstations and mobile IT work on the biomechanics of the upper extremities. A round table will be organized at the end of the symposium.

## Effect of active pauses on muscle activation pattern and muscle oxygenation in women with and without trapezius myalgia doing repetitive tasks

Letícia B. Januário (presenter), Afshin Samani, Marina Machado Cid, Pascal Madeleine, Ana Beatriz Oliveira

**Background.** Neck-shoulder pain is the second most common work-related musculoskeletal disorder. This may be explained by lack of muscular rest when performing static and repetitive work; lack of muscular rest can lead to continuous and sustained activation of small motor-units and reduced blood flow. It has been suggested that active pauses can produce potential benefits, changing electromyographic (EMG) static patterns and improving muscle oxygenation among computer workers. This study investigated a simulated repetitive task and compared the effects of active pauses on two populations.

**Methods.** 35 subjects were selected, 17 healthy females ( $24.8 \pm 2.5$  years) — 18 with neck pain ( $24.3 \pm 3.9$  years). Subjects with neck pain were included if they had moderate/intense pain in the neck for more than six months and were clinically diagnosed with tension neck syndrome or cervical syndrome. All subjects performed 40 minutes of simulated task at a pre-set pace. Every two minutes, participants performed an eight-second pause, either passive or active. EMG electrodes were placed at clavicular upper trapezius (C-UT), acromial upper trapezius (A-UT), middle trapezius (MT), lower trapezius (LT) and serratus anterior (SA) muscles from the dominant arm. Root mean square (RMS), relative rest time (RRT), exposure variation analysis (EVA) and normalized mutual information (NMI) were obtained. A near-infrared spectroscopy (NIRS) probe was placed on the dominant upper trapezius to extract the mean values of oxyhemoglobin (O<sub>2</sub>Hb), deoxyhemoglobin (HHb) and total hemoglobin (THb).

**Results.** Preliminary results showed that RRT differed between pause types for A-UT and was higher for active compared with passive pause (20.5%;  $p < 0.02$ ), also a significant difference was found on NMI between the pair A-UT and MT with active pause decreasing NMI when compared with passive ones (8.9%;  $p < 0.02$ ), both for neck pain group.

**Discussion.** These results show potential benefits of active pauses especially on subjects that have neck pain.

## Use of sit-stand stations during the first two months after their introduction

Dechristian Franca Barbieri (presenter), Svend Erik Mathiassen, Divya Srinivasan, Willian Miranda dos Santos, Ana Beatriz de Oliveira

**Background.** There is increasing evidence that sedentary behaviour during the workday is associated with negative health effects. In this context, interventions to reduce total sedentary time and breaking up periods of continuous sitting during computerized office work are urgently needed. Several reviews conclude that introducing sit-stand stations may lead to positive effects, but they also state that long-term interventions in real occupational settings are still rare. Therefore, the aim of this study was to investigate usage of sit-stand tables among Brazilian office workers during an intervention lasting two months.

**Methods.** Nine office workers (6 females, 3 males; age 42 [SD 12] years) participated. The workers received traditional sit-stand tables and ergonomics information. They then used the workstation for two months. The tables were furnished with a system that recorded and kept track of table use during the intervention period. Table use early and late in the intervention period was compared using the Wilcoxon signed-rank test for repeated measurements.

**Results.** In the beginning of the eight-week intervention period, workers, in median, changed table position 2.4 (1.9 – 4.7) times per day, decreasing to 2.3 (1.0 – 3.3) times at the end ( $P=0.09$ ). Moreover, we also found a non-significant decrease in total time standing per day, from 88.6 (67.4 – 94.3) minutes to 58.8 (33.1 – 95.7) minutes ( $P=0.31$ ).

**Discussion.** Two months after introducing sit-stand tables, some decrease in usage could be seen, if not statistically significant. Based on this, we emphasize that introduction of sit-stand tables should be accompanied by continued encouragement of the workers, preferably informed by a personalized follow up of actual use.

## Sit -stand workstations and training: examining the role of user control

Michelle Robertson (presenter)

**Background.** Given the high prevalence of work-related musculoskeletal disorders (MSDs) among intensive computer users, concerns exist about the escalating numbers of computer-related and work-related MSDs.

**Methods.** This randomized controlled trial examined the effects of an office ergonomics training program combined with a sit-stand workstation on instrumented measures of computer activities, cognitive demands perceptions, musculoskeletal discomfort and performance. Participants performed a simulated customer service job for eight hours per day, over 15 days and were assigned as ergonomics trained (n=11) or minimally trained (n=11) group. The training consisted of 1.5-hour interactive instruction, sit-stand practice periods and ergonomic reminders.

**Results.** Ergonomics-trained participants exhibited lower exerted forces, significantly less frustration, reduced sedentary behaviour, minimal musculoskeletal discomfort across the 15 days, with significantly higher performance compared to the minimally trained group who displayed higher exerted forces and frustration, and had a significantly higher number of symptoms.

**Discussion.** These results suggest that training in conjunction with a sit-stand workstation plays an essential role in preventing symptoms in computer users.

SYMPOSIUM 21, WEDNESDAY, JUNE 22, 10:30AM – 12:00 PM, ROOM 201A

## Models of work-related musculoskeletal disorders: a round table discussion for new development

**Chair: Mats Hagberg, Professor and Chief Physician, Occupational and Environmental Medicine, University of Gothenburg, Gothenburg, Sweden**

“All models are wrong but some are useful.” Models are needed in order to gain new knowledge and to initiate research and prevention. In 1993, Armstrong et al published the paper “A conceptual model for work-related neck and upper limb musculoskeletal disorders” (Scand J Work, Environ Health), although model development and discussions among the authors had begun in 1983. At that time, quite a few “scientific experts” questioned the existence of work-related musculoskeletal disorders (MSDs). The model was needed to communicate the idea of work-related MSDs and to initiate scientific research, action and prevention. That model has since been frequently cited in different areas such as ergonomics, rehabilitation, general practice and occupational medicine.

New models have also been developed; some of these are the synthesis of later models, while others feature diversity. Examples of successful models that have been developed target disability and return to work. Health economic models are recent arrivals, designed to address occupational MSDs. New models to be developed in the future may consider developments in molecular medicine as well as in neurology, psychiatry, sociology and exercise.

This symposium – a round table discussion – will look into the future for modelling work-related MSDs. Examples of questions that will be addressed include: Should there be special models for practitioners? How do we encompass RTW in workplace health promotion? In workplace health promotion, should exercise training be included in models of work-related disorders? Are mental, psychosocial and psychiatric factors still neglected in our models?”

## Modelling personal and occupational factors in musculoskeletal disorders

Rahman Shiri (presenter), Eira Viikari-Juntura

**Background.** The etiology of musculoskeletal disorders is multifactorial. Personal, physical and psychosocial factors contribute to the risk of musculoskeletal disorders. Existing models for work-related musculoskeletal disorders are largely based on occupational factors with less emphasis on personal factors.

**Methods.** The results of systematic reviews and meta-analyses were used to model the role of personal and occupational factors in musculoskeletal disorders. Attributable fractions in the multifactorial situation were estimated for the contributions of personal and occupational factors to the risk of musculoskeletal disorders.

**Results.** The contribution of personal factors to the risk of MSDs is as high as that of exposure to physical workload factors. The contribution of obesity, smoking, physical inactivity and depression to the risk of low-back pain is larger than that of exposure to physical workload factors (over 38% vs. over 33%). Over a third of the risk for carpal tunnel syndrome is explained by a square-shaped wrist, obesity, diabetes, degenerative or inflammatory arthritis and hypothyroidism.

**Discussion.** There may be synergistic effects between occupational and personal factors on the risk of MSDs. A conceptual model including possible pathways for the effects of personal factors on work-related MSDs will be presented. Preventive measures for work-related MSDs should include both personal and occupational factors.

## Modelling recovery from work-related musculoskeletal disorder through intelligent workplace exercise

Karen Sjøgaard (presenter), Gisela Sjøgaard

**Background.** Physical activity can alleviate musculoskeletal disorders (MSDs) in general, and the workplace presents a highly relevant arena for the treatment of MSDs. However, designing exercise programs to target work-related disorders at specific workplaces calls for special considerations; different work tasks and exposures impact differently on employees' health and the aim of the exercise program is to enable the employee to stay in the job.

Therefore, the exercise must take into account work exposure, physical capacity and activity, intensity and location of the MSD, productivity at work and sick leave. Finally, important issues to be considered are the individual preferences that motivate participation and the barriers that are present in specific job sectors. Exercise programs can be tailored regarding intensity, duration, frequency, contraction-type, effect on endurance/strength as well as being muscle-group specific.

**Methods.** We have developed and improved the concept of "intelligent physical exercise training" (Holtermann et al, BMC PublicHealth 2010 10:120; Sjøgaard et al, BMC PublicHealth 2014 14:652) by conducting workplace randomized controlled trials (RCTs) with common essential factors within a wide variety of jobs and with highly different exposures — from sedentary to physically heavy tasks. Physical exercise training was performed for one hour per week, usually divided into two to three sessions.

**Results.** The employer was necessarily highly involved in order to allow such activities and to support the participation of employees. The specific exercise training programs were based on evidenced sports sciences training principles, of general high intensity, and tailored to work exposure, employee health status and physical capacity. The training sessions were supervised and the adherence was monitored for motivational purposes.

**Discussion.** Targeting MSDs with exercise presents a continuum through prevention, treatment, and prevention of consequences. Therefore, apart from a decrease in musculoskeletal disorders other effect measures have been included so as to also show beneficial side effects such as: productivity, work ability, return to work, sick leave and risk factors for other life style diseases related to lack of physical activity.

## The “pyramid of disability” as a conceptual model for work-related musculoskeletal disorders

Bradley Evanoff (presenter), Ann Marie Dale, Alexis Descatha

**Background.** The multifactorial nature of musculoskeletal disorders (MSDs) has been well described: personal, psychosocial and workplace physical exposures are all associated with higher rates of MSDs in working populations. Etiology research is complex because MSDs at any body part may present a diverse set of outcomes, ranging from symptoms of discomfort to long-term work disability; and, different work-related risk factors may affect different stages of MSD severity. For instance, risk factors assessed among workers with long-term disability from MSDs may be different from risk factors assessed among newly symptomatic workers. We have proposed a simple conceptual model that may clarify this issue for researchers and practitioners.

**Methods.** Our proposed model is based on a “pyramid of disability,” with the base consisting of workers without MSD symptoms. Some workers subsequently experience symptoms but do not seek treatment; others seek treatment, and a smaller number progress to short-term or chronic functional impairment and work disability. Therapeutic interventions, work related and non-work related exposures to physical and psychosocial stressors, medical co-morbidities, workplace policies and a variety of other personal and social factors can mediate transitions between levels of this pyramid.

**Results.** There are suggestions in the existing literature that work-related biomechanical factors are more strongly associated with initial incidences of MSDs, while psychosocial and psychological factors may be more strongly associated with longer term outcome and prognosis. Few studies have examined the risk factors for transitions between different stages of symptoms and disability.

**Discussion.** We suggest that future research consider that factors influencing the onset, progression and recovery from different stages of MSD severity are probably different, and that assessments of work-related etiology should take into account different stages of MSD severity and progression toward impairment and disability. This admittedly simple model may encourage further discussions and practical studies in the areas of etiology, prevention and treatment.

## Modelling work-related musculoskeletal disorders from a health economic perspective: the direct and indirect costs at different levels

Mats Hagberg (presenter)

**Background.** Health economics is a fairly young discipline with different definitions. Usually, health economics divides costs into direct cost and indirect cost. Direct costs are those attributed to care, treatment and drugs. Indirect costs include loss of production, e.g. sick leave, absenteeism and presenteeism (being present at work while sick). A free example of an instrument for health economics that is available in different languages and geared to different disorders (e.g. low-back pain) is the WPAI (Work Productivity and Activity Impairment: [www.reillyassociates.net](http://www.reillyassociates.net)).

Other health outcome measures include the EQ-5D and the SF-36, which use algorithms to translate metrics into economics. The quality-adjusted life-year (QALY) is a generic measure of disease burden that includes both the quality and the quantity of life lived.

A model for work-related musculoskeletal disorders needs to consider different levels of health economics. For individuals, this means the direct costs of drugs, health care appointments/insurance and loss of income. At the company/organizational level, direct costs include occupational health care and sick leave benefits while the indirect costs count loss of production and replacement costs. At the societal level, the costs of lost production are societal costs.

At present, there is no generally accepted model for computing return of investment (ROI) on the prevention of work-related musculoskeletal disorders at the individual, organizational or societal level.

Pharmaceutical companies are now paying much more attention to the health economics of general musculoskeletal disorders in order to promote new drug treatments for specific disorders like rheumatoid arthritis and Bechterew's disease. A question that arises is: How do we model the economic impact of work-related musculoskeletal disorders in order to motivate primary, secondary and tertiary prevention? Furthermore, how can we engage researchers to address the economic implications in all studies of work-related musculoskeletal disorders?

SYMPOSIUM 22, WEDNESDAY, JUNE 22, 10:30AM – 12:00 PM, ROOM 201C

## Physical exposure and back disorders in occupational life

**Chair: Matthias Jaeger, Head, Biomechanical Ergonomics Work Group, IfADo-Leibniz Research Centre for Working Environment and Human Factors, Leibniz, Germany**

The goal of this symposium is to provide comprehensive investigations of the relationship between physical exposures to manual materials handling or awkward postures in occupational life and the risk for the development of disc-related diseases in the low back.

After the reunification of Germany, an occupational disease was proposed for potential workers' compensation. This new occupational disease was described as "intervertebral disc diseases of the lumbar spine caused by lifting or carrying heavy objects over many years or caused by activities in an extremely trunk-flexed posture over many years etc." Hence, criteria for the assessment of diverse disease expressions and biomechanical loadings became necessary.

An initial approach, the Mainz-Dortmund Dose Model, was derived by transforming each potential overloading exposure — characterized by lumbosacral compressive force — and summarizing all loadings into a cumulated dose for shifts and occupational life.

However, due to limited knowledge about dose-response relationships, a multi-centric, case-control study, the German Spine Study EPILIFT, was developed to examine the life-time workload of 915 patients with disc herniation, or with disc-space narrowing, and 901 population controls. An increased disease risk was found for all four case groups (males/females, herniation/chondrosis).

The EPILIFT Exposure Criteria Study was conducted to develop a mathematical model for capturing the dose-response relationship and accounting for appropriate threshold values for compressive force, trunk-inclination angle and shift dose.

## Background of epidemiological studies in Germany to analyze dose-response relationships between biomechanical, low-back load and lumbar-disease risk

Matthias Jaeger (presenter), Annetrin Bergmann, Ulrich Bolm-Audorff, Rolf Ellegast, Peter Morfeld, Klaus Schäfer, Andreas Seidler, Alwin Luttmann

**Background.** In Germany, specified lumbar diseases may be compensated if distinct exposure criteria are fulfilled. In the commonly used Mainz-Dortmund Dose Model (MDD), exposure is described by the lumbosacral-disc compressive force and, in short, by the cumulated dose for shifts and lifetime. The EPILIFT study was subsequently undertaken to address the limited epidemiologic knowledge.

**Methods.** In EPILIFT, 915 patients with lumbar disc herniation or disc-space narrowing and 901 population controls were prospectively recruited. Exposure data were gathered in personal interviews and used for task-specific, disc-force computations. Cumulative lumbar load was quantified applying exemplary dose models; odds ratios versus lifetime doses were calculated. In EPILIFT 2, data were re-analyzed applying 30 dose models of five model groups varying the thresholds of compressive force, trunk inclination, daily dose etc. systematically. All models were tested regarding the quality of fit.

**Results.** Increased disease risks were found for every case group (males/females with herniation/chondrosis). Based on the best-fitting dose models per model group, combination models joining the optimal thresholds were defined specifically for the four case groups and used for the identification of the dose doubling the disease risk.

**Discussion.** Exposure-risk relations are verified for both genders and both disease entities. Gender-related critical exposure values are proposed for workers' compensation evaluation procedures.

## Multi-model methodology for estimating cumulative dose models to analyze physical exposure effects

Peter Morfeld (presenter), Ulrich Bolm-Audorff, Rolf Ellegast, Oliver Kuß, K. Schäfer, Andreas Seidler, Matthias Jäger

**Background.** The EPILIFT exposure criteria study is a reanalysis of the EPILIFT case control study. Statistical analyses are confronted with three challenges: (1) dosimetric modeling — candidate dosimetric models vary considerably in thresholds for lumbar disc compressive forces, degree of trunk forward inclination and daily doses; (2) epidemiological modeling — the structure of the best risk model is unknown and may be complex; and (3) exposure criteria — the risk analysis should try to derive an estimate of the long-term dose that is associated with a doubling of risk (doubling dose).

**Methods.** A multi-model analysis (MMA) was performed in two tiers, averaging models with the help of information criteria. Fractional polynomials (FPs) of the second and fourth degrees were fitted to all sensible dosimetric models. In the first step of the MMA, best thresholds were estimated separately for each property of interest by appropriate weighting. Weighting was defined by the relative information of each FP (Akaike weighting). These best thresholds were inserted simultaneously to yield combined dosimetric models that were used to define the reference dose in all further analyses. In the second step of the MMA, all continuous regression curves and confidence bands were averaged across the reference dose. The OR estimates were smoothed by FPs of the fourth degree. These curves were used to derive a doubling dose with confidence limits by inversion.

**Results.** The MMA was applied to four sub-studies (gender: male/female, outcome: prolapse/chondrosis). The approach is demonstrated for the sub-study investigating the prolapse prevalence among men.

**Discussion.** The MMA method presents a potential solution for specification of the optimal dosimetric and/or epidemiological models if a priori criteria are missing.

## Dose-response relationship between lifetime physical exposures to manual materials handling or trunk-inclined postures and lumbar-spine diseases

Andreas Seidler (presenter), Annekatriin Bergmann, Ulrich Bolm-Audorff, Rolf Ellegast, Peter Morfeld, Klaus Schäfer, Matthias Jäger

**Background.** This analysis of the original EPILIFT study data aimed to derive a dose model (including appropriate threshold values) that describes the dose-response relationship between physical exposure (manual materials handling and trunk-inclined postures) and lumbar spine diseases “at best.”

**Methods.** Lumbar-disc compressive force, degree of forward bending, and daily dose were changed separately (and afterward simultaneously). The Akaike information criterion (AIC) was used to evaluate model fit, applying fractional polynomials and multi-model approaches. These analyses were based on continuous exposure variables, whereas the original EPILIFT study performed analyses of categorical exposure variables.

**Results.** The calculation of threshold values made use of the information of several dose models representing a broad range of threshold values. As a result of this in-depth analysis, the following thresholds were established as a “best estimate”: lumbar-disc compressive force of 3.2 kN among men and 2.5 kN among women; 45 degree of forward inclination of the trunk for both genders; daily dose threshold of 2.0 kNh among men and 0.5 kNh among women; doubling (lifetime) dose of about 7 MNh among men and 3 MNh among women.

**Discussion.** This in-depth, reanalysis of the EPILIFT case-control study data constitutes an important basis for the determination of the dose-response relationship between physical exposure and lumbar-spine diseases. According to our study results, lumbar-spine diseases are strongly associated with manual materials handling or trunk-inclined postures among men and women.

## Simplified procedure for lumbar-disc compressive force estimation in cumulative spinal-dose calculations

Rolf Ellegast (presenter), Annekatrin Bergmann, Ulrich Bolm-Audorff, Matthias Jäger, Peter Morfeld, Klaus Schäfer, Andreas Seidler, Dirk Ditchen

**Background.** In the EPILIFT study — a population-based, multi-centre case-control study — retrospective spinal-workload dose calculations were originally based on detailed biomechanical analysis of lumbar disc compressive forces using the 3-D dynamic, biomechanical model “The Dortmund.” As detailed biomechanical calculations are too complex for practical use in occupational-disease assessment procedures, the objective of this study was to develop a simplified procedure for estimating lumbar compressive forces, and to evaluate its accuracy.

**Methods.** 964 EPILIFT subjects with relevant occupational physical exposures were selected. Corresponding detailed exposure data sets (manual materials handling, working in awkward postures) of 4,450 work shifts served as input data for linear regression analysis of the relationship between lumbar compressive forces and handled object weights in biomechanically comparable working situations. Cumulative spinal shift-doses were computed on the basis of compressive forces calculated by means of both “The Dortmund” and a set of regression equations. The accuracy was validated via the correlation-coefficient  $R^2$ , the intra-class correlation coefficient ICC and the Bland-Altman plot. Spinal lifetime exposures for all EPILIFT-subjects were calculated with both procedures to compare the resultant dose-response relationships between occupational exposures and lumbar-spine disease risk.

**Results.** A set of 11 regression-equations for lifting and carrying tasks was derived. 72% of 4,450 spinal shift-doses calculated with the simplified method showed less than  $\pm 10\%$  deviation to those quantified with “The Dortmund.” The comparison of the daily doses calculated in the two different ways lead to a correlation coefficient  $R^2$  of 0.873 and an ICC of 0.933. The Bland-Altman plot revealed average deviations of  $0.03 \pm 1.5$  kN and 95% limits of agreement of  $\pm 3$  kN. The dose-response relationships were adequately reproducible with the simplified method.

**Discussion.** The developed procedure can be considered to be sufficiently accurate for retrospective lumbar-disc compressive forces estimation. There are still deviations in specific workload situations, so that it cannot generally replace biomechanical expert methods.

## Application of cumulative dose models to indicate occupational back exposure in praxis

Ralf Schick (presenter), Klaus Schaefer

**Background.** Exposures to manual handling of objects or awkward postures can lead to disc-related diseases in the low back. This has been confirmed by the German Spine Study EPILIFT and by the Exposure Criteria Study EPILIFT 2 in a dose-related manner. To use this information in the occupational practice, investigations were performed in different branches to calculate typical cumulative dose values for a day and a year.

**Methods.** In field studies, object masses, postures, frequency and carrying distance were investigated during typical working. These investigations were repeated on different days and in different companies. With these data, cumulative dose values for a typical day and a typical year were calculated using the regression equations from the Mainz-Dortmund Dose model (MDD) in order to estimate the intervertebral-disc compressive force related to object mass, handling mode and posture as well as the cumulative doses. The results were compared and summarized.

**Results.** About 20 occupations from the trade and logistics sectors were investigated and typical dose values were calculated. The sectors investigated were in food, building materials and the furniture trade. The dose values can be used for the assessment of occupational lumbar-spine disease and also for the prevention of musculoskeletal exposures in the occupational practice.

**Discussion.** Within specified industrial sectors, exposures to the manual handling of objects are similar. Therefore, typical exposures can be described and typical dose values for a day and for a year can be calculated.

SYMPOSIUM 23, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, BALLROOM B

## Sustainable prevention of work-related MSDs: gender analysis and development of effective interventions (Part I)

**Chair: Marie Laberge, Assistant Professor, School of Rehabilitation, University of Montreal, Montreal, Canada**

Increasingly, evidence and theories are suggesting that work-related musculoskeletal disorders (MSDs) are not experienced in the same way by men and women. For example, while men are more often exposed to heavy physical workloads, women are more likely to be exposed to repetitive work and psychosocial risk factors. Thus, the development of occupational health and safety (OHS) interventions to prevent work-related MSDs must consider sex and gender. Goldenhar (2001) proposed a three-step “intervention research process” to develop effective OHS interventions: intervention development, implementation and evaluation. This symposium, the first of two on the subject, illustrates how sex and gender may be considered at each step. Presentations will be followed by discussion of the investigation and strategies needed to improve consideration of sex and gender at all stages of the process. The audience will be asked to discuss how they ensure that sex and gender are taken into account when they develop interventions in order to ensure that measures are both effective and that they favour social justice.

## Sex/gender and motor control: what should you know before planning an intervention?

Julie Côté (presenter), Kim Emery

**Background.** Neck/shoulder musculoskeletal disorders (MSDs) are increasingly common among workers, but especially so among women. The reasons for this are likely multifactorial and encompass a variety of biopsychosocial factors.

**Methods.** Expanding on a critical review paper published in 2012, we update the most recent experimental research results and highlight sex/gender differences in repetitive upper limb movement-related motor control characteristics. Indeed, our most recent studies highlight sex/gender differences in sensory and pain detection thresholds, in proprioception, in individual muscle variability and in multi-muscle functional connectivity during repetitive arm tasks and during computer work. All of these differences are also incorporated into a description of the fatigue response of men and women. In addition, other recent work on manual material handling of women also contributes to an understanding of the link between coordination patterns and muscle strength characteristics.

**Results.** By integrating these various research results that all focus on gaining a better understanding of how motor control of men and women may differ, it is becoming increasingly possible to approach an understanding of sex/gender differences in MSD reports, and to identify sex/gender-sensitive factors that ergonomic practitioners may consider taking into account when adapting the workplace for optimal health of both men and women.

**Discussion.** This presentation will provide an overview of the recent research results on sex, gender and motor control emanating from McGill's occupational biomechanics and ergonomics lab. From there we will formulate conclusions and recommendations relevant for practitioners in accounting for sex/gender in their practice, and finally, we will discuss future research directions and ongoing networking and capacity training activities as part of the Chair in Gender, Work and Health supported by the Canadian Institutes for Health Research (CIHR) and Quebec's **Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST)**.

## Development of integrative prevention to improve workers' health: a gender-sensitive approach

Benedicte Calvet (presenter), Marie Laberge, Johanne Saint-Charles, Nicole Vézina

**Background.** The links between the lack of recognition of the constraints of women's workstations and prevention practices are well known. For example, it has been shown that primary prevention strategies are more developed in male-dominated industries (Vézina et al, 2011). Inequalities between men and women were found in occupational injuries management. As well, Lippel (1999, 2003) explains that in female-dominated jobs, prevention efforts are less common, and women's occupational health problems are under-compensated. As we move towards "integrated prevention," we may prefer that such gender differences not be maintained but, on the contrary, that "integrated prevention" be a lever for developing more effective prevention programs by taking into account the diversity of populations.

**Methods.** A scoping review and semi-structured interviews were conducted in order to understand the meaning of the concept of "integrated prevention," and to explore gender consideration in prevention. This search led to the identification of 35 papers. A total of 20 individual interviews were carried out with stakeholders involved in each level of prevention (e.g. occupational therapists or occupational health and safety managers).

**Results.** Diverse definitions of integrated prevention emerge both in literature and in our interviews, and it appears that this concept is not really established in practice since stakeholders are rarely involved in several levels of prevention. With regards to gender, most stakeholders interviewed referred to the sexual division of labour (business sectors, workstations, etc.) as an explanation for differences in the prevention and rehabilitation of women and men. Neither the literature review nor the interviews establish links between gender considerations and integrated prevention directly.

**Discussion.** Integrated prevention seems to be an interesting way to fulfill the need for equity in prevention. In this presentation, we will propose an integrated prevention model with a gender-sensitive approach that brings a systemic perspective on the health of men and women in

## Gender differences in duration of work absence for non-traumatic work-related musculoskeletal disorders

Susan Stock (presenter), Nektaria Nicolakakis

**Background.** In Quebec, non-traumatic musculoskeletal disorders (MSDs) represent 35% of workers' compensation injuries and illnesses. From 1995 to 2002, the number of compensated MSD cases declined, but duration of work absence for these disorders increased. In this study we sought to analyze gender differences in duration of non-traumatic MSD work absence in two more recent data sources.

**Methods.** We used data from the Québec 2007-2008 Survey on Working and Employment Conditions and Occupational Health and Safety to estimate the gender-specific, 12-month prevalence and work absence duration for non-traumatic work-related MSDs. We used 2005-07 and 2010-12 Quebec workers' compensation data to measure trends in the annual (1) mean number of compensated cases of non-traumatic MSD work absence, (2) mean and median duration of MSD work absence, and (3) proportion of absences of >90 days among those with a compensated MSD work absence.

**Results.** The survey data estimated that 260,000 workers had a work absence of at least one day for a non-traumatic work-related MSD. The mean work absence duration was 19.9 days for women, 14.7 days for men. The proportion of workers with a work absence >90 days was 10% in women, 3.5% in men.

From 2005-07 to 2010-12, the annual mean number of compensated cases of non-traumatic MSDs decreased for both genders (men: 19,700 to 13,800; women: 11,500 to 8,900), but the duration of work absence increased and was significantly higher in women than in men respectively, increasing from 76.9 to 79.2 and from 66.4 to 72.5 days. Among those absent, the proportion with work absences >90 days was greater for women than for men (2010-2012: 21.7% vs. 17.8%).

**Discussion.** Understanding the determinants of gender differences in duration of work-related MSD work absence could guide appropriate gender-sensitive disability prevention and return-to-work strategies, improve workers' quality of life and decrease the huge economic burden of work disability.

## When management indicators make women's work invisible: the case of personal support workers in Ontario

Martin Chadoin (presenter), Karen Messing, Tamara Daly

**Background.** This paper discusses the links between management indicators and the invisibility of women's work as personal support workers (PSW) in nursing homes.

**Methods.** Data are drawn from observations and field notes specifically focused on the work of 37 PSWs (35 women) in five Ontario nursing homes and 143 key informant interviews with PSW, nurses, managers, families and other care providers. We found that, during the day, a PSW normally cared for eight to 12 residents and documented the condition of each of their residents, how they acted and ate, as well as any use of physical restraints.

**Results.** Despite individualized task assignments, the work of PSWs was commonly performed collectively. Documentation was very demanding and often conflicted with care routines. However, documentation and the management indicators produced were important for determining government funding levels, which in turn determined staffing levels. The documentation for official purposes did not show the complexity and challenges of PSW work as revealed by qualitative analyses. Not documenting the complexity contributed to a vicious cycle: having left much of the real work undocumented, PSWs lost funding resources, which increased workload, leading to further under-estimation.

**Discussion.** We argue that the indicators concealed the real work of the PSWs, who in fact had to develop strategies to "work around" documentation requirements in order to perform care. We postulate that problems with documentation can contribute to "organizational silence," leading, through overload, to occupational accidents and illnesses. Our study highlights the need to transform management indicators and tools to make visible the hidden work of care in nursing homes.

SYMPOSIUM 24, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 201A

## Expanding OHS impacts: the commercialization of leading-edge MSD research and knowledge

In today's complex market, commercializing research findings is often encouraged as a way to turn research findings into practical tools for use by the workplace parties and to fund future research. This symposium looks at issues related to the research commercialization of MSD research.

## Making research practical: an entrepreneur's views of research

Glenn Cullen (presenter), Kim Slade

## Research and business: defining market need and research questions

Lora Cavuoto (presenter)

**Background.** A funded project evaluated the interaction of sleep-based fatigue and workload, as well as fatigue development. It also tested fatigue-mitigating interventions.

**Discussion.** This session explores (1) the relationship between the researcher and business partner, (2) the process of defining market need, (3) research methodologies, and (4) intervention evaluation to support product development.

## Successful industry research partnership: adapting to the changing landscape

**Alison Burgess (presenter)**

**Background.** Canadian universities are increasingly opening up their doors to industry and community organizations to provide students with a more hands-on educational experience. With respect to research, universities are making an effort to develop research programs that are aimed at solving societal problems. In line with that notion, many of the new grant-funding opportunities available to university faculty members place an emphasis on partnerships. How universities and faculty members adapt to this changing landscape in grant funding will have a direct impact on their success rates.

**Discussion.** In this session, we will look at examples of successful collaborative projects. This will lead to an open discussion about accessing universities and how to strategically set up collaborative research projects to be productive and beneficial for all parties.

## Engaging partners to develop serious game

Michael Williams-Bell (presenter)

**Background.** Firefighters have high injury rates. Musculoskeletal injuries due to lifting, twisting and bending, often in awkward positions while under mental and physical strain, contribute greatly to these high rates with up to one-third of these injuries being low-back injuries. Additionally, one-third of firefighter injuries are due to contact or exposure to fire, many of which are preventable with better decision-making. The purpose of this research was to determine at what level and rate of rise in core body temperature are cognitive impairments observed.

**Methods.** In order to conduct this research, 19 firefighters were recruited to undergo treadmill exercise at UOIT's ACE climate chamber, in two hot, humid conditions, with different rates of rise in core temperature, at 30°C/50% humidity and 35°C/50% humidity. Throughout exercise the firefighters' core temperature continued to increase and at various points (pre-test, 37.8°C, 38.5°C, 39.0°C, post-test, post-recovery) their cognitive function was assessed using either a traditional cognitive assessment battery or a more 'realistic' simulation of fire ground decision making through a serious game.

**Results.** Decrements in certain aspects of cognitive function were identified with the traditional assessment battery; however, only memory recall approximately 20 minutes following exercise was observed with the serious game.

**Discussion.** The current version of the serious game was modified to include various levels of difficulty that could be implemented as training scenarios for firefighters. This provides an avenue to use video game technology for training that helps develop proper decision-making skills in simulated heat stress conditions and emergency situations, thus requiring minimal expense and equipment, and minimizing any potential undue risk. Ultimately, combining the current research with previous work will provide tolerable work times before firefighters attain a core temperature that could potentially result in impaired cognitive function.

SYMPOSIUM 25, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 202A

## Motor variability in working life: Determinants and effects on health and performance (Part I)

**Chair: Divya Srinivasan, Assistant Professor, Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Va., U.S.A.**

Motor variability is an emerging area of research in occupational life. Growing evidence suggests that motor variability has the potential to increase biomechanical exposure variation in repetitive work without affecting production. Several research groups are working on this topic from different perspectives. The purpose of this symposium, the first of two on this subject, is to explore the relevance and possible contributions of motor variability to health and performance in different settings in working life and examine which personal factors influence inter-individual differences in motor variability. Discussion will address future directions and methodological challenges for motor variability research from an occupational context through presentations and discussions from leading experts in the field.

## Gender differences in muscle-activity responses to a fatiguing short-cycle repetitive task

Divya Srinivasan (presenter), Kathryn Sinden, Svend Erik Mathiassen, Julie Coté

**Background.** More women suffer from musculoskeletal disorders (MSDs) in the neck-shoulder and hand-arm regions than men, even when they are performing similar jobs. Fatigue is a known predictor of MSDs, and gender differences in fatigue responses could help explain the difference in MSD occurrence. This study aimed to assess the extent to which genders differ in fatigability by examining muscle-activity responses when performing a low-force, repetitive arm-task leading to muscle fatigue in the neck-shoulder region.

**Methods.** 108 healthy individuals (55 males, 53 females) repeatedly touched two targets placed at shoulder height in front of them. The targets were placed at 30% and 100% of arm's length and touched at a rate established by a 1Hz metronome until the subjects reported a perceived exertion of 8 on the Borg CR-10 scale for the neck-shoulder region. Bipolar surface EMG was recorded from the upper trapezius, anterior deltoid, biceps and triceps. Task duration and EMG amplitude (average and cycle-to-cycle variability) during the first minute (baseline) and last minute (fatigue-terminal) were compared between men and women.

**Results.** There were no gender differences in task duration, EMG variability at baseline, or change in average EMG amplitude with fatigue. Change in EMG variability from baseline to fatigue-terminal was lower for women than men in the upper trapezius (7.2% vs. 30.6% increase,  $p=0.02$ ), and higher for women than men in the biceps (11.8% increase vs. 23.2% decrease,  $p=0.0006$ ).

**Discussion.** This is the first study to report gender differences in muscle-activity responses to a fatiguing, dynamic manual task relevant to working life based on a comprehensive sample of healthy individuals. Despite no differences in task duration, there may be gender differences in the physiological mechanisms behind fatigue adaptations: while women may use compensatory mechanisms mainly involving the elbow, men may use more shoulder-driven strategies. These gender differences in muscle-activity responses may contribute to explaining why women suffer more from neck-shoulder MSDs than men.

## Influence of posture variation in a repetitive manual task on maximal acceptable work pace and upper body kinematics

Tessy Luger (presenter), Tim Bosch, Marjolein Douwes, Dirkjan Veeger, Marco Hoozemans, Michiel de Looze, Svend Erik Mathiassen

**Background.** It is generally agreed that constrained postures during assembly work can lead to musculoskeletal disorders in the neck and shoulders. In a controlled experiment, we investigated the extent to which more variation of upper arm postures in a one-hour repetitive task influences maximal acceptable work pace (MAWP), perceived exertion (RPE), kinematics and muscle activity.

**Methods.** 13 participants (6 females, 7 males; age 26 (SD 3) years) performed a pick-and-place task for one hour, using their dominant hand to move pins between two targets. We compared three conditions in which the hand was moved: (1) horizontally, at an intended upper arm elevation of 30°; (2) obliquely, at an upper arm elevation between 20° and 40°; and (3) vertically, at an upper arm elevation between 10° and 50°. Using a psychophysical approach — with imposed work paces changing every two minutes (7-13 cycles/min) — we arrived at the MAWP of each participant. Postures of the arm, trunk and shoulder were recorded throughout, as was the activity of selected muscles (not reported here). Participants reported their RPE (Borg CR-10) at baseline and at MAWP.

**Results.** The kinematics data confirmed that the conditions had similar average upper arm elevations (32.3° (SD 1.0°) but differed in variation (arm elevation SD: 5.2°, 8.1°, 10.9°). Increased posture variation did not lead to changes in MAWP (10.7, 10.6, 10.8 cycles/min), though it did lead to slightly lower RPE values (average increase from baseline: 5.4, 4.8, 4.7).

**Discussion.** Increased biomechanical variation has been suggested to reduce the risk of developing musculoskeletal disorders. Even though our data suggest that there may be a trend towards a positive effect of variation on work perception, the increase in posture variation imposed here was not sufficient to influence performance. Further analyses of arm, shoulder and trunk kinematics and muscle activity patterns may reveal biomechanical differences of interest between the protocols.

## Identification of individual working styles in a long-cycle assembly task using kinematic and EMG variables

Jennie Jackson (presenter), Divya Srinivasan, Svend Erik Mathiassen

**Background.** Increased motor variability while performing repetitive tasks has been suggested to decrease the risk of developing musculoskeletal disorders. However, support for this positive effect is lacking outside of short, simple, highly controlled tasks. It is also currently unknown whether or not existing motor variability metrics are viable for characterising occupational tasks. The purpose of this study was to assess motor variability during a long-cycle simulated occupational task. Using metrics previously validated for short-cycle tasks, this study aimed to determine the extent to which: (1) individuals differed in motor variability with respect to kinematics and/or EMG activation; (2) individual motor variability was consistent across days; and (3) kinematics and EMG motor variability were correlated.

**Methods.** Following a stringent, three-day training regime, 15 females proved sufficiently proficient to participate. On two occasions, participants performed 36 cycles of an assembly task (combining gross and fine motor skills) at 110 MTM pacing (51 s per cycle). For each cycle, multiple upper arm kinematic and trapezius EMG summary mean and SD variables were calculated; for each variable, the variability across the 36 cycles was assessed. The relative size of variability across individuals, and the consistency of each individual's motor behaviour across days were assessed using kinematic and EMG variables. The correlation between kinematic and EMG variables was also assessed.

**Results.** Distinct individual behaviours were observed across days: some participants were clearly more consistent in their motor behaviour than others. Further, a high correlation was found between some kinematic and muscle activation variables.

**Discussion.** Using previously validated upper arm assessment metrics, we were able to differentiate between individuals performing a long-cycle assembly task based on their degree of motor variability. Given the nature of our study task, we believe the metrics that we found to be successful at identifying individual behaviours could be used for assessing field tasks.

## Variability in repetitive and fatigued shoulder work

Peter Keir (presenter), Alison McDonald, Daanish Mulla, Calvin Tse

**Background.** Kinematic and muscular variability has been suggested as both a strategy to compensate for fatigue, prolonging task performance and also as a negative consequence of fatigue. The kinematic and muscular degrees of freedom of the shoulder complex make it a prime candidate to evaluate variability and fatigue. The purpose of this work was to examine between and within subject variability in the response to shoulder fatigue through three different protocols with increasing task/movement complexity.

**Methods.** Variability was examined with three separate groups. A university research ethics board approved all protocols and participants provided informed written consent. Fatigue protocol 1 (F1, n=10) examined muscular and kinematic variability in simple planar shoulder motions following a fatigue protocol that targeted the rotator cuff muscles. Participants repeated the protocol on a second day to compare within subject responses between days. Fatigue protocol 2 (F2, n=10) examined the muscular and kinematic response to an anterior deltoid fatigue protocol during simulated repetitive work. Participants completed 20 cycles of pre-fatigue repetitive work, followed by a fatigue protocol and then 60 cycles of post-fatigue repetitive work. In the third fatigue protocol (F3, n=20), participants performed repetitive work until exhaustion. Across the three studies, variability was evaluated with standard deviation and median absolute deviation.

**Results.** Following the rotator cuff fatigue protocol (F1), even during simple, planar motions, participants exhibited between and within subject variability in their kinematic and muscular responses. In the more complex, simulated repetitive work (F2), changes in variability observed throughout the post-fatigue work cycles were dependent on both the variable examined (muscle, joint angle) and the work-cycle.

**Discussion.** The large potential for variability within the shoulder complex may explain mixed findings in the literature and aid in explaining how the same workplace demands may result in injury for some individuals but not for others.

SYMPOSIUM 26, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 203A

## Cohort studies using technical field measurements of sedentary work and/or occupational physical activity: protocols, experiences, results and prospects (Part 1)

**Chair: Andreas Holtermann, Professor, Physical Workload and Musculoskeletal Disorders, National Research Centre for the Working Environment, Copenhagen, Denmark**

Both occupational physical activity and sedentary work are documented to predict musculoskeletal disorders (MSDs), sickness absence, cardiovascular disease (CVD) and mortality. However, existing studies are based primarily on self-reported information or observations, which may be imprecise and potentially biased. Our knowledge regarding exposures to occupational physical activity and sedentary work in different occupational populations, and their dose-response relations to MSDs, sickness absence, CVD and mortality may therefore not hold. Recently, cohort studies using technical field measurements of sedentary work and/or occupational physical activity have been initiated or planned. These cohort studies may provide novel, valid and detailed information of these exposures and their associations to health-related outcomes. However, they are challenging to perform, costly, and several decisions need to be made with respect to recruitment strategies, measurement techniques, durations and analyses.

This symposium, the first of two on this subject, will present and discuss measurements protocols, practical experiences, results and prospects of novel or planned cohort studies using technical field measurements of sedentary work and/or occupational physical activity.

## The Danish Physical Activity Cohort with Objective measurements: cohort profile

Marie Birk Jorgensen, Julie Lagersted-Olsen, Morten Villumsen, Nidhi Gupta, Mette Korshøj, Camilla Hartmann Pedersen, Pascal Madeleine, Afshin Samani, Karen Søgaard, Andreas Holtermann (presenter)

**Background.** Current available research on the association between physical work demands and musculoskeletal pain has been criticized for using self-reported data, cross-sectional design, insufficient adjustment for potential confounders and inadequate follow up on the recurrent and fluctuating pattern of musculoskeletal pain. In this abstract, we report on the profile of the Danish Physical Activity Cohort with Objective Measurements (DPhacto). DPhacto investigated the association between objective diurnal field measurements of physical activities and provides follow up on pain.

**Methods.** Eligible workers (n=2,107) from 15 Danish companies within the cleaning, transportation and manufacturing sectors were invited to participate in the study. Workers responded to a baseline questionnaire and participated in physical tests. They also wore accelerometers and heart rate monitors for four consecutive days. Finally, workers responded to monthly text messages regarding pain and quarterly questionnaires concerning the consequences of pain on work activities, social activities and work ability for a one-year, follow-up period.

**Results.** 1,087 (52%) workers participated – 901 from blue-collar occupations and 185 from white-collar occupations. Analyses of the representativeness of the study population indicated that it was representative of the background target population, except that women were slightly more likely to consent to participate. Objective measurement devices were mounted on 909 workers in total and response rate to the monthly text messages was >80%. Almost all (99%) participants provided their social security number, which offers a unique opportunity for longitudinal register-based follow up.

**Discussion.** Opportunities for high quality, prospective analyses on the association between physical activities at work and leisure that account for health and work-related outcomes are enabled by a number of factors. These include: successful recruitment of participants; good follow-up rates; and, large variance in types and amounts of physical activities during work and leisure within the measured population.

## Occupational differences in sedentary and moderate/vigorous activity exposure of young adults

Leon Straker (presenter), Erin Howie, Pieter Coenen, Genevieve Healy, Joanne McVeigh

**Background.** Exposure to sedentary time and moderate/vigorous physical activity (MVPA) have both been linked to significant health outcomes. The physical demands of work systems vary and thus the activity exposures and attendant health risks are likely to vary between occupations. As young adults are developing the work and non-work lifestyles that will influence their current and future health and productivity, an understanding of the occupational differences in exposures is important. This study examined the sedentary time and MVPA of young adults on weekdays and weekend days by occupation.

**Methods.** This was a cross-sectional study of 306 (46.4% female) young adults (22.2±0.7 years) from the longitudinal pregnancy cohort Raine Study who provided accelerometry and occupation data and met the study inclusion criteria of working full time (≥38h/wk) or studying full time. Actigraph GT3x+ monitors were worn on the hip for a week using a continuous wear protocol, with one-minute epoch vertical axis data categorised by common intensity cut-points. Occupation was self-reported and coded to the national classification system into: managers, professionals, techs/trades, community service, clerical, sales, drivers, labourers and students. Differences were tested using one-way ANOVA with Tukey post-hoc comparisons.

**Results.** Daily sedentary and MVPA time varied by occupation on weekdays and weekend days. For example, clerical workers (604min/day), professionals (602min/day), managers (570min/day) and students (568min/day) had the highest weekday sedentary exposure; labourers (504min/day), tech/trades (512min/day), sales (534min/day) and drivers (535min/day) had the lowest. Drivers (33min/day) and managers (30min/day) had the highest weekend day moderate/vigorous exposure and clerical (16min/day), community service (18min/day) and students (21min/day) had the lowest.

**Discussion.** These findings demonstrate the potentially important variations in exposure to sedentary time and MVPA across occupations and reinforce the proposition that work systems need to be designed to provide appropriate activity profiles for workers.

## Research protocol and profile of the “Danish observational study of eldercare work and musculoskeletal disorders” (DOSES)

Kristina Karstad (presenter), Karen Sjøgaard, Birgit A. Greiner, Alex Burdorf, Reiner Rugulies, Andreas Holtermann

**Background.** Adverse physical and psychosocial working conditions are both considered to be important determinants in the high occurrence rate of musculoskeletal disorders (MSDs). However, currently the scientific documentation supporting a causal relationship is hotly debated, as most evidence on this topic relies on self-reported data and inadequate follow up on the recurrent and fluctuating pattern of MSDs. The aim of the DOSES project is to investigate the prospective association between observed physical and psychosocial working conditions and time-varying occurrence of MSDs and their consequences.

**Methods.** DOSES is a prospective cohort study with a one-year follow up on MSDs. We invited 943 Danish eldercare workers from 20 nursing homes to participate in the study; 553 (59%) agreed to participate. At baseline, physical (i.e. patient-handling activities and use of ergonomic devices) and psychosocial (i.e. interruptions, impediments and emotional demands) working conditions were assessed by workplace observations. Approximately 4,700 observations were performed over the course of more than 900 hours of observation. In addition, accelerometer-based measurements of participants' physical activities (e.g. walking, running) and postures (e.g. forward-bended back) were conducted for a minimum of four consecutive days, including at least two workdays. Using monthly text messages, we assessed low-back and neck/shoulder pain with reference to days with pain and pain intensity (and their consequences) and to MSD-related sickness absence and bothersomeness during the follow-up period.

**Results.** Data was collected from September 2013 to January 2016. Results from observed physical and psychosocial working conditions and the accelerometer measurements will be presented together with an overview of the registered MSD data at the conference.

**Discussion.** Using workplace observations, technical measurements of physical activities and postures, and monthly follow up on MSDs, DOSES will go beyond the methodological weaknesses of previous studies. Results will contribute to a more comprehensive understanding of the influence of physical and psychosocial working conditions on occurrence of MSDs.

SYMPOSIUM 27, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, BALLROOM B

## Sustainable prevention of work-related MSDs: gender analysis and development of effective interventions (Part 2)

**Chair: Marie Laberge, Assistant Professor, School of Rehabilitation, University of Montreal, Montreal, Canada**

Increasingly, evidence and theories are suggesting that work-related musculoskeletal disorders (MSDs) are not experienced in the same way by men and women. For example, while men are more often exposed to heavy physical workloads, women are more likely to be exposed to repetitive work and psychosocial risk factors. Thus, the development of occupational health and safety (OHS) interventions to prevent work-related MSDs must consider sex and gender. Goldenhar (2001) proposed a three-step “intervention research process” to develop effective OHS interventions: intervention development, implementation and evaluation. This symposium, the second of two on the subject, illustrates how sex and gender may be considered at each step. Presentations will be followed by discussion of the investigation and strategies needed to improve consideration of sex and gender at all stages of the process. The audience will be asked to discuss how they ensure that sex and gender are taken into account when they develop interventions in order to ensure that measures are both effective and that they favour social justice.

## Questioning how gender is taken into account in the action plans of participatory ergonomic interventions aimed at preventing work-related MSDs

Valerie Albert (presenter), Nicole Vezina Henriette Bilodeau

**Background.** Work modifications tend to target male employees more often than other genders. Gender should thus be considered at each step of an ergonomic analysis in order to assist stakeholders in developing an action plan that will improve work situations for both men and women.

**Background.** The objective was to identify how gender is taken into account in the action plan of participatory ergonomics interventions.

**Methods.** An ongoing prospective multi-site evaluation (from July 2015 to March 2016) of the development phase of ergonomic interventions was performed using a multiple-case study design. Ergonomic interventions (n=4) were carried out by emerging ergonomists (EEs) — interns working on their master's degrees. For each case, data was collected in real time through a logbook that kept track of every action performed (type of activity, stakeholders involved, duration, goals, results) and three in-depth individual reflexive interviews with the EE, following each step of the ergonomic intervention development phase: (1) request analysis; (2) analysis of work situations; and (3) adoption of an action plan.

**Results.** Preliminary results for the first step (request analysis) indicate that accident or absence records do not always provide the data necessary to allow a gender analysis. Furthermore, the needs and problems most frequently prioritized by stakeholders as requiring ergonomic interventions steered the EEs towards work situations where the hazards were the most obvious or explicit and that mostly involved male workers. For the second step, EEs will analyze work situations and compare the work activities of both women and men where possible. The final step will assess the nature of the action plan selected by stakeholders and the strategies used by the EEs to influence the choice of the work modifications to be implemented.

**Discussion.** Preliminary findings suggest that, in participatory interventions, stakeholders' perceptions related to gender can be an obstacle to the adoption of an action plan geared towards improving work situations for both women and men.

## Utilization-focused evaluation of the implementation of OHS learning tools employed by teachers in the Quebec work-oriented training path: is gender considered?

Marie Laberge (presenter), Andréane Pinet

**Background.** The Quebec Work-oriented Training Path (WOTP) is a high-school curriculum that aims to develop employment skills among adolescents with learning difficulties. The WOTP offers programs centred on apprenticeships, hence enabling students to learn semi-skilled tasks. The population targeted is also concerned about occupational health and safety (OHS) hazards due to workplace conditions (manual jobs) and low job tenure. Because this program is highly gender-segregated in terms of jobs and hazards, the research team wanted to know if teachers modulate their supervisory role or methods to take gender differences into account when implementing OHS prevention tools.

**Methods.** The results come from an implementation study that aimed to understand how OHS learning tools developed by Laberge (2011) were used in practice by teachers involved in the WOTP. The study design is a multiple case study using a *Utilization-focused Evaluation* approach. Ten teachers participated in a training session and were then free to use and adapt any of the seven OHS learning tools to suit their students' needs. Data was collected via semi-structured interviews, direct observation, various log books and follow-up grids, along with verbatim transcripts of three follow-up meetings and one wrap-up meeting.

**Results.** The findings illustrate relatively weak adaptation to gender specificities, and a perpetuation of stereotypes when using the prevention program. Young men, who represent the majority of WOTP candidates, are more often placed in jobs that a risk of a sudden accident; young women are more often placed in work situations that present well-documented risk factors for Work-related MSDs over the longer term (static, repetitive, working with public). The findings showed that teachers often underestimate Work-related MSD risk factors in female job settings.

**Discussion.** In conclusion, it would be advisable to develop teacher training programs that improve gender considerations during pedagogical intervention and supervision.

## Work-related MSD prevention and education: why the supervisory tools used by teachers in charge of trainee placements in male-dominated training for semi-skilled trades should be gender-sensitive

Aurelie Tondoux (presenter), Marie Laberge

**Background.** In Quebec, a semi-skilled vocational training program prepares students with learning disabilities for the labour market through traineeships. Both male and female trainees are exposed to risk factors for musculoskeletal disorders (MSDs) at their training locations and this issue needs to be addressed by teachers.

**Methods.** This paper presents findings from a current action-research study that aims to develop a tool to assist teachers in assessing OHS risks factors at the training sites. Nine teachers were accompanied by an ergonomist while visiting the training locations to see their students (19 female and 55 male trainees).

**Results.** The most common jobs were stock handler in a retail store (24 trainees) and cook's helper (15 trainees). For the other 35 students, the majority of men work in traditionally male-dominated trades such as mechanics and carpentry, and most women work in pet shops, daycare settings and hair salons. When questioned about MSD risk factors, teachers talk about manual materials handling, because it is one of the main training tasks. However, it is more difficult for teachers to recognize other risk factors during their visits when: (1) they cannot see the student at the workstation because employers restrict their access or visitation privileges; (2) the job requires physical tasks at specific times of day and the visit happens at a different time; and (3) the student is just waiting around because the training takes place during days with low work activity.

**Discussion.** The last two scenarios have been seen more often with female trainees, which is why the tool that is to be developed should include a gender-sensitive approach that will allow the teacher to recognize MSD risk factors even when it proves difficult to see trainees in action at work. This tool must also address the "invisible risk factors" (e.g. static workload), which is more common in female-predominant work settings.

SYMPOSIUM 28, WEDNESDAY JUNE 22, 3:30PM – 5:00PM, ROOM 201A

## Physical load risk assessment methods for practitioners

**Chair: Marjolein Douwes, Senior Scientist, Work, Health and Technology, TNO, Rijswijk, The Netherlands**

Risk assessment methods are commonly used to evaluate exposures to physical loads in order to identify hazards at work and indicate avenues for improvement. Different methods to suit different purposes (i.e. different kind of exposures) and end users are available. Recently, new assessment methodologies have been developed with non-expert users as the target group. Presenters will describe and discuss the need for new methods and the involvement of end users during development. Results of recent developments, improvement and validation activities, and impact studies will also be featured. Discussions will also touch on the lessons learned and the direction of future research and development activities.

## Facilitating improvement measures in manual handling using the RAMP-tool

Carl Lind, Linda Rose (presenter)

**Background.** In the manufacturing and logistics industry, many tasks include heavy or repetitive manual handling and often adverse postures. This may increase the risk of work-related musculoskeletal disorders and low-back pain, and result in extensive costs due to quality deficiencies. In order to reduce these negative effects, risk management, which includes participation of the practitioners, can be an effective strategy. Therefore, a project was initiated with the aim of developing a risk-management tool that can be used by occupational health and safety (OHS) practitioners and managers.

**Methods.** Project development was carried out by researchers at KTH in cooperation with OHS-practitioners and managers from companies in the manufacturing and logistics industries. Literature on physical ergonomic risk factors, assessment tools and ergonomic standards was scrutinized and integrated into the tool. In order to improve the usability of the tool, several prototypes were continuously tested on intended end users throughout the development process.

**Results.** The project resulted in the development of the RAMP-tool: *Risk Assessment and Management tool for manual handling Proactively*. The RAMP-tool includes a two-stage assessment, from screening of risk factors using RAMP-I, to assessment using RAMP-II. The results from the assessment are presented in the results module at different levels of detail depending on user needs. For each identified risk, the tool presents possible solutions in five areas: technology and design, organization, employees, vision and strategies, and environment. This can facilitate discussions at the workplace and form the basis for action plans.

**Discussion.** This tool addresses a broad range of risk factors commonly observed in the manufacturing and logistics industries and it is currently used by several organizations in Europe. The tool not only assesses risks related to manual handling, but also aids the process of handling the risks and finding appropriate actions.

## An OHS practitioner tool for improving pushing and pulling operations

Carl Lind (presenter)

**Background.** Manual pushing and pulling (MPP) is common in industrial manufacturing and logistics and has been associated with low-back pain and shoulder disorders. Although several tools have been developed, their usability for occupational health and safety (OHS) practitioners has been questioned. Moreover, several of these tools lack guidance for acceptable hand forces and may only include a small number of factors that affect a worker's capacity in MPP. The aim of this study was to develop a new tool for OHS practitioners to assess MPP under a range of situations.

**Methods.** The push/pull-tool, which is part of the RAMP tool, was developed by researchers at KTH in cooperation with an expert group consisting of researchers and experienced ergonomists. The tool consists of nine multipliers that are based on psychophysical, biomechanical and physiological studies. The usability of the tool was evaluated by 22 ergonomists using a questionnaire; the reliability of the tool was assessed by six ergonomists and technicians with reference to five different MPP jobs.

**Results.** This tool presents the results of an assessment in three different risk/action levels, and as a score predominantly that is intended to guide and motivate improvement measures. MPP operations with frequencies ranging from one/day to 240/hour — and with a travel distance of up to 60 metres — can be assessed. In order to enhance its scope, several factors that affect the capacity are included; e.g. MPP using one hand, in teams, in hot ambient temperature, with low shoe-floor friction levels or with force exertions to the side. Initial evaluation of its usability and reliability indicates that both ergonomists and technicians can make reliable assessments using this tool.

**Conclusion.** This new tool can be used by OHS practitioners for assessment and design of a range of manual pushing and pulling operations and to facilitate improvement measures.

## Study protocol of the validation of new Key Indicator Methods

**Andre Klussmann (presenter), Ulf Steinberg, Felix Brandstaedt, Marianne Schust, Bernd Hartmann, Hansjuergen Gebhardt, Patrick Serafin, Dirk Ditchen, Falk Liebers**

**Background.** Three Key Indicator Methods (KIMs) ([www.keyindicatormethods.eu](http://www.keyindicatormethods.eu)) are presently available for risk assessment regarding manual lifting, holding and carrying of loads (KIM-LHC), manual pulling and pushing of loads (KIM-PP) and manual handling operations (KIM-MHO). Based on a literature review, six types of physical straining working conditions are defined and differentiated: (1) lifting, holding and carrying loads, (2) pushing and pulling of loads, (3) manual handling operations, (4) whole-body forces, (5) awkward body postures, and (6) body movement. Considering these types of physical exposures, the existing KIMs are revised and three KIMs are developed de novo. Subsequently, all methods need to be tested and validated under practical conditions.

**Methods.** The revised and new KIMs will be validated regarding concurrent validity, objectivity, reliability and practicability. The cross-sectional validation study was designed in companies in Germany. It is intended to include 1,200 employees at 120 different work places in 2016. Theoretical background, definitions used of the physical work, assumed causal relationships, aims and study design of the validation study for the different aspects of validity, statistical approaches and ethical aspects are a priori defined in a study protocol.

**Discussion.** The (further) development of KIMs is part of a joint project (MEGAPHYS) funded by the Federal Institute for Occupational Safety and Health (BAuA) and the German Social Accident Insurance (DGUV). Further MEGAPHYS partners are Institute of Ergonomics at the Darmstadt University of Technology (IAD) and Leibniz Research Centre for Working Environment and Human Factors (IfADo). The main aspects of this study protocol of validity study will be presented. It is intended to publish the validated Key Indicator Methods in 2017.

## Pretesting of new Key Indicator Methods in Germany using techniques of qualitative research

Felix Brandstaedt (presenter), Andre Klussmann, Andreas Schaefer, Patrick Serafin, Ulf Steinberg, Marianne Schust, Bernd Hartmann, Dirk Ditchen, Detlef Trippler

**Background.** The BAuA-developed screening tool Key Indicator Method (KIM) is currently being revised and further developed for all typical types of physical workload in Germany. In order to prove applicability and practicality of the first drafts, a pretesting study was started in 2015.

**Methods.** The pretesting study includes tests of three already existing and revised methods, and three new KIMs in up to 50 companies of different sizes and in different sectors located in Germany. In 2015, 67 companies that volunteered were contacted. Quantitative and qualitative information will be used to identify bottlenecks and provide necessary information for adjustment of the key items and associated scales.

**Results.** As of September 2015, tests have been performed in 34 companies in different sectors, ranging from < 250 up to > 1,000 employees. Six drafts of KIMs were tested on a total number of 107 tasks. According to current results, users appreciate the improved KIMs and confirm the need for practice-oriented screening tools for assessing physical workload.

**Discussion.** The analysis of the received responses is still in progress. Results and conclusions of the pretest of the improved KIMs will be presented. The validated KIMs will be published in 2017.

## Towards a better understanding of exposure limits for occupational postures

Pieter Coenen (presenter), Marjolein Douwes, Swenneke van den Heuvel, Tim Bosch

**Background.** Awkward occupational body postures are considered to be significant risk factors for musculoskeletal disorders (MSDs). Although risk assessment tools and guidelines for working postures are common, exposure-outcome associations of postures and MSDs have not been well quantified (in terms of duration, frequency and intensity). The aim of this study was to assess the predictive value of working postures for MSDs and to establish occupational posture exposure limits.

**Methods.** Workers from 34 companies in the Netherlands (n=789) were recruited and took part in measurements of physical exposure at the workplace using video observations (i.e. addressing kneeling/crouching, trunk flexion and rotation, neck flexion and rotation and arm elevation). Self-reported MSDs in the low back, neck and upper and lower extremities were noted. Associations with the duration and frequency of each of the postures with MSD were assessed using logistic regression. Exposure limits were established using ROC-curves after which exposures were categorised into high and low risk.

**Results.** Significant associations for kneeling/crouching and trunk flexion to low-back pain and arm elevation to shoulder and neck symptoms were shown (e.g. trunk flexion to low-back symptoms: OR 1.40 [1.01 1.95]). Cut-off points (discriminating between low and high risk exposures) are shown (e.g. trunk flexion >17.74 postures/day and arm elevation >0.72 hours/day are considered to be of risk).

**Discussion.** Our results give insight into the dose-response associations of working postures and MSDs and provide evidence-based exposure limits that can be used in future occupational safety and health guidelines and risk assessment tools. Moreover, our results show that intensity, duration and frequency should be considered in risk assessments and in guidelines for working postures.

## A new risk assessment method for push and pull tasks for practitioners

Marjolein Douwes (presenter), Reinier Könemann, Frank Krause, Tim Bosch, Marco Hoozemans

**Background.** Employers need valid but simple risk assessment tools to prevent work-related musculoskeletal disorders. In 2009, the Dutch Ministry of Social Affairs and Employment started a research program to assist Dutch companies in meeting their obligations to protect the health and safety of their employees. As part of this program, TNO developed several online risk assessment tools for practitioners. This paper describes the development of a new tool for the risk assessment of push and pull tasks.

**Methods.** Development of the tool came after a number of steps, including: defining criteria and determining whether or not they were satisfied by existing tools; studying the epidemiological literature on risk factors for pushing and pulling; and assessing the reliability of two existing tools. Based on the results of these inquiries, we decided to develop a new tool. This tool is based on the psychophysical data for pushing and pulling of Snook and Ciriello (1991). These data reflect the maximum acceptable push and pull forces employees can exert under different conditions without straining themselves or becoming unusually tired, weakened, overheated, or out of breath. For the risk assessment, the tool requires information on the mass that needs to be pushed or pulled, force direction, frequency, hand height, distance and cart and environment characteristics. The output of the tool is a maximum object weight or risk index. Several issues that we came across will be discussed, such as a lack of epidemiological data on pushing and pulling and defining health limits.

**Results.** This new tool will help companies to estimate if push and pull tasks yield a risk on musculoskeletal disorders and define adequate preventive measures. The tool will be tested in the field before making it freely available to all occupational health practitioners.

SYMPOSIUM 29, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 202A

## Motor variability in working life: Determinants and effects on health and performance (Part 2)

**Chair: Divya Srinivasan, Assistant Professor, Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, Va., U.S.A.**

Motor variability is an emerging area of research in occupational life. Growing evidence suggests that motor variability has the potential to increase biomechanical exposure variation in repetitive work without affecting production. Several research groups are working on this topic from different perspectives. The purpose of this symposium, the second of two on this subject, is to explore the relevance and possible contributions of motor variability to health and performance in different settings in working life and examine which personal factors influence inter-individual differences in motor variability. Discussion will address future directions and methodological challenges for motor variability research from an occupational context through presentations and discussions from leading experts in the field.

## Effects of modified computer work posture on upper body muscle activity variability

Julie Côté (presenter), Amanda Farias, Larissa Fedorowich

**Background.** Musculoskeletal disorders (MSDs) are common among computer users. Prolonged computer use involves low load, sustained activity of the neck and upper limb muscles which may lead to MSDs. Consequently, some workplaces are exploring the use of non-traditional computer workstations that allow working in postures other than the traditional, seated posture facing a screen. In theory, this could help promote some variability in neck/shoulder muscular patterns. The objective of the study was to measure the effects of performing a 90-minute computer task in two different neck postural conditions and in three whole-body postural conditions on muscular variability.

**Methods.** In Study 1, 20 healthy adults performed a computer task in three sessions. Study participants were in a seated, standing or walking posture. In Study 2, 27 healthy adults performed a similar computer task either with a laptop or with a dual-monitor setup. The computer task combined reading, typing and search-and-find tasks, separated equally between the two monitors in Study 2. Surface electromyography (EMG) was recorded from trunk (Study 1), and neck and shoulder muscles (both studies) for 30 seconds every nine minutes. EMG variability was computed by quantifying coefficient of variation (CoV) across 30 one-second EMG RMS values in every 30-second block. Results of Study 1 showed that lower trapezius CoV was about 65% higher in both standing and walking compared to sitting computer work; and lumbar erector spinae (LES) CoV increased with time in seated and standing conditions ( $p < 0.05$ ) to reach the constant LES CoV levels displayed during walking towards the end of the task. In Study 2, there were no effects of monitor numbers on CoV, and there was only one significant CoV increase with time, which was for the right middle trapezius (76%,  $p = 0.04$ ).

**Discussion.** Computer work in alternative postures is increasingly popular and it may present some advantages; however, the effects of alternative postures on neck-shoulder variability are unclear.

## Variability in pattern of muscular activity during a fatiguing repetitive task

Afshin Samani (presenter), Divya Srinivasan, Svend Erik Mathiassen, Pascal Madeleine

**Background.** Muscle fatigue develops at markedly different rates among individuals. The pattern of variation in muscle activity has been suggested as a determinant of the rate of fatigue development. This variation can occur between muscles or between compartments of a muscle. Thus, we investigated the pattern of muscular activity in shoulder and arm regions during a fatiguing repetitive work task.

**Methods.** 21 healthy young women performed a repetitive pipetting task at 2.8 seconds/cycle. The session continued until the subject rate of perceived exertion reached 8 on Borg CR-10 scale. High density (HD) surface electromyogram (EMG) over upper trapezius, and bipolar EMG from extensor carpi radialis, flexor carpi radialis, biceps, triceps, deltoideus anterior, serratus anterior, upper and lower trapezius were collected to investigate intra- and inter-muscle variation patterns. EMG amplitude and mean power frequency (MPF) were obtained for all the recorded EMG signals. The barycenter of activity over the HD-EMG grid was also determined. Normalized mutual information (NMI) was determined for each pair of muscles. The extent of variability of the outcomes was also assessed.

**Results.** As fatigue developed, EMG amplitude increased and the MPF decreased for all muscles except the MPF for upper trapezius and deltoideus. The activity of trapezius was higher on the lateral side of HD-EMG grid than on the medial side and the barycenter showed a lateral shift across time. NMI between the muscle pairs also increased with fatigue. The variability of the investigated outcomes was not associated with the time to the task ending.

**Discussion.** Myo-electrical manifestations of muscle fatigue were observed but none of the outcomes had an association with the rate of fatigue development. Using multivariate approaches, synergistic pattern of muscular activity is yet to be investigated.

## Variation in torso, head, neck, and shoulder postures during computer vs. non-computer interactions during office work

Jennifer Garza (presenter), Jack Dennerlein, Proof Team

**Background.** Computer work is associated with musculoskeletal disorders, but the factors responsible for this association are still unclear. Postural variability, or the lack thereof, during work tasks is known to affect the development of musculoskeletal disorders, especially computer related musculoskeletal disorders. The objective of this study was to determine whether there were differences in postural variability among office workers performing computer work compared to non-computer interactions.

**Methods.** As part of the PRedicting Occupational biomechanics among Office workers (PROOF) study, torso, head, neck and shoulder postures of 120 office workers were measured during a two-hour period while they performed their regular work at their own workstations. Computer interaction monitoring software that was installed on each participant's computer recorded when participants were interacting with the computer. G-Link accelerometer data loggers recorded postures continuously throughout the measurement period. Postural variability was calculated as the 90th – 10th percentile postures, and paired t-tests were used to compare postural variability during computer vs. non-computer interactions.

**Results.** Postural variability was significantly ( $p < 0.05$ ) greater during non-computer interactions across all postures for all torso, head, neck, and shoulder postures. Postural variability during computer interactions ranged from 10 to less than 30 degrees for all postures, while postural variability during non-computer interactions ranged from 20 to greater than 70 degrees.

**Discussion.** Lower postural variability was observed during computer interactions compared to non-computer work among office workers. This lower variability may contribute to the development of musculoskeletal disorders in this population.

## Motor variability in relation to physical activity

Pascal Madeleine (presenter)

**Background.** The variability of human movement has attracted a lot of interest over the last few decades and motor variability is seen as a natural and important feature of human motor behaviour present in everyday activities. However, despite the attention, motor variability remains a puzzling issue due to the vast numbers of constructs used to describe it. This presentation will focus on the internal and external sources of variability as well as modifiers such as pain and training.

**Methods.** Results from new cross-sectional and longitudinal studies will be presented. The presentation will encompass repetitive tasks of daily life like butchers' work, computer work and stair descent in the presence or absence of neck-shoulder, low-back and knee pain. Electromyography (EMG) and 3D kinematics data were collected. The size (standard deviation) and structure (sample entropy) of variability were computed for EMG and kinematics time series to describe internal and external sources of variability. Absolute and relative reliability results will be presented as well as results on changes in motor variability in response to pain and training.

**Results.** Changes in motor variability found in the presence of pain included smaller increments of variability of arm movement, less complex trunk movement and lower EMG readings from lower extremities ( $p < 0.05$ ). A multimodal intervention focusing on training indicated potential for changing the pattern of motor variability among young females suffering from knee pain.

**Discussion.** The results indicate that motor variability is changed in the presence of altered sensory information like pain. More importantly, the pattern of motor variability can be changed in response to a multimodal intervention.

SYMPOSIUM 30, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 203A

## Cohort studies using technical field measurements of sedentary work and/or occupational physical activity: protocols, experiences, results and prospects (Part 2)

**Chair: Andreas Holtermann, Professor, Physical Workload and Musculoskeletal Disorders, National Research Centre for the Working Environment, Copenhagen, Denmark**

Both occupational physical activity and sedentary work are documented to predict musculoskeletal disorders (MSDs), sickness absence, cardiovascular disease (CVD) and mortality. However, existing studies are based primarily on self-reported information or observations, which may be imprecise and potentially biased. Our knowledge regarding exposures to occupational physical activity and sedentary work in different occupational populations, and their dose-response relations to MSDs, sickness absence, CVD and mortality may therefore not hold. Recently, cohort studies using technical field measurements of sedentary work and/or occupational physical activity have been initiated or planned. These cohort studies may provide novel, valid and detailed information of these exposures and their associations to health-related outcomes. However, they are challenging to perform, costly, and several decisions need to be made with respect to recruitment strategies, measurement techniques, durations and analyses.

This symposium, the first of two on this subject, will present and discuss measurements protocols, practical experiences, results and prospects of novel or planned cohort studies using technical field measurements of sedentary work and/or occupational physical activity.

## Design, methods and preliminary results from a study of objectively measured work exposure related to musculoskeletal health in physically demanding occupations

Bo Veiersted (presenter), Lars-Kristian Lunde, Markus Koch, Morten Wærsted, Stein Knardahl

**Background.** Most employers, employees and health-care providers assume work in the construction and health-care sectors to be physically demanding. A high level of mechanical risk factors at work — combined with a reduced capability of the individual — may increase the risk for musculoskeletal disorders and reduce work ability. The aim of this project is to study “how heavy is heavy work?” and analyze work-related factors that may determine work ability and health in occupations with physically demanding tasks, and with an emphasis on senior workers.

**Methods.** This prospective observational cohort study uses a comprehensive work exposure measurement protocol at basis and a questionnaire at basis and every sixth month for two years. 594 workers were included (response rate 47%) and technical measurements were performed for 127 of these. Activity and work postures were recorded by accelerometers (ActiGraph), muscle activity and indirect force use by electromyography (Mobi8), vertical ground reaction forces were recorded by using pressure-measurement insoles (Medilogic) in the shoes of the participants and heart rate was recorded by Actiheart. ActiGraph and Actiheart were kept on continuously for four-five days. All instrumentation was used during one working day. Individual fitness, health status and muscle strength were examined prior to measurements. All basis measurements have been completed (October 2015), questionnaire follow up is ongoing.

**Results.** Data analyses on objectively measured work exposures and their relation to health are ongoing. Self-reported mechanical exposures and heart rate reserve (HRR) as a mean of several working days were higher among construction workers compared to health care workers, and self-reported work ability was lower. HRR decreased by age, but self-reported work ability was rather stable for the different age groups.

**Discussion.** Knowledge gained from this study may be used to improve working conditions, not only making it possible for the seniors to stay longer in working life, but also to prevent work-related health risks for all age groups.

## Design and experiences of objective measurements of physical activity during retirement transition in the Finnish Retirement and Aging Study

Anna Pulakka (presenter), Jussi Vahtera, Sari Stenholm

**Background.** Our aim is to present the design of the Finnish Retirement and Aging Study (FIREA-FPS) and discuss experiences of objective physical activity measurements among older workers approaching their retirement. We will also examine whether or not self-reported physical activity level is associated with participation in accelerometer measurements.

**Methods.** FIREA-FPS is nested within a large occupational cohort, Finnish Public Sector Study (FPS), and focuses on participants retiring in 2013–2018. FIREA-FPS participants are invited to take part accelerometer measurements after they have responded to a questionnaire 18 months prior to their estimated retirement date. The aim is to enroll 1,200 participants to undertake objective activity measurements using wrist-worn ActiGraph accelerometers. The study will run between 2014 and 2018. The one-week accelerometer measurements will be repeated annually four times around the retirement transition and a subsample of 400 participants will also wear an accelerometer on their thigh. In the annually administered questionnaire, we have inquired about self-reported physical activity and calculated weekly metabolic equivalent task (MET) hours. The activity levels of those who took part in the wrist accelerometer measurements were compared to those who did not take part with student's t-test. In a diary accompanying the accelerometer, we asked participants to report their comments on the activity measurement.

**Findings.** Of the 741 eligible participants who responded to the survey (age range 58–64), 329 (44%) consented and 412 (56%) did not consent to the wrist accelerometer measurements during the first year of the study. Mean (SD) MET-hours/week for the participants were 27.4 (23) and for the non-consenting 28.8 (26),  $p=0.78$ . Most of the participants reported no problems with the accelerometer, although 29% mentioned minor inconvenience, such as large size of the device and/or skin irritation.

**Conclusions.** Wrist-worn accelerometer is feasible for retiring occupational cohort. Self-reported physical activity levels prior to invitation to the accelerometer measurements were similar among consenting and non-consenting.

## Objective measurements of physical activity in the Norwegian HUNT Study

Paul Jarle Mork (presenter), Vegar Rangul, Ottar Vasseljen, Tom Ivar Lund Nilsen

**Background.** The Nord-Trøndelag Health Study (the HUNT Study) is one of the largest health studies ever performed. It is a unique database of personal and family medical histories collected over three intensive surveys (HUNT1 in 1984-1986, HUNT2 in 1995-1997, and HUNT3 in 2006-2008). More than 106,000 adults participated in one or several HUNT surveys. The fourth HUNT survey (HUNT4) — starting in August 2017 — will include one week of objective measurement of physical activity in about 50,000 adults ( $\geq 20$  years) and 10,000 adolescents (13-19 years).

**Methods.** Physical activity will be measured by small, lightweight tri-axial accelerometers placed at the upper back and on the front of the thigh. Heart rate will be recorded by photoplethysmography embedded in a wristband. Currently we are working on the technical solutions and on the development of algorithms for detection of different daytime activities such as sitting, standing, walking, running and cycling. These algorithms will also include possibilities for further sub-grouping of activities like moving while standing (“shuffling”), walking stairs and forward bending of upper body while standing. The sensor set up will also allow for identification of body movements and different postures while lying down (prone, supine and on right/left side). A validation study is currently being carried out to investigate whether nocturnal body movements and/or changes in body position can be used to identify sleep-wake cycles as recorded by polysomnography.

**Discussion.** We envisage that the objective measurements of physical activity in HUNT4 will open for exciting research that will provide new and important insights into the relation between physical activity and musculoskeletal disorders. The technical solutions, analytic approach and possibilities for research based on the HUNT data material will be presented.

## Thigh inclinometer measurements of 5,000 persons in the Swedish CARDioPulmonary BioImage Study (SCAPIS)

Peter Palm (presenter), Johan Sundström, Andreas Holtermann, Mikael Forsman

**Background.** The **Swedish CARDioPulmonary BioImage Study (SCAPIS)** is an ongoing cohort study aimed at finding risk markers for heart and lung disease. A collaboration between six Swedish universities, SCAPIS will examine 30,000 participants (aged 50-65 years) for risk markers for heart and lung disease and reference data collected from accelerometers (ActiGraph GT3X) attached to the hips of participants. Additionally, Uppsala University research will employ a second accelerometer attached to the thighs of 5,000 participants to gather data about sitting time and daily physical activities. The purpose is to present the study protocol with a view to sharing practical experiences from collecting accelerometer data from a large-scale study and to discuss the potential for using this cohort to study risk factors for MSDs.

**Methods.** Axivity AX3 accelerometer units will be taped directly to the skin on the front side of the participants' thighs on their first visit to the study centre. The accelerometers will be removed on their second visit after seven days. The two accelerometers will be synchronized by shaking them together both before and after the data collection. Also, participant national identification numbers will be gathered to enable future follow ups in national registers.

**Results.** As of spring 2016, data have been obtained from 1,000 participants.

**Discussion.** The study protocol and practical experiences that may be valuable to other researchers performing data collection with accelerometers in large scales studies will be shared.

SYMPOSIUM 31, THURSDAY, JUNE 23, 10:30AM – 12:00PM, BALLROOM B

## Panel on gender, work and musculoskeletal disorders

Chair: Joy MacDermid, Professor and Assistant Dean, School of Rehabilitation Sciences, McMaster University, Hamilton, Canada

Is it possible to measure gender when you don't have a measure of gender? Analyses of secondary data

Peter Smith (presenter)

Considering sex and gender in studies of recovery and return to work

Joy MacDermid (presenter)

## Considering sex and gender in applied ergonomics: firefighting as context

Kathryn Sinden (presenter)

## Considering sex and/or gender in structure and mechanisms of the musculoskeletal system

Julie Côté (presenter)

## Considering sex and gender in occupational health policies and program

Mieke Koehoorn (presenter)



## Emerging issues in the prevention and management of work-related MSDs

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SESSION 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 201A

## Movement variability highlighted during an assembly activity

Martine Annie Gilles (presenter), Aurélie Remy, Pascal Wild, Jean Charles Guélin, Clarisse Gaudet, Jonathan Savin

**Background.** Movement variability is often neglected when analyzing work situations. It is also practically ignored when designing work situations, as designers are focused on the goal of defining standard procedures that minimize production cycle times. In this context, the aim of this laboratory study was to characterize the variability of the movement involved in performing an assembly task and, more particularly, the influence of the age of the operator and of the pace of work on the coordination of the upper limbs.

**Methods.** 65 subjects belonging to three age groups (30-35, 45-50, 60-65 years) assembled parts at two work paces: comfortable and rapid. The task was to assemble a handle and a support by means of two nuts. For each pace, each assembly required from 12 to 15 seconds; the task was repeated for a period of 20 minutes. The analysis of the assembly process focused on coordination of the upper limbs and was conducted using video recordings and an observation table specifically developed for the task.

**Results.** This analysis made it possible to identify 44 types of coordination for assembling the parts, three of which corresponded to 78% of the assemblies made. According to the preliminary statistical analyses, neither the age of the subject nor the pace of work significantly changed the number of types of coordination used.

**Discussion.** Although neither age nor pace seemed to be influencing factors for the task studied, these findings show that wide variability can exist in performing an assembly task. Neglecting movement variability as a factor in the design of a work situation could result in the future activity of the operators being understood only partially, leading to the risks not being fully assessed.

## An econometric analysis of variability in net costs of a safe resident handling program in a chain of nursing homes

Supriya Lahiri (presenter), Saira Latif, Ernest Boakye-Dankwa, Laura Punnett

**Background.** Skilled nursing facilities providing elder care have high employee back injury rates. Our prior net-cost analysis showed that investment in a Safe Resident Handling Program (SRHP) in a chain of nursing homes had an overall positive return on investment (ROI) through reduction of employee compensation claims (medical costs and indemnity) and turnover. However, there was substantial variability among 120 skilled nursing facilities. The goal of this analysis was to identify center-specific factors associated with favourable economic outcome of the SRHP.

**Methods.** We compiled data for multiple nursing facility characteristics, including worker demographics and responses to a national survey of nursing home employees' job satisfaction, all averaged at the level of the individual nursing home. Econometric modeling examined variability in net costs of investment per facility (dependent variable in ordinary least square multivariable regression) as a function of variables such as socio-demographic factors and employee satisfaction.

**Results.** Employee survey responses to satisfaction with training (p-values 0.048-0.088, multiple models) and perceived adequacy of equipment and supplies (p-values 0.02-0.037) were positively associated with economic success of the intervention among the different facilities. First language (English yes/no), work experience and age were used as controls, but did not contribute to model fit. Other workforce variables (e.g. clinical staffing ratio) and resident experience descriptors (occupancy rate, ability to perform activities of daily living) were also not significant.

**Discussion.** The ability to identify and address relevant predictors of success or failure might reduce the barriers to the implementation of similar interventions and enhance their practical value.

## An investigation of alternative work methods for emergency dispatch workers

Carolyn Sommerich (presenter), Kailyn Cage, Steven Lavender

**Background.** Emergency dispatchers work long hours, primarily while seated, and with limited opportunity for worker-initiated breaks, raising concerns for adverse health effects associated with prolonged sitting. A study was conducted to determine the effectiveness of two specific interventions—a mini-exercise cycle and a standing mat with footrest—in reducing prolonged static sitting behaviour in a sample of dispatchers.

**Methods.** The study consisted of a baseline and intervention period (one week each). Both periods consisted of five days of data collection for the week. All activity data were collected with a three-axis accelerometer, activPAL™. A total of 18 experienced emergency dispatch workers participated in the study. During the baseline week, participants worked as they normally would. During the intervention week, a mini exercise bike, standing mat and footrest were made available for participant use. A recommendation of two minutes of cycling activity during every 20 minutes of sitting was provided to participants, along with the suggestion to work in a standing position for 15-30 minutes at least once per shift.

**Results.** There was a significant decrease ( $p=0.0116$ ) in the percentage of time spent sitting between the baseline and intervention week. A significant decrease in the number of uninterrupted, 20-minute intervals spent sitting between the baseline and intervention week was also observed ( $p = 0.0061$ ). During the intervention week, the proportion of time spent standing was greater than the proportion of time cycling ( $p=0.0196$ ).

**Discussion.** The interventions implemented had a significant impact on reducing prolonged sitting periods and the total amount of sitting in general, which demonstrates the potential effectiveness of the interventions for this type of work and work environment. It is expected that, with a longer habit-forming period and some modifications to the implementation, these interventions could have a positive, long-term impact.

## An evaluation of interventions to prevent and manage musculoskeletal discomfort in global corporate offices

Kishore Madhwani (presenter), Pranab Nag, Ravimohan Hanasoge, Guharajan Nadarajan

**Background.** Increasingly, there is a perceived need to spread awareness about office ergonomics. The challenge is to educate employees to enable them to arrange workstations ergonomically to suit their body dimensions, to maintain ideal work postures, take rest breaks and perform desk stretches. The aim of this study is to promote safer working conditions and to explore effective communication methods to achieve this objective.

**Methods.** A cross-sectional study of corporate employees is being undertaken (2014 - 2016) in India and South East Asia. The study includes: (1) a web-based evaluation to assess musculoskeletal discomfort using the Nordic Questionnaire (shared online in local languages at baseline and after three months). After completing the questionnaire, respondents are directed to animation graphics illustrating ideal work postures, desk stretches and eye protection. There are also explanations on how to organize workstations ergonomically (n = 250); (2) 40-minute workshop training in a mock office workstation and education on work postures, stretches and eye protection (n = 310); and (3) 10-minute live demonstrations on each office floor on a currently occupied work-station (n = 622).

**Results.** Web-based baseline evaluation assessed prevalence of symptomatology (24%) and subsequent three-month evaluation will assess reduction in symptomatology and enhanced awareness (as study is currently ongoing, results will be shared later).

40-minute workshop training — undertaken in Indonesia, Vietnam and India — is a useful intervention that has increased awareness by >92%, though it should be noted that very few employees attend a 40-minute session.

10-minute live demonstrations — undertaken in Indonesia, Vietnam, Singapore and India — increase awareness by >90%.

When both of the above interventions were tested for statistical significance, the 40-minute workshop was superior in Indonesia ( $p < 0.05$ ).

**Discussion.** Very few employees attend 40-minute workshops, although they are superior. However, the 10-minute live demonstration comes across as a novel and practical intervention: it is brief, it is undertaken at the workstation, it enhances awareness in a maximum number of employees, and it instills a perception of caring. The web-based evaluation appears useful in situations where language is a barrier and where onsite visits are not feasible.

SESSION 2, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 201C

## Putting evidence in context: what works in occupational health and safety

Emma Irvin (presenter), Stephen Bornstein, Kim Cullen, Amanda Butt, Dwayne Van Eerd, Leslie Johnson, Steve Passmore, Sarah Mackey, Ron Saunders

**Background.** Work-related injuries and disorders are burdensome for workers and employers as well as for healthcare and compensation systems. To take effective preventive action, those designing and implementing interventions need to know the latest scientific evidence on what works in (OHS). In addition, they need to know what is most likely to work in their specific geographic, jurisdictional and industrial context. Growing amounts of information are available but OHS knowledge users have limited time and/or capacity to locate, assess, synthesize and contextualize this literature.

**Methods.** Through a collaboration involving researchers and an advisory panel of OHS stakeholders in Manitoba, Memorial University's SafetyNet Research Centre and the Institute for Work & Health (IWH), our team is developing and testing an innovative methodology for synthesizing current scientific knowledge and tailoring it for use in specific contexts. The methodology combines features of the "Contextualized Health Research Synthesis Program" (CHRSP) developed at the Newfoundland and Labrador (NL) Centre for Applied Health Research with systematic review techniques and synthesis reports pioneered at IWH. In addition to developing an innovative set of methods suitable for OHS stakeholders in Manitoba and other jurisdictions, this project will produce a handbook and a sample knowledge synthesis contextualized for the specific resources, capacities and challenges of Manitoba.

**Results.** Our results will be transferred to end users in Manitoba through various modes of dissemination. The methodology will also be transferred to end users in NL and Ontario through a set of end-of-project webinars.

**Discussion.** The project will produce a practical and relatively inexpensive way for OHS stakeholders to develop increased research synthesis capacity. Stakeholders will also benefit from advances in research made elsewhere and enhance their utilization of current knowledge about the causation, prevention, and treatment of occupational injuries and diseases tailored to the context of their province's industries, workplaces and compensation system.

## Best practices for identifying best practices, and teaching workers to use them

Carrie Taylor (presenter)

**Background.** Ergonomists are often challenged to train workers to use “best practices”; however, textbook techniques that work in one situation are not always applicable in other work environments.

**Methods.** Ergonomists and safety professionals who promote “off-the-shelf” techniques such as “bend your knees,” when the loads or workstations do not accommodate this method, run the risk of losing credibility, and thereby rendering their training ineffective.

**Results.** Companies that are pursuing engineering controls for musculoskeletal hazards often have a legitimate need to provide training for workers as an interim measure in order to ensure that workers are using optimum biomechanics for tasks with high force and awkward posture requirements.

**Discussion.** This paper presents a method for identifying best practices in the workplace, for substantiating these practices, and for developing training to enable workers to use these practices successfully in a variety of applications.

## Key informants' perspectives on MSD prevention and management commitment, training and workers' participation

Amin Yazdani (presenter), Richard Wells

**Background.** Musculoskeletal disorders (MSD) related to work have a high personal, organizational and societal burden. The purpose of this study was to better understand the key informants' experiences, perceptions and perspectives on the importance of management commitment, training and worker participation in MSD prevention.

**Methods.** Key informants include experienced consultants, managers, researchers, union representatives and policy makers. For this study, 23 key informants, selected and recruited using personal contacts and a snowball technique, agreed to participate. Semi-structured interviews and verbatim transcriptions were made. Most of the interviews were conducted by phone and the language of the interviews was English. Interviews typically lasted 45-60 minutes. A thematic analysis approach was used to report participants' experiences, perceptions and perspectives.

**Results.** The key informants said that strong management commitment would ultimately result in sustainability of prevention programs, as well as increasing the performance of the organization. Participants also said that linking MSD prevention to productivity and developing business cases could positively influence management's attention and support for MSD-prevention initiatives.

The participants argued that training programs for MSD prevention should be incorporated into organizational-wide training strategies. It was said that "strategic positioning," and the use of common tools and language, may result in an effective training program that would consequently improve health and safety in the workplace.

Key informants suggested that the participation should not be seen as "negotiation." It was recommended that prevention activities, using participatory approaches, should be integrated into a broader management system within the organization and that this could be achieved by linking prevention goals to current practices in organizations such as "management of change" and "user participation."

**Discussion.** The integration of MSD prevention activities into organization-wide approach and alignment with other organizational goals was suggested as an effective way to achieve a sustainable approach to MSD prevention.

## Ergonomics and research to practice (r2p) in the construction industry

Laura Welch (presenter), Eileen Betit

**Background.** Evidence-based interventions exist to prevent musculoskeletal injuries and illnesses, but passive diffusion often fails to get them into the hands of end users. R2p is particularly important in the construction industry where a disproportionate number of workers develop work-related musculoskeletal disorders (MSDs.)

**Methods.** The Center for Construction Research and Training (CPWR)'s r2p program includes a focus on ergonomics. As part of this initiative, CPWR held a symposium, "*Best Practices for Health/Safety Technology Transfer in Construction,*" and used another project to explore the industry's knowledge/attitudes on ergonomics, and established a masonry partnership to test dissemination strategies. 50 construction stakeholders participated in the symposium. Interviews on knowledge/attitudes were conducted with 23 contractor representatives and 27 union staff, and 48 workers participated in four focus groups. The partnership used its networks to raise contractors' and workers' awareness and use of interventions.

**Results.** Many construction stakeholders believe work-related MSDs are an inevitable part of the job. The interviewees reported limited availability of tested and effective tools that both reduce physical demand and get the job done efficiently and effectively. Yet for each major obstacle identified, the stakeholders offered solutions. The most important factors identified in the symposium, and reinforced by the other projects' findings, to advance the use of ergonomic interventions were (1) partnerships, (2) an effective business case, (3) usability of the intervention, (4) understanding the construction culture, and (5) the impact of external factors. The symposium's recommendations resulted in a researchers' patent and licensing guide, a business case model and case studies covering development, testing, manufacturing and marketing.

**Discussion.** Successful r2p in the construction industry requires more than a good intervention. It must include an understanding of the culture of the industry, sustainable partnerships and a primary focus on stakeholder needs.

SESSION 3, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 201C

## Identifying high-risk workplaces for work-related musculoskeletal disorders in Washington State

Ninica Howard (presenter), Stephen Bao, Daniel Hunter, Alysa Haas, Barbara Silverstein

**Background.** This study sought to identify high-risk workplaces for work-related musculoskeletal disorders (MSDs) of the back, shoulder, hand/wrist and knee, and identify workplace factors that may contribute to high work-related MSD workers' compensation rates.

**Methods.** Workers' compensation claims data was used to characterize work-related MSDs in Washington State. Physical exposure to work-related MSD risk factors was compared between pairs of companies (matched by size) with low and high work-related MSD claims rates. For each of six industries, eight pairs of companies participated in work-related MSD exposure assessments. Exposure to work-related MSD risk factors was evaluated using several validated methods. Results from the exposure assessment informed the development of industry-specific exposure checklists.

**Results.** Work-related MSDs of the back, upper extremity and knee accounted for 43% of the compensable workers' compensation between 2002 and 2010 in Washington State. Work-related MSD indemnity costs were \$3.87 billion for this period compared to \$8.22 billion for all compensable claims. In health care, more workers in companies with high-back work-related MSD claims rates spent more time standing (OR=1.874, 95%CI: 1.068-3.285) and performing heavy lifting (OR=2.580, 95%CI: 1.359 – 4.899) than workers in companies with low-back work-related MSD claims rates. In manufacturing, high hand/wrist work-related MSD claims rate companies had more repetition (OR=1.951, 95%CI: 1.216 – 3.130), more pinch forces (OR=2.666, 95%CI: 1.365 – 5.205) and higher Strain Index risk level (OR=2.238, 95%CI: 1.225 – 4.086). In wholesale and retail, more jobs among the high-back work-related MSD claim rate companies required prolonged standing for greater than six hours (OR=4.567, 95%CI: 1.916 – 10.888) and heavy, frequent lifting, as per the Washington State's Caution Zone (OR=15.333, 95%CI: 1.866 – 126.022).

**Discussion.** From our evaluations, we have shown that risk factors may not be the same between industry groups and, therefore, industry-specific tools or checklists may simplify the evaluation process.

## The obliquity strategy: a key to progress in MSD prevention?

Patrick Neuman (presenter)

**Background.** This paper argues that musculoskeletal disorder (MSD) prevention efforts would benefit from the application of an indirect approach — an “obliquity strategy.” Ergonomics is a profession that is frequently called on to help companies with MSD problems. Research evidence has shown that ergonomists spend most of their time engaged in the “organizational work” of making change, not in the assessment or analysis of problematic work, which is usually quickly assessed. Furthermore, while the occupational health and safety (OHS) agenda has led to ergonomists becoming active in organizations, this agenda has also, ironically, limited the application of ergonomics to narrowly defined OHS processes.

**Methods.** Intervention research has shown that engineers and managers become more interested in applying ergonomics when they understand the quality and productivity benefits. The quality and productivity agendas in workplaces are generally much stronger and have more change capacity than OHS-based processes, which are frequently relegated to an organizational sidecar with little influence in development and design processes. Considerable research evidence has linked MSD risk factors with reductions in work quality and productivity. This opens the door for a “goal hooking” strategy for OHS: MSD prevention can be better realized when it is connected to more powerful agendas.

**Results.** We have observed that to achieve this linkage, the ergonomist must be seen to contribute directly and fully to the given performance agenda of the other stakeholders in the workplace. This may involve including attention to relevant human factors that might not themselves be directly associated with MSDs, while also including those factors that are.

**Discussion.** While some members of the safety community express reluctance to contribute to business interests, we argue that contributing to an organization’s strategic objectives can yield better results in MSD prevention than when OHS is pursued directly — an approach referred to as the “obliquity strategy” to MSD prevention.

## Comparison of lifting techniques among non-trained workers, trained workers and trainers

Mohammad Abdoli-Eramaki (presenter), Ibrahim Aboud, Mohamed Mohamud, Sonia Isoufi

**Background.** In spite of considerable resources spent to train workers, musculoskeletal disorders are still the most common type of injury in Ontario workplaces. The objective of this study was to compare the kinetics and kinematics of lifting and lowering among trainers, trained workers and untrained workers.

**Methods.** 203 healthy volunteers participated in this study at the 2015 Partners in Prevention conference. Two digital camcorders were placed approximately 10 feet away from participants at 90-degree angles. Participants completed questionnaires and were instructed to lift and lower a 10-kg load from the floor to elbow height. 3D-SSPP was used to analyze videos at the point of lifting and lowering. Joint moments were normalized based on body height and weight of each participant. ANOVA was utilized to evaluate the impact of gender and training on the kinetics and kinematics of various body joints.

**Results.** 65.3% of participants did not lift the way they indicated on the questionnaire. 79.6% of participants did not lower as they indicated on the questionnaire. Females lifted and lowered the load in a manner more consistent with their answers in the questionnaire than did men. Differences in the joint moments between trainers, trained participants and untrained participants were insignificant. However, the difference was significant with the pictures the trainers, trained participants and untrained participants drew in the questionnaire.

**Discussion.** Commonly used lifting methods cannot easily be perceived by either trained or untrained participants. Moreover, regular verbal and visual instructions used for training might not prompt conforming lifting patterns among individuals. Newly developed and widely accepted lifting styles are recommended for training manual handling lifters.

## Taking the next step: operationalizing a behaviour-based approach to musculoskeletal injury prevention interventions

Paul Rothmore (presenter), Paul Aylward, Jodi Oakman, David Tappin, Jodi Gray, Jonathan Karnon

**Background.** Using the stage-of-change (SOC) approach in the development of ergonomics advice may improve advice implementation; however, there is little evidence that it has been adopted by practitioners. This paper investigates barriers and facilitators to the development of ergonomics advice using behaviour-change tools, such as the SOC approach. It presents a SOC assessment tool developed for use by ergonomics practitioners.

**Methods.** 23 ergonomics practitioners participated in three focus groups to inform the development of a web-based survey and the proposed SOC assessment tool. The subsequent web-based survey of members of the Human Factors and Ergonomics Societies of Australia and New Zealand (HFESA/HFESNZ) (n=219, 31% response rate) further explored barriers to the implementation and evaluation of ergonomics advice.

**Results.** Targeting of advice according to the risk profile and attitudes of the managers and workers was identified as a potential facilitator to advice implementation; however, formal measures to assess readiness to change were not used. Many participants were unaware of behaviour change models (n=98, 45%) and reported that the application of behaviour change principles was outside their current area of expertise (n=45, 21%). After viewing the proposed SOC tool, few participants indicated they would be unlikely to use the tool (n=38, 17%), with the majority either likely (n=80, 37%) or uncertain (n=57, 26%).

**Discussion.** Findings from this study suggest the limited application of the SOC-based approach to work-related musculoskeletal injury prevention is due to a suitable tool not being available, the need for training in the application of the SOC approach and the lack of access to relevant research findings. We have sought to involve practitioners in all facets of the research and have met with encouraging results. The final translation of the SOC assessment tool into professional ergonomics practice will require both a clear demonstration of its real-world usability to practitioners and the provision of training in the application of the SOC approach.

SESSION 4, MONDAY JUNE 20, 3:30PM – 5:00PM, ROOM 201C

## Effects of driving and whole body vibration on reaction times in truck drivers: findings from a pilot study

Bronson Du (presenter), Fangfang Wang, Philip Bigelow, Hugh Davies, Peter Johnson

**Background.** Driver fatigue is a prevalent factor associated with commercial motor vehicle accidents and is clearly important to public road safety. It is believed that exposure to whole-body vibration (WBV) leads to both cognitive and physical fatigue. The purpose of this study was to compare two air-ride truck seats to determine if there were differences in WBV exposures and the subsequent cognitive fatigue measured using the psychomotor vigilance task (PVT).

**Methods.** In a crossover study design, 17 truck drivers performed the PVT immediately before and after their 10-hour shift. Drivers drove trucks with their existing seat (ES) and a new seat (NS) believed to have superior WBV attenuation performance. Full-shift WBV exposure measurements were collected from the seat of the trucks using tri-axial accelerometers according to ISO 2631-1.

**Results.** There was a significant difference ( $p=0.009$ ) in WBV exposures between the ES ( $n=16$ ) and the NS ( $n=13$ ), with mean ( $\pm$ SE) z-axis WBV exposures of  $0.56\text{m/s}^2$  ( $\pm 0.03$ ) and  $0.44\text{m/s}^2$  ( $\pm 0.03$ ), respectively. PVT performance over the shift declined with the ES (reaction times increased by 9 ms), but improved with the NS (reaction times decreased by 16 ms) ( $p= 0.02$ ). When shift start and end times were accounted for, seats did not have an effect on reaction times; however, PVT performance improved over the course of the shift when the drivers' shifts started at a diurnal low (times between 22:00 and 06:00) and ended at a diurnal high (times between 06:00 and 22:00), and vice versa.

**Discussion.** Truck seats with lower WBV exposures appear to have a positive effect on truck driver vigilance. However, the diurnal effect of shift work is an overlying factor for driver vigilance, and must be taken into account in future studies.

## A randomized controlled trial evaluating the ability of truck seats to reduce whole body vibration exposures and self-reported adverse health outcomes

Peter Johnson (presenter), Monica Zigman, Jennifer A. Ibbotson, Lovenoor Aulck, Jack Dennerlein, Jeonh Ho (Jay) Kim

**Background.** Epidemiological studies have shown associations between whole body vibration (WBV) and low-back pain (LBP). Using a randomized controlled trial design over a 12-month period, this study evaluated seating interventions designed to reduce WBV exposures and self-reported adverse health outcomes.

**Methods.** 40 truck drivers were randomized into two groups: (1) a placebo group who received a new, industry-standard air-suspension seat (n=20), and (2) an intervention group who received an active-suspension seat (n=20). Pre- and post-intervention WBV exposures and self-reported health outcomes [LBP using a 10-point scale, back function using the Oswestry Disability Index (ODI) and general health using the Short-Form (SF)-12 health survey] were successfully collected from 32 drivers (16 placebo; 16 intervention).

**Results.** Pre-intervention, there were no differences in the predominant, z-axis daily average weighted [A(8)] or cumulative, impulsive [VDV(8)] WBV exposures between the two groups ( $p$ 's>0.93). Post-intervention, relative to the placebo group with the air-suspension seats, the intervention group with the active-suspension seats experienced a significant reduction in the A(8) exposures (31%,  $p=0.002$ ); however, the between-seat differences in VDV(8) exposures were negligible (9%,  $p=0.35$ ). Pre- and post-intervention, there was no change or only slight degradations in the LBP, ODI and SF-12 scores in the placebo group; however, there was a 30% reduction in LBP outcomes, a 4.6 point reduction in the ODI score, and stable or improved SF-12 scores in the intervention group. The improvement in LBP and ODI outcomes was not statistically significant, but the magnitude of the changes was clinically significant/meaningful.

**Discussion.** Based on the significant/substantial differences in A(8) exposures and the lack of substantial change or difference in VDV(8) exposures between the two groups, our results indicate that the changes in self-reported health outcomes are likely to be associated with the changes in the A(8) exposures.

## The effect of a multi-axial suspension on whole body vibration exposures and muscle loading on the neck and low back in an agricultural tractor application

Jeong Ho Kim, Jack Dennerlein, Peter Johnson (presenter)

**Background.** In off-road vehicles where predominant exposure axis is not necessarily vertical (z-axis) but either fore-aft (x-axis) or lateral (y-axis), the current seats designed to reduce vertical whole body vibration (WBV) exposures may be less effective when compared to a multi-axial (vertical + lateral) suspension seat. Therefore, the purpose of this study was to determine whether there are differences between a single-axial (vertical) and multi-axial suspension seat in WBV exposures and muscle activity in the low back, neck and shoulder regions.

**Methods.** In a repeated-measures design with a total of 11 experienced vehicle operators, using two different seats (single-axial and multi-axial suspension seat), this study measured the WBV exposures as per International Organization for Standardization (ISO) 2631-1 WBV standards resulting from six agricultural tractor vibration profiles simulated on a six-degree-of-freedom motion platform. Muscle electromyography (EMG) was measured on shoulder (trapezius: TRAP), neck (splenius capitis: SPL and sternocleidomastoid: SCM), and low back (erector spinae: ES).

**Results.** While there was no difference in the fore-aft (x-axis) and vertical (z-axis) WBV exposures between the seats, the mean ( $\pm$ SE) lateral (y-axis) measures on the multi-axial suspension seat [A(8)  $0.73 \pm 0.02$  m/s<sup>2</sup> and VDV(8)  $14.0 \pm 0.4$  m/s<sup>1.75</sup>] were lower ( $p < 0.0001$ ) than on the single-axial suspension seat [A(8)  $0.81 \pm 0.02$  m/s<sup>2</sup> and VDV(8)  $15.8 \pm 0.4$  m/s<sup>1.75</sup>]. The 50<sup>th</sup> percentile left ES EMG on the multi-axial suspension seat was approximately 34% lower than that on the single-axial suspension seat, while the right ES EMG did not differ between the seats. The EMG data on SPL, SCM, and TRAP were also relatively lower on the multi-axial suspension seat.

**Discussion.** The study showed that the multi-axial suspension may have potential to reduce the WBV exposures and muscular loading on the low back, neck and shoulder among agricultural vehicle operators.

## Measuring the use of tethered tools while working at heights

Maria Wiener (presenter), Wilkistar Otieno, Naira Campbell-Kyureghyan

**Background.** Working at heights is integral to globally expanding needs, yet safety standards are lacking concerning the use of tethered tools to prevent injury, fatality, lost time and equipment damage. Currently, no research on the multifaceted impact of tethered tool use exists, despite the fact that they are necessary to maintaining safety while working at heights. The goal of this project was to measure exposures and identify the trends for tethered tool usage while working at heights by surveying employees in the Coast Guard (CG) and in renewable energy generation companies.

**Methods.** A customized questionnaire consisting of 24 questions was developed to collect personal and work-related information to assess trends in tethered tool use amongst those in the CG and wind power industry. Questionnaires were distributed online and 83 completed surveys were returned and analyzed.

**Results.** A majority of the respondents (72.5%) used tethered tools. Of the non-tethered tool users, 82% revealed that the employer didn't provide them with the opportunity. Hand tools most commonly used in both industries include screwdrivers, hammers, wrenches, pliers and manual wire cutters. Pearson correlation revealed a strong positive relationship between tethered tool usage and frequency of use, and between being provided with tethered tools and frequency of use ( $p < 0.05$ ). Interestingly, 75% of those surveyed reported dropping a tool while at their job. Frequency of tethered tool use also had strong positive relationships ( $p < 0.05$ ) with dropping a tool tethered to self, dropping a tool tethered to a structure, wearing a vest and wearing a tool belt.

**Discussion.** The results of this survey allowed identification of tethered tool usage patterns, tool carrying methods, and types of tools used in the field. This is an imperative first step in identifying how to increase tethered tool usage in industry in order to ultimately decrease the likelihood of accidents or injuries in the field.

SESSION 5, TUESDAY, JUNE 21, 10:30AM – 12:00PM, ROOM 204C

## Musculoskeletal disorders as a fatigue failure process: implications and research needs

Sean Gallagher (presenter), Mark Schall

**Background.** Evidence from epidemiology studies, in vitro tests of cadaver tissues, animal studies, and in vivo studies strongly suggest that musculoskeletal disorders (MSDs) may be the result of a fatigue failure process. If this theory is correct, there are important theoretical implications for prior work.

**Method.** Fatigue failure theory and techniques were examined to evaluate implications with respect to musculoskeletal tissues. Research gaps were then considered in this context.

**Results.** The following implications were among those revealed in this analysis:

*MSD Risk Factors:* The exponential S-N curve indicates that cycles to failure is highly dependent on the level of stress, suggesting a force-repetition interaction with respect to MSD risk (observed in epidemiology studies). Fatigue failure theory may provide a unifying framework for all physical MSD risk factors.

*Cumulative damage:* A major goal of MSD risk assessment has been to ascertain cumulative loading effects in musculoskeletal tissues. Fatigue failure theory offers validated methods to assess cumulative damage in materials.

*Individual factors:* The S-N curve is indexed to the ultimate stress of a material, which in humans will vary substantially according to age, gender, and anthropometry. Fatigue failure suggests that guidelines sensitive to individual factors may be important in MSD prevention.

*Rest:* Biological tissues are unique in that they are self-healing materials. The rest necessary to heal is likely related to the damage accumulated, estimable by techniques above. During loading periods, a decreased duty cycle may increase cycles to failure by decreasing mean stress on tissues.

**Discussion.** If MSDs are the result of a fatigue failure process, much research is warranted. Such research headings might include: better characterization of strength and fatigue life for key tissues; thresholds for damage nucleation and propagation; beneficial vs. detrimental tissue loading; improved models of tissue loading; and, epidemiological studies to examine MSD risk from a fatigue failure perspective.

## The influence of individual characteristics on fatigue life of musculoskeletal tissues: implications and recommendations

Rong Huangfu (presenter), Sean Gallagher, Mark Schall

**Background.** An important tenet of fatigue failure theory is that the rate of development of cumulative damage in a material exposed to repeated stress is indexed to its ultimate strength. Given exposure to the same absolute level of stress, a weaker tissue will accumulate damage more rapidly than a stronger tissue. Tremendous variability is present in the strength of musculoskeletal tissues due to individual characteristics such as age, gender, and anthropometry. This paper examines these factors and implications for musculoskeletal disorder (MSD) prevention.

**Method.** Data regarding the ultimate strength of lumbar spines by age and genders were obtained from data provided by Jager and Luttmann (1991). Tremendous variability is apparent in this data, with weaker female spines (aged 50-60) having an average spine strength of 2,100 N and a stronger male spine (aged 20-30) having a strength of 10,600 N. Table 1 presents predicted fatigue life when exposed to a repeated 2,000 N spinal load, based on fatigue life regressions from cadaver testing of lumbar spines (Brinckmann et al, 1988; Gallagher et al, 2007).

Table 1 – Predicted cycles to failure of spine motion segments exposed to 2 kN load.

		20-30 years	30-40 years	40-50 years	50-60 years
Males	Mean + 1SD	100,070	95,737	54,762	33,746
	Mean	43,796	42,053	17,134	7,597
	Mean – 1SD	7,597	7,597	1,139	164
Females	Mean + 1SD	30,632	29,123	20,796	8,360
	Mean	15,993	10,905	5,564	1,139
	Mean – 1SD	6,199	1,918	382	9

**Discussion.** Individuals with stronger tissues are imbued with a substantial advantage with respect to damage due to repetitive loading. Predicted cycles to failure for a 2kN load vary more than four orders of magnitude from older female spines to young male spines. Stronger spines are capable of withstanding higher loads than weaker spines, a fact that may be critically important in MSD prevention efforts.

## Human-robot collaborations as job interventions for physical stress

Margaret Pearce, Bilge Mutlu, Julie Shah, Robert Radwin (presenter)

**Background.** Collaborative robots are an emerging technology in manufacturing that can offer flexible intervention for reducing or eliminating physical stress. These collaborative robots (“cobots”) are designed to be safe around humans and operate without physical barriers, broadening the range of scenarios where they can contribute to a task. Paired with a human worker, cobots can reduce relative stress. However, if work elements are not assigned optimally, the pairing can increase the task makespan (i.e. time) and make the intervention less desirable to employers.

**Methods.** An optimization algorithm distributed work elements of a task between a human worker and a robotic partner such that the overall time, physical stress, or a combination of time and stress was minimized. Stress was quantified using a modified version of the strain index (SI). We analyzed four selected tasks that involved repetitive or strenuous work and showed opportunities for collaboration, using a Baxter cobot. The tasks included sheet metal processing, food service, stocking and product manufacturing.

**Results.** Work elements that featured poor hand/wrist posture, high intensity exertions, or high frequency were assigned to the cobot when reducing stress was more important than minimizing time. Using the optimization algorithm, we observed that the SI can be reduced by roughly 40% on average with no impact on makespan. When time is not a factor, the SI can be reduced up to 70%.

**Discussion.** This method can be used to explore tradeoffs between improving time and human physical stress by adjusting the weighted importance of one factor over the other. The cobot particularly reduced the SI in “pick and place” tasks that involved poor hand/wrist posture, such as when items need to be moved above the worker’s head. A broad range of jobs may see comparable benefits, including stocking, putting away dishes, parts retrieval and more.

## Factors at the transition: understanding return-to-work decisions

Carol Kennedy (presenter), Dorcas Beaton, Kenneth Tang, Robin Richards, Iona MacRitchie, Monique Gignac

**Background.** Workers with health conditions juggle diverse decision-making issues related to transitioning in and out of work. This study sought to examine environmental and personal factors related to an individual's experience with return-to-work (RTW) transitions.

**Methods.** This was a qualitative, interview study. A constructivist grounded theory approach investigated work experiences of two groups: (1) injured workers (IW) attending WSIB Shoulder & Elbow Specialty Clinic; and (2) individuals with inflammatory arthritis (IA). Interviews were digitally audio-recorded and transcribed verbatim. Transcripts were entered into NVivo12 for textual data analysis and coded for emergent themes using constant comparative methods.

**Results.** 25 interviews were conducted (n=12 IW; n=13 IA). IWs represented workers with longer-term claims (>6 months), but still with ongoing claims and all in physically demanding jobs. Most individuals in the IA group had rheumatoid arthritis and had lived with the disease for many years. Findings revealed:

(1) Work provided value and importance (i.e. meaning) to participants (financial and personal). RTW was an important goal.

(2) Thresholds for ability to work often included "working through pain" to keep one's job, role and income. Workers described a turning point in their decision to go off work. Factors related to not working were internal (e.g. amount of pain, fatigue and impact on expected outputs of work) and external (lack of ongoing support within workplace, unwillingness to disclose condition/limitations).

(3) Discordant messages among stakeholders (employer, system, health providers) created tension and barriers to success.

**Discussion.** Workers described several factors beyond their medical condition that were related to RTW decision-making. The value and meaning of work was pervasive. The factors associated with RTW transitions were more similar than different in persons with work-related injuries and work-relevant chronic disorders like IA. Converging processes for both groups with more emphasis on self-management/patient activation types of interventions may be appropriate and useful for RTW.

SESSION 6, TUESDAY, JUNE 21, 1:30PM – 3:00PM, ROOM 201C

## Bracing matters: workers using their environment to make their tasks easier

Monica Jones (presenter), Matthew Reed, Don Chaffin, Ulrich Raschke

**Background.** Workers often encounter physical barriers when trying to complete various occupational task demands. Such barriers constrain posture but also provide the opportunity to brace against the object with the non-task hand, thigh or other body parts. Biomechanical analyses of tasks with bracing are difficult to conduct because the addition of unknown bracing forces produces a mechanically indeterminate system.

**Methods.** Force and posture data were gathered in a laboratory study. Subjects exerted one-handed isometric exertions in an experimental set-up that was representative of industrial workspaces with kinematic constraint that afford thigh and hand bracing opportunities.

**Results.** Quantitative parameterization of bracing and associated postures suggests that the choice of force generation strategy and posture behaviour is governed by biomechanical criteria. Posture and force empirical models were developed based on the laboratory data and these behaviour-based models formed the template for implementation into Siemens Jack, the commercially available, digital human model (DHM) software.

**Discussion.** This research serves to acquaint practitioners, particularly those who use digital human models (DHM), to consider bracing. It contributes to the accuracy and validity of Siemens Jack, a tool widely used for ergonomic analysis of products and workspaces, thus lowering the incidence of work-related injuries.

## Differences in disability duration for musculoskeletal injuries by sex/gender: an emerging issue for management of work-related MSDs

Mieke Koehoorn (presenter), Christopher McLeod, Sheilah Hogg-Johnson, Katherine Lippel, Lillian Tamburic

**Background.** Women experience longer disability duration for work-related musculoskeletal disorders (MSDs) than men. The objective of this study was to investigate if differences could be explained by socioeconomic characteristics or by having children in the home.

**Methods.** Accepted workers' compensation claims for back strain (n=157,706), fractures/dislocations (n=32,966) and repetitive strain injuries (RSI) (n=21,946) were extracted for workers in the Canadian province of British Columbia, 2001-2010. Quantile regression investigated the effect of pre-claim wage, receipt of a government low-income subsidy (separate from workers' compensation benefits) and having dependents (<18 years) on total disability days, censored at one year. Models by type of MSD were stratified by sex, and adjusted for occupation, age and prior claim.

**Results.** Despite women having longer disability duration than men overall, the effect of low income and dependents was similar for women and men. For example, predicted disability duration for back strains at the 50th percentile of the distribution was 15 days (women) and 11 days (men) for workers with no dependents and no low-income subsidy; duration increased by six days (women) and four days (men) for those with dependents and a subsidy. For fractures/dislocations, disability duration was 46 days (women) and 41 days (men) for workers with no dependents and no low-income subsidy; duration increased by five days (women) and by seven days (men) for workers with dependents and a subsidy. For RSIs, disability duration was 35 days (women) and 19 days (men) for workers with no dependents and no low-income subsidy; duration decreased by one day (women) and increased by two days (men) for those with dependents and a subsidy.

**Discussion.** Persistent differences in disability duration by gender/sex are not fully explained by socio-demographic or socioeconomic characteristics. The next analysis will investigate if the differences in disability duration are explained by work accommodation options and/or health service utilization.

## Biomechanical evaluation of optimal leg lifting

Hamed Pardehshenas (presenter), Sanaz Agha, Mohammad Abdoli

**Background.** The objective of this study was to compare muscle activation patterns during six different lifting conditions. In reference to our recent study of over 200 participants conducted at the Partners in Prevention conference, initial results demonstrated that there was no significant difference in the lumbar spinal moments between the trained testers and untrained participants. This indicates that an absence of an optimal type of lifting culminates in poor practice of the lifting task.

**Methods.** A repeated measures biomechanical methodology was used to test the main effect on muscle activation patterns of six lifting conditions including (a) squat, (b) full-squat, (c) stoop, (d) wide-open leg, (e) straddle feet, and (f) open-hip. Male and female participants were recruited to lift 15-20% of their body weight. SEMG signals were recorded from eight sites at the ES (L5 level), IO, RF, GM, BF, AL, LD, and gastrocnemius in accordance to SENIAM. Motion capture was used, but the results have not yet been analyzed.

**Results.** Wide-open, followed by open-hip and squat-leg lifts, are the most optimal lifting conditions in which all the eight muscles are coordinated and uniformly take part in lifting activity. It is no surprise that the stoop was observed to save the knee joint at the expense of overloading the passive structures of the low-back region, while a full-squat performs the task by virtue of a tremendous level of activation of all lower extremities.

**Discussion.** Poor training and lifting strategies set in motion a series of events leading to musculoskeletal disorders. Although there is room for further investigation into the field of manual materials handling, in light of our results, it seems that the current training protocols should be replaced with biomechanically efficient ones.

## Standing up for workplace health: guidance for office environments

Carrie Taylor (presenter), Karen Hoodless, Josie Blake

**Background.** Standing in office environments has been widely promoted as an effective intervention for the prolonged sitting “disease” that the media has reported to be “killing us.” Employees, human resources professionals, safety professionals and health-care providers are in need of information to help decide whether or not standing at work would be beneficial for a particular person and, if so, how to implement this change. This presentation reviews:

- indications and possible contra-indications for standing work
- prioritizing “nice to do” vs. “need to do” when providing sit/stand stations
- currently available options in the market, and their features, benefits and limitations
- guidance for employers and employees as they introduce standing to their work day.

**Discussion.** In summary, standing at work can have health benefits, but only if it is introduced with employee awareness and training, and with appropriate expectations.

SESSION 7, TUESDAY, JUNE 21, 1:30PM – 3:00PM, ROOM 204C

## Quick and dirty ergonomics: When is this approach appropriate?

Josie Blake (presenter), Carrie Taylor

**Background.** A full and detailed assessment of a musculoskeletal disorder (MSD) hazard involves considerable time, and occasionally the assessment is received reluctantly if it identifies hazards that are not easy to correct. Some clients have asked us to offer less formal assessments — an approach that offers the advantage of more “advice” in a shorter period of time. We have, until recently, been unwilling to provide this type of “quick and dirty” consulting in the belief that it can sometimes cause more harm than good. For example, if we don’t assess the risk of injury on a job, the client cannot distinguish tasks that present significant MSD hazards from those that present a mild inconvenience. If a significant financial investment will be required to address a recommendation, the client often requires a more robust assessment. Similarly, without a detailed assessment, the ergonomist cannot objectively compare the effectiveness of various alternative solutions.

**Methods.** In spite of these concerns, we undertook a 16-week project where a client asked us to visit their site on a regular basis with the goal of providing suggestions for as many MSD hazards as possible.

**Results.** The ergonomist provided hands-on ergonomics (hazard identification and control) training for all workers and followed up on their concerns. She also investigated issues on a list that had been generated by the health and safety professional at the site. The ergonomist wrote brief “rapid ergo directives” (REDs) that identified the hazard and provided suggestions for minimizing risk. She offered follow-up support, and facilitated vendor quotes for products that she suggested. The client found that this approach met their needs and requested further support for another location.

**Discussion.** This presentation describes the advantages and disadvantages of this approach, and offers suggestions regarding when it is appropriate.

## Pushing ergo upstream: selling ergonomics to engineers

Karen Hoodless (presenter), Carrie Taylor, Josie Blake

**Background.** For over 20 years, ergonomists have worked largely reactively, housed in safety departments. They have been responsible primarily for determining whether or not a job needs to be modified in order to mitigate injury risk.

**Methods.** Despite these efforts, the incidence of musculoskeletal disorders (MSDs) has not declined substantially. Ergonomists' recommendations are often dismissed as "too expensive" or not "justifiable," especially if lower cost administrative controls, such as job rotation or behaviour-based training, are available.

**Results.** However, in the past few years, some companies have begun to regard ergonomics as a potential tool to be used in the service of productivity and quality improvements.

**Discussion.** This presentation provides a few examples from the literature and from our experience, and offers suggestions to help ergonomists to "sell" ergonomics to engineers as a purely cost-saving measure.

## Ergonomic benefits from a laparoscopic instrument with rotatable handle piece: importance of operation field area and working height

Benjamin Steinhilber (presenter), Florian Reiff, Robert Seibt, Monika A. Rieger, Bernhard Kraemer, Ralf Rothmund

**Background.** Surgeons that perform laparoscopic surgery are facing increased levels of biomechanical stress leading to an augmented risk for musculoskeletal complaints and disorders in the shoulder-neck region and arm-hand region. This study investigated the effects of a laparoscopic instrument (LI) with a 360° rotatable handle piece (rot-HP) on biomechanical stress and precision in different areas of the operation field at two working heights (WHs).

**Methods.** 57 healthy subjects (27 men, median age 26) without experience in laparoscopic surgery performed a static-precision-task in four (A-D) quadrants (QUADs) of the operation field with the rot-HP or a fixed standard handle piece at an ergonomically adjusted lower working height (LWH) or a higher working height (HWH). In each QUAD a nip had to be grabbed and held within 30s without touching a surrounding ring (diameter 2 cm). Biomechanical stress was assessed by muscular effort, wrist joint angles and arm postures, which were recorded by surface electromyography (sEMG), goniometry and gravimetric position sensor, respectively. Precision was quantified by the number of mistakes (ring contact) during the task.

**Results.** In QUAD C the rot-HP reduced muscle activity of the flexor carpi radialis by 14% relative to a reference contraction but just missed statistical significance ( $p=0.05$ ). For the other areas, muscle activity did not differ between LIs. Task performance at the LWH using the rot-HP led to a more neutral wrist joint angle in QUAD B, and C. However it was impaired in QUAD A and the HWH mitigated the effects of the rot-HP. Arm postures were less affected by the handle piece and there was no difference in precision between handle pieces.

**Discussion.** Biomechanical stress can partially be reduced by the rot-HP without limiting precision. However the effects depend on LI location in the operation field and an ergonomically adjusted WH is crucial for effectiveness.

SESSION 8, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 204C

## Prescription analgesic patterns before and after a workers' compensation claim: a historical population-based cohort study of workers with low-back pain disorders in British Columbia

Nancy Carnide (presenter), Sheilah Hogg-Johnson, Pierre Côté, Andrea Furlan, Mieke Koehoorn

**Background.** Little is known about opioid use before a workers' compensation (WC) claim, which may influence post-claim prescribing. The objective is to compare and contrast opioid and other analgesic dispensing patterns before and after a work-related, low-back pain (LBP) injury.

**Methods.** We conducted a population-based historical cohort study of workers (n=99,233) with accepted lost-time WC claims for soft-tissue LBP from 1998-2009 in British Columbia, Canada. Administrative prescription and health data from Pharmanet and Population Data BC were linked. Data on opioid, non-steroidal anti-inflammatory (NSAID), and skeletal muscle relaxant (SMR) prescriptions dispensed one year before and after injury date were collected. Prescription patterns were compared pre- to post-injury in eight-week periods.

**Results.** The cumulative proportion of claimants who were dispensed opioids, NSAIDs, and SMRs one year pre-injury was 19.7%, 21.2%, and 6.3%, respectively, increasing to 39.0%, 50.2%, and 28.4% one year post-injury. Most received one to two prescriptions, and most receiving opioids received weak (89.2% pre, 85.0% post) and short-acting (98.2% pre, 97.1% post) opioids.

The proportion of claimants dispensed prescriptions was stable prior to injury (4.4%-5.7% in any eight-week period for opioids/NSAIDs, 1.1%-1.4% for SMRs), followed by a sharp increase within eight weeks post-injury. Compared to the eight-week period preceding injury, the proportion of claimants receiving opioids, NSAIDs, and SMRs within eight weeks post-injury increased by 534%, 825%, and 2,155%. Dispensing dropped precipitously thereafter and by 48 weeks post-injury was nearing pre-injury levels. Cumulative days supply for each drug class remained 20-30% higher post-injury than pre-injury. Among claimants with opioid prescriptions, the proportion receiving strong and long-acting opioids increased over time beginning pre-injury through 48 weeks post-injury.

**Discussion.** Analgesics are commonly prescribed before and after injury. For most claimants, injuries were acute and post-injury treatment was conservative, though a small subgroup of more persistent users exists and may be struggling with recovery.

## Is there an association between temporal patterns of sitting and low-back pain? A cross-sectional study

Mette Korshøj (presenter), Nidhi Gupta, Julie Lagersted-Olsen, David Hallman, Marie Birk Jørgesen, Andreas Holtermann

**Introduction.** Low-back pain (LBP) is a major global health challenge. Sitting is a suggested risk factor for LBP among blue-collar workers. Previously, information on sitting time has been collected by self-reports, which are imprecise and biased compared to objective measurements. Therefore, we aimed at investigating the association between objectively measured sitting time and LBP among blue-collar workers.

**Methods.** The analysis is based on the DPHACTO cohort, and included 601 Danish blue-collar workers recruited from the cleaning, manufacturing and transport sector. Cross-sectional information on LBP intensity (range 0-10) was collected by questionnaire. Objective measurements of sitting were collected using two accelerometers (ActiGraph GT3X+) worn on the thigh and trunk during 1-5 workdays. Sitting time was split into occupational and leisure time and analyzed as the total duration, and divided in temporal patterns of uninterrupted long (> 30 min), moderate (> 5 – 30 min) and short (< 5 min) bouts by the exposure variation analysis method. Association between sitting and LBP intensity was analyzed using univariate ANOVA adjusted for age, sex, smoking, BMI, job seniority and occupational lifting and carrying activities. Additionally, total sitting was adjusted for physical activities (standing, walking, running, walking in stairs and biking) and sitting in opposite domain (occupational/leisure); and temporal pattern variables were mutually adjusted for other lengths of sitting bouts.

**Results.** No associations were seen between total sitting time and LBP (occupational  $B=0.017$ ,  $p=0.53$ ; leisure  $B=0.008$ ,  $p=0.76$ ). No associations seen between long (occupational  $B=-0.002$ ,  $p=0.97$ ; leisure  $B=0.010$ ,  $p=0.75$ ), moderate (occupational  $B=0.025$ ,  $p=0.50$ ; leisure  $B=0.006$ ,  $p=0.90$ ), or short (occupational  $B=0.035$ ,  $p=0.63$ ; leisure  $B=-0.009$ ,  $p=0.95$ ) bouts of uninterrupted sitting and LBP.

**Discussion.** Objectively measured sitting time was not associated with LBP among blue-collar workers, pointing toward other factors being attributed to LBP. Thus, this finding needs to be investigated in prospective designs.

## The effect of leisure-time physical activity on sciatica: a systematic review and meta-analysis

Rahman Shiri (presenter), Kobra Falah-Hassani, Eira Viikari-Juntura, David Coggon

**Background.** The role of leisure-time physical activity in sciatica is uncertain. This study aimed to estimate the effect of physical activity during leisure-time on lumbar radicular pain and sciatica.

**Methods.** Comprehensive literature searches were conducted in PubMed, Embase, Web of Science, Scopus, Google Scholar and ResearchGate databases from 1964 through August 2015. A random-effects meta-analysis was used, and heterogeneity and publication bias were assessed.

**Results.** 18 (4 cross sectional [n= 10,046 participants], r case control [n=9,350] and 10 cohort [n= 82,024]) studies qualified for a meta-analysis. In comparison with no regular physical activity during leisure-time, moderate level of physical activity (1-3 times a week) during leisure-time was inversely associated with lumbar radicular pain or sciatica (pooled adjusted OR = 0.75, 95% CI 0.61-0.92,  $I^2 = 0\%$ , 6 studies, n = 64,768). However, the reduction in risk for more frequent activity ( $\geq 4$  times a week) was lower (pooled adjusted OR = 0.91, 95% CI 0.75-1.10,  $I^2 = 0\%$ , 8 studies, n = 75,771), and the overall association with physical activity for at least once a week was not statistically significant (pooled adjusted OR = 0.89, 95% CI 0.75-1.05,  $I^2 = 62.7\%$ , 11 studies, n = 75,948). There was no evidence of publication bias.

**Discussion.** This meta-analysis suggests that moderate level of physical activity during leisure-time may protect against the development of lumbar radicular pain and clinically verified sciatica. However, it is difficult to exclude the possibility of confounding and reverse causation. The continuing uncertainties would best be resolved by intervention studies rather than further observational research.

## A randomized controlled pilot study of the effectiveness of wearing unstable shoes on reducing low-back pain and disability in nurses

Edgar Vieira (presenter), Denis Brunt

**Background.** Up to 75% of nurses report low-back pain. Emerging interventions that may help manage low-back pain need to be evaluated. Therefore, the objectives of this study were to evaluate if wearing unstable shoes reduces low-back pain and disability in nurses.

**Methods.** 20 matched female registered nurses who were working at hospitals and in homecare — despite having low-back pain — were randomized to an intervention (n=10) or to a control group (n=10). The mean (standard deviation) age was 31 (5) years for the control and 34 (6) years for the intervention group; height was 161 (5) cm and 165 (7) cm, respectively. Low-back disability and pain levels were assessed biweekly (weeks 0, 2, 4, and 6) using a visual analogue pain scale and the Oswestry Low Back Pain Disability Questionnaire. The intervention group received unstable shoes at Week 2 to wear for at least 36 hours/week for a month.

**Results.** The mean pain level was 6 (1) at baseline vs. 6 (2) at Week 6 for the control group, and 5 (1) vs. 1 (1) for the intervention group. The mean disability level was 31% (9) at baseline vs. 28% (7) at Week 6 for the control, and 27% (12) vs. 13% (5) for the intervention group. There were no significant changes over time on pain or disability levels for the control group. The intervention group reported lower levels of pain on Weeks 4 (mean difference  $\geq -1.4$ ,  $p \leq 0.009$ ) and 6 (mean difference  $\geq -3.1$ ,  $p < 0.001$ ). Disability levels were also lower on Week 4 (mean difference =  $-5\%$ ,  $p$  NS) and 6 (mean difference =  $-14\%$ ,  $p = 0.020$ ).

**Discussion.** Wearing unstable shoes reduced low-back pain and disability in nurses and might be helpful as part of the management and rehabilitation of back pain.

SESSION 9, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 203B

## Using a digital video analysis to identify and model firefighter trunk and knee postures during a lift task

Ze Lu (presenter)

**Background.** The task of lifting a high-rise pack during firefighting is associated with increased risk of incurring musculoskeletal disorders. However, wearing personal protective equipment (PPE) could change the kinematics obtained from simulations in a rigorous laboratory setting. To improve injury prevention in the occupational context, it is essential to obtain precise kinematic information with reliable assessment methods. The purpose of this study was to (1) apply a valid two-dimensional movement analysis method, Dartfish, to identify firefighters' trunk and knee postures during a firefighting lift task while wearing PPE, and (2) to model multiple linear regression relationships among the kinematic variables.

**Methods.** This study analyzed video footage of 48 active-duty firefighters lifting a high-rise pack from floor to shoulder level. Movement information including trunk and knee flexion angles and hip vertical displacement was extracted from video files via frontal and sagittal frames using Dartfish. Descriptive statistics were calculated to characterize firefighter lower extremity posture. Stepwise regression strategies were applied to fit a regression model. Generalizability issues were examined by shrinkage calculation. All statistical tests were two-tailed and an effect was considered significant if  $p < 0.05$ .

**Results.** Firefighters require  $110^\circ$  of left knee flexion,  $155^\circ$  of right knee flexion and  $140^\circ$  of trunk flexion to lift a high-rise pack from floor to shoulder level. Hip vertical displacement was 25% of individual height. Regression analysis found the multiple linear regression relationship as follows:

Frontal frame: relative hip vertical displacement=0.16; hip diff angle -0.28; knee mean angle +46.55,  $R^2=0.42$  & shrinkage=17% ( $p < 0.01$ )

Sagittal frame: relative hip vertical displacement=0.30; hip mean angle -0.17; knee mean angle +4.95,  $R^2=0.53$  & shrinkage=4% ( $p < 0.01$ ).

**Discussion.** The R-square values suggest 42% (53%) of the variance in relative hip vertical displacement was explained by this model. Regression modeling facilitates the analyses of occupational kinematics with precision.

## Postural analysis and factors of musculoskeletal risk of paramedics inside ambulances

Martha Villa (presenter), John Rey

**Background.** Musculoskeletal injuries are one of the major problems associated with the tasks performed by paramedics. Some studies have shown a significant number of injuries in the lumbar region (36% of registered cases) (Hogya and Ellis, 1990). On average, paramedics spend over 32% of their time with trunk flexed and in rotation (Prairie and Corbeil, 2014). However, Mexican standards governing ambulance specifications do not provide parameters to establish better working postures situation for paramedics. This study recognizes the effect of the physical characteristics (dimensions, location and organization) of four different ambulances on paramedic postures.

**Methods.** An analysis of four groups of three participants each, who conducted a simulation inside the ambulance using three different clinical cases, was performed. Postures were analyzed using three cameras located in the passenger compartment and were subsequently evaluated by the REBA method.

**Results.** It is acknowledged that ambulances have fixtures and equipment beyond the functional range of paramedics that present high levels of risk for developing musculoskeletal problems, with 74.07% mainly affecting the neck, shoulders and legs, and 72.09% affecting the arms and wrists. Risk factors include the tension generated in the muscles, the unsteadiness of the platform when performing flexion, and rotation of the trunk to grip the team. Vehicle movement and vibration may also constitute risk factors.

**Discussion.** In conclusion, it is essential to review the disposition of equipment, and to ensure that it is more easily accessible and comfortable for paramedics, in order to contribute to paramedic safety and optimal patient care.

## Perspectives of occupational health and safety knowledge users on research use

Dwayne Van Eerd (presenter), Siobhan Cardoso, Ron Saunders, Trevor King, Sara Macdonald, Emma Irvin

**Background.** Knowledge transfer and exchange (KTE) is concerned with generating, disseminating and implementing the best available evidence. Research use or utilization is the use of research or evidence to guide practice. The objective of the project was to examine the experiences and perspectives of occupational health and safety (OHS) knowledge users regarding research use.

**Methods.** An online survey was sent to 690 OHS knowledge users in Ontario exploring aspects of research use. A subset of the survey respondents were invited to participate in either an interview (n=6) or focus groups (n=7) to explore aspects of research use in more detail. The survey, interviews and focus groups covered aspects of acquiring research findings, assessing research findings, adapting the findings for use and applying (using) research findings in decision-making.

**Results.** There were 236 survey responses (34% response rate) over three months. Results indicate that OHS knowledge users consider research use important however, organizational support varied based on leadership and resource availability. Many respondents reported limited time to acquire and use research. A majority of respondents indicated they acquired and used research evidence in their work. Furthermore, respondents appreciated having research consolidated and made easily accessible for it to be most useful in their job roles. Individual interviews and focus groups revealed credibility as a recurring theme related to acquiring and assessing research. Tailoring messages and audience context were themes related to adapting and applying research. Time and resources were consistently noted as barriers to research use.

**Discussion.** OHS knowledge users in Ontario indicate that research use is important in their decision-making process. The majority of participants reported using research in their jobs. We explore the barriers and enablers of research use and how this may impact on KTE strategies.

## Mixed approach for MSD prevention: a meat cutting study

Adriana Savescu (presenter), Aude Cuny-Guerrier, Gilles Reno

**Background.** The cutting performance of a knife is considered one of the determinants of musculoskeletal disorders (MSDs) in the meat-cutting sector (Claudon and Marsot, 2003; McGorry, Dowd et al, 2003). Cutting performance is affected both by knife maintenance and the organization of knife maintenance (Vézina, Prevost et al, 1999). In the context of subcontracting, the organization of knife maintenance can involve workers from different employers working at the same production site. Divergent opinions regarding the cutting capacity of knives emerge especially in this context. This could be due to different evaluation criteria.

**Methods.** The aim of this study was to show how a “mixed approach,” proposed by the authors, has allowed for the identification and discussion of criteria for evaluating the cutting capacity of knives according to both the job and to company affiliation.

The methodology mobilized three meat-cutting sites including three modes for the organization of knife sharpening. The mixed approach associates quantitative evaluations (the force required to cut a reference material) before and after sharpening, in-site sharpening analysis and interviews performed either individually or in pairs.

**Results.** The values of the quantitative evaluation of knives are grouped in an interval of 30N to 35N. The statistical analysis shows that these values are significantly influenced by the mode of organization. The individual and in-pairs interviews with meat cutters and/or sharpeners, and the in-site sharpening analysis, allowed for the identification of common criteria and specific criteria to meat cutters or sharpeners.

**Discussion.** In conclusion, the quantitative evaluation exceeded its contributory role for knowledge and became a tool for discussion during the interviews made in pairs. Indeed, it facilitated the ability of the cutting operators and the sharpeners to transcend accusatory speech and build together a vision of the “knife that cuts” by evaluating the criteria of knife cutting capacity.

SESSION 10, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 203B

## Experiences of work ability in young workers: an exploratory interview study

Maria Boström (presenter), Kristina Holmgren, Judith K Sluiter, Mats Hagberg, Anna Grimby-Ekman

**Background.** Young workers can anticipate working for many years and therefore need good work ability from the start of their career. Little is known about young workers' experiences of their work ability. The aim of this study was to explore the experiences of — and influences on — work ability in young workers with reference to their circumstances in work and life.

**Methods.** This was a qualitative study of a strategic sample of 12 female and 12 male workers aged 25-30 years either employed or who had recently left work. Participants were recruited from the five-year follow up of a Swedish cohort. Semi-structured interviews were performed to explore the experiences of work ability in these young workers. Systematic text condensation inspired by phenomenology was used in the analysis.

**Results.** Work ability was experienced as a complex consisting of four themes, each with three subthemes. Alertness and energy, as well as the possession of sufficient education, work skills and life experience necessary to engage meaningfully in work, were perceived to be fundamental for work ability and were also seen as being the responsibility of the worker. Moreover, work ability can be improved or diminished by the psychosocial work environment, work organization and private life. Optimal work ability was achieved when all themes were integrated in a positive way.

**Discussion.** Work ability was experienced as the responsibility of individual workers and as an attribute that could be influenced by work circumstances and private life. To promote good work ability among young workers, work ability must be understood in its specific context. Whether or not the understanding of work ability found in this study applies generally to young adults needs to be explored more research of the general population.

## Work and children: what do we not know – but need to know – about musculoskeletal impacts?

Susan Gunn (presenter), Hester Lipscomb

**Background.** Our knowledge about work-related musculoskeletal disorders comes largely from studies of adults in developed countries. Cross-occupational comparisons have led to guidelines for risk reduction and injury prevention such as the NIOSH lifting equation. However, we know very little about the occupational risks to young workers who form a significant part of the workforce in developing countries.

**Methods.** We report on four concurrent studies conducted under the auspices of the ILO, which investigate the impacts of work on children and youth who manufacture bricks — an occupation employing over three million children in over 20 countries worldwide. Structured interviews and clinical exams were conducted in Afghanistan, Nepal, Bangladesh and Pakistan with 817 child workers, aged 11-17, and a comparison group of 788 children. This paper describes the young workers' tasks and their musculoskeletal symptoms. It also suggests practical measures for immediate risk reduction, as well as youth employment policy.

**Results.** Consistent and significant ( $p < 0.01$ ) differences were observed in all four countries among children who manufacture bricks compared to those who do not. An average of 70% of working children (compared to 31.5% of non-workers) experienced pain over the last year, much of it in the back and neck. Over half suffered a sprain or serious structural injury within the last year. Gender is clearly a factor in the type of musculoskeletal injury; age is not.

**Discussion.** These studies reveal a more serious situation than was expected and present disturbing dilemmas given the social context in which the children work; management of disorders and sustainable employment take on completely different meanings in a world where eight-year-olds work alongside their parents to put bread on the table. The importance of the studies lies in the possible solutions they reveal. Furthermore, the studies provide facts that are crucial in convincing families to prioritize schooling over putting a child to work.

## NIOSH's musculoskeletal health research program

Stephen Hudock (presenter), Jessica Ramsey, Thomas McDowell

**Background.** The U.S. National Institute for Occupational Safety and Health (NIOSH) is about to enter the third decade of the National Occupational Research Agenda (NORA), a partnership program to stimulate innovative research and improved workplace practices. The program is comprised of 10 industry-based sector research programs and seven health outcome based cross-sector research programs. The musculoskeletal health research program is one such cross-sector.

**Methods.** In 2013, musculoskeletal disorders accounted for approximately one-third of all U.S. workplace lost-time injuries and illnesses. The median days away from work for a musculoskeletal disorder was 11 days compared to eight days for all lost-time injuries and illnesses. The public health burden is substantial and associated costs, both direct health-care costs and indirect costs, are estimated to be well over \$1 billion USD per year.

Recently, NIOSH conducted a series of reviews of the musculoskeletal research program's strategic plan, research focus, and project activities.

**Results.** Based upon the findings of those reviews, the program's research focus has shifted from basic/etiologic research towards intervention effectiveness, surveillance and information dissemination. The shift in focus extends to both internal and extramural research including funding opportunities and priorities.

**Discussion.** This presentation highlights the recent changes and future research directions of the NIOSH Musculoskeletal Disorders Health and Safety Cross-Sector Program.

## Association of frailty and pre-frailty with worklessness among 50- to 64-year olds

Karen Walker-Bone (presenter), Keith T. Palmer, Stefania D'Angelo, Catherine Linaker, Clare Harris, David Coggon, Avan Aihie Sayer

**Background.** Worldwide, there is a growing economic imperative for people to work beyond the traditional retirement age. It is important to explore determinants of work loss at older ages, and particularly to identify predictors of premature “worklessness” and consider strategies for prevention or intervention. At older ages, frailty is a syndrome that describes reduced muscle strength and function and that has been shown to be an excellent predictor of morbidities including falls, fractures and hospital admissions — and mortality. We investigated the relationship between frailty and pre-frailty and worklessness among U.K. workers aged 50-64 years.

**Methods.** We incepted a U.K. population-based cohort aged 50-64 years from across England. Participants completed a baseline questionnaire, which inquired about demography, lifetime occupational history, self-rated health, anxiety and depression, mechanical and psychosocial exposures, musculoskeletal pain and five questions to assess the Fried criteria for frailty and pre-frailty (fatigue, weight loss, mobility, grip strength and walking speed).

**Results.** In total, we obtained baseline questionnaires from > 8,000 men and women across England. Two-thirds reported that they were still in paid work; one-third reported that they were no longer working, one in three of whom had left work for a health reason. 45% of those who had left work for a health reason cited musculoskeletal disorders as the main reason. A score of > 3/5 for frailty was highly and significantly associated with not being in work (OR 10.5, 95% CI 7.9-14.1) and, in particular, with having left work for a health reason (OR 29.6, 95% CI 22.7-38.6). Frailty was also significantly associated with taking sick leave in the past 12 months and with musculoskeletal pain.

**Discussion.** Frailty is significantly associated with adverse work outcomes in this age group as well as musculoskeletal pain. This finding may lead to new biomarkers for predicting worklessness and/or guide strategies for prevention.

SESSION 11, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 203B

## A practical program to mitigate and prevent computer-related MSDs in a fast-paced workplace

Suparna Damany (presenter)

**Background.** Work-related musculoskeletal disorder (MSD) mitigation and prevention programs need to be efficient and effective for today's fast-paced, stressful and deadline-oriented work environment. However, to implement a successful program, it has to be "do-able." This is a description of a program implemented by the author at a global company.

**Methods.** An ergonomics program was developed to target a 250-employee department within a global company. The program was based on the principles of increasing movement and blood flow through whole body movement, improving muscle flexibility, neural glide, and increasing general strength while staying at the workstation, except for group stretch sessions once per month.

The program began by enlisting management support, job safety analyses and awareness talks. Mitigation was achieved through one-on-one sessions and specific exercise development, done at the workstation. For mitigation, participants who were symptomatic received instructions and exercise programs tailored for them, and that could be completed within the work day at their workstation, while performing their job duties. Monthly follow ups and "tweaking" of the programs were provided, which increased compliance and commitment. Soon, the exercises became a habit. For injury prevention, an awareness talk explained the biological basis and the need for injury prevention, and an injury prevention program was launched. This consisted of a 12-month program, with a different set of exercises each month, specifically targeting high-risk areas for the job duties (based on the Job Site Analysis, a process which included the employees and management).

**Results.** Both programs have been highly successful, as indicated by surveys, reduced visits to the company doctor, fewer workers' compensation claims and the enlistment into the program of more departments within the company.

**Discussion.** Challenges included busy schedules and long days — often with the inability to exercise at the end of the day — travel-schedule conflicts, use of mobile devices, software that required prolonged mouse manipulation and management support.

## A study of musculoskeletal disorders due to hand-held devices

Deepak Sharan (presenter), Joshua Samuel Rajkumar

**Background.** Hand-held devices (HHD) are widely used for communication and entertainment purposes such as audio or visual media, Internet access and gaming. High numbers of musculoskeletal disorders (MSDs) associated with excessive HHD usage have been reported. The aim of this study was to find out the risk factors and clinical features of MSD among individuals using HHD and the outcome of treatments for MSD.

**Methods.** A retrospective analysis was conducted on individuals with complaints of musculoskeletal symptoms reported after using HHD. A total of 92 subjects, five to 60 years old, were evaluated in the study. Evaluation and diagnosis was done by a single orthopaedic and rehabilitation physician between the years of 2005-2015. A subjective questionnaire was used to collect details and was completed using HHD. The inclusion criteria were sending a minimum of 25 text messages or emails from HHD per day, browsing the Internet or playing games for more than one hour per day using the HHD, which was followed by onset of symptoms.

**Results.** The prevalence was more evident among the male participants, with 80.43% (n=74) affected with musculoskeletal problems due to HHD. The commonly used HHD by the affected individuals was a Blackberry (41.3%, n=38) followed by touchscreen smartphones (25%, n=23) and iPhones (13.04%, n=12). Myofascial pain syndrome was the most commonly diagnosed co-morbid clinical condition in 68.47% of individuals, followed by thoracic outlet syndrome (41.3%) and fibromyalgia syndrome (14.13%). After the rehabilitation, following a sequenced protocol, the VAS scale showed significant reduction in pain levels ( $p < 0.01$ ).

**Discussion.** In common with our earlier studies on MSD due to HHD, tendinosis of extensor pollicis longus, myofascial pain syndrome of adductor pollicis, first interossei and extensor digitorum communis were the common positive clinical findings presented in all the individuals.

## Effectiveness of an eye exercise program in the prevention of computer vision syndrome among computer workers

Deepak Sharan (presenter), Rajarajeshwari Balakrishnan, Joshua Samuel Rajkumar

**Background.** Computer vision syndrome (CVS) is a “complex of vision and eye problems that are experienced during and related to computer use.” Several occupational factors can lead to CVS, including poor position in relation to the computer, lighting that produces glare or reflections, blurred images, failure to blink often enough to moisten the surface of the eyes, use of corrective lenses that are inappropriate or misdiagnosed, and minor visual defects. The aim of the study was to assess the effectiveness of an eye exercise program in reducing and preventing CVS among computer workers.

**Methods.** A prospective experimental study was conducted on 120 computer professionals in a developing country who were diagnosed with CVS based on symptoms and ergonomic workplace analysis. The workers were randomly assigned to two groups: (1) Group A (n=60) with mean age  $29\pm 3$  years, received standardized eye exercises and visual ergonomics advice, and (2) Group B (n=60) with mean age of  $31\pm 3$  years, received only visual ergonomics advice. Participants in Group A were instructed to carry out each exercise 20 times every two hours. The study duration was four weeks. VAS scale for visual pain and tear break up time test (TBUT) for dry eyes were the primary outcome measures. These were performed at the baseline, at four weeks after the intervention and after three months.

**Results.** Group A showed significant differences in the scores of VAS ( $p<0.05$ ) and TBUT ( $p<0.05$ ) when compared to Group B. Eye aching, redness and irritability was also reduced in Group A compared to Group B. The improvement in Group A was maintained at a follow up of three months, and no recurrence of CVS symptoms was reported.

**Discussion.** The addition of standardized eye exercises is an effective addition to visual ergonomics advice for alleviating the symptoms of CVS in computer workers.

SESSION 12, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 203B

## Activities of subcontractor first-line supervisors and MSD prevention: collective regulations with employees of the user company

Aude Cuny (presenter), Caroly Sandrine, Coutarel Fabien, Aublet-Cuvelier Agnès

**Background.** The way the work process is organized for subcontracted work can give rise to the employees of the subcontractor being organizationally dependent on the employees of the client. Such dependency can limit the situational room for maneuver that the subcontractor's employees have, thereby increasing the risk of musculoskeletal disorders (MSDs). First-line supervisors constitute the last level that can influence this dependence in the way they participate in organizing the work of the operatives they supervise. Focusing on subcontracted teams working in the meat-cutting industry, our aim was to investigate how first-line supervisors manage dependent operatives and the implications for MSD prevention.

**Methods.** The method was a qualitative research-based analysis of the activities of two subcontractor, first-line supervisors in different meat-cutting companies. Our methodology relied on observations of these supervisors (spread over different times of days and years) as they managed the supervised team. The supervisors were then shown video recordings of their activities to identify any underlying aims in the observed situations.

**Results.** Both supervisors sought to limit organizational dependence by collectively working with employees to manage the production process. The collective activity took the form of the supervisor cooperating with and helping, in a spirit of mutual assistance, cutting operatives or supervisors, depending on the production being observed. The mutual assistance observed allowed the supervised operatives room to maneuver. The aims expressed, performance or health, vary depending on the supervisor and the representation of the risk.

**Discussion.** Better understanding conditions for development of collective regulations between the subcontractors and the employees of the user company is a relevant avenue to be pursued for improving the prevention of MSDs in subcontracted work. We need to understand goals pursued by employees of the user company.

## Physical job demands are associated with smoking, pain and work limitations in construction workers

Jack Dennerlein (presenter), Michael Grant, Justin Rodger, Justin Manjourides, Cassandra Okechukwu

**Background.** Construction jobs have high rates of musculoskeletal disorders (MSDs) and poor health behaviours, including the highest prevalence of smoking out of all occupational groups. Both the MSDs and the health behaviours may influence the wellbeing and the work role function of the worker. This study's objective was to examine associations of job demands and ergonomic practices with construction workers' reported pain, smoking, diet and work limitations.

**Methods.** Construction workers from 10 commercial construction sites in the Boston area completed surveys, which assessed job demands, ergonomic practices, smoking habits and diet (n=658). In addition, modified NordicQ assessed pain and an abbreviated, six-item work limitations questionnaire assessed work role function. Multivariable linear and logistic regression models tested key associations. All models controlled for confounding variables (e.g. age, race, gender, trade, and job status) meeting a cut-off level of  $p < 0.2$ .

**Results.** Having high job demands was significantly associated with an increased probability of currently smoking (OR = 1.45: 95%CI 1.011 - 2.08), increased risk of pain related work-interference in the past three months (OR = 1.51: 95%CI 1.06-2.15), and decreased work role function ( $\beta = -0.20$  reduction 95%CI = -0.31 - -0.10). Higher ergonomic practices was associated with reduced pain-related work interference (OR = 0.73 95%CI 0.554, 0.959). Currently smoking was associated with increased pain-related work interference (OR = 1.46: 95%CI 1.01 – 2.13) and consumption of unhealthy foods was associated with both pain-related work interference (OR = 1.310 95%CI 1.035 1.659) and work limitations (OR = -0.09 95%CI -0.15, -0.02).

**Discussion.** Multifactorial associations between job demands and ergonomic practices with health behaviours and work limitations exist, suggesting potential shared causal pathways within the work organization of construction workers. Programs to improve health of construction workers need to consider work factors and the nature of construction work.

## Musculoskeletal disorders prevention research: learning from research on bricklayers

Henk Van der Molen (presenter), Allard van der Beek, Monique Frings-Dresen

**Background.** A circular research framework for optimizing the prevention of work-related musculoskeletal disorders (MSDs) has been proposed. Our aim was to retrospectively apply this framework to decades of Dutch research performed to prevent work-related low-back complaints among bricklayers.

**Methods.** The six-step research framework (van der Beek et al, to be submitted) contains a sequential focus on: (1) occurrence of MSDs, (2) risk factors for MSDs, (3) underlying mechanisms, (4) development of interventions, (5) evaluation of interventions, and (6) implementation of interventions. Research efforts aimed to prevent work-related low-back complaints among bricklayers were summarized.

**Results.** Step 1 and 2: systematic review. Consistent evidence for increased risk of MSDs among bricklayers, especially in the low back, was established. Manual materials handling in combination with deep bending were assessed as risk factors.

Step 3: experimental laboratory study. Biomechanical load associated with varying conditions such as weight, frequency and working heights revealed that low working height was associated with the highest lumbar compression forces.

Step 4: participatory ergonomics approach. Devices to optimize working height were developed and selected as potentially effective and acceptable.

Step 5: controlled field studies. A substantial reduction of trunk flexion  $>60^\circ$  and less reported local discomfort of the low back were found when using devices to optimize working height.

Step 6: qualitative interviews and prospective cohort study. Bricklayers were more aware of health risks than employers. Using measures to adjust working height were associated with recovery from low-back complaints in a 4.5 year time frame.

**Discussion.** Involvement of different research methods and disciplines is thought to be necessary to successfully implement evidence-based measures. However, reduction of work-related MSDs remains a challenge. Low attributional fractions of exposures and insufficient implementation are caveats. Health impact assessment is an alternative short-term approach to evaluating scenarios of preventive interventions on MSDs.

SESSION 13, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 204A

## How to prevent work-related MSDs during lean management implementation?

Sebastien Bruere (presenter)

**Background.** Lean management looks to have some effects on work-related MSDs. However, its philosophy is not far from the definition of an organization that avoids constraints and promotes the development of a gestural variety — the “enabling organization” concept. In this research, we raised the question: How do we prevent work-related MSDs during the implementation of lean projects? We tried to find out which factors of organizational work allow actors to make a lean project an enabling organization.

**Methods.** This exploratory research has been based on the method of multiple case studies. Five case studies of lean projects were documented by means of 15 individual interviews and document collection. For each project, at least two players were interviewed and documents associated with the project were collected, whenever it was possible.

**Results.** We were able to identify several factors that contribute to an enabling organization: (1) at the organizational level, a position should be established for a union actor who is knowledgeable about the project (there should also be access to an external mediator); (2) at the business level, efforts must be made to enable stakeholder participation — the principles of “paritarisme” should guide the actions and decisions of local officials; and (3) at the production level, value stream mapping should be used to track the organization’s actions and decisions, organize key performance indicators, spell out the rules for close supervision and the expectations for vertical and horizontal cooperation and facilitate the means for employee knowledge inputs.

**Discussion.** These qualitative results gives us some insights into how the mechanisms that contribute to lean management may sometimes lead to positive workplace health outcomes and sometimes lead to poor outcomes. The identified factors may also serve as guidelines for trade unions and consultants who plan lean projects and for health and safety managers.

## Work disability prevention and management: an analysis of Colombian Labour Risk System

Diana Cuervo (presenter), Marisol Moreno-Angarita

**Background.** This research focuses on the framework of the Colombian Labour Risk System and the inefficiencies in the system that prevent the return to work of people who have suffered workplace accidents or occupational disease.

Workers perceive that they do not have the support necessary to ensure reinstatement after an accident or incident at work temporarily incapacitates them and may even result in an increased risk of being laid off. Physicians lack knowledge about the concepts of disability, rehabilitation and reinstatement with the result that temporary incapacities may be prolonged, and become a barrier that prevents workers from returning to work. There is ignorance on the part of employers and a refusal and/or inability to reintegrate persons with disabilities.

**Methods.** In this context, the following research question arises: What conceptual, procedural and legal adjustments should be made to Columbia's model for addressing occupational hazards in order to protect workers and promote a balanced relationship between financial compensation and return to work?

The methodology employed mixed methods. A document review was conducted to establish the state of the current models of care for labour risks with reference to the legislative regime in Colombia and in other countries that have developed workplace-based approaches to disability management and prevention for injuries caused by work. Contrasts with the Colombian model were observed and developed through interviews with 34 different stakeholders.

**Results.** This project aimed to prompt discussion within the Colombian Labour Risk System and address issues concerned with work disability prevention and assist with understanding and comprehending the complexity of the relationships between work and health and perceptions about justice.

**Discussion.** This study will surely prompt stakeholders to explore, analyze, discuss and conceptualize the elements of the existing Labour Risk System and provide inputs that contribute to understanding the complexity of the issues and to developing more appropriate, equitable and fair solutions in response to identified gaps in the system.

## Leading OHS indicators for musculoskeletal health, safety and disability management

Sheilah Hogg-Johnson (presenter), Colette Severin, Michael Swift, Selahadin Ibrahim, Cameron Mustard, Lynda Robson, Peter Smith, Ivan Steenstra, Benjamin Amick

**Background.** Workplace parties and occupational health and safety (OHS) professionals are increasingly interested in assessing OHS performance using leading indicators rather than lagging indicators such as injury rates. The study objective was to evaluate the psychometric performance of the Organizational Policies and Practices (OPP) instrument, including structural validity, reliability and predictive validity.

**Methods.** Persons most knowledgeable about OHS in Ontario workplaces from 10 sectors were recruited to complete a survey including the 27-item OPP for their workplace. A subset of respondents repeated the survey two weeks later. The 27 items yielded five subscales: safety practices (SP), active safety leadership (ASL), ergonomics practices (EP), disability prevention (DP), and people-oriented culture (POC). Subscales were evaluated for internal consistency and test-retest reliability. Confirmatory factor analysis (CFA) was used to assess structural validity. Survey data were linked to workers' compensation injury claims for the two years following survey administration to assess predictive validity using overall claim rate, claim rate for musculoskeletal disorders (MSDs) and disability duration for MSDs as outcomes with negative binomial and Cox regression models controlling for sector, size and region.

**Results.** Completed surveys were obtained from 1,639 workplaces with repeated surveys for 191. Cronbach's "a" for the five subscales showed good internal consistency (0.84 – 0.92). Test-retest reliability ICCs were SP 0.77, ASL 0.69, EP 0.67, DP 0.82, POC 0.80 and considered adequate when above 0.70. The five-subscale structure was confirmed with excellent CFA goodness of fit (RMSEA 0.041, CRI 0.95, TLI 0.94). Higher values of SP, EP and POC significantly predict lower overall claim rates. Higher values of EP marginally and DP significantly predict lower MSD claim rates. Higher values of EP and DP are significantly associated with faster times to return to work.

**Discussion.** Psychometric properties of the OPP subscales are promising. Further investigation of validity is warranted.

## Managing safety and operations: the effect of joint management system practices on safety and operational outcomes

Emile Tompa, Lynda Robson (presenter), Anna Sarnocinska-Hart, Robert Klassen, Anton Shevchenko, Sharvani Sharma, Sheilah Hogg-Johnson, Benjamin Amick, David Johnston, Anthony Veltri, Mark Pagell

**Background.** Work injury research has typically focused on occupational health and safety (OHS)-related practices and outcomes, with little attention to other organizational practices and outcomes. Operations management research, concerned with operational effectiveness and efficiency, has been similarly narrowly focused. As a result, there has been little research in recent decades that simultaneously studies the relationship between operational best practices (such as lean production) and OHS best practices, as well as their impact on both operational and OHS outcomes. Can best practices in operations and OHS co-exist or even enhance one another in terms of outcomes, or is there a trade-off?

**Methods.** This study sought to determine whether or not management-system practices directed at both OHS and operations (joint management system (JMS) practices) result in better outcomes in both areas compared to management systems that run these practices separately. We ran separate regression models for OHS and operational outcomes using data from a survey along with administrative records on injuries and illnesses. We found that organizations with JMS practices had better operational and safety outcomes than organizations without these practices. They had similar OHS outcomes as those with operations-weak practices and, in some cases, better outcomes than organizations with safety-weak practices. They had similar operational outcomes as those with safety-weak practices and better outcomes than those with operations-weak practices.

**Discussion.** Our study findings suggest that organizations with JMS practices can achieve high performance in both safety and operations, without needing to compromise one or the other.



## Field evaluations of MSD prevention policies, programs and practices

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SESSION 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 201B

## How should job rotation be designed for manufacturing industrial workers? A systematic review

Rosimeire Padula, Maria Luiza Caires Comper (presenter), Jack Dennerlein, Emily Sparer

**Background.** Several reasons justify the use of job rotation as an organizational strategy. Therefore, the parameters adopted to evaluate the effects of job rotation intervention are different among the studies. The aim of this study was to define the main parameters used for planning and implementation of job rotation programs in manufacturing industries.

**Methods.** Independent systematic searches were conducted in MEDLINE, EMBASE, Business Source Premier, ISI Web of Knowledge, CINAHL, PsYINFO, Scopus and SciELO databases for articles published in peer-reviewed journals. The review process consisted of first deciding which studies to include through review of (1) the titles and (2) reading the abstracts. Then, full text was reviewed by two independent researchers.

**Results.** From 10,809 potential articles, 71 were read for full text analysis, and 15 studies were included for data extraction. There was great variability in parameters described to define job rotation schedules. In most of the studies, biomechanical and organizational factors were used, and included aspects related to posture, movement frequency, level of exposure and complexity level of task. Mathematical equations and algorithms are frequently used for creating proposals for switching between tasks. Job rotation shifts tended to vary between one and two hours in each study.

**Discussion.** We found a few current studies on job rotation in manufacturing industries. These studies reported little about the strategies used to perform the rotation. Many of the equations proposed to define how the schedules rely on a variety of parameters without describing how they determined the job rotation success.

## The effectiveness of job rotation to prevent work-related musculoskeletal disorders: a cluster randomized clinical trial

Maria Luiza Caires Comper (presenter), Jack Dennerlein

**Background.** Job rotation has often been used where the level of exposure cannot be reduced by using other ergonomics interventions. However, there is no evidence in scientific literature supporting the effectiveness of job rotation to prevent and control musculoskeletal complaints. The aim of this study was to investigate the effectiveness of job rotation to prevent musculoskeletal disorders in industrial manufacturing workers.

**Methods.** This study employed a cluster randomized controlled trial with blinded assessment of outcomes. This study was conducted at four production sectors within the Brazilian textile industry. The sectors were randomized into intervention and control groups considering similar exposure factors of the task. Both groups received ergonomics training; the intervention group performed a job rotation program for 12 months. The primary outcome measure was absence from work due to sick leave. Other outcomes measured were musculoskeletal symptoms, job factors for musculoskeletal pain and disorders, psychosocial factors and fatigue, and general health and productivity. The difference between the groups and respective confidence intervals were calculated using linear mixed models.

**Results.** After 12 months, the job rotation program did not have an impact on the number of working hours lost due to sick leave caused by a symptom or disease of the musculoskeletal system (mean -0.93, 95% CI -2.94 to 1.09). There was no significant difference between groups for the other secondary outcomes ( $p > 0.05$ ).

**Discussion.** This study is the first RCT conducted with a large population of industrial workers. The job rotation program was no more effective than the control group in preventing musculoskeletal disorders in industrial workers for outcome measures. These results challenge the theory that job rotation is a good organizational strategy for the control of musculoskeletal complaints. However, care should be taken in translating the results to all manufacturing industries; it is necessary to consider the specifics of the job.

## Evaluation of an ergonomic intervention in Swedish flight baggage handlers

Eva Bergsten (presenter), Svend Erik Mathiassen, Johan Larsson, Lydia Kwak

**Background.** Flight baggage handling is a worldwide occupation where baggage and cargo is sorted, loaded and unloaded on and off aircraft. With the ultimate purpose of reducing and preventing musculoskeletal disorders among flight baggage handlers in Sweden, the Vocational Training and Working Environment Council (TYA) — a council formed by employers and unions in the Swedish transportation sector — initiated and implemented a project (2010-2012). This project revealed that ergonomics equipment was not used properly, and this was considered a major factor of concern. Therefore, in 2014, a training program was initiated at one handling company aimed at improving ergonomics, behaviour and attitudes. We evaluated the implementation process with regard to process items, intermediate outcomes, barriers and facilitators for the purpose of gaining knowledge that could facilitate successful implementation in other handling companies.

**Methods.** A mixed methods design was applied based on qualitative and quantitative data. We evaluated six process items: recruitment, context, reach, dose delivered, dose received and satisfaction. We also evaluated the intermediate outcomes of the intervention: skills, confidence and behaviour in the workforce, and the barriers and facilitators for successful implementation. Data was retrieved using company data, course evaluations, web questionnaires, and telephone interviews with company “observers” and key persons.

**Results.** The implementation process was judged to be feasible with regard to some of the process items. According to the informants, workplace behaviour related to use of equipment had, however, not changed after the training period. Reported barriers were (1) insufficient time and leadership support for practicing new procedures during and after the training, (2) simultaneous reorganization of teams and work tasks, and (3) lack of follow-up to the training, which would have supported good performance, according to the informants.

**Discussion.** The implementation process was hampered by barriers, some of which could be addressed in future ergonomics training programs in other baggage handling companies.

SESSION 2, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 201B

## A gap analysis of MSD prevention activities in a comprehensive construction safety management program

Ann Marie Dale (presenter), Amin Yazdani, Nick Collins, Vicki Kaskutas, Richard Wells, Bradley Evanoff

**Background.** Musculoskeletal disorders (MSDs) are a leading work-related health concern among construction workers. Ergonomic MSD prevention programs in construction do not typically encompass most elements required for an effective occupational health and safety management system. Incorporating MSD prevention into existing multi-level safety assessment and training procedures may more effectively address hazard recognition and prevention. We will conduct a gap analysis of MSD hazard recognition and controls, which will serve as baseline measures for an intervention study that adds MSD prevention as a major focus to a standard construction safety management program.

**Methods.** MSD prevention-related information from three large construction projects was reviewed and logged. Data included materials from safety and management meetings, worker training, inspections, and pre-task safety analysis (PTSA) forms. We surveyed workers regarding musculoskeletal symptoms, and ran worker focus groups to identify barriers and facilitators to using ergonomically sound work methods. We also performed worksite observations to identify MSD hazards and controls, which were compared to corresponding PTSA forms.

**Results.** Minimal MSD prevention information was conveyed during orientation training or foremen's meetings. Toolbox talks delivered by the general contractor addressed ergonomics during one of 29 training sessions, while the subcontractors addressed ergonomics in six of the 44 sessions. Researcher observations of 25 worker groups identified ergonomic hazards for 72% of the work tasks observed, but only 20% had implemented effective controls. The PTSA forms identified ergonomic hazards in 40% of the same work tasks covered by observations in the planned and written controls for 16% of these hazards. Results from worker surveys and focus groups will be available spring 2016.

**Discussion.** Early results identified few MSD prevention activities within the construction safety program and limited recognition of ergonomic hazards by foremen and workers. This gap analysis will guide development of the construction safety management program and serve as a measure of baseline performance.

## OHS workplace interventions for upper extremity MSDs: an update of the evidence and messages

Dwayne Van Eerd (presenter), Emma Irvin, Claire Munhall, David Rempel, Shelley Brewer, Allard van der Beek, Jack Dennerlein, Jessica Tullar, Kathryn Skivington, Clint Pinion, Benjamin Amick

**Background.** In the United States, upper extremity musculoskeletal disorders (MSDs) and low-back pain are the leading diagnoses of disabling work-related injuries, accounting for 29% of all injuries and illnesses (Silverstein and Evanoff, 2011). In Canada, MSDs account for between 40% to 60% of lost-time claims since the year 2000 (WSIB, 2009; WCB Nova Scotia, 2009; WorkSafeBC, 2009; WCB Manitoba, 2010). Workplace and work process hazards contribute to the development of upper extremity MSDs; however, there is little consensus on effective ways to reduce or eliminate hazards. The objective of this project is to update the review of workplace-based upper extremity MSD prevention with a view to updating the key messages.

**Methods.** The team of researchers and stakeholders followed a systematic review process developed by the IWH: research question formulation; literature search; relevance review; quality appraisal; data extraction; and, evidence synthesis. A best-evidence synthesis approach was adapted from Slavin (1986), based on three aspects of the evidence: quality, quantity, and consistency. Synthesis of the evidence on a particular upper extremity MSD intervention-health outcome relationship is ranked on a scale from strong to insufficient evidence. The following electronic databases were searched from January 2008 until December 2012: MEDLINE, EMBASE, Cumulative Index to Nursing & Allied Health Literature (CINAHL), Canadian Centre for Occupational Health and Safety's CCINFO web, Cochrane Library and Ergonomic Abstracts. The search yielded 9909 non-duplicate references.

**Results.** We found 26 high and medium quality studies that were relevant to answer our research question. We combined the 26 studies from 2008 to 2013 with 35 from the original review to synthesize the evidence. Our synthesis reveals strong evidence for resistance training and moderate evidence for stretching programs, mouse use feedback and forearm supports in preventing MSD symptoms or disorders.

**Discussion.** Stakeholders were consulted to help frame the resulting recommendations. Stakeholder involvement ensured practical messages about these interventions.

## Addressing essential skills gaps among participants in an OHS training program: a pilot study

Ron Saunders (presenter), Siobhan Cardoso, Curtis Breslin, Karen Myers

**Background.** Over 40% of people in Canada between 16 and 65 years old have difficulty with such basic skills as understanding what they read or doing simple calculations. We are piloting the use of essential skills curriculum within an OHS program to see if this can improve learning outcomes. The hoisting and rigging program offered by the training centre of local 506 of the Labourers' International Union of North America is designed to teach workers how to rig loads safely for lifting by different kinds of construction equipment. The content for the program was developed by the Infrastructure Health and Association (IHSA).

**Methods.** A team involving curriculum specialists in essential skills, the IHSA and the training centre is developing a modified version of the training program to address gaps in the interpretation of documents and numeracy skills. Some trainees will pursue the regular program; others the modified program. To keep the duration of training the same, those taking the regular program will have additional review exercises. (Total duration is three days.) Trainees will complete tests of essential skills levels before and after training, will complete a written test of safety knowledge after training, and will be assessed in use of equipment at the training centre. A subset of trainees will be assessed on equipment by assessors not involved in the training nor aware of which group the trainee is from. We will compare the results for the two groups while controlling for age, educational attainment and first language.

**Results.** By June 2016, we will be able to report on the specific essential skills gaps of the trainees.

**Discussion.** If the pilot is successful, it will provide a model that could be emulated in other occupational health and safety (OHS) training programs that serve a trainee population with essential skills gaps.

## Whole body vibration exposures and truck drivers' health status in the United States

Jeong Ho Kim, Margaret Hughes (presenter), Jack Dennerlein, Peter Johnson

**Background.** Whole body vibration (WBV) exposures have been associated with low-back pain (LBP). Therefore, as part of a two-year randomized controlled trial, WBV exposures were evaluated in truck drivers to determine if there were any associations between WBV and general and musculoskeletal health status.

**Methods.** As part of a two-year randomized controlled trial, this study measured WBV exposures as per the International Organization for Standardization (ISO) 2631-1 standards from a subset of 34 truck drivers from four different truck terminal sites of a large national trucking company in the United States. Musculoskeletal pain was measured using a standardized 10-point visual analog scale; and physical and mental health was assessed using Short Form 12-item (SF-12) health survey.

**Results.** The daily vector-sum WBV exposures A(8) (Mean  $\pm$  SD:  $0.50 \pm 0.02$  m/s<sup>2</sup>) were at the ISO action limit (0.5 m/s<sup>2</sup>) whereas the predominant z-axis A(8) exposures ( $0.36 \pm 0.02$  m/s<sup>2</sup>) were below the action limit. VDV(8) exposures showed that both the predominant z-axis ( $9.4 \pm 0.4$  m/s<sup>1.75</sup>) and vector sum exposures ( $10.4 \pm 0.3$  m/s<sup>1.75</sup>) were above the ISO action limit ( $9.1$  m/s<sup>1.75</sup>). Across all the musculoskeletal pain outcomes (n = 32), LBP was the most severe ( $4.1 \pm 2.7$ ). The SF-12 health survey (n = 32) showed that the drivers had significantly lower physical (p < 0.01) and mental (p < 0.03) health status than the general U.S. population. When the A(8) and VDV(8) exposures were grouped into tertiles (low, medium and high), stronger associations between WBV exposures and health status were observed with the A(8) exposures; however, the differences between exposure tertiles did not reach statistical significance.

**Discussion.** This study showed that the cumulative-impulsive VDV(8) exposures were more prominent compared to the continuous-average A(8) exposures. However, truck driver musculoskeletal pain and general health was more strongly associated with the A(8) exposures.

SESSION 3, MONDAY JUNE 20, 3:30PM – 5:00PM, ROOM 201B

## Successes and challenges of implementing a comprehensive ergonomics and wellness, total worker-health intervention on commercial construction sites

Michael Grant (presenter), Kristen Ironside, Justin Manjourides, Cassandra Okechukwu, Jack T. Dennerlein

**Background.** Despite the high prevalence of musculoskeletal disorders (MSDs) and high-risk health behaviours, integrated health protection and health promotion is not the norm for commercial construction workers. The worksite environment sets the working conditions that affect both worker MSDs and the ability to enact healthy behaviours. The objective of the study was to evaluate a worksite based, integrated intervention program targeting musculoskeletal disorders, diet, and tobacco use and present the challenges and successes encountered during intervention implementation.

**Methods.** Construction workers on 10 commercial construction sites in the Boston area (5 intervention, 5 control) completed baseline and one month follow-up surveys that assessed job demands (WLQ Short Form), ergonomic practices, smoking habits and diet (n=211). A mixed methods approach was used to evaluate the intervention. Focus groups and key informant interviews were analyzed for thematic content.

**Results.** We observed a positive, however, non-significant intervention effect size of 0.33 on the short form work limitations scale, similar to observations in other intervention studies. Changes in other outcomes such as work practices, pain severity, were small and non-significant. Our qualitative methods identified key challenges to implementation, including competing safety and production priorities and break practices leading to inconsistencies in intervention delivery. A key barrier was the capability of subcontractor companies to make changes. Prompted by topics addressed during health week, workers expressed concerns about the quality of food served at food trucks, poorly managed stress, alcohol abuse and air quality.

**Discussion.** The intervention developed from this research provides a step toward improving health outcomes for workers on a worksite-specific basis. The improvement in work limitations can affect worker productivity as well. It is important to understand the challenges and successes of intervention delivery in order to inform and improve future worksite-based interventions.

## Effects of an ergonomic intervention on posture and discomfort of office workers: a cluster randomized controlled trial

Fernanda Barros, Cristiane Moriguchi, Tatiana Sato (presenter)

**Background.** The effects of postural ergonomics intervention for preventing musculoskeletal disorders among office workers are not readily apparent. It is necessary to identify the results of interventions by means of objective measurements of occupational exposures. Thus, this study aims to evaluate the effectiveness of an ergonomics intervention using objective measures of work postures and perceived discomfort among office workers in a cluster randomized controlled trial.

**Method.** 60 office workers took part in this study. The allocation was performed by cluster randomization, considering the rooms in which they work as the grouping unit. Thus, experimental (EG; n=30) and control groups (CG; n=30) were compared before (T1) and 30 minutes (T2) after the intervention. The EG received furniture adjustments and postural orientation and the CG walked for 15 minutes. Perceived discomfort was evaluated by a visual analogue scale and head, upper back and upper arms postures were recorded by inclinometry. A linear mixed model analysis was performed to compare groups at the two assessments. Mann Whitney test was applied to compare the groups for discomfort.

**Results.** For the upper arms, a significant group by time interaction was found. The EG showed a reduction in upper arm elevation at T2 (difference about 8°) and the CG showed similar values (difference about 1.3°). Upper back flexion angles significantly reduced in both groups at T2 and head posture was similar for groups and time. Perceived discomfort significantly decreased for the EG (mean about 2 mm) and increased about 0.7 mm for the CG.

**Discussion.** The furniture adjustment was important to reduce the upper arm exposure and perceived discomfort. Active pause was beneficial for improving the upper back posture probably due to the postural variation. These results highlight the importance of using objective measurements to evaluate the effectiveness of ergonomic interventions.

## Evaluation of facilitators and barriers to implementing ergonomic solutions in construction

Laura Welch (presenter), Lisa Jaegers, Ann Marie Dale, Bradley Evanoff

**Background.** Construction workers experience high rates of musculoskeletal disorders (MSDs), and diffusion of ergonomic solutions to reduce their risks for MSDs is a challenge. We evaluated implementation of ergonomic solutions in among construction trades to describe both opportunities and difficulties for diffusing innovations.

**Methods.** During a four-year participatory ergonomics study among construction trades, we collected data on the implementation of ergonomic solutions through worker surveys, focus groups, contractor and industry representative interviews and researcher field notes. We defined an ergonomic solution as an existing or new device or technology that can be used to reduce MSD risk factors in construction-related tasks. We adapted an existing framework (Weinstein, 2007 *IJOEH*, 13, 46-55) to code intervention attributes including relative advantage, usability, compatibility, complexity, trialability and observability; we also coded level of adoption for each observed solution.

**Results.** We identified 19 ergonomic solutions, categorized as equipment, positioners, hand tools, power tools, manual material handling devices, personal protective equipment, and design for safety technology. Eight solutions received positive ratings for all six attributes; of these solutions, only three were implemented frequently, two of which were in the workers' control. Most solutions were implemented intermittently (n=9); all had four or more positive attributes. Two solutions that were implemented only rarely (n=4) — and one solution not implemented (n=3) — had all six positive attributes. Barriers for solutions that were not frequently implemented despite positive attributes included: required use of an extra tool; tool did not always fit the task; equipment was only used for large jobs; and, using the solution required extra planning or coordination with other workers.

**Discussion.** Implementation of ergonomic solutions in construction is challenging due to multiple barriers — even for solutions with positive attributes. Many barriers lie outside the control of individual workers; improved prevention of MSD requires greater engagement by contractors.

SESSION 4, TUESDAY JUNE 21, 10:30AM – 12:00PM, ROOM 201B

## Evaluation of two guidance strategies on the use of ergonomic measures

Steven Visser, Henk Van der Molen (presenter), Judith Sluiter, Monique Frings-Dresen

**Background.** Ergonomic measures are available to reduce high physical work demands among construction workers; for example, scaffolding consoles can be used to assist with work in upright positions. Nevertheless, ergonomic measures are not implemented widely in daily practice. Our aim was to study the effects on the implementation and use of ergonomic measures of a face-to-face (F2F) strategy and an e-guidance (EG) strategy of a participatory ergonomics (PE) intervention in the construction industry. .

**Methods.** The effect of two PE guidance strategies on the use of ergonomic measures was evaluated in a cluster randomized parallel intervention trial with a follow up at six months. The design of the study was described in Visser et al (2014). 12 construction companies were randomly assigned to F2F (N=6) or EG (N=6). In both guidance strategies, a steering committee was installed consisting of the director, prevention worker, work planners, supervisors and construction workers. Ergonomic consultants guided the companies through face-to-face contact in F2F, or through email contact in EG. The percentage of workers using ergonomic measures was assessed using questionnaires at baseline and after six months.

**Results.** Two companies received the face-to-face guidance strategy and completed the intervention. Three companies received the e-guidance strategy and one completed the entire intervention. Seven companies did not implement any ergonomic measures. Among four types of ergonomic measures, only the use of ergonomic measures to adjust working height changed over time ( $p=0.001$ ) between the F2F (+1%) and the EG (+10%). The use of newly-implemented ergonomic measures was 23% for F2F and 42% for EG after six months ( $p=0.271$ ).

**Discussion.** This study showed that the guidance through the internet or email can be used to guide steering committees associated with a PE intervention. The biggest challenges with this guidance strategy are getting the intervention started and keeping companies alert to completing the intervention.

## The effectiveness of an “ergonomic” keyboard for reducing musculoskeletal symptoms

Nancy Baker (presenter), Krissy Moehling, Seo Young Park

**Background.** “Ergonomic” keyboards are recommended to reduce musculoskeletal symptoms (MSS). However, there have been few longitudinal studies examining the effectiveness of these keyboards, and they are equivocal. This study examined whether a fixed split keyboard (Microsoft Natural Ergonomics 4000 Version 1.0) was more effective at eliminating MSS in computer operators over five months than a standard keyboard. We hypothesized that significantly more subjects using the fixed split angled (FSA) keyboard would report no symptoms in comparison to those using a standard (ST) flat keyboard.

**Methods.** In this randomized, prospective cross-over trial, 77 computer users with MSS were assigned to one of two orders: Group 1 received the ST keyboard first and the FSA second; Group 2 was reversed. Subjects completed Weekly Discomfort Surveys weekly. After five months, subjects switched to their second keyboard for five more months. The results of these surveys were dichotomized to those with and without MSS.

**Results.** At baseline, 72 (93.5%) subjects reported neck MSS, 66 (85.7%) low-back MSS, 69 (89.6%) right hand MSS, and 46 (59.7%) reported left hand MSS. We ran GEE logistic regression models, which included variables for period, group assignment and an interaction term. The number of subjects reporting MSS significantly reduced over time for neck and low-back discomfort. There was no significant difference by keyboard assignment (FSA vs. ST) or by keyboard assignment over time. When we graphed the results, we saw that most subjects’ MSS was eliminated within the first two months of the study, regardless of keyboard. The number of subjects with MSS remained stable for the rest of the study.

**Discussion.** “Ergonomic” keyboards are no more effective at eliminating MSS than standard flat keyboards. Health professionals who do computer workstation redesign should consider carefully before recommending an ergonomic keyboard.

## Prevalence and risk factors associated with upper extremity musculoskeletal disorders in Iranian bakers

Mehrzad Ebrahemzadih (presenter)

**Background.** The first goal of the study is to survey the prevalence of musculoskeletal disorders (MSDs) in four zones: the neck, shoulder, hand/wrist, and back. The second goal of the study is to survey the risk factors producing upper limb musculoskeletal disorders by using the OCRA index method.

**Methods.** Four data collection methods were used in this analytic-descriptive and cross-sectional study. Observation and interview methods used questionnaires and check lists. Randomly, 384 samples were collected for MSD prevalence, and 423 samples for the OCRA index exposure survey were collected by cluster ratio sampling.

**Results.** In this study, findings indicated that MSD prevalence was high in the studied bakery workers and that most disorder and pain were reported in back, knees and hand/wrist. The highest percentage of neck MSDs (7.1%) and shoulder MSDs (27.8%) were related to selling and baking tasks respectively; the highest percentage of hand/wrist MSDs (33/3%) and back MSDs (38.1%) were related to baking tasks. There was a significant correlation between shoulder, hand/wrist and back MSD with bakery and task type, and effect of job background on MSD prevalence was improved in the above four zones.

**Discussion.** The rather high prevalence of MSDs among young (average age 30 years) and inexperienced workers — and in light of the risk assessments performed — should be taken as a serious warning.

## Encouraging postural breaks: findings from a two-year behaviour change study

Claire Williams (presenter), Andrew Baird, David Sheffield, Elaine Denning

**Background.** Musculoskeletal disorders (MSDs) remain a major health problem, with insufficient postural change implicated in their prevalence. Self-report data suggest that office workers sit for long periods without getting up. The theory of planned behaviour (TPB) outlines factors thought to impact on intention to behave in a certain way, highlighting (though not addressing) a gap between intention and behaviour. External prompts or reminders, and the writing of implementation intentions (if/then plans), have been used to close this gap for other behaviours in office environments.

**Methods.** This IOSH-funded study investigated whether or not these plans and prompts increased the number of short (30-second) postural breaks taken by “desk-bound” office staff. The reasons behind success or failure were examined via focus groups (n= 31). Objective postural break data (n=195) were collected using waist-mounted, BACK-TRACK™ data loggers at three time points; before, immediately after and several months after intervention. All groups, including the control group, were given written encouragement to take more, 30-second postural breaks. One group wrote if/then plans about postural changes; one received an external prompt to move (provided by the BACK-TRACK™ device); and one combined intervention group wrote if/then plans and received the external prompt.

**Results.** Data reveal that this population takes regular postural breaks, even at baseline (=3.34 postural breaks per hour). Writing if/then plans were effective in doubling the odds that a meaningful increase in postural breaks would be achieved. External buzzing prompts did not affect the number of breaks taken, and no intervention effect on pain was found.

**Discussion.** Participants reported a number of factors that influenced their break taking; these are classified using the TPB, to which a number of additional factors are integrated. A list of recommendations describing how to incorporate all the findings from this study into health and safety practice are outlined.

SESSION 5, TUESDAY JUNE 21, 1:30PM – 3:00PM, ROOM 201B

## Safe patient handling: does literature support adoption?

Kermit Davis (presenter), Susan Kotowski

**Background.** There are many safe patient-handling initiatives, including training on using proper body mechanics, use of slide boards or mechanical lifts, or culture shifts about manual handling. However, there are few clear answers on the efficacy of any of these methods. The objective of this literature review was to determine the strength of the evidence on whether or not lift devices protect the care provider.

**Methods.** 30 papers were identified and reviewed that reported data about prevalence of usage, spine loading, and effectiveness of lift devices in reducing injuries.

**Results.** Usage of different handling devices appears to vary greatly depending on the facility: slide boards and no assist devices (54% and 60%, respectively) are used more often than lifts (27% to 43%, on average). It is clear that lifts reduce biomechanical loading during transfers: floor lifts reduced loading by 1000 N (26%) for compression and 260 N (31%) for shear, while reductions were larger for ceiling lifts, 2100 N (48%) for compression and 480 N (57%) for shear force. The 13 studies that investigated the impact of using lift-assist devices reported an average of 50% reduction in injuries, while nine studies investigating impact on costs reported a 59% reduction.

**Discussion.** Overall, lifts were found to reduce spine loading and, ultimately, the injuries from handling patients. Although the evidence is overwhelming that lift-assist devices protect caregivers, there must be barriers that prevent caregivers from using them all the time. Barriers seem to include: lift is not available or close by; lift takes too long to use; and, caregiver not trained in lift use. The findings are strong that safe patient-handling equipment reduces risk of low-back injuries but the methods of overcoming these major barriers must be addressed in most facilities in order to actually see benefits.

## Determinants of low-back pain in nursing home workers after implementation of a safe resident-handling program

Judith Gold, Laura Punnett (presenter), Rebecca Gore

**Background.** Health-care workers have high rates of low-back pain (LBP) related to handling patients. Within a large chain of nursing homes, we found reductions in biomechanical load and compensation claims costs within three years following the implementation of a safe resident-handling program (SRHP). However, LBP symptom prevalence showed no decline during this time period.

**Methods.** Worker surveys were conducted at two years (F3) and five to six years (F5) post-SRHP implementation. Robust Poisson regression models examined LBP prevalence and cumulative incidence in relation to self-reported job exposures and health behaviours. In each survey, the outcome was LBP during the last three months with at least mild severity during the last week.

**Results.** LBP prevalence was 37% (431/1154) at F3 and cumulative incidence was 22% (51/228 eligible) at F5. In a multivariable model, F3 LBP prevalence was associated with composite physical exposure, psychological job demands and prior back injury, while frequent lift usage and intense exercise frequency were protective (Table 1). At F5, the multivariable model included frequent lift usage at F3 (prevalence ratio (PR) = 0.39 [0.18-0.84]), and F5 work-family imbalance (PR = 1.82 [1.12-2.98]).

Table 1. Prevalence ratios (95% CI) for low-back pain in nursing home workers, F3 (n = 1154); robust Poisson regression multivariable model.

Frequent use of lift (always/often/sometimes vs. rarely/never)	0.88 (0.75-1.03)
Composite physical exposure score	1.05 (1.02-1.07)*
Psychological job demands	1.17 (1.09-1.25)*
Prior back injury	2.14 (1.78-2.57)*
Intense physical exercise frequency (vs. none)	
> 3x/wk	0.62 (0.45-0.85)*
3x/wk	0.64 (0.49-0.84)*
1-2x/wk	0.76 (0.61-0.96)*
Some < 1/wk	0.97 (0.78-1.20)
Age	1.00 (0.99-1.00)*

\*: p < 0.05

**Discussion.** Several years may be required before resident lifting device usage reduces LBP symptoms in nursing home workers. Frequent intense physical exercise and reducing job physical and psychosocial demands may also help reduce LBP.

## Conditions for the prevention of musculoskeletal and psychosocial disorders: The case of the hospital sector

Elsa Laneyrie, Sandrine Caroly, Alexis Descatha; presenter – Aude Cuny

**Background.** Facing a labour shortage in the health-care sector — and longer careers — hospitals have difficulty managing absenteeism and maintaining their compliment of nurses. This problem is compounded by the social context of psychosocial risks and musculoskeletal disorders.

**Methods.** Faced with these difficulties, a research project on the prevention of occupational risks called ORSOSA was implemented. Working with internal institutional stakeholders (occupational medicine, care management, human resources management), this approach aims to improve work organization. The aim of the research is to understand how internal stakeholders at an institution can promote risk reduction and implement sustainable prevention approaches. We propose three hypotheses on favourable factors for the mobilization of stakeholders: the presence of a practitioner initiating a preventive approach; the internal stakeholders' need to make connections between the care facilities' preventive approach and their individual activity; and the development of the collective work by stakeholders enabling them to acquire new resources in their daily activity.

**Results.** We followed the implementation of the ORSOSA approach in three geriatric care services. We have implemented a qualitative methodology based on the use of a logbook by the practitioners, different types of interviews and observations.

Our results lead us to identify four categories of conditions for the mobilization of stakeholders when deploying a preventive approach: in connection with the organizational context (diversity of occupational health projects present in the establishment), stability of the stakeholders, the strategies used by practitioners (several strategies have been identified at different deployment time), the link made by internal stakeholders between their individual activity and the implementation process (which connects stakeholders in the process) and, finally, the development of collective activity (new logistical resources, human, financial identified).

**Discussion.** Several determinants of the mobilization of stakeholders during a preventive approach have been identified in this research.

## The impact of an integrated hospital-wide safe patient handling and mobilization program on the reduction of lifting injuries

Jack Dennerlein (presenter), Elizabeth O'Day, Deborah Mulloy, Glorian Sorensen, Dean Hashimoto

**Background.** Hospital workers have high rates of musculoskeletal disorders due to the physical demands of patient handling. However, patient handling and mobilization activities in hospitals are fundamental components of patient care. Best practice guidelines suggest that injury prevention approaches include the evaluation of every patient for their mobilization capabilities and needs, and that mobility assistance technology, such as power lifts, be integrated in the patient-care plan. The study's objective was to evaluate the effects of a comprehensive, hospital-wide, safe patient handling and mobilization program on work practices and worker injuries that integrated mobility assessment and technology into the patient care plans. Other essential elements included leadership commitment at all levels, bedside mentoring of patient-care workers, and extensive access to lifting and mobilization technology for hospital workers.

**Methods.** Baseline (n =1,591) and follow-up (n=1,470) worker surveys assessed work practices associated with patient handling and self-reported pain while an integrated employee payroll and injury database provided recordable injury rates. Data were collected concurrently at two hospitals — the study hospital with the program and a comparison hospital.

**Results.** Safe and unsafe patient handling practice scales at the study hospital improved significantly ( $p < 0.0001$  and  $p = 0.0031$ , respectively) with no differences observed at the comparison hospital. We observed significant decreases in recordable injury rates associated with the neck and shoulder (RR = 0.68, 95% CI 0.46 – 1.00), lifting and exertion (RR = 0.73, 95% CI 0.60 – 0.89), and pain and inflammation (RR = 0.78, 95% CI 0.62 – 1.00) at the study hospital. Changes in rates at the comparison hospital were not statistically significant.

**Discussion.** A hospital-wide safe patient handling and mobilization program improved work practices and reduced recordable worker injuries. This study demonstrates the potential impact of using a systems approach based on recommended best practices.

SESSION 6, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 201B

## Effects of workplace-based physical exercise on muscular capacity and symptoms in office workers

Anelise Cabral, Fernanda Barros, Roberta Padovez, Nívia Araújo, Tatiana Sato (presenter)

**Background.** Neck-shoulder pain is associated with a mismatch between work demands and physical capacity. This study aimed to evaluate the effects of a workplace-based exercise program on shoulder strength and resistance, and neck-shoulder symptoms according to the workers' adherence.

**Methods.** 34 office workers were evaluated. Shoulder abduction strength was measured by dynamometry and resistance was measured by the maximum time supporting 15% of the maximum isometric strength. Neck-shoulder pain was evaluated by the Nordic Musculoskeletal Questionnaire and a Pain Numeric Rating Scale. Evaluations were performed before and 12 weeks after the exercise implementation. The program consisted of a 15-minute session, delivered twice a week over 12 weeks. It was composed of a warm-up, shoulder strengthening and stretching exercises (2, 8 and 5 minutes respectively). Workers were grouped according to adherence: low (0-<34%; n=4), medium (34-<68%; n=17) and high (68-100%; n=13).

**Results.** There was no interaction effect between group and time. There was a significant increase in strength and resistance after the implementation of the exercises for all groups, with a mean increase of about 21N in strength and 20 seconds on resistance. Nine workers (26%) became asymptomatic for neck and eight (23%) for shoulder, with a mean reduction of 0.2 points for neck and 1.0 for shoulder pain.

**Discussion.** The exercise program increased shoulder strength and resistance and reduced neck-shoulder pain; the group adherence did not influence the results. It may be attributed to the reduced sample size. The low adherence group was composed of workers with higher strength since they performed exercises outside the workplace. They justified the low adherence by the fact that the workplace program was too light. Thus, it seems to be relevant to investigate physical habits before starting a workplace-based exercise program in order to achieve better results.

## Rotator cuff tendinopathy in supermarket cashiers

Rita Silva-Pereira, Florentino Serranheira (presenter), Ricardo Ribeiro, Fátima Lopes, António Sousa-Uva

**Background.** Rotator cuff tendinopathy (RCT) is a major occupational health problem in supermarket cashiers. Cashiers' manual work, especially repeated and sustained shoulder abduction and flexion, heavy lifting and forceful manual exertion, are important risk factors for RCT. Nevertheless, despite frequent high scores in risk-assessment evaluations, workers only report shoulder pain and seek medical help in advanced stages of RCT. The objective of this study was to examine RCT symptoms, signs, and ultrasound image changes in supermarket cashiers to find a better procedure to facilitate early RCT diagnosis.

**Methods.** 44 workers participated in this study (28–47 years). Each subject underwent three different shoulder assessments: symptoms questionnaire, clinical evaluation (“painful arc test,” “empty can test” and “Hawkins-Kennedy impingement test”) and ultrasound.

**Results.** With respect to the right shoulder, 26 workers (59.1%) had referred shoulder symptoms. Of the 44 cashiers, at least 16 workers (36.4%) complained of left shoulder pain. According to the clinical examination, 15 and 11 subjects (34.1%; 25.0%), respectively, scored positive results for all tests. According to the imaging findings, 16 and 17 subjects (36.4%; 38.6%) had changes in the anatomical structures of the shoulder, right and left, respectively. Relationships between different approaches were not significant. The “empty can test” reveals good relationships between symptoms ( $\chi^2$  Wald (1) = 7.260,  $p=0.007$ ) and was the most sensitive (81%) and specific (60.9%) clinical test. These results were also a predictive variable for RCT diagnosis based on ultrasound ( $\chi^2$  Wald (1) = 6.854,  $p=0.009$ ) as a gold standard, with ROC = 0.714 and a sensitivity of 75% and a specificity of 67.9%.

**Discussion.** Results in this study suggest the “empty can test” may be highly predictive of RCT in supermarket cashier health monitoring. Carrying out studies in larger samples is necessary to draw reliable conclusions for work-related RCT prevention.

## Implementation of a worksite-adapted physical activity program targeting trunk muscle endurance and flexibility among vineyard workers

Romain Balaguier (presenter), Pascal Madeleine, Nicolas Vuillerme

**Background.** In France, viticulture is particularly affected by work-related musculoskeletal disorders (MSDs). In a pilot study, we reported that vineyard workers are highly exposed to biomechanical risk factors linked to work-related MSDs. This led us to conceive and implement a worksite-supervised adapted physical activity (APA) program to specifically target the lower back region of vineyard-workers. The purpose of this study was to evaluate the effectiveness of a supervised APA program among vineyard workers.

**Methods.** 29 vineyard workers volunteered to participate and were divided into two groups: (1) intervention (n=15) and (2) control (n=14). Between January and May 2015, the intervention group followed a 10-week APA program, including 15 minutes of warm-up before the working day and two weekly sessions of trunk strengthening and flexibility sessions. The control group did not benefit from this program. Trunk muscle endurance and flexibility, low-back pressure pain thresholds and quality of life were assessed for both groups both before and after the program.

**Results.** A compliance of 100% was observed for the 160 APA sessions. In addition, after the APA program, trunk muscle endurance and flexibility, pressure pain thresholds in the lower back region and quality of life were significantly increased for the intervention group compared to baseline ( $p < 0.05$ ). Conversely, no significant change was observed in the control group.

**Discussion.** The implementation of a 10-week worksite-supervised APA program in vineyard workers was found to be effective: (1) the compliance was extremely high, and (2) positive effects on trunk strength and flexibility, pain sensitivity and quality of life were reported.

## Convincing stakeholders to make changes in work situations through modification in their representations

Valerie Albert (presenter), Nicole Vezina, Henriette Bilodeau

**Background.** Inducing changes in stakeholders' representations (or views) regarding a problematic work situation is an important intermediate effect sought by ergonomists to mobilize stakeholders in implementing work modifications to reduce musculoskeletal disorders among workers. However, the specific mechanisms of action leading to changes in stakeholders' representations remain unknown. The objective of this evaluation is to identify which actions or information transmitted to stakeholders contributed to changes in their representations and to decisions regarding which work modifications should be implemented.

**Methods.** An ongoing prospective evaluation (from July 2015 to March 2016) using a multiple-case study design compares four ergonomic interventions carried out by emerging ergonomists (EEs) on their final year-long internship leading to a master's degree. For each case, data is collected in real time with a logbook to keep track of every action performed (type of activity, stakeholder(s) involved, duration, goals, results) and initial stakeholders' representations. Individual interviews are also performed with EEs and stakeholders (decision-makers and workers concerned by the work modifications).

**Results.** Based on the EEs' perspectives, preliminary results indicate that presentation of short videos of the work activity to illustrate complexity and vicious circles and to illustrate links between production and health problems may be useful strategies. Looks of astonishment from stakeholders or changes in their positions regarding possible solutions support the EEs' hypotheses regarding changes in representations. Further results will be provided regarding the stakeholders' perspectives on the actions or information transmitted by EEs that led to changes in their representations, which will be compared to EEs' perspectives.

**Discussion.** To our knowledge, this is the first evaluation in ergonomics to document changes in stakeholders' representations from a stakeholder's perspective. Knowledge of these mechanisms of action can improve the effectiveness of the mobilization phase of ergonomic interventions, which is crucial for a successful implementation of work modifications.

SESSION 7, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 201B

## Influences of duty cycle and tool mass during overhead work

Helen Nogueirav (presenter), Maury Nussbaum

**Background.** Work-related musculoskeletal disorders (MSDs) in assembly work are associated with work exposures involving high exertion levels and high tool masses, short cycles, and overhead work. Regarding the latter, there is consistent evidence linking the risk of shoulder MSDs with overhead work postures. However, many assembly tasks still require overhead work and there is limited information regarding either specific task-based risk factors or relevant guidelines. The aim of the current study was to evaluate the effects of duty cycle and tool mass on endurance time, and the development of shoulder fatigue during overhead tasks.

**Methods.** A total of 24 males and 12 females completed the experimental procedures. Participants performed a simulated overhead task with different combinations of three tool masses (0.5, 1.25, and 2.0 kg) and three duty cycles (33, 50, and 67%), intended to represent a range of working conditions. Participants performed a subset of the nine conditions for one hour, over three days. Predictions were made as to whether or not given conditions could be maintained for two hours without substantial discomfort by extrapolating perceived discomfort to a threshold of 7 on a 10-point scale. This approach yielded estimated endurance times for all but the “hardest” task (20 kg and 67%), for which endurance times were quite short.

**Results.** Both duty cycle and tool mass had substantial effects on the development of fatigue and estimated endurance times, though duty cycle appeared to be more influential.

**Discussion.** Gender differences were not substantial except when using the highest tool mass. Overall, it is recommended that overhead work involving tool masses greater than 1.25 kg should be avoided, as should duty cycles greater than 50%. Interactive effects of duty cycle and tool mass were found during overhead work, and such interactive effects are considered important to improve work productivity without adverse health consequences.

## Prismatic glasses and the reduction of neck pain in dental personnel

Agneta Lindegard (presenter), Inger Arvidsson

**Background.** Physical risk factors at work are frequently present in dentistry, particularly during work in the oral cavity. Prismatic glasses are like bifocal glasses, where the lower part of the glass is replaced by prisms that bend the light path downwards. The aim of this study was to investigate the effects on perceived exertion, self-reported neck pain and clinically diagnosed conditions in the neck, of an intervention with prismatic glasses among dental personnel.

**Methods.** The study population consisted of dental personnel from 78 out of 110 dental care units. One intervention group (n=371) and one reference group (n=193) was formed. All participants were assessed at baseline and after 12 months by means of postal questionnaires and clinical examinations. The study was conducted as a “natural” intervention following the implementation of prismatic glasses in the dental care organizations in the region.

**Results.** The intervention group reported higher prevalence of neck pain, as well as a higher prevalence of clinical diagnoses in the neck at baseline, compared to the reference group. Compared to the reference group, individuals who received prismatic glasses improved significantly more with respect to musculoskeletal pain ( $p=0.047$ ), diagnoses in the neck ( $p=0.025$ ), perceived exertion ( $p=0.003$ ) and work ability ( $p=0.040$ ). A preventive effect of the glasses was indicated.

**Discussion.** Recommendations should include the use of prismatic glasses both as primary and secondary prevention for work-related neck pain in dental personnel. Such glasses should also be tested in other working situations, including those characterized by high visual demands in sustained and awkward neck postures.

## Do active pauses change the pattern of electromyographic activity during repetitive manual tasks?

Leticia Bergamin Januario (presenter), Afshin Samani, Marina Machado Cid, Pascal Madeleine, Ana Beatriz Oliveira

**Background.** Increasing variability of electromyographic (EMG) activity pattern during stereotyped monotonous work has been suggested an effective method for preventing pain and the development of work-related musculoskeletal disorders (MDSs). In practice, implementing a regime of regular pausing during usual working time can be used to promote variability. Short periods of submaximal isometric muscle contractions have been shown to alter the pattern of muscular activity and oxygenation during computer work. This study aims to investigate a standardized repetitive manual task and explore the effects of such pauses on neck-shoulder muscles.

**Methods.** 17 healthy females ( $24.8 \pm 2.5$  years) took part in the study. A portable device (Myomonitor IV, DelSys, Boston, U.S.A.) was used to record EMG. Electrodes were placed at clavicular upper trapezius (C-UT), acromial upper trapezius (A-UT), middle trapezius (MT), lower trapezius (LT) and serratus anterior (SA) right muscles. Additionally, near-infrared spectroscopy (NIRS) was used to measure the right upper trapezius oxygenation. Subjects performed 40 minutes of simulated assembly task that involved filling holes on a panel board with small wooden objects at two different paces (16 and 25 pieces/min). Task performance was intercalated with two types of pauses performed in upright sitting position for eight seconds. Pauses could be either a resting period with the palms of hands on the laps (passive) or a shoulder shrug with 30% MVC (active). Root mean square (RMS), relative rest time (RRT), exposure variation analysis (EVA) and normalized mutual information (NMI) were calculated for EMG. Further, oxyhemoglobin (O<sub>2</sub>Hb), deoxyhemoglobin (HHb) and total hemoglobin (THb) concentrations were obtained from NIRS.

**Results.** Initial results showed that the location of EVA centroid differed between pause types for LT at fast pace ( $p < 0.03$ ) and underlined a more variable activity pattern for active ( $1.36 \pm 0.24$ ) compared with passive pause ( $1.25 \pm 0.13$ ).

**Discussion.** It seems that active pauses may have beneficial effects (i.e. increased variability) during repetitive tasks performed at faster paces.

## A union-driven MSD prevention project

Terri Aversa, Rosemary Ku (presenter), Nicolette Carlan, Richard Wells, Philip Bigelow (presenter)

**Background.** In a previous project, we partnered with multiple labour unions to develop a method of documenting 27 types of physical loads (climbing, lifting, computer use, etc.) at the workplace level. Loading types associated with the development of musculoskeletal disorders (MSDs) were emphasized. There was moderate to good agreement on the loads experienced by workers, and the duration of those exposures observed by both management and labour respondents compared favourably with those of an ergonomist based upon a walkthrough. The survey was developed as a surveillance tool, but workplaces told us that they found it useful in planning their health and safety and MSD-prevention activities.

**Methods.** A large public sector union decided to implement the tool in a retail sector within its jurisdiction. The 6,000 employees of the organization's stores represent only 4% of the union's membership, but they account for 25% of all worker compensation appeals for MSDs. These workers move, load and unload heavy cases of product every day. The union decided to use the survey, independent of the employer's involvement, in an attempt to create a climate of change.

**Results.** The research team met with the union chairs of the joint of health and safety committees and individual health and safety representatives to modify the survey for their needs and produce an electronic version. The survey was made available to over 100 stores and warehouses.

**Discussion.** Over the next few months the union will be using the survey data to approach joint health and safety committees, managers and fellow members to take steps to limit hazards. We will be reporting on the changes in the workplace that have taken place.

SESSION 8, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 201B

## Workplace practices aimed at preventing prolonged work disability in workers compensated for work-related musculoskeletal disorders: a multiple case study

Iuliana Nastasia (presenter), Durand Marie-José, Coutu Marie-France, Collinge Cécile, Ana Cibotaru

**Background.** The objective of this study is to describe the actual workplace practices for preventing prolonged work disability in workers compensated for work-related musculoskeletal disorders (MSDs) in Quebec.

**Methods.** A multiple case study was conducted in four establishments. Multiple sources of data were used for each case: the content of policies, formal and informal procedures and interviews with key actors (supervisor, RTW coordinator, colleague, and worker) involved in 14 cases of workers returning to work after an absence from their regular work. Embedded units of analyses were considered in inter- and intra-organization analysis; specifically, we were looking at differences and similarities between cases.

**Results.** The return-to-work (RTW) policies and procedures seemed unevenly formalized, lacking clarity and precision. The actions observed in the workplace can be associated with one or more of five specific phases of RTW process: absence, modified work, gradual and progressive RTW, RTW to the regular task, and follow up. One or more actors can apply sequences of actions differently. There are three categories of actors within the workplace who are particularly active in the RTW process: the RTW coordinator, the worker and the supervisor. The roles and responsibilities of actors are not always clearly defined and are not consistently understood among the participating establishments. As a direct consequence, coordination between the actors' actions inside the workplace is difficult.

**Discussion.** Considering the differences and/or the similarities among the distinct workplace environments allows us to better understand the different realities and constraints of the practical contexts of implementation of RTW policies, procedures and practices. Furthermore, contrasting the theoretical bases of workplace interventions pertaining to RTW employees with work-related musculoskeletal disabilities with the reality as observed by the case studies allows us to better understand the gap between what it is recommended and what it is being put into practice.

## Does the organization make a difference? An evaluation of Women's Work Environment program

Lena Niemi Birgersdotter (presenter), Ruth Carlsson, Minke Wersäll

**Background.** From 2011-2014 the Swedish Work Environment Authority had a special assignment from the Swedish government to visualize women's health in working life and prevent early retirement from work due to problems in the work environment, with an emphasis on conditions related to musculoskeletal health and ergonomics. In 2015, the authority received a new assignment to deal with the dissemination of the results and conclusions of the project and to evaluate the program from 2011-2014.

**Methods.** The evaluation will be carried out through interviews within the organizations where inspections took place from 2011-2014. In total, more than 4,000 organizations and enterprises were inspected. The aim of the evaluation is to see what effect the inspections have had on the organizations in terms of gender perspective and the assessment of risks for musculoskeletal disorders. On the basis of the interviews, there will be an analysis of how the Swedish Work Environment Authority can continue to work for equal opportunities for good work environment conditions for both women and men.

**Results.** A brief summary of the Women's Work Environment program with the results and conclusions will be presented, as well as the results of the evaluation. At the time of the conference, preliminary results will be available from the evaluation. Five areas are covered in the project: state of knowledge compilation with a focus on organizational and social factors, communication, updating of skills, inspection and evaluation of the impact of the project on the authority, and an evaluation of the inspections done during the program over 2011-2014.

**Discussion.** It is important that the organization takes into account what gender means in work environment management. A learning organization has to visualize, compare and reflect in order to take effective preventive measures for a sustainable work environment.

## Effectiveness of a matching-fund program to motivate workplace health and safety improvements

Alysha Meyers (presenter), Steve Wurzelbacher

**Background.** Workers' compensation (WC) systems are the largest source of occupational injury information in the U.S., with millions of claims in some single state databases. This overall WC system information has tremendous potential for musculoskeletal disorder (MSD) prevention purposes, but remains largely underutilized. WC insurers also offer prevention services and programs, and collect information on insured employers — including ergonomic risk/control assessments. Since 1999, the Ohio Bureau of Workers' Compensation (OHBWC) has offered a Safety Intervention Grant (SIG) program where thousands of employers have been provided matching funds to insured employers to implement safety/health engineering controls. In 2015, OHBWC will award \$15 million in SIG grants. The objective of this study was to evaluate the effectiveness of the SIG program among affected employees in terms of WC claim frequency, WC claim cost per employee, and geometric mean cost per claim.

**Methods.** Pre- and post-intervention WC metrics were compiled for the employees designated as affected by the interventions grants awarded from 2003 to 2009. Poisson, two-part and linear regression models with repeated measures were used to evaluate differences in pre- and post-data by employer size, specific industry, and intervention type (ergonomic, safety, ventilation, and multiple-purpose), controlling for time trends independent of the interventions.

**Results.** Intervention effects varied by employer size, specific industry and intervention type. Post-intervention for total WC claim frequency rates (both medical-only and lost time claims) decreased 66% overall [n=468 employers, confidence interval (CI)=-42 to -81], WC-paid cost per employee decreased 81% (CI=-73 to -88), and WC geometric mean paid claim cost decreased 30% (CI=-13 to -44). However, the effect varied by intervention type.

**Discussion.** The insurer-supported safety/health engineering control program was effective in reducing WC claims and costs for affected employees. Other state-based and private insurers may benefit from implementing similar intervention grant programs.

## A cohort study of a 10-week exercise intervention to improve work posture and neck/shoulder symptoms in dental health students

Venerina Johnston (presenter), Xin Yi Yiu, Andrea Maguire, Marcelle Johnson, Charlotte Wåhlin

**Background.** Dental workers, including students, experience a high incidence of neck/shoulder symptoms. However, research into interventions has been scarce and largely focused on tools and technological modifications. This pilot study investigates the feasibility and the benefits of a 10-week neck/shoulder exercise intervention on work posture and musculoskeletal symptoms in dental health students.

**Methods.** Students in their clinical years with ( $n = 13$ ) and without ( $n = 10$ ) neck/shoulder musculoskeletal symptoms participated in a 10-week resistance exercise program for two minutes per day, five days per week. Work posture (evaluated with the Rapid Upper Limb Assessment tool, RULA), muscle strength measures, and self-rated symptom severity and function at work and at leisure were collected pre- and post- intervention. Feasibility was determined with six items scored on a five-point Likert scale. Paired sample t-tests were used to examine the differences in RULA scores, strength measures and neck symptom severity from baseline to post-intervention. Shoulder symptom differences were evaluated with Wilcoxon Signed-Rank Test due to its non-normal distribution. Statistical significance was set at  $p < 0.05$ .

**Results.** Work posture score improved by 1.88 (95% CI 1.05-2.70,  $p < 0.01$ ) points on the RULA, and isometric maximal strength of neck flexor and extensor muscles by 17.2% (95% CI 6.9-27.6%,  $p < 0.01$ ) and 23.2% (95% CI 10.2-36.3%,  $p < 0.01$ ) respectively. Isometric strength of the shoulder elevators, and symptom severity at the neck/shoulder showed no improvement post-intervention. Adherence to training was 77%. Most students reported that the exercises were easy to perform with the main barrier being time.

**Discussion.** 10 weeks of exercise was feasible for dental health students and, likely, beneficial, with considerable improvements in work posture and neck muscle strength. Future randomized controlled trials are required to establish the efficacy of such interventions in improving work posture and in reducing neck/shoulder symptoms in dental practitioners.

SESSION 9, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 201B

## Determinants of osteoarthritis linked to occupational radiography: epidemiologic surveillance: Preliminary results of the D.O.L.O.R.E.S. pilot study

Samuel Huntley (presenter), Eryn Apanovitch, Breanne Young, Katerina Santiago, Xuan Yang, Armando Alvarez, Vanessa Seoane, Robert Irwin, Kristopher Arheart, John Pitcher, Ty Subhawong, Alberto Caban-Martinez

**Background.** Despite the disproportionate burden of osteoarthritis (OA) documented in employed U.S. construction workers as compared to less physically demanding occupations, there are few strategies to identify and prevent OA progression in these workers at the jobsite. Using a novel, non-invasive experimental ultrasound protocol (as opposed to standard x-ray) and clinical biomechanical knee assessment, we examine in this pilot study if self-reported, doctor-diagnosed knee OA is associated with (1) workplace physical exposures and (2) ultrasound guided knee imaging in a convenience sample of commercial construction workers.

**Methods.** Data collection is ongoing and will be completed in March 2016. 400 construction workers recruited from South Florida construction sites will complete a brief, paper-based screening survey to assess for doctor-diagnosed knee OA and history of worker physical jobsite exposures. 50 workers who report a past diagnosis of knee OA and 50 workers who report chronic knee pain (i.e. lasting  $\geq 3$  months) will be invited to complete another survey that includes the validated Knee injury and Osteoarthritis Outcome Score (KOOS) survey instrument, receive a bilateral knee examination, and have ultrasound images of both knees captured using a portable ultrasound machine at the worksite. To date, six workers have completed our study protocol.

**Results.** Among the six workers having completed the study protocol with mean age 49 years ( $\pm$ S.D.=13.7), one worker (16.7%) reported a prior knee OA diagnosis. Two workers (33.3%) reported knee pain with mean severity on a 10-point Likert scale of  $4.7 \pm 2.7$  with a range from 2.50 to 7.75. The mean ( $\pm$ S.D.) KOOS subscale scores were: symptoms= $69.6 \pm 8.4$ , pain= $85.6 \pm 18.7$ , activities of daily living= $80.9 \pm 37.3$ , sports and recreation= $86.7 \pm 26.0$ , and quality of life= $89.6 \pm 12.9$ .

**Discussion.** Preliminary surveys, ultrasound and knee examination data suggest that our pilot study protocol is feasible and was accepted by workers and site management at the first construction site.

## The necessity for effective prevention of work-related MSDs by improving the present statistics system for occupational diseases

Minori Nakata (presenter)

**Background.** Japan is one of the first countries to acknowledge that work-related musculoskeletal disorders (MSDs) were caused by the introduction of computer systems at work. During late 1950s, many big Japanese banks, insurance companies, and governmental offices introduced computer-aided office work systems. In those days, all the data for the computers were supplied by using punch-card-reading systems, and these punched cards were provided by so-called keypunchers. Even early computer systems had the ability to handle enormous amounts of data instantly, therefore keypunchers were forced to produce vast amount of punched-cards continuously all day long. The demand was harsh and relentless.

**Methods.** In the beginning, card punching was regarded as light work. However, a number of keypunchers began to suffer severe musculoskeletal pain — sometimes so serious as to prevent sleep. There were significant conflicts at workplaces all over Japan. After long struggles and lawsuits, this computer-related agony — so-called “key-punchers’ disease” — was acknowledged as work-related MSD in 1964. In 1972, it was designated as “occupational cervicobrachial disorder (OCD)” by the Japan Society for Occupational Health Association.

**Results.** OCD became well known, and various counter measures were introduced. The number of acknowledged OCD cases reached 546 in 1975. The number decreased once to 149 cases in 1995, but increased again up to 673 cases in 2013.

**Discussion.** Statistics for occupational disease in Japan adopt two different publication methods. The annual number of all acknowledged cases for each occupational disease are only accessible within the authorities, and only the numbers of those who are on sick leave more than four days are available to the public — including to work-related MSD specialists. The latest numbers show very low figures, i.e. 140 OCD cases for 2013. Thus, the system for publication may be misleading and hinder the prevention of work-related MSDs in Japan. This report will present further discussions about this.

## One-year effects of a workplace integrated-care intervention for workers with rheumatoid arthritis

Cecile Boot, Myrthe Van Vilsteren, Jos Twisk, Romy Steenbeek, Alexandre Voskuyl, Dirkjan Van Schaardenburg, Han Anema; presenter – Allard van der Beek

**Background.** Rheumatoid arthritis (RA) is associated with work disability and limitations in work functioning. In contrast to earlier work that focused on return to work, we developed an intervention program to support patients with RA who are still working to reduce at-work productivity loss. The objective of this study was to evaluate the effectiveness of a workplace-integrated care intervention on at-work productivity loss in workers with RA compared to usual care.

**Methods.** In this randomized controlled trial, 150 workers with RA were randomized into either the intervention or the control group. The intervention group received an integrated care and participatory workplace intervention. Outcome measures were the Work Limitations Questionnaire (WLQ), Work Instability Scale for RA (RA WIS), pain, fatigue and quality of life (RAND 36). Participants filled out a questionnaire at baseline, and at six and 12 months later. We performed linear mixed models to analyze the outcomes.

**Results.** Complete follow-up data was available for 143 participants (loss to follow up 4.3%). Participants were on average 50 years of age and mostly female. After 12 months, no significant intervention effect was found with respect to at-work productivity loss. We also found no significant intervention effects on any of the secondary outcomes.

**Discussion.** We did not find evidence for the effectiveness of our workplace integrated-care intervention after 12 months of follow up. It is hypothesized that the work limitations perceived by the participants were not sufficiently severe for improvement. Future studies should focus on investigating the intervention in groups of workers with severe limitations in work functioning, or an unstable work situation.

## Maximum acceptable weights for one-handed lifting and lowering tasks performed by male and female Chilean workers

Manuel Gutiérrez (presenter), Marta Martinez

**Background.** Chilean labour legislation lacks methods to assess work conditions related to one-handed manual material handling. The objective of this study was to determine the maximum acceptable weights for one-handed lifting and lowering tasks performed by male and female workers.

**Methods.** The study was carried out in a public hospital, in a metallurgical company and at a food service company in the province of Concepción in Chile. 17 male workers and 17 female workers participated in the research. A psychophysical method was used to determine maximum acceptable weight (MAW) (Snook et al 1970).

**Results.** The maximum acceptable weights that protect 10%, 25%, 50%, 75% and 90% of men and women workers were established for handling loads between the level of the floor and elbow height, and between elbow height and vertical arm reach. The frequencies of manual material handling were every 10 seconds, one minute, 30 minutes, one hour and eight hours.

**Discussion.** The results were compared with bibliographic references (Liberty Mutual Tables) of maximum acceptable weights performed with two hands. It was found that the two-handed MAWs were between 42% and 82% higher than those obtained with one hand. Therefore, it is necessary to carry out more research to establish tolerable limits for one-handed manual material handling, which can support the development of labour standards.



## Biology of work-related MSDs

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SESSION 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 201C

## Finger flexor tendon orientation as a function of forearm and wrist postural change

Elizabeth A. Salas (presenter), Anne Moore

**Background.** Job-related postural requirements are a contributor to musculoskeletal loading and thus, are relevant to MSD risk. Forearm and wrist postures deviated from neutral have been associated with increased musculoskeletal loading, decreased strength and increased discomfort (Khan et al, 2009). Magnetic resonance imaging (MRI) has previously been used to investigate the effect of wrist posture on musculoskeletal loading associated with carpal tunnel syndrome (Keir & Wells, 1999). The objective of this study was to investigate the effect of forearm rotation on changes in orientation of finger flexor tendon trajectories in the distal forearm.

**Methods.** MRI was used to scan the right wrist of participants in nine postures, three wrist (30° flexion, neutral, 30° extension) and three forearm rotation postures (40° pronation, neutral, 60° supination), while maintaining 10N of finger flexion force. Relevant structures were segmented, and tendon centrelines calculated in Mimics (Materialise, Belgium). Changes in tendon trajectories with respect to the radius were evaluated using a custom Matlab program.

**Results.** Preliminary results for two participants show tendon excursions in the frontal plane of the index superficialis tendon relative to neutral mid posture of up to 10.4° ulnarly in the extended/supine posture, which has been reported among postures with the highest discomfort during repetitive tasks (Khan et al, 2009). Angle displacements of 15° and 9° were seen in the frontal and sagittal plane respectively over the full ROM.

**Discussion.** Tendon sweep can be relevant in repetitive tasks with implications on friction between internal structures. Changes in tendon angles modify their line of action, potentially resulting in mechanical disadvantage for grip force generation.

### References

Khan, A.A. et al, (2009). *Ergonomics*, 52: 1265–1275.

Keir, P. & Wells, R. (1999). *Clin Biomech.*, 14: 635-645.

## Simultaneous activation of the trapezius and serratus anterior muscles in different positions for sEMG normalization

Marina Machado Cid, Letícia Bergamin Januário (presenter), Roberta de Fátima Carreira Moreira Padovez, Ana Beatriz Oliveira

**Background.** A single type of submaximal contraction can be used to normalize surface electromyography (sEMG) signals of all muscles of interest. However, there is still no consensus in the literature regarding the best upper limb position to evoke simultaneous activation of the shoulder muscles frequently investigated in occupational studies. The aim of this study was to evaluate which one of the most frequently reported positions evokes greatest muscle activation of the trapezius and serratus anterior muscles in submaximal contractions.

**Methods.** 38 subjects were evaluated (19 men and 19 women). The sEMG was recorded from the clavicular (CUT), acromial (AUT), transverse (TT) and lower (LT) trapezius portions, and from the serratus anterior (SA). The contractions were performed with the load determined from the body weight (RC1) and corresponding to 20% of the AUT maximum contraction (RC2), with the arm abducted to 90° in the frontal plane (P1); with the upper limb elevated to 90° in the scapular plane (P2); and with shoulder flexed to 125° in the sagittal plane, with protraction of the scapula (P3). Repeated measures ANOVA and Friedman tests were applied, with post-hoc analysis through Bonferroni and Wilcoxon tests.

**Results.** Considering the AUT, P1 [RC1(0.104±0.044mV); RC2(0.150±0.069mV)] and P3 [RC1(0.096±0.044mV); RC2(0.149±0.073mV)] had significantly higher activation in both RC1 (P=0.000;P=0.011) and RC2 (P=0.000) than P2 [RC1(0.085±0.034mV); RC2(0.128±0.062mV)]. For the SA, P3 [RC1(0.027±0.028mV); RC2(0.035±0.035mV)] evoked the greatest activation in both RC1 (P=0.000) and RC2 (P=0.001). The LT had greatest activation in P2 [RC1(0.055±0.031mV); RC2(0.073±0.039mV)] for both RC1 (P=0.000) and RC2 (P=0.001).

**Discussion.** In general, P1 and P3 showed similar average activation of CUT and AUT, evoking higher activation than P2. The P3 generated the highest activation for SA in both contractions; while P2 evoked the greatest activation for the LT. Since occupational studies focus on CUT/AUT, P1 and P3 are preferred positions.

## Optimal elbow angle for typing on a tablet

Jangwhon Yoon (presenter), Jihyun Lee

**Background.** Tablets are much heavier than smartphones and are more prone to lead to musculoskeletal disorders in the neck and upper extremity. The aim of this study was to understand the effects of tablet location on the recruitment of muscles in the neck and upper extremity.

**Methods.** 15 healthy volunteers without any history of neuromuscular disorders or ongoing pain were enlisted and typed the lyric while listening to a song for five minutes at three tablet locations. A 601g iPad2 was located vertically at 70, 90, and 130 degrees of elbow angle in sitting. Typing duration, typing error, perceived fatigue and preference were measured. Recruitment of selected neck, upper back and elbow muscles using surface electromyography were collected at one, three and five minutes of typing. The data were analyzed using one-way ANOVA for performance and preference and repeated ANOVA measures for muscle recruitment.

**Results.** Self-reported discomfort increased significantly in the neck, upper back, shoulder, elbow and wrist over time. Angle of elbow joint affected the self-reported discomfort only at the elbow joint. There was no difference in typing speed or error among the different elbow angles. Muscle recruitment of all part of trapezius and biceps brachii decreased as elbow angle increased, while the levator scapula increased significantly. Subjective preference was highest in elbow angle of 90-degree flexion.

**Discussion.** Findings of this study showed that elbow angle and typing duration affects muscle recruitment in the neck and upper back independently. Duration affected self-reported discomfort more, while elbow angle had more influence on muscle recruitment. Findings of this study may provide valuable information for tablet users to help prevent musculoskeletal disorders in the upper extremities.

## The effect of full finger flexion on the deformation of median nerve at carpal tunnel

Ping Yeap Loh (presenter), Hiroki Nakashima, Satoshi Muraki

**Background.** The demands of computer use in daily work tasks are increasing tremendously across different occupations. Peripheral input devices such as keyboards, mice and joysticks are used to accomplish work tasks. However, intensive computer use may lead to work-related musculoskeletal disorders such as carpal tunnel syndrome, which affects the median nerve at the wrist. For example, forceful and repetitive hand-finger movements, such as finger movements during keyboard typing, or grasping and gripping — to operate a mouse or a joystick — may increase intra-carpal tunnel stress. Furthermore, the excursion of the finger flexor and forceful gripping force increase the biomechanical stress that can lead to the deformation of the median nerve inside the carpal tunnel. The aim of this study was to investigate the changes of median nerve cross-sectional area (MNCSA) at three finger postures, namely relaxed-finger (Rel), full fist (FF, full finger flexion without grip force) and full grip (FG, full fist with grip force).

**Methods.** 12 right-handed healthy male participants (age=23.8 ± 1.5 years; height=171.2 ± 4.8 cm; weight=63.5 ± 6.7 kg) were recruited. Ultrasound examination of median nerve was performed with GE Healthcare Ultrasound System (LOGIQ e). Three finger postures (Rel,FF,FG) were examined at wrist neutral position. ImageJ was used to quantify the MNCSA. One-way repeated ANOVA was used to analyze the changes of MNCSA.

**Results.** The MNCSA at Rel, FF, and FG are 7.6 ± 1.5mm<sup>2</sup>, 5.7 ± 1.4mm<sup>2</sup>, 5.2 ± 1.1mm<sup>2</sup>, respectively. The effect of finger posture is significant on the changes of MNCSA [F(2, 22)=43.99, p<0.01]. The MNCSA at Rel is significant larger than FF and FG (p<0.05) while the MNCSA at FF is larger than FG (p<0.05).

**Discussion.** Our results indicate that full grip causes the greatest deformation of the median nerve. Therefore, forceful gripping should be reduced so as to minimize compression stress on the median nerve.

SESSION 2, TUESDAY, JUNE 21, 10:30AM – 12:00PM, ROOM 201C

## The association of sickness behaviours, serum and brain cytokines with the performance of high-demand tasks and aging in a rat model of overuse

Mary Barbe (presenter), Dong Xin, Jenny Hadre, Ann E Barr-Gillespie

**Background.** Systemic inflammation is known to exaggerate sickness behaviours, including decreased social interaction. This study aimed to determine if these behaviours increased in aged versus young rats performing high repetition and high force tasks.

**Methods.** Since we have observed systemic inflammation in our rat model of work-related overuse that increased with aging, we sought to determine if these behaviours were increased in aged versus young adult female Sprague-Dawley rats performing a high repetition reaching and grasping task. We also assessed, in each age group, the effects of training to a high force versus a low force level for 10 minutes/day for four to six weeks, before performing a high repetition low force (HRLF) task for two hours/day for six weeks.

**Results.** Aged HRLF task rats showed greater declines in social interaction behaviours than young adult HRLF task rats, as did aged rats that trained to high force, compared to aged rats that trained to low force and age-matched controls. Young adult rats that trained to high force had decreased social interaction behaviours post training and at HRLF task in week three (and then recovery) than age-matched controls; young adult rats that trained to low force showed no declines. Serum levels of IL-1beta and IL-6 were increased in both age groups after training to high force; IL-1beta levels showed resolution in both age groups, while IL-6 levels resolved only in young adult task rats. Brains of rats (both age groups) with decreased social interaction behaviours showed increased IL-1beta, IL-6 and IL-6 receptor immunoexpression in blood brain barrier cells. IL-6 and IL-6 receptor immunoexpression were also significantly increased in aged rats in several brain regions, including the anterior cingulate cortex.

**Discussion.** Increased sickness behaviours occurring from work-related overuse — behaviours that may equate with increased sickness absence in humans — are enhanced with aging and high physically demanding job tasks, and are associated with increased levels of inflammatory cytokines in serum and brain changes in aged mammals.

## Biochemical biomarkers for MSDs: systematic review results

Judith Gold (presenter), David Hallman, Fredrik Hellstrom, Martin Bjorklund, Svend Erik Mathiassen, George Piligian, Mary Barbe

**Background.** Although the potential for musculoskeletal disorder (MSD) biomarkers to detect subclinical disease and monitor MSD severity was discussed more than 20 years ago, only one review on biochemical biomarkers exclusive to humans has been published (Saxton 2000). The aim of this study was to systematically summarize biochemical biomarker research in neck and upper extremity MSDs that could appear in a work-related context. Two research questions guided the review: (1) Are there biochemical markers associated with neck and upper extremity MSDs? (2) Are there biochemical markers associated with the severity of neck and upper extremity MSDs?

**Methods:** A literature search was conducted in PubMed and SCOPUS. 87 studies met primary inclusion criteria. Following a quality screen, data were extracted from 44 sufficient-quality articles.

**Results.** Most of the 87 studies were cross-sectional and utilized convenience samples of patients as both cases and controls. A response rate was explicitly stated in only 11 (13%) studies. Less than half of the studies controlled for potential confounding through restriction or in the analysis. Most sufficient-quality studies were conducted in older populations (mean age in one or more analysis group > 50 yrs). In sufficient-quality articles, 82% demonstrated at least one statistically significant association between the MSD(s) and biomarker(s) studied. Evidence suggested that: (a) the collagen repair marker TIMP-1 is decreased in fibroproliferative disorders, (b) 5-HT (serotonin) is increased in trapezius myalgia, and (c) triglycerides are increased in a variety of MSDs. Only five studies showed an association between a biochemical marker and MSD severity.

**Discussion.** While some MSD biomarkers were identified, limitations in the articles examined included possible selection bias, confounding, spectrum effect (potentially heterogeneous biomarker associations in populations according to symptom severity or duration) and insufficient attention to co-morbid conditions. A list of recommendations for future studies is provided.

## Development of a treatment protocol based on the biophysiology of computer-related MSDs

Suparna Damany (presenter)

**Background.** Understanding the biology of computer-related musculoskeletal disorders (MSDs) can provide a solid foundation for a protocol for treatment as well as prevention of these injuries. This author has treated these conditions successfully for almost two decades, and has developed a comprehensive treatment protocol for these conditions. The treatment protocol is based on addressing each piece of the biophysiological “puzzle” of a computer-related musculoskeletal injury.

**Methods.** A case study will be presented about a patient with a work-related musculoskeletal injury. Based on the findings, and the multi-system interaction, a protocol for treatment will be developed and its biological basis and outcomes will be explained.

**Results.** Work-related MSDs due to computer-related overuse can be successfully and completely treated if each piece of the multi-faceted syndrome is addressed at the correct time line.

**Discussion.** Biological elements of computer-related MSDs include muscle tissue and myofascial tissue, joint alignment, neural compression and length, vascular compromise, soft tissue flexibility, muscle weakness, muscle endurance and autonomic involvement. The case study will demonstrate how each of these elements can be systematically treated, and how the body systems can be re-trained to work together again.

## The association between sickness behaviours in a rat model of overuse and systemic inflammatory cytokines and anti-inflammatory drugs

Mary Barbe (presenter), Dong L Xin, Jenny Hadrevi, Ann E Barr-Gillespie

**Background.** Systemic inflammation in the form of increased inflammatory cytokines is known to exaggerate sickness behaviours, including decreased social interaction and increased aggression. Since we have observed increased local tissue and serum inflammatory cytokines in our rat model of work-related overuse, we sought to determine if these sickness behaviours are induced in our model and, if present, the effectiveness of anti-inflammatory treatments.

**Methods.** Young adult, female rats were used. All underwent an initial training period to learn a high force reaching and grasping task for 10 minutes/day, five days/week, for five weeks. Subsets of trained-only rats received ibuprofen or anti-TNFalpha treatment during training. Decreased social interaction behaviours, increased aggression, and increased serum levels of several inflammatory cytokines observed in untreated trained-only rats were prevented by both prophylactic treatments, supporting an underlying inflammatory mechanism. Additional untreated trained rats went on to perform a high repetition high force (HRHF) reaching and grasping task for two hours/day, three days/week, for six to 12 weeks. In week five, HRHF rats were divided into four groups: untreated HRHF rats that continued the task for two or eight more weeks; HRHF rats that were ibuprofen treated for two or eight weeks, or anti-TNFalpha treated for two weeks, while continuing the HRHF task; or switching a group of HRHF to a low repetition low force task for six to 12 weeks (as an ergonomic task reduction).

**Results.** Untreated HRHF rats showed increasing sickness behaviours through week 12, increased serum inflammatory cytokines (including IL-1beta, IL-6, TNFalpha) and immunoexpression of these same three cytokines in blood brain barrier ependymal cells. Each secondary treatment attenuated these changes, with anti-TNF-alpha treatment showing the greatest effectiveness.

**Discussion.** Increased sickness behaviours occurring from work-related overuse — behaviours that may equate with increased sickness absence in humans — are a consequence of increased circulating inflammatory cytokines.

SESSION 3, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 203A

## Associations between biomarkers and changes in pain and functional ratings in subjects with unspecific neck pain

Fredrik Hellstrom (presenter), Jenny Hadrevi, Martin Björklund

**Background.** Effective prevention and treatment is based on the ability to identify signs and symptoms and to direct interventions towards the underlying mechanisms. This requires knowledge of disease mechanisms and can only be acquired through conducting longitudinal studies. In this study we examined if possible biomarker candidates from cross-sectional studies were also related to changes in neck pain intensity and physical functioning among females with work-related unspecific neck pain.

**Methods.** Blood samples were collected at baseline and one week after an 11-week intervention aimed at increasing physical functioning and reducing pain. Based on cross-sectional data, eight metabolites (nonanoic-acid, adenosine-5-monophosphate, inositol-1-phosphate, succininc-acid, threonic-acid, DL-cysteine, erythrose-4-phosphate, cholesterol) were analyzed (GC-MS). Based on literature, eight cytokines (TNF- $\alpha$ , IL-6, IL-8, IL-10, Eotaxin, VEGF, MIP-1 $\beta$ , MCP-1) were analyzed by Mag-Plex. Fold-change for each metabolite and cytokine was calculated. Change in physical functioning was measured with % change in Neck Disability Index (%NDI), and change in pain intensity the previous week was measured with the 0-10 Numeric Rating Scale (Ch-NRS).

**Results.** 27 subjects were included (mean age 48 years). IL-6, IL-10, MCP-1, TNF- $\alpha$  were below detection levels. Using Pearson's correlations, succininc-acid ( $p=0.077$ ,  $r=-0.345$ ) and nonanoic-acid ( $p=0.047$ ,  $r=0.386$ ) but no detected cytokines ( $p>0.2$ ) showed associations with %-NDI. In a multiple linear regression ( $Adj\_r^2 = 0.23$ ) with %NDI as independent variable, succininc-acid ( $p=0.038$ ,  $\beta -0.378$ ) and nonanoic-acid ( $p=0.024$ ,  $\beta = 0.415$ ) were significant. Using Spearman's rank correlation, eotaxin ( $p=0.13$ ,  $r=0.351$ ), nonanoic-acid ( $p=0.08$ ,  $r=0.346$ ), cholesterol ( $p=0.12$ ,  $r=0.316$ ) showed associations with Ch-NRS. In further analysis, using ordinal linear regression (Nagelkerke = 0.34) with Ch-NRS as independent variable, eotaxin was significant ( $p=0.036$ ).

**Discussion.** There are associations between changes in subjective pain ratings or physical functioning and changes in underlying biochemical markers. This indicates that biochemical markers could be useful tools to evaluate interventions aimed at reducing work-related unspecific neck pain

## The Concavity Index: a novel approach for quantifying intervertebral disc degeneration

Menekse Salar, Richard Sesek (presenter), Mark Schall (presenter)

**Background.** Low-back pain (LBP) is one of the most common and costly musculoskeletal conditions facing the working world. There is growing evidence that LBP is associated with intervertebral disc degeneration, a natural consequence of aging. The degree of disc degeneration can be evaluated using T2-weighted magnetic resonance imaging (MRI) images and the five-level Pfirrmann classification system. Despite its good inter and intra-observer agreement, the Pfirrmann classification system relies on subjective ratings of disc degeneration. In this study, we propose an objective, quantitative method for evaluating intervertebral disc degeneration known as the Concavity Index.

**Methods.** 50 subjects (25 male, 25 female) aged 20-40 (mean = 31.1 years, SD  $\pm$  5.4) without any self-reported chronic episodes of low-back pain were examined on a whole body 3T MRI machine (Siemens Verio open-bore). T2-weighted MRI scans of the sagittal profile of the participant's lumbar endplates (L2-S1) were evaluated by three trained examiners. Each examiner measured the height and the concavity levels of the lumbar discs. These measures were used to calculate a Concavity Index (concavity level divided by disc height). The Concavity Indices were compared to their corresponding Pfirrmann classifications and respective intra-observer reliabilities were evaluated for each method.

**Results.** A linear relationship between average Concavity Index and corresponding Pfirrmann classification was observed. While overall agreement among Pfirrmann raters was high, 10% of ratings disagreed by two or more categories. Concavity indices had an average coefficient of variation of just 0.95% across all participants and lumbar regions.

**Discussion.** The Concavity Index shows promise for objectively quantifying low-back health and predicting future low-back pain. The measure also allows for relative comparisons because it is a continuous measure. Future research on the Concavity Index is warranted.

## Differentiating lumbar discovertebral changes associated with occupational biomechanical overload: integrated magnetic resonance imaging appraisal

Roberta Bonfiglioli (presenter), Matteo Di Lello, Angela Camagni, Francesco Marinelli, Andrea Andreone, Dimitris Papadopoulos, Lea Bono, Maurizio Zompatori, Francesco Saverio Violante

**Background.** The aim of this study was to assess the association between occupational biomechanical risk factors and spatial distribution of intervertebral disc degeneration along the lumbar spine. A better awareness of the characteristics and distribution of discovertebral changes could be useful for appropriate clinical management of workers affected by low-back disorders and for the design of occupational intervention strategies.

**Methods.** According to a cross-sectional study design, consecutive patients aged 18-70 and referred for magnetic resonance imaging (MRI) of the lumbar spine were recruited in 2014. History of personal and family musculoskeletal diseases and injuries, current and past exposure in manual jobs and during leisure time, were assessed by interview and self-administered questionnaire. Information about spine postures, lifting and pushing or pulling operations were collected. Neuroradiologists evaluated the prevalence of intervertebral disc pathology: anular tears, degeneration and bulging/herniation.

**Results.** The interviewed group consisted of 83 patients, 40 females and 43 males, mean age and BMI were respectively  $47\pm 14$  years,  $25,2\pm 4,6$  kg/m<sup>2</sup> for females,  $45\pm 14$  years and  $25,6\pm 3,8$  kg/m<sup>2</sup> for males. Participants were divided into four groups: not exposed, employed in manual jobs for 25 years. The overall presence of intervertebral disc pathology increased with age for men. Disc pathology at lumbar level L5-S1 was associated with male gender (OR: 3,0; 95% CI: 1,2-8,0), but not clearly with length of employment >25 years (OR: 1,5; 95% CI: 0,40-5,5). Presence of disc herniation at any level was not associated with manual jobs.

**Discussion.** Data show the multifactorial nature of disc pathology and gender differences in the distribution and characteristics of disc pathology. Age, more than manual job, seems to affect the presence of intervertebral disc alteration. Prospective studies and a large group sample are needed to better explore the relationship between occupational biomechanical overload and the level of lumbar disc pathology.

## An evaluation of occupational loads that contribute to spine, disc degeneration

Youngki Kim (presenter), Suhong Park, Dongmug Kang, Jongeun Kim

**Background.** Age is related to the degeneration of the spine. However, occupational load can also contribute to the progress of degeneration. In particular, we assume that occupational load can increase the expression of genes related to the spine and disc degeneration. This study was performed to evaluate occupational loads that contribute to L-spine and disc degeneration.

**Methods.** The study case group included 135 male manual workers with disc herniation who made outpatient visits between 2009 and 2014. 80 male hospital office workers served as the control group. Study subjects already had L-spine MRI results. So we compared L-spine MRI between cases and controls. And we conducted blood sampling to determine the difference between cases and controls in the expression of genes related to disc degeneration.

**Results.** This study is ongoing. Spine and disc degeneration tended to increase with aging according to L-spine MRIs. But case group subjects showed higher risk for facet joint arthritis, disc degeneration, central stenosis than the controls in all age groups. We will later examine the differences between cases and controls in the expression of genes related to disc degeneration. We will also analyze whether or not occupational load can affect spine and disc degeneration in L-spine MRI and the expression of s related to disc degeneration.

**Discussion.** If our hypothesis is correct that occupational load can increase the expression of the genes related to degeneration, the definition of work-related musculoskeletal disorder will need to be extended, and this result will be helpful to workers seeking compensation.

SESSION 4, THURSDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 201C

## Median nerve affection during seasonal repetitive work with moderate force

Sorosh Tabatabaeifar (presenter), Susanne Wulff Svendsen, Birger Johnsen, Gert-Åke Hansson, Anders Fuglsang-Frederiksen, Poul Frost

**Background.** Little is known about the time course of changes in median nerve function in relation to variations in occupational mechanical exposures to the wrist. We studied this relation using mink skinning as a natural experiment. Mink skinning is hand-intensive seasonal work.

**Methods.** We included 11 male workers without median nerve symptoms and performed dominant-sided nerve conduction studies (NCS) pre-, mid-, end- and post-season. For a subset of the workers, we characterised the exposures by full-shift technical measurements. Questionnaire information about symptoms and disabilities was also obtained. The study took place in winter 2014/2015.

**Results.** The mean age was 35-37 years (SD 10.2), and the mean number of seasons with skinning 89 (range 2-26). The single-task job of skinning mink was characterised by a high median velocity of flexion/extension of the wrist (22 °/s), a moderate percentage of time in non-neutral wrist postures (20% time with flexion/extension >45° or ulnar/radial deviation >20°), and moderate forearm extensor force requirements (90th percentile 11% of maximal voluntary electromyographic activity). The season lasted 22 days with mink skinning on 20 of them. From pre- to end-season, the mean distal motor latency (DML) increased 0.41 ms (95% CI 0.27-0.56,  $p < 0.001$ ), the mean sensory nerve conduction velocity (SNCV) digits 2 and 3 decreased 6.3 m/s (95% CI 2.5-10.2,  $p = 0.004$ ) and 6.2 m/s (95% CI 1.9-10.6,  $p = 0.010$ ), respectively. DML and SNCV were unchanged for the ulnar nerve across the wrist. Symptoms and disabilities increased significantly from pre- to end-season, where three workers had developed carpal tunnel syndrome according to symptoms and NCS. 3 to 6 weeks post-season, the NCS parameters had reverted to normal as had symptoms and disabilities.

**Discussion.** Reversible median nerve symptoms may result from three weeks of seasonal work with high repetitiveness and moderate force.

## The prediction of health risks in heavy equipment vehicle operators based on average-continuous and cumulative-impulsive whole body vibration exposures

Peter Johnson (presenter), Luz Marin, Lope H. Barrero, Andrés Rodríguez, Estefany Rey, Jack Dennerlein, Hugo Piedrahita

**Background.** The purpose of this study was to characterize whole body vibration (WBV) exposures in heavy equipment vehicle (HEV) operators using ISO 2631-1 (traditional) and ISO 2631-5 (new) WBV exposure metrics, and to compare the predicted health risks across the different WBV exposure parameters ( $A(8)$ ,  $VDV(8)$  and  $S_{ed}(8)$ ).

**Methods.** Full-shift, 12-hour continuous WBV measurements were collected from 119 HEV operators in 11 types of HEVs operated in an open-pit coal mine. For each HEV, the predominant axis of exposure was determined (for  $A(8)$  and  $VDV(8)$ ) as prescribed by ISO standards and European Union Vibration Directive, and vector sum WBV exposures were also calculated and compared (for  $A(8)$ ,  $VDV(8)$  and  $S_{ed}(8)$ ).

**Results.** The results showed that the predominant axis of exposure was related to, and dependent on, the HEV's average speed, which was dictated by the type of HEV and, the substantially higher vector sum WBV exposures indicated the presence of more than one predominant axis of exposure. There were differences across the WBV exposure parameters regarding health risk predictions; the cumulative-impulsive exposure parameters,  $VDV(8)$  and  $S_{ed}(8)$ , were higher and reduced acceptable HEV operation times by one-half to two-thirds relative to average-continuous  $A(8)$  exposures. Based on the predominant axis and vector sum impulsive exposures, the operation of most HEVs would be limited to less than four and two hours a day, respectively.

**Discussion.** The observed differences in acceptable vehicle operation times across WBV exposure parameters impacts the prediction of health effects and may introduce some uncertainty regarding how to best represent HEVs operators' actual exposure. Future studies examining exposure-response relationships should attempt to determine the differences between and the relative importance of average-continuous and cumulative-impulsive WBV exposures in predicting adverse health outcomes.

## The relationship between muscle strength at retirement age and heavy manual work

Karen Walker-Bone (presenter), Stefania D'Angelo, Holly Syddall, Keith T Palmer, Cyrus Cooper, David Coggon, Avan Aihie Sayer

**Background.** Modern workplaces have reduced the need for heavy manual work. To measure the impact of this change on long-term health, we investigated the association between lifetime exposure to heavy workplace physical activity and grip strength at retirement age. Grip strength is an important predictor of long-term health and physical function in older people and better grip strength is positively associated with survival.

**Methods.** Data came from the U.K. Hertfordshire Cohort Study, in which information had been collected on lifetime exposure to physical activities at work (standing/walking  $\geq 4$  hours/day; lifting  $\geq 25$  kg; and heavy work sufficient to induce sweating). Grip strength was measured three times in each hand and the maximum value taken. Multivariable linear regression was used to investigate associations between lifetime occupational activity and grip strength at age 66 years, controlling for confounders.

**Results.** Complete data were available from 1418 men who had worked for at least 20 years. Men who reported standing/walking  $\geq 4$  hours/day for  $\geq 36$  years had significantly worse grip strength than men reporting low levels, but the relationship disappeared after adjustment for confounders. Men who reported 26-46 years of heavy lifting had significantly attenuated grip strength compared with men reporting lower levels of exposure after adjustment for age and anthropometry ( $\beta = -1.22$  kg; 95%CI -2.17 to -0.26kg). Working at physical intensity enough to induce sweating was not significantly associated after adjustment.

**Discussion.** Heavy manual work and physically demanding occupational activities did not maximize hand grip strength at the normal age of retirement. Any advantages of participating in regular physical occupational activity may be outweighed by socio-economic confounders and health inequalities associated with being in manual social classes.

## Assessment of an air-filled seat pad for reducing whole body vibration exposure in professional automobile drivers

Per Jonsson (presenter), Peter W Johnson

**Background.** An automobile seat's ability to attenuate road-related perturbations will affect the driver's exposures to whole body vibration (WBV) and, potentially, to subsequent injury. The objective of this study was to compare the vibration attenuation performance of traditional foam and spring automobile seating to an alternative seat design.

**Methods.** WBV exposures were measured in four subjects while an automobile was driven to induce extreme vehicle wear. Tri-axial WBV exposures were collected from the seat and floor and compared under two conditions: (1) subjects sat on the stock foam and spring seat and (2) subjects sat on a dual chamber, air-filled seat pad. WBV exposures (A(8)), seat effective amplitude transmissibility (SEAT) and power spectrum densities (PSDs) were calculated.

**Results.** WBV exposures were high according to the European Union Vibration Directive (European-Council 2002) and the A(8) WBV exposures, measured from the floor of the automobile, averaged  $1.6 \text{ m/s}^2$ . Compared to the stock foam and spring seat, which reduced WBV exposures by 6% on average, the air-filled seat pad reduced WBV exposures an additional 27% on average (range 4 to 33%). The PSDs indicated that a substantial amount of vibration energy had moderate (4 to 8 Hz) to high frequency content (8 to 30 Hz) and that the air-filled seat pad was more effective at reducing WBV energy in those frequency ranges. The higher the frequency content of the vibration energy the less seat displacement was needed to absorb the vibration.

**Discussion.** With its superior handling of the shorter-displacement vibration energy of moderate to high frequency content, it appears that the air-filled seat pad could replace foam in many on-road seating applications and reduce WBV exposure up to an additional 33%. The reduction in WBV exposures may reduce low-back pain, especially in highly exposed vehicle operators who drive automobiles all day long.



## Measuring exposures in a new world of work

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SESSION 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 202A

## Whole body vibration exposure among long haul drivers and the potential for knowledge utilization

Philip Bigelow (presenter), James Dickey, Bronson Du, Peter Vi, Emile Tompa, Nicolette Carlan

**Background.** Whole body vibration (WBV) exposure data is hard to come by. This is especially true for workers, like drivers, who have multiple workplaces. Our goal is to collect evidence about driver vibration exposure for different trucks travelling along rural and paved roads and highways. We are engaged in a study of 25 long-haul trucks in Manitoba. The ultimate objective is to reduce exposures by providing evidence to designers and purchasers about chassis and seat suspension, as well as cab isolation.

**Methods.** To collect data, we partnered with a trucking company and with seat manufacturers and health and safety associations. We created a social network that provided us with a sufficiently large sample to quantify exposures. We will also transfer the knowledge generated and test the use of that knowledge throughout this network. To capture the exposure data, accelerometers were placed on the seatpan and on the chassis of different trucks carrying a variety of loads on a variety of roadways.

**Results.** Our preliminary results indicate that type of seat and truck, in addition to road conditions, influence vibration exposure. Preliminary data shows the majority of the WBV were found to be at the health hazard zone of 0.5 m/s/s. These exposures will be replicated in a laboratory study using a multi-axis motion platform. This will determine seat optimization by evaluating the vibration attenuation characteristics of common suspension seats under these conditions.

**Discussion.** We have collected sufficient data to develop a spectrum of exposures. The laboratory studies will evaluate the performance of different industrial seats. This information will form the basis of Phase 2 of the study to transfer knowledge to a diverse workplace about WBV exposures when purchasing new equipment.

## A simplified head-neck, dynamic model for evaluation of whole body vibration in helicopters

Ya Huang (presenter), Eric (Yong) Chen

**Background.** Aircrew aboard modern rotorcraft are constantly exposed to intense vibration at the harmonic frequencies of the main rotor head at rotational speeds. Anecdotal reports of low-back and neck pain among pilots have increased along with extended range and longer flying times. A key indicator of health risks associated with whole body vibration (WBV) is subjective discomfort time dependency (SDTD). SDTD is strongly associated with “tonic” neck muscle activity, in which muscle maintains constant contraction in response to motion at frequencies higher than 2 Hz.

**Methods.** The present study compares a passive, multi-body dynamics model of the head-neck mechanism in the mid-sagittal plane of the human body with the measured motion of a helicopter pilot. Frequency response functions of motion transmitted in the fore-and-aft, vertical and pitch axes are used to estimate effects of WBV on neck muscle activity and subsequent SDTD. Given the motion transfer function between the floor and the seat, and between the floor and the backrest, it is possible to predict the backrest-to-head transmissibility that approximates the tonic neck muscle activity. Such an analytical approach will be able to help the development of motion isolation equipment (e.g. seats, harnesses and helmets) and reduce demand on tonic neck muscle activity at specific frequency, excitation magnitude and direction.

**Discussion.** Evaluation and guidance developed from frequency weighting functions of subjective discomfort (ISO 2631-1:1997) would mean a considerably short air-time, usually only a couple of hours, which is impractical to implement. The second goal of the study is to compare the frequency range of increased SDTD estimated from the dynamic head-neck model with the characteristics of frequency weighting functions employed by current ISO standards.

## The effects of sex and obesity on three-dimensional trunk motion assessment of paramedics in real-life emergency conditions

Philippe Corbeil (presenter), André Plamondon, Jerome Prairie, Dominique Larouche, Sandrine Hegg-Deloye, Marie Authier

**Background.** Many work accidents suffered by paramedics are related to the physical aspects of the job and low-back injuries are common. Prairie and Corbeil (2014) found that paramedics made trunk motions while giving medical care and during patient handling activities that could significantly increase the risk of low-back disorders. Because most paramedics are men, there has been very little interest in how female paramedics work. Obesity, which is an emerging issue in occupational health and safety, has also received little attention regarding its effects on the work of paramedics. The aim of this study was to document sex differences and the impact of obesity on the trunk motion exposure of paramedics while on the job by using continuous recordings of back postures during work activities.

**Methods.** This field study involved observing and the collecting data on 100 paramedics (35.4±11.1 years old; 11.3±10.5 years of experience; 24% female; 4% obese women and 6% obese men) during consistent eight- or 12-hour day and night work shifts. The instrumentation consisted of two inertial sensors (Xsens Technologies B.V.) measuring the absolute and relative orientation between trunk and pelvis in real-life situations. Two methods were used to analyze postural data: exposure variation analysis and amplitude probability distribution function.

**Results.** Observation of 175 work shifts, including 42% in winter, allowed the analysis of 531 cases of emergency medical assistance, treatment and transport. Awkward postures for the back were observed among all sub-groups of paramedics. Significantly higher amplitudes of sagittal and lateral back flexion and back rotations were observed in healthy-weight male paramedics when compared to other sub-groups ( $p < .05$ ).

**Discussion.** This study reinforces the utility of direct measurements of three-dimensional trunk motion on the job as a sensitive tool for use in assessing the biomechanical loading of the spine associated with workplace dynamics and the risk of low-back disorders.

## Implementing the RMQ approach to maximum acceptable effort: assessing cumulative hand activity within jobs and across job rotations based on duty cycle

Curtis Vandergriendt, Jim Potvin (presenter)

**Background.** Recent research has proposed the use of duty cycle (DC) to determine the maximal acceptable effort (MAE) for repetitive tasks (Potvin, 2012). A challenge has been to apply this approach to jobs involving different hand-intensive tasks to determine the related cumulative exposure.

**Methods.** A new method had previously been developed to calculate a time-weighted root mean quartic (RMQ) value as a representative effort, to be compared to the MAE for the cumulative duty cycle. With this, we assessed hand activity in a cyclical manufacturing process involving hand-intensive tasks for the majority of jobs or workstations. 16 workers, across two shifts, were surveyed for perceived hand effort for all tasks that they perform throughout the process using a visual analog scale (Latko et al, 1997). All jobs were observed and recorded with video for frequency and task duration analysis. Using the average perceived effort, task frequency and task duration for each task, an RMQ analysis was performed for each of 10 jobs or workstations, within the process, to determine a representative MAE for each job and a subsequent risk ratio. Further, the RMQ approach was also used to assess the representative MAE and risk ratio for an entire shift, based on existing and proposed job rotation schedules.

**Results.** Seven of the 10 jobs assessed were found to have risk ratios greater than 1.0, with three jobs being greater than 2.0. Similarly, the current job rotation, as well as proposed designs, were found to have risk ratios greater than 1.0. Results of the analysis and recommendations were shared with the facility and have prompted immediate action and solution investigation.

**Discussion.** This case example from industry will be shared to highlight a practical implementation of the RMQ approach for an MAE assessment for both individual jobs and job rotation design.

SESSION 2, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 202B

## Scientific background of practical methods to evaluate static postures at work

Bernd Hartmann

**Background.** Static body postures are the second most common cause of musculoskeletal complaints and disorders. However, for occupational health and safety practitioners and supervisors, assessing static body postures on the job is difficult because of the lack of a scientifically based global strategy. Through an analysis of the scientific literature, approaches for a practical method of assessing static postures can be found. These methods can be carried out by persons without either special knowledge or special equipment.

**Method.** Searches on the effects of static workload were conducted using PubMed (Reviews – 2,005; all 2006 to 2015) with reference to the time dependence on the effects of static workload and the existing methods for assessment. A scheme for assessing body postures was derived.

**Results.** Physiological backgrounds are static muscle strain in permanent tension at maximum of 15% maximum force and efforts are limit factors. The different muscle groups (upper or lower back, shoulders, arms, hip region and legs) must be distinguished; small muscles are particularly sensitive. The effect on different body parts were differentiated, although there are scientific shortcomings of the lower extremities. Awkward posture is an issue of constant muscle contraction. We need two stages of time: (1) relationship between load and unload time; and (2) total duration of postural load per working day. Awkward postures need the demarcation from load manipulation and working with large forces in different postures. A cumulative assessment of the mechanical load of postures, loads manipulation and power expenses would be able to cover up the exposure to awkward postures.

**Discussion.** The intent is to provide a method of assessing static postures developed according to these principles of practice. Its validation should occur on the basis of medical investigation with discomfort and strain, and in comparison to biomechanical capture of the positions and time with a body-related investigation system.

## Comparing postural responses to push and pull task demands using optical motion vs. inertial measurement

Sol Lim (presenter), Andrea Case, Clive D'Souza

**Background.** Wearable measurement instruments such as inertial sensors provide precise quantifiable posture information in field studies. However, their application for quantifying posture changes as a proxy measure of different levels of physical task demand is relatively unexplored. To investigate feasibility, a preliminary laboratory study was conducted focusing on isometric push-pull exertion tasks. The study was aimed at comparing changes in trunk posture using traditional optical motion capture (mocap) and inertial sensor measurements in systematically varying conditions of task demand.

**Methods.** 10 right-handed participants (age:  $23.5 \pm 3.8$ ) exerted isometric horizontal hand forces on a height-adjustable handle. Task demand was parameterized as hand posture (one vs. two-handed), direction (push vs. pull), location (handle heights at shoulder, mid-back, and hip) of force application, and force intensity (75%, 50%, and 25% of subject's maximum voluntary push exertion). Dependent variables comprised flexion-extension and axial rotation (twisting) of the trunk and pelvis measured using inertial sensors located on the upper (T6) and lower trunk (L5/S1), respectively, with optical marker triads attached atop.

**Results.** Preliminary findings from mocap data indicate that pelvic flexion increased significantly in pushing by 8.79 degrees compared to pulling ( $F(1,179) = 244.122, p < 0.01$ ). Trunk flexion relative to the pelvis showed significant main decrease in handle heights at shoulder and mid-back relative to hip ( $F(2,119) = 143.217, p < 0.01$ ). Force intensity, force direction and hand condition were also found to be significantly different according to task conditions. Analysis of inertial sensor data and comparison with mocap estimates is ongoing.

**Discussion.** Results using optical measurement indicate that hip and trunk flexion-extension and axial rotation change predictably in response to various task conditions. Systematic understanding of changes in body postures will yield algorithms for quantifying physical workload associated with non-neutral postures. Results can facilitate the use of wearable technologies for field-based exposure assessment, particularly in variable or non-repetitive manual work.

## Evaluation of ergonomic risk factors, musculoskeletal symptoms, exertion and workload among physiotherapists

Joshua Samuel Rajkumar, Deepak Sharan (presenter), Rajarajeshwari Balakrishnan, Amruta Kulkarni

**Background.** Physiotherapists (PTs) play an important role in the rehabilitation of neuromusculoskeletal disorders. However, PTs are themselves also highly exposed to risk factors for work-related musculoskeletal disorders (MSDs) because of their reliance on the application of manual force to perform their work. The aim of this study was to evaluate the ergonomic risk factors, musculoskeletal symptoms, exertion and workload among PTs at a neuromusculoskeletal rehabilitation centre.

**Methods.** A total of 100 PTs working at a neuromusculoskeletal rehabilitation centre in a developing country participated in this prospective survey study. The PTs were evaluated by means of a self-reported questionnaire that elicited data on demographics, job details, health status, etc. In addition, the Work Style Questionnaire, Nordic Musculoskeletal Pain Questionnaire and the Borg CR 10 & NASA Task Load Index were also collected. Inclusion criteria were: PTs that had worked for a minimum of six months in the same rehabilitation centre; PTs who had treated adult and paediatric cases for a minimum of six hours per day; and PTs who had taken no more than 15 days of leave over the previous six months.

**Results.** The mean age of the PTs was  $28 \pm 1.5$  years. The average years of experience of the PTs was  $2.8 \pm 1.5$  years. On average, the PTs worked for  $8 \pm 1.2$  hours per day for six days a week. Only 16% of the PTs exercised regularly, and 74% of the PTs complained of pain or discomfort within the past six months. The most common pain sites were lower back (57.25%), neck (52.4%) and upper back (50%). 66% of the subjects reported an adverse work style risk (total score  $>28$ ). The perceived exertion and workload were also high: more than 75% of the PTs had scores of  $>15$  (Borg CR 10) and  $>50$  (NASA Task Load Index), respectively.

**Discussion.** PTs working with both adult and paediatric patients had a high risk of developing work-related MSDs, and 74% already reported musculoskeletal pain. Appropriate recommendations were given based on results to ensure prevention of work-related MSDs.

## Relevance of pathomechanisms in developing appropriate exposure assessment models for work-related musculoskeletal disorders

Martin Forde

**Background.** The modern work environment demands that ergonomists and epidemiologists evaluate increasingly varied and complex occupational exposures and make determinations concerning links between exposures and typically subtle and non-specific musculoskeletal health problems. A better understanding of the underlying pathogenesis of work-related musculoskeletal disorders (MSDs) could help ergonomists and epidemiologists to (1) design better exposure assessment tools, and (2) to construct process pathogenic models that accurately describe the biochemical, immunologic and morphologic events that take place from exposure to clinical outcomes.

**Methods.** Several pathomechanisms that are potentially relevant to the pathology of work-related MSDs were reviewed, and their relevance in designing appropriate exposure assessment metrics was assessed

**Results.** A process-modeling approach is outlined that could be used to capture the dynamic nature of bio-physiological and pathogenic processes. Additionally, the importance of developing and using exposure profiles — in which the temporal patterns are clearly elucidated — is discussed.

**Discussion.** It is likely that epidemiologists in future will design better studies by proposing a priori pathogenic process model(s) to accompany their research design and then collect exposure information in a form appropriate to the needs of their chosen model(s).

SESSION 3, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 202A

## Duration of head extension among office workers with neck pain compared to healthy controls

Deokhoon Jun (presenter), Venerina Johnston, Shaun O'Leary

**Background.** Prolonged static postures of the head and neck during computer work are considered to be a risk factor for neck pain. However, studies investigating onsite working posture have shown conflicting results, possibly due to a lack of objective measures. This study compares the working posture of office workers with and without neck pain during computer work.

**Methods.** The head, upper trunk, and neck posture (defined as the angle between head and upper trunk) of 98 asymptomatic (mean age  $39.1 \pm 10.52$  years, 58% females) and 42 symptomatic (current neck pain or discomfort) (mean age  $37.5 \pm 8.9$  years, 72% females) office workers was recorded while they performed their usual work for one hour wearing 3D accelerometers on the head and trunk. Flexion/extension of the head and upper trunk was calculated to identify the angular movements in degrees and the proportion of time spent in specified neck angular sectors. Independent t-tests were used to evaluate differences in neck posture between the workers with and without neck pain.

**Results.** While both groups adopted some degree of trunk flexion ( $0^\circ$  and  $30^\circ$ ) during the recorded work period, the group with neck pain spent more time in relative head extension compared to a more flexed head posture exhibited by the asymptomatic group (total mean neck angle:  $-14.54^\circ$  vs  $-17.42^\circ$ ;  $p < 0.003$ ).

**Discussion.** Office workers with neck pain demonstrated a different pattern of head and trunk orientation compared to asymptomatic office workers during office work. These findings may be informative for preventing and managing neck pain in office workers.

## Low-back pain and self-reported task durations: results of an experimental study

Jean Pulido, Lope H. Barrero (presenter), Svend E. Mathiassen, Jack T. Dennerlein

**Background.** Self-reported task durations are frequently used as input when assessing exposures related to musculoskeletal disorders (MSDs), in spite of being associated with errors. This work aimed to estimate the extent to which low-back pain status, true task duration, biomechanical load and pace influence errors in self-reported task durations.

**Methods.** 48 workers with—and 48 workers without— low-back pain, matched by gender, age group and job type, were recruited through a health service provider. T-tests confirmed that matching was successful. Each worker performed three standardized tasks— i.e. shelving boxes, filing journals and typing texts—in a combination of the following conditions: one of three durations (60, 80 or 100 minutes); two paces in shelving (walking at 3 km/hr vs. 6 km/hr); and two loads in shelving (box weight 1.25 vs. 2.5 kg). Participants were asked about the perceived duration of each task immediately after the work session while being aware of the total duration of the session. Posture and kinematics of the back (iLMM™) and heart rate (portable Polar®) were monitored throughout sessions.

**Results.** Regression analyses indicated that task type, true task duration and low-back pain status affect errors in self-reported task durations. Workers with low-back pain overestimated the shelving task more than workers without pain, by 15 to 36 minutes, depending on the true duration of the task. This occurred at the expense of a larger underestimation of the other two tasks, and mainly the typing task.

**Discussion.** Since errors in self-reported task duration appear to be significantly dependent on the worker's musculoskeletal pain status, as well as factors in the job, we recommend that efforts be made to correct such errors by calibration modeling, or, at a minimum, that researchers be aware of this potential effect on exposure assessments and on epidemiological research that deals with work-related MSDs.

## Improving neck postures during tablet use

Veerle Hermans (presenter), Luc De Vriendt, Alain de Keyser

**Background.** Recent research demonstrates risks for MSDs due to awkward neck postures during home tablet use. In this project, we analyzed whether or not two different types of helping devices could optimize posture during office tasks: (1) the use of a tablet holder with external keyboard, and (2) the influence of biofeedback information.

**Methods.** To analyze the use of tablets in a working environment, an online questionnaire was sent to all 129 professionals at a company who were tablet users; 63 responded. Afterwards, participants were invited to analyze neck posture during two representative tablet tasks. 20 subjects were positioned at an optimized ergonomic workstation. They performed the tasks with and without the use of a tablet-helping device (Logitech ultrathin keyboard cover). For each task, after five minutes, subjects were provided with biofeedback information (auditory signal) on their neck position (BodyGuard®). Statistical analysis was performed using SPSS.

**Results.** 53% used a tablet between one and three hours per day, and 54% had been using a tablet for longer than one year. Reading emails, internet surfing and reading newspapers were the most popular tasks. The use of the tablet holder improves the neck posture, specifically for the movie-watching task ( $p < 0.01$ ). However, when an interaction with the keyboard is necessary, more flexion of the neck occurs and thus the effect of the tablet holder is slightly less, although still significant ( $p < 0.05$ ). With biofeedback, a further optimization of the neck posture was found in both tasks ( $p < 0.01$ ).

**Discussion.** This experiment confirmed that neck postures during office tasks can be improved using a tablet holder with external keyboard. Furthermore, the use of biofeedback creates awareness and further improves neck position. Based on the results of this study, recommendations are given to (new) tablet users of the company regarding optimization of body postures when working at a tablet.

SESSION 4, MONDAY, JUNE 20, 3:30PM – 5:00PM, ROOM 202A

## Physical demands of paramedic work in real-life emergency conditions

Philippe Corbeil (presenter), André Plamondon, Dominique Larouche, Jérôme Prairie, Sandrine Hegg-Deloye, Marie Authier

**Background.** The demands of paramedic work under emergency conditions are not well defined. Physical demands analysis should take into account workers' age, sex and work experience, among other variables. This study aimed to assess paramedics' exposure to critical, physically demanding tasks in their work, and to characterize the physical demands of the job in real-life emergency conditions.

**Methods.** This field study involved observing and collecting data on 100 paramedics (35.4±11.1 years old; 11.3±10.5 years of experience; 24% female) during consistent eight- or 12-hour day and night work shifts. Measurements were made of equipment and patient weights, heights lifted, distances, duration and work/rest cycles associated with performing critical, physically demanding job tasks. Energy demands were quantified by instrumenting the participants with electronic heart rate monitors (Polar) and using the Borg CR10 scale.

**Results.** Observation of 175 work shifts allowed the analysis of 531 cases of emergency medical assistance, treatment and transport. Only 10% of these transports received a Priority 1 evacuation/transportation to hospital. The mean perceived exertion of an intervention was 2.4/10 (Q1=1 & Q3=3). The three most difficult tasks, as perceived by paramedics, were movements with a stairchair loaded with a patient, medical care in the field and client-handling activities, including transferring or moving the client from one surface to another. Tasks perceived as "hard" on the CR10 scale accounted for less than 10% of the sample of emergency medical interventions.

**Discussion.** Critical tasks are not frequent but still pose a high risk. Importantly, various sub-groups of paramedics or individuals do not apply the same forces or use the same strategy to perform the required task, resulting in different energy demands. Our results suggest that more emphasis should be placed on improving individual skills (e.g. decision-making techniques) and team-level intervention strategies, rather than on imposing physiological employment standards.

## Use of MAPO to assess the risk for work-related MSDs among personal care workers working in nursing homes

Kin Cheung (presenter), Grace Szeto, Shirley Ching, Godfrey KB Lai, Lily Chan

**Background.** Limited research has been conducted worldwide to evaluate the risk factor of the workplace for contributing to employees' work-related musculoskeletal disorders (MSDs). Personal care workers (PCWs) in nursing homes (NHs) are particularly at risk for work-related MSDs because their work requires them to provide direct patient care, which carries risks associated with patient manual handling.

**Methods.** MAPO technique was used to assess the risk level for patient handling in NHs. MAPO index has been found to be significantly associated with acute low-back pain (LBP), with an index of 0-1.5, 1.5-5.0 and >5.0 corresponding to absent, present and high risk for LBP respectively. 27 NHs in Hong Kong participated in this MAPO assessment. All assessments were conducted by one researcher and the measurements were validated by another researcher or by staff at the nursing homes.

**Results.** Among 27NHs, six (22.2%) were operated by non-governmental organizations, 10 (37.0%) were private in "enhanced bought place scheme" (i.e. government-bought places in private facilities), and 11 (40.7%) were private. Most NHs operated on 12-hour shifts (n=20, 74.1%). Only three NHs had adjustable beds and 50% did not have hoists. The ratio of non-cooperative residents and partially cooperative residents to PCW was 3.1 (SD=2.0) and 3.2 (SD=1.5) respectively. Only two (7.4%) NHs provided adequate and sufficient lifting devices and four (14.8%) NHs provided sufficient and adequate minor aids. The means of wheelchair factor, environment factor and training factor were 0.9 (SD=0.2), 1.0 (SD=0.3), and 1.0 (SD=0.4) respectively. As a result, the mean of the MAPO index was 13.1 (SD=10.7), with two NHs (7.4%) within the range of 0-1.5; 6 NHs (22.2%) within 1.5-5.0; and 19 NHs (70.4%) greater than 5.0.

**Discussion.** The findings of high MAPO index indicated that the PCWs working in NHs are at high risk for work-related MSDs. Appropriate strategies are necessary for improving their working conditions.

## Physical workload and home condition among homecare aides

Chuan Sun (presenter), Laura Punnett, Margaret Quinn, Bryan Buchholz, Pia Markkanen, Catherine Galligan, Susan Sama, Rebecca Gore

**Background.** Homecare aides are a fast-growing workforce as the U.S. population ages. Aides are often exposed to high physical workloads through client-handling activities and housework tasks. These tasks may be strenuous enough to cause low-back pain. The home is a unique workplace where the aides usually work alone, and may or may not have specific equipment for client-handling tasks. The aim of this study was to investigate the work environment of homecare aides and the physical exposures that might make their visits more challenging.

**Methods.** The cross-sectional study used a self-administered survey with two sections: one for the aide's general work arrangements, and one for each of the most recent five clients visited. The first section included topics such as how the aide is hired and their general experience with client handling devices. The client visit section includes client's health conditions, their home environment, and the physical activities performed during the last visit.

**Results.** Aides hired by the client (CHA) usually care only for one client, while aides hired by agencies (AHA) usually care for multiple clients. About 20% of the aides used client-transfer devices such as slide board, etc., in the last year. Agency-hired aides reported higher usage of slide boards (AHA: 24.1%, CHA: 16.3%,  $p=0.0005$ ) than the client-hired aides. Over half of the total client visits include client-handling, direct care activities, and cleaning or housework tasks.

**Discussion.** Homecare aides are exposed to multiple client-care tasks, including heavy client lifting and housework. The comparison between the tasks of CHAs and AHAs suggests that CHAs are more likely to perform client handling tasks than AHAs. However, CHAs are less likely to have access to client-handling devices. Highly demanding physical tasks need to be addressed in future interventions.

SESSION 5, TUESDAY, JUNE 21, 10:30AM – 12:00PM, ROOM 203A

## Metrics for quantifying variation in biomechanical exposure data: what does the literature show us?

Francisco Locks Neto (presenter), Gert-Ake Hansson, Ana Beatriz Oliveira

**Background.** Studies focusing on biomechanical exposure and work-related musculo-skeletal disorders (MSD) have suggested that a more varied workload is beneficial for a worker's health — especially in jobs characterized by repetitive movements and/or constrained postures. It is assumed that variation in biomechanical exposure can prevent the development of work-related MSD, by varying the load distribution, regarding both time and location, on the muscles and joints. This study aims to identify the most frequent methods used to quantify variation in biomechanical exposures that have been reported in the literature.

**Methods.** A systematic literature search was conducted in the main online electronic databases using the following key words: work, biomechanical exposure, physical exposure and exposure variation. A manual search of relevant articles from refereed journals was also conducted. The studies included contained variation as an outcome of interest and described how variation was quantified.

**Results.** The initial search resulted in 274 articles, and 27 were identified as eligible. Biomechanical exposure was frequently studied through muscular activity (electromyography – 15 studies) and posture and movements (inclinometry/accelerometry – 9 studies). Exposure variation analysis (EVA) was the most frequently reported method, accounting for 20 of the included studies. The interpercentile range — the analysis of the mean (within-minute) and standard deviation (between-minute) of a new time series — derived from the difference of two APDF percentiles (95<sup>th</sup>-5<sup>th</sup>/90<sup>th</sup>-10<sup>th</sup>) was the second most-used method, identified in seven articles. Three studies reported the application of both methods. Coefficient of variation, exposure contrast and job variability ratio (JVR) are metrics also reported in the literature.

**Discussion.** Quantifying variation of biomechanical exposure is a topic frequently addressed. The two most-used methods have different approaches; both can be informative for understanding variation in an occupational context. New approaches, which are interesting to evaluate, have also been proposed.

## Comparing the Quick Exposure Check with risk assessments based on no specific method

Teresia Nyman (presenter), Peter Palm, Kristina Eliasson, Mikael Forsman

**Background.** Risk assessments should be cost effective, valid and reliable, but many methods are insufficiently tested. Further, ergonomists often perform their assessments by sole observation, without using any specific method. The purpose of the study was to evaluate the inter-rater reliability of Quick Exposure Check (QEC), and to compare the results with ergonomists' "own assessments."

**Methods.** 12 experienced ergonomists made assessments at their own pace of 10 videoed work tasks without using any specific method. Workers' ratings and additional work data were provided. Overall risk, as well as risk for eight body regions, was rated as high (red), moderate (yellow) or low (green). The ergonomists were then trained, and the risk assessments were repeated using QEC (overall risk and four body regions). Multi-observer, linearly weighted kappas were computed.

**Results.** The consistency of risk level among observers differed markedly between the tasks. The average proportional agreement was 40% and the linearly weighted kappa 0.40 for the "own assessments," and 76% and 0.42 for QEC (converted to three levels). For the eight body regions, the averaged proportional agreement of the "own assessments" was 48% and the linearly weighted kappa 0.23. The lowest weighted kappa, 0.12, was seen for the right arm/elbow. For QEC, the corresponding figures were 76% and 0.61 (range 0.43-0.87) respectively. The inter-rater reliabilities of the over-all risk levels ("own" and QEC) were on the line between fair and moderate. The weighted kappa was below 0.4 (slight to fair range) for several body regions when using the "own assessment." When using the systematic QEC method, the corresponding kappas for the body regions were only slightly higher (which may be partly explained by the work data that was provided).

**Discussion.** It is evidently hard to assess risk levels reliably. It may be time to more fully combine observations with validated methods of direct measurements.

## Content and quality of questionnaires for assessment of physical functioning in MSDs: a systematic review of the literature

Birgitta Wiitavaara (presenter), Marina Heiden

**Background.** In order to determine which interventions are effective in the treatment of musculoskeletal disorders, valid and reliable instruments are required. However, there is a lack of consistency in the use of outcome measures, both in research and in treatment, that makes comparisons difficult or impossible; the content and quality varies widely between questionnaires. This study focuses on the measurements of the physical functioning of people with MSDs. The aim of this systematic review is to investigate how physical function is measured in people with musculoskeletal disorders or chronic pain. Specifically we want to determine: (1) What instruments are used to measure physical function in people with musculoskeletal disorders or chronic pain? (2) What do those instruments measure? (3) What is the methodological quality of these instruments?

**Method.** The study was performed as a systematic literature review in the data bases PubMed, Cinahl, Web of Science, and Scopus, using the same set of keywords and Boolean operators. The selection of relevant articles was performed by reviewing the title and abstract first, and the article text thereafter. Selected articles were classified according to the "ICF Classification of Functioning, Disability and Health." Subsequently, articles will be examined with respect to relevant quality indicators using the "Cosmin checklist."

**Results.** 69 relevant questionnaires were found and were sorted into groups according to focus. As a first step, neck and arm-shoulder-hand questionnaires were analyzed. The ICF-classification revealed that the included items belonged to the components "body functions" and "activity/participation," and the included domains varied significantly between the questionnaires. The quality of the instruments will be determined in the next step.

**Discussion.** A review and analysis of this kind makes it possible for researchers and clinicians to more easily select the most suitable questionnaire for their purpose based on the content and quality of the questionnaire.

SESSION 6, TUESDAY, JUNE 21, 10:30AM – 12:00PM, ROOM 203B

## Assessing workers' ability to recognize lifting risk factors for low-back pain: investigating the efficacy of a simple educational message

Binh Ngo (presenter), Richard Wells, Jack Callaghan, Philip Bigelow, Irene Lambraki, Nicolette Carlan, Illia Tchernikov, Peter Vi, Kim Slade-Traynor

**Background.** Since expertise in ergonomics is rare in many workplaces, simple educational messages to identify low-back injury (LBI) hazards were developed by academic experts and knowledge translation professionals in health and safety associations. This study examined lifting risk perceptions of workers and the efficacy of a simple educational message on improving their ability to recognize key LBI hazards.

**Methods.** 178 participants from multiple sectors were shown 44 lifting videos. These videos represented 36 different tasks varying in factors such as lifting height origin/destination, weight or twisting. Participants rated each video, from 0-10, on how likely they believed each lifting task could eventually lead to a LBI. One of two educational messages was then shown to the participants. The intervention message spoke of the risk of low-lying lifts and the control spoke of back-belt use in industry. After reading the message, participants rated the 44 lifting videos again, but in a different order. Participants' risk ratings were correlated to a biomechanically-based tool (3DMatch) that estimated low-back loading.

**Results.** As lifts deviated from a light weight waist-to-waist height lift (mean Likert score=0.421 units), risk perception ratings increased. The highest rated tasks were the medium weight floor-to-waist stoop lift and the heavy floor-to-floor lift (mean Likert scores=7.73 and 7.38 respectively). Pre-post score differences were used to assess message efficacy. Of the 36 tasks, 19 significantly changed in the group that got the lifting height message, compared to three in the group that got the back-belt message. Participant risk ratings correlated positively, albeit only moderately, with 3DMatch (R-value=0.495,  $p < 0.05$ ).

**Discussion.** The results support the use of a simple message to increase conceptual awareness of the important hazard of lifting objects from near the ground. This increased recognition is the first step in the injury prevention cycle of identifying hazards, assessing risks and controlling hazards.

## Lifting demands of daycare workers: the effect of the caregiver to child ratio regulations

Tara Diesbourg (presenter), Nadia Rego Monteil, Geneviève Dumas

**Background.** The Child Care and Early Years Act categorizes young children (not yet in school) into three groups: infants (0 - 18 months), toddlers (18 - 30 months), and preschoolers (30 months - 6 years). Based on these age groups, and on behavioural characteristics of the children in each age group, caregiver-to-child ratio regulations have been established for licensed child care centers (1:3, 1:5 and 1:8 for infant, toddler and preschool groups respectively).

**Methods.** A survey of 32 local daycare workers revealed that 81% of the caregivers has, or has had, low-back pain (LBP). An observation was carried out in five daycare centres in Kingston, Ontario to investigate the risk of low-back injury for caregivers among the three child age groups. The lifting demands of 22 subjects were logged over half of a regular shift using video data and a record of the weights and timings of all objects and children that were lifted. L4/L5 spine compression was estimated for each caregiver, for each lift using 3D-SSPP software (University of Michigan, U.S.).

**Results.** Average cumulative low-back estimation per shift was 3,462 (SD = 977) N·h for infants, 3,698 (SD = 1242) N·h for toddlers and 1,674 (SD = 472) N·h for preschool workers. Based on these values, caregivers working with younger children (infants and toddlers) are at an increased risk for low-back injury (63% of the recommended limit by the Mainz-Dortmund dose model). Preschool caregivers performed fewer lifts over the course of the observation (20.5 lifts compared to 40.5 for infants and 45.0 for toddlers), and therefore showed much lower cumulative low-back compression forces.

**Discussion.** These preliminary findings suggest that, in spite of a greater autonomy of toddlers, toddler caregivers are at an increased risk for low-back injury and may benefit from a decreased caregiver-to-child ratio.

## Associations between lower extremity musculoskeletal disorders and tibial acceleration measures

Mohini Dutt (presenter), Steven Lavender, Carolyn Sommerich, Ajit Chaudhari

**Background.** We have found lower extremity musculoskeletal symptoms to be prevalent in distribution center employees working in manual material-handling jobs. This project aimed to develop risk models predictive of lower extremity symptoms based upon lower extremity biomechanical exposure measures such as cumulative and peak tibial accelerations and individual risk factors.

**Methods.** A survey assessing individual factors and their experience with lower extremity musculoskeletal symptoms was completed by 133 participants who also volunteered to wear accelerometers that quantified their bilateral tibial acceleration exposures during two hours of normal work activities. The survey and accelerometer data were used to develop models exploring relationship between the likelihood of self-reported lower extremity symptoms and the relevant biomechanical and individual exposure variables.

**Results.** Multivariate logistic regression models with acceptable sensitivity and specificity were developed that link individual factors and biomechanical exposure measures with the symptoms in the hip and thighs, knees, and ankles and feet. Out of the 133 individuals that were included in the analysis, there were 98 cases of individuals who had previously experienced symptoms in one or more regions of the lower extremity. The variables predictive of symptoms in these three regions are listed below:

- Hip and thighs – cumulative and peak tibial accelerations, age, smoking, BMI, job tenure
- Knees – cumulative and peak tibial accelerations, smoking, job tenure, participation in physical activity at leisure
- Ankles and feet - peak tibial accelerations, age, smoking, BMI, job tenure, outsole hardness of shoe

**Discussion.** This study identified specific biomechanical and individual risk factors that are associated with increased risk of lower extremity symptoms among distribution centre workers. Understanding these associations is necessary to determine thresholds that can be used to identify safe versus unsafe exposures levels for the lower extremities, and to determine the effectiveness of potential control measures (insoles, floor mats, etc.).

## Assessing energy balance, physiological reactions and nutritional practices in Ontario fire rangers during fire deployment

Ayden Robertson (presenter), Céline Larivière, Caleb Leduc, Zach McGillis, Tammy Eger, Alison Godwin, Sandra Dorman

**Background.** Ontario fire rangers have high annual rates of injury, with fatigue cited as a contributing factor. The seasonal occupation of wildland firefighting involves long hours of physical labour for up to 14 consecutive days. Fire rangers are exposed to a variety of environmental hazards that create a workplace environment that is conducive to developing fatigue. The purpose of this study was to evaluate energy balance, physiological reactions and nutritional quality in Ontario fire rangers.

**Methods.** Data were collected during the 2014 fire season (May to September) from fire rangers operating out of an Ontario Fire Management Headquarters (FMH). Participants wore a Zephyr BioHarness3 heart-rate variability (HRV) monitor while on deployments which, upon analysis in FirstBeat SPORT software, provided measures of energy expenditure and physiological status (physical activity, stress, recovery). Participants also maintained daily food logs using an iPod Touch, which were analyzed using NutriBase Pro10 software to provide measures of energy intake and nutritional quality.

**Results.** HRV data indicate that fire rangers exhibit high physical demands for fire suppression activities leading to high daily energy expenditure (>4000kcal/day), while spending more time in periods of physical activity and stress, and less time in recovery during fire deployments relative to shifts at the FMH. Furthermore, it was observed that fire rangers consume insufficient kilocalories (<4000kcal/day) to match their energy demands, resulting in daily negative energy balance, while also deviating from macronutrient and micronutrient intake recommendations.

**Discussion.** The data has formed the foundation for the development of fatigue mitigation strategies — including task-specific training programs and improved on-deployment nutritional strategies — aimed at reducing injuries and improving fire ranger wellbeing. This study is the first to use this comprehensive methodology in an occupational setting and is expected to be used in future occupational research.

SESSION 7, TUESDAY, JUNE 21, 1:30PM – 3:00 PM, ROOM 203B

## Assessing the biomechanical loads on nurses associated with the use of slings and mechanized patient lifting equipment

Steven Lavender (presenter), Shasank Nagavarapu, William S. Marras

**Background.** Prior studies investigating the efficacy of mechanized patient lifting equipment have not investigated the biomechanical loads experienced when slings used with mechanized lifting equipment are (1) placed under patients prior to lifting, and (2) removed at the completion of the transfer. The objective of this research was to assess the compression and shear loads on the spine that are experienced during these patient-handling tasks.

**Methods.** 12 nurses placed and removed a lifting sling under two simulated patients of differing weights (54 and 100 kgs) who were trained not to assist the research participant. Bed heights for these tasks were: 56 cm, standing knuckle height (mean 71 cm), and 93 cm above the floor. Two methods of performing these tasks were evaluated: (1) the sling was placed (or removed) with the nurse remaining on one side the patient's bed, and (2) the nurse performed components of the task from both sides of the bed. Peak compression, anterior posterior (A/P) shear force, and the lateral shear force at each intervertebral disc level within the lumbar spine was estimated using an EMG-driven biomechanical model.

**Results.** With the heavier patient, with the mean compressive forces during the sling placement task were very close to the 3400 N limit used by NIOSH. The mean A/P shear force at the L5/S1 level and lateral shear at the L1/L2 level and above exceeded published tolerance threshold limits for disc failure. Increased bed height significantly reduced compression values. Overall, there were no clear advantages of using one method over the other.

**Discussion.** Back injuries still persist in the nursing profession, despite the increased use of mechanical patient lifting equipment. This work shows that placing a sling under a patient generates biomechanical loads that could potentially contribute to spine injuries, particularly when working with heavy patients.

## Sensitivity analysis of surface electromyography during different lifting conditions

Mikkel Brandt (presenter), Afshin Samani, Lars L. Andersen Andersen, Pascal Madeleine

**Background.** Excessive physical exposures (e.g. heavy lifting or working with a bent or twisted back) are recognized as risk factors for back pain and long-term sickness absence among construction workers. Technical evaluation, with measurements of surface electromyography (sEMG), may enable quantification of the physical exposure, if the EMG is adequately sensitive in discriminating between different lifting conditions. With funding from the Danish Council for Independent Research (DFF – 4092-00320), the aim of this study was to investigate the amplitude of sEMG in lifting conditions performed with different loads.

**Methods.** 18 male participants performed lifting tasks with 3, 15 and 30kg loads from the floor to a table. All loads were lifted by the subjects moving their feet within a short reaching distance (forearm length), while the 3kg and 15kg load were lifted with a long reaching distance ( $\frac{3}{4}$  arm length) and twisted back. The subjects undertook a familiarization trial before performing the three lifts in each condition in a randomized order with one minute in between. We measured sEMG bilaterally from erector spinae and normalized amplitude to a MVC.

**Results.** The normalized sEMG amplitude increased with the level of load; 45, 60 and 77% for 3, 15 and 30kg respectively ( $p < 0.01$ ). There was a significant difference among the lifting conditions; notably between the 3kg load with a twisted back (41%) condition and both of the other conditions; i.e., the forearm length (45%) and the  $\frac{3}{4}$  arm length (44%) conditions (both  $p < 0.01$ ). With the 15kg load, there was a significant difference between  $\frac{3}{4}$  arm length (65%) condition and both of the other conditions; i.e., forearm length (60%) and the twisted back (60%) (both  $p < 0.01$ ).

**Discussion.** The sEMG was found to be sensitive enough to detect the increase in load during lifting but not necessarily the difference in lifting conditions.

## Revised NIOSH lifting equation for job rotation: the cumulative lifting index

Jay Kapellusch (presenter)

**Background.** The aim of this study was to demonstrate: (i) a recently developed continuous frequency multiplier (FM) for the Revised NIOSH Lifting Equation (RNLE), and (ii) a Cumulative Lifting Index (CULI) algorithm to quantify physical exposure from job rotation. It also aimed to compare performance of the new FM to the original, categorical FM (Waters et al, 1993) and the CULI to previously reported techniques to summarize LIs for workers with job rotation.

**Methods.** A dataset of 157,500 two-task jobs was simulated using different combinations of Frequency Independent Lifting Index, lifting frequency and duration (hours per day) of lifting. Task-level Lifting Indexes (LIs) were calculated using the original FM and then summarized at the job level using: (1) peak task LI based on actual task duration (task-peak), (ii) peak task LI assuming the task was performed for an eight-hour work shift (shift-peak), and (3) time-weighted-average (TWA) LI. Similarly, CULI was calculated for each simulated job using the recently developed continuous FM.

**Results.** The CULI includes exposures from each task in a job using an incremental approach, conceptually similar to the RNLE's Composite Lifting Index. Compared to CULI, TWA estimated lower risk of low-back pain (LBP) for 18-30% of jobs, and shift-peak estimated higher risk for 20-25% of jobs, when using the RNLE's generally accepted risk limits (LI  $\leq 1$  is low-risk, and LI  $> 3$  is high-risk). Task-peak exposure showed 90% agreement with CULI, but ignores all but one task in a job.

**Discussion.** The CULI appears to address the tendency towards underestimated and overestimated physical exposures from the TWA and shift-peak approaches, respectively. CULI may be valuable for job designers where accounting for all tasks performed is important. Should the task-peak approach be simpler, it might be more useful in epidemiological studies to improve data analysis efficiency.

## Is objectively measured sitting and standing at work associated with low-back pain among Norwegian health care and construction workers?

Lars-Kristian Lunde (presenter), Markus Koch, Kaj Bo Veiersted

**Background.** Research has indicated that time sitting and standing, and the ratio between them, is linked to low-back pain. Still, the research on this topic is inconclusive, and reviews have not found high-quality evidence to support this hypothesis. However, the studies reviewed are based on self-reported data, which may have reduced validity. Recent research using objectively measured sitting data, did find high sitting time to be associated with high low-back pain. Therefore, it is important to evaluate the association between sitting and standing at work and low-back pain using objectively measured data. The objective of this study was to investigate the association between objectively measured time spent sitting and standing and the ratio between them and low-back pain.

**Methods:** From a cohort of 594 workers in the health and construction sectors, sitting and standing were measured in 127 subjects for up to four consecutive workdays using two accelerometers (Actigraph GT3X+) and analyzed using Acti4. Low-back pain was reported for the previous four weeks. A pain score ranging from 0-12 for LBP was categorized into four levels of pain ranging from no pain (0), via mild (1) and moderate (2-3) to moderate/severe pain ( $\geq 4$ ). Adjusted multivariate logistic regression was used to investigate association between time sitting, standing and stand-to-sit ratio and low-back pain.

**Results.** The group spent an average of 36% ( $\pm 22$ ) of the workday seated. The average maximal length of continuous sitting was 8% ( $\pm 4$ ) of the workday. For standing, the respective numbers were 30% ( $\pm 13$ ) and 2% ( $\pm 1$ ). 58% of the total cohort reported low-back pain. Data are currently being analyzed and results will be ready in Spring 2016.

**Discussion.** Objectively measured activities will contribute to increased knowledge about the relationship between the amount of sitting and standing and low-back pain and, thus, add precision to recommendations for preventing low-back pain.

SESSION 8, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 203B

## Factors affecting the use of IMUs in forearm rotation assessment

Andrew Lagree (presenter), Elizabeth Salas, Anne Moore

**Background.** Forearm rotation exposure has been recognized as contributing to musculoskeletal disorders (MSDs) including ROM (Grevsten and Sjogren, 1996), velocity and acceleration (Marras and Schoenmarklin, 1993) and years of exposure (Hughes et al, 1997). Forearm rotation exposure identification ranges from the approach used in RULA (wrist twist, yes/no), through proprietary monitors that strap the length of the forearm. More recently, inertial measurement units (IMUs) have been used to document forearm rotation. The purpose of this study was to evaluate the use of forearm mounted IMUs assessing material in the hands, variables calculated and the effect of sensor coupling with the forearm.

**Methods.** 19 healthy, right-handed men, 18-55 years old were equipped with 15 Vicon reflective markers and two Xsens IMUs on their dominant arm. Participants turned handles in a 3x3 grid pattern, on two vertical surfaces created from either plastic or metal. The handles were adjusted such that their forearm was horizontal with no shoulder abduction when grasping the middle handle. Six rotations of the forearm were performed, alternating between pronation and supination for each handle. Instantaneous postures (RMSE) and summarized data (amplitude probability distribution function) were compared between IMU and Vicon measurements, and between materials. To assess sensor coupling, forearm rotation was defined to occur around an anatomically based axis system and compared to the physical movement of the IMUs themselves within Vicon.

**Results.** IMU sensors best matched Vicon when summary data was used (maximum 3.9° deviation APDF vs. maximum 15° deviation RMSE). Also, summary data was less affected by material in the hands. For summarized ROM exposure, IMUs mounted on the forearm are adequate.

**Discussion.** Further work is required to explore how the instantaneous discrepancies would affect their use in future modeling of the forearm kinematics.

## Trapezius oxygenation and hemodynamics during work: a field study using EMG and near infrared spectroscopy

Judith Gold (presenter), Charlotte Lewis, Svend Erik Mathiassen, Guilherme Elcadi

**Background.** Relative blood volume (RBV) and muscle oxygenation (TSI) can be measured using near infrared spectroscopy (NIRS), but no studies have used NIRS with workers performing their job in the field. The study aims were (1) to assess day-to-day within-subjects dispersion in NIRS measurements during work, and (2) to determine whether trapezius RBV and TSI differed between office and industrial workers. Electromyography (EMG) measured trapezius muscle activity.

**Methods.** Portable NIRS and EMG instruments were adhered to the trapezius of healthy female industrial ( $n = 8$ ) and office ( $n = 10$ ) workers for approximately four hours on two separate days. Mean and standard deviation (SD) RBV, TSI and 50th percentile EMG were calculated for both days separately. Participants were videotaped to demarcate work and rest periods, and to qualitatively assess ergonomic exposures. Two-way mixed effects models were constructed to examine outcomes, with occupation (office/industrial) and work/rest as fixed effects and subject as a random effect.

**Results.** Industrial workers appeared to have more variable arm postures and handled heavier loads than office workers. The between-days variability of RBV and TSI indicated that NIRS performed well in an occupational setting. Median trapezius EMG showed an effect of occupation ( $p < 0.0001$ ), and an interaction between occupation and work/rest ( $p < 0.0001$ ). As expected, industrial workers had higher median EMG overall and during work, but office workers had a higher EMG during rest. Similar results for EMG SD were found. Mean RBV and RBV SD were greater in industrial workers. No effects on mean TSI were found. However, TSI SD was higher in industrial workers, while TSI SD was greater in office workers during rest.

**Discussion.** NIRS had a satisfying reliability and showed face validity with respect to expected responses to occupational work. NIRS shows promise as a method for measuring hemodynamics in the field.

## Evaluation of two types of reference contraction on recordings of forearm extensor muscle activity

Camilla Dahlqvist (presenter), Catarina Nordander, Lothy Granqvist, Gert-Åke Hansson

**Background.** Many occupations involve excessive and prolonged muscular load. Surface electromyography (EMG) can be used to obtain quantitative measures of such load. In order to compare the muscular load between different subjects, or jobs, it is necessary to have a reliable reference contraction. Some research groups use maximal isometric wrist extension to activate the extensor muscles. Our group has hitherto used a maximal hand grip around a dynamometer as reference contraction. However, we occasionally see higher EMG amplitudes during work than those obtained during the reference contraction, indicating that the muscles have not been maximally activated when using hand grip. The aim of the present study was to evaluate wrist extension and hand grip as reference contractions of the forearm extensors, in terms of amplitude and reproducibility.

**Methods.** Six women and six men participated. The electrical activity of the right forearm extensors was recorded during the two types of reference contraction on three separate occasions.

**Results.** The group mean EMG amplitudes for wrist extension was 1.3 times greater than that for hand grip. The reproducibility over the three occasions, in terms of the group mean of coefficient of variation (CV), was 14% for wrist extension, while corresponding value for hand grip was 23%. When the mean EMG amplitudes for hand grip was normalized to the mean EMG amplitude for wrist extension for each participant, a value greater than 100% was found for hand grip in one subject.

**Discussion.** The highest ratio between the group mean EMG amplitude and the group mean CV, was obtained using wrist extension. A factor of 0.8 can be used for comparisons between forearm extensor recordings using wrist extension and hand grip as reference contractions. Further investigation is needed to confirm that these results are valid during actual work.

## Is there a best way to crank a lever? The scapula posture perspective

Jia-Hua Lin (presenter), Xu Xu, Raymond McGorry

**Background.** Cranking a landing gear is a common task performed by truck drivers to raise or lower trailers. This task poses a risk for the shoulder joint due to the required forceful exertion and the posture constrained to the hand-handle interface. As a potential occupational risk, there has been no guideline for best practices among truck drivers. An operator can crank facing perpendicular (front) or parallel (side) to the crank rotation.

**Methods.** In this laboratory study, the effects of cranking method and resistance on scapular range of motion and shoulder muscle activities were observed. Scapular posture was measured by tracking an optical surface marker cluster, which is a validated non-invasive method. EMG was monitored on 16 muscles contributing to shoulder movement.

**Results.** The results indicate that when cranking from the side, the scapular range of rotation was  $30\pm 9.0^\circ$ , which was more than from the front ( $24\pm 9.7^\circ$ ). The range increased from  $25\pm 8.7^\circ$  to  $29\pm 10.5^\circ$  as the resistance increased from no load to 20 Nm. Seven muscles (all three deltoid muscles, middle trapezius, supraspinatus, infraspinatus, and teres minor) demonstrated that when the crank resistance was low, the front cranking method resulted in lower activity than the side cranking. When the crank resistance was 20 Nm, the muscle activity on these seven muscles was greater when cranking from the front than from the side.

**Discussion.** Based on these observations, we suggest that when the resistance is low (lowering the trailer) the driver should stand facing the trailer. On the contrary, it is advantageous to stand parallel to the trailer and crank while raising the trailer to apply the full body strength to reduce the shoulder load.

SESSION 9, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 202A

## A cross-sectional study of alternations between physical and mental tasks

Helena Jahncke (presenter), Staffan Hygge, Svend Erik Mathiassen, David Hallman, Susanna Mixter, Eugene Lyskov

**Background.** Health and well-being at work is generally assumed to be associated with sufficient physical and mental variation. Job rotation, where workers typically alternate between different physical tasks, is a popular initiative. Controlled experiments suggest that favourable effects are associated with alternations between mental and physical tasks, but little is known about this intervention in real work. The aims of this study were (1) to describe the occurrence of alternations between mental and physical tasks, and (2) to identify key determinants of such alternations.

**Method.** We developed a questionnaire combining established questions with specific questions about alternations. Workers from two occupations (industrial and non-industrial blue-collar work), in jobs containing both physical and mental tasks, were included in the study. 122 (55 females) out of 293 workers approached at four companies answered the questionnaire.

**Results.** On average, the workers alternated 3.5 times per day between mental and physical tasks. In the non-industrial companies, workers reported wanting more alternations than they had, while desired and actual alternations did not differ in the industrial companies. This effect of occupation on the difference between the number of alternations wanted and the actual alternations available was significant ( $p < 0.001$ ). Furthermore, there was a general preference for performing a physical task after a mental task, and vice versa. This main effect of primarily performed task type (i.e. either physical or mental) on preferred subsequent task type was significant ( $p < 0.001$ ). In a univariate analysis, gender appeared to be a strong determinant of the occurrence of alternations, but the effect was absorbed when adding the occupation variable.

**Discussion.** Within the studied companies, work offered alternations between mental and physical tasks and there was a preference among workers to alternate between tasks. Occupation rather than gender was a key determinant of the number of alternations reported.

## Assessing return-to-work status questionnaires in an occupational rehabilitation population

Eleanor Boyle (presenter), J. David Cassidy, Pierre Côté

**Background.** We investigated the reliability and validity of a self-report return-to-work questionnaire in a cohort of injured workers recruited from community-based rehabilitation clinics.

**Methods.** Two research assistants independently administered the baseline questionnaire on two separate occasions and a follow-up questionnaire was administered six weeks later. The questionnaires contained work-related questions (i.e. currently working, if duties of the job have changed, etc.) that were used to create a four-category work status measure. Pain-related questions and a recovery question were also asked. We obtained loss-of-earnings data from the compensation board. The short-term reliability and convergent validity of the four-category work status measure were assessed.

**Results.** We recruited 75 injured workers, and 57 completed the test-retest baseline questionnaire, and 51 completed the follow up. The mean age was 45.3 years and 58% were female. We recruited a mixture of musculoskeletal injured workers. Most were in the acute stage, but 17% were injured for more than a year. We found excellent short-term reliability ( $\kappa = 0.90$ ) of current working status using an algorithm based on answers to five questions on work status. The reliability for the single question of current working status was slightly lower ( $\kappa = 0.71$ ). Study participants who were not working had higher levels of pain-related disability than those who were working. There was moderate agreement between self-reported working status and administrative data on receiving any loss of earnings payment.

**Discussion.** Our results suggest that our self-reported questionnaire on work status provides a reliable and valid measure of return-to-work.

## Different EMG normalization methods and implications for field-based data acquisition of muscle activity

Ornwipa Thamsuwan (presenter), Kit Galvin, Maria Tchong-French, Margaret Hughes, Peter Johnson

**Background.** New semi-automated mobile harvesting platforms have been introduced where workers stand on the platform as it slowly moves through the trees. This method may replace the traditional method of picking fruit by climbing ladders. The goals of this study were to use electromyography (EMG) to compare shoulder muscle activity between the two harvesting methods and to compare two EMG normalization methods.

**Methods.** Trapezius EMG was measured on 16 orchard workers during their actual harvesting throughout the entire day: eight workers harvested apples from a moving platform, and eight used ladders. EMG was normalized in two ways: (1) using sub-maximal reference voluntary electrical activation (%RVE), and (2) using the peak muscle activity during the first 1.5 hours of work (95<sup>th</sup>tile dynamic EMG). To compare the normalization methods, EMG amplitudes were characterized in terms of the 10<sup>th</sup>, 50<sup>th</sup> and 90<sup>th</sup> percentiles, representing static, median and peak muscle activity, respectively. EMG signals were first analyzed in frequency domain to identify shifts in frequency; this indicated when the electrodes were losing contact with the skin. Then, the subsequent data was analyzed in the time domain to characterize muscle activity levels.

**Results.** Normalizing EMG to peak dynamic contractions gave substantially less between-subject variation than the %RVE normalization — this yielded better statistical power for the comparison of the two groups of workers. The frequency domain EMG calculations were helpful to indicate when electrodes came off the skin, a challenge in field studies.

**Discussion.** This study characterized muscle activity in a very challenging field environment. The frequency-domain analysis first indicated the good portions of data for the subsequent time-domain analysis. The substantially lower between-subject variation with the dynamic normalization may have important and practical implications for the future collection and interpretation of field collected EMG data.

## Influence of different visual display unit configurations on physiology and performance

Mark Brütting (presenter), Dirk Ditchen, Jürgen Büniger, Peter Schäfer, Jens Petersen, Rolf Peter Ellegast

**Background.** In German offices, classic visual display unit (VDU) workstations with one 19-inch display are more and more replaced by VDU workstations with multiple, or larger, displays. Since physiological and cognitive effects of these changes are not yet well examined, we compared alternative VDU workstations with respect to performance and physiological parameters.

**Methods.** We investigated three different configurations of 22-inch monitor displays: configuration “hh” (two horizontal displays), configuration “hv” (one horizontal, one vertical display) and configuration “h” (a single horizontal display) as a reference. 10 subjects participated in the tests working for approximately 2.5 hours at each configuration and conducting three different standardized tasks: comparison of texts, typing of text and sorting records in a table (spread sheet work). In addition to performance parameters, we determined physiological stress and strain by measuring body kinematics (CUELA), electrical activity of the Mm. Trapezius (SEMG), office chair movements (inertial sensor), eye movements (eye tracking), visual acuity before and after tests (smartphone app), perceived exertions and subjects’ preferences (questionnaires).

**Results.** Results showed preferences favoured a VDU with two displays. We found significant differences concerning quality and quantity of the conducted tasks depending on display configuration. In contrast, SEMG results showed significant differences for type of tasks only. While rotational movement of the office chair took place to a small extent (up to 7°) only, most of the movements were carried out by head (up to 20°) and/or eye-movements. A change of visual acuity after the experiments could not be detected.

**Discussion.** Only small differences in limiting physiological factors were found for the various VDU configurations but individuals’ performance and preferences argue in favour of the use of multiple displays. The results of this study can be helpful for design recommendations of VDU workplaces and for advising employees.

SESSION 10, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 202B

## The DASH (Disabilities of the Arm, Shoulder and Hand) at work: a review of its use and measurement properties

Carol Kennedy (presenter), Dorcas Beaton, Shireen Harbin

**Background.** The DASH (Disabilities of the Arm, Shoulder and Hand) Outcome Measure is a well-recognized instrument for measuring upper-limb function and symptoms. The self-completed questionnaire includes the 30-item DASH, 11-item *QuickDASH* and optional modules (i.e. Work, Sports/Performing Arts). The objective of this review is to identify how the DASH is being used in worker populations and to summarize the measurement properties.

**Methods.** The DASH database is maintained in Reference Manager and populated by monthly systematic searches of MEDLINE, EMBASE, and CINAHL for which results are screened for relevance. We searched this database (n=1,948) for titles and abstracts including terms “worker” or “employ” to identify potentially relevant articles. Inclusion criteria included: (1) DASH used in measurement testing or application study (used as outcome measure in a study), and (2) population included worker or workplace population (including healthy and injured workers). Two reviewers independently screened selected studies (title/abstract) for inclusion. Those deemed as potentially relevant then moved forward to full article review and data extraction. Analysis included a descriptive summary of included studies and measurement properties.

**Results.** The search identified 43 studies (n=10 measurement testing; n=33 application) to be included in the literature synthesis. Measurement testing has been reported for the *QuickDASH* (n=5), Work module (n=4) and translated versions (n=2 German DASH; n=1 Turkish DASH). Most studies included injured workers, n=2 in healthy populations for normative data. Types of measurement testing included: *QuickDASH*—construct and criterion validity, responsiveness; Work module—internal consistency, construct and criterion validity; translated versions—internal consistency, test-retest reliability, construct validity, interpretability. Application studies used a range of versions: DASH, *QuickDASH*, Work module, and translated versions. Study designs included cross-sectional, cohort (retrospective, prospective) and randomized controlled intervention trials.

**Discussion.** Measurement studies in worker populations have mostly been done on shorter versions of the DASH (*QuickDASH* and Work module). However, application studies are using all versions.

## Predicting shoulder fatigue using a three-compartment model with graded motor units

Alison McDonald (presenter), Michael Sonne, Calvin Tse, Peter Keir

**Background.** Muscle fatigue is associated with potential long-term effects on worker health and negative impacts on workplace economics. Sonne & Potvin (2015) recently improved the physiological fidelity of a three-compartment model of fatigue (Xia and Frey-Law, 2008) to create a graded motor unit model for tasks with varying force-time histories. The purpose of this study was to examine fatigue prediction for a repetitive, fatiguing shoulder flexion task and a submaximal work protocol.

**Methods.** The model was tested with two separate groups who provided written informed consent. Protocols were approved by a university research ethics board. The two fatigue protocols were an anterior deltoid protocol, alternating between static and dynamic shoulder flexion tasks (ADF, n=12) and a fatiguing repetitive work task protocol (WPF, n=20). In the model, coefficients of F and R serve as muscle fatigue and recovery rates. The proportion of motor units that are active ( $M_A$ ), fatigued ( $M_f$ ) and at rest ( $M_R$ ) are predicted at each time point and force level. Optimal F and R coefficients for each task were determined using a subset of 10 participants using maximum voluntary contraction (MVC) and endurance times. The predicted coefficients were tested on the remaining two participants and evaluated using the RMSD between the predicted and the experimental fatigue level.

**Discussion.** The ADF optimization resulted in an RMSD of 23.0% MVC. Overall, there was an RMSD of 21.0% MVC when applying the model to all 12 participants with the anterior deltoid fatigue protocol. There was a large range in strength decline between participants (8.1-67.6% MVC) likely due to shoulder complexity, explaining the large RMSD between the predicted and experimental strengths. These results provide support for the incorporation of the graded motor unit fatigue model into digital human models for prediction of shoulder fatigue.

## The quantitative measurement of workload to define exposure thresholds in cumulative trauma disorders applied in rotator cuff injury: a cohort study

David Alvarez Rincón (presenter), Natalia Perez-Velez

**Background.** Cumulative trauma disorders (CTDs) are the cause of sizable losses in labour environments throughout the world, measured as days away from work, permanent disability and significant productivity loss. Qualitative measuring methods are frequently used for workload assessment due to their relative low cost. However, high subjectivity, poor replicability and the inaccurate conclusions yielded by qualitative methods increase the need for quantitative, evidence-based methods for CTD evaluation that make it possible to define exposure thresholds. The aim of this study is to generate robust and reliable evidence that can be used by prevention systems and within workers' compensation processes (causation assessment) to measure inadequate workload exposures.

**Methods.** A retrospective cohort study was designed with workers from different departments. Workload characteristics were compared from the point of starting with the company until the point of injury — sizing up workload between workers who developed rotator cuff injury (RCI) and workers who did not. Inclusion and exclusion criteria were applied rigorously to finally accept 455 workers. Their entire clinic histories were analyzed with a view to obtaining important clinical variables. Each job was assessed to get daily exposure times for different shoulder movement angles, repetitive motions, loads, vibration and rest/break periods. The cohort survival experience was appraised by Kaplan-Meier function. Exposure thresholds and RCI risk were obtained using a multivariate Weibull regression model.

**Results.** The median age for starting at the company was 31 years; 60% were women and 10% had university education. Cohort following median was 7.5 years. 48.5% workers developed RCI after 10 working years (median). The hazard ratio was obtained for different time-exposure tiers, yielding time-exposure thresholds of shoulder range movement, repetitive motions, loads and vibration, adjusted by rest/break periods and significant covariates.

**Discussion.** Quantitative measuring of workload exposure thresholds in CTDs yields a reliable musculoskeletal injury risk assessment with broad practical application for primary prevention and within workers' compensation processes.

## The Work-Related Questionnaire for the UPper extremity (WORQ-UP): factor analysis and internal consistency

Bas Aerts, Paul Kuijer (presenter), Annechien Beumer, Denise Eygendaal, Monique Frings-Dresen

**Background.** Upper extremity musculoskeletal disorders are one of the major causes of absence from work. Until recently, daily orthopaedic practice has paid scant attention to the factor of work. The Work-Related Questionnaire for the UPper extremity (WORQ-UP) may be useful in orthopaedic practice for identifying work-related limitations in patients with upper extremity disorders. 17 items of the WORQ-UP were retrieved based on literature and on interviews with patients and clinical experts. In the present study, we tested the dimensionality of the items (factor analysis) and calculated the internal consistency.

**Methods.** 150 patients from the target population (50 patients with shoulder disorders, 50 patients with elbow disorders and 50 patients with hand-wrist disorders) filled in the WORQ-UP. Exploratory factor analysis (EFA) was performed including direct oblimin oblique rotation. After determining the number of factors, Cronbach's alpha (CA) was calculated for factor.

**Results.** Four factors with Eigenvalue (EV) > 1.0 were found. The EV of the factors was respectively: Factor 1 = 5.78, Factor 2 = 2.38, Factor 3 = 1.81 and Factor 4 = 1.24. The factors together explained 65.9% of the variance. Factors were named: exertion, dexterity, tools and equipment, and mobility. The CA for these factors was respectively 0.88, 0.74, 0.87 and 0.66.

**Discussion.** The 17 items of the WORQ-UP resemble four factors: exertion, dexterity, tools and equipment, and mobility. Each individual factor, except Factor 4 (mobility) had a CA above 0.7. Based on these values, and the development of the WORQ-UP in collaboration with experts and patients from the target population, it can be concluded that the WORQ-UP has a high content validity in combination with high internal consistency.

SESSION 11, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 202B

## Quantifications of body posture of forklift truck operators

Ming-Lun Lu (presenter)

**Background.** Forklift truck operations exhibit many risk factors associated with musculoskeletal disorders (MSDs). When the forklift truck is loaded in a manufacturing setting, forklift operators often drive in reverse direction to avoid product damage. Driving a forklift truck in reverse direction results in awkward trunk and neck posture. In combination with additional risk factors such as prolonged sitting and whole body vibration from the seat, forklift operators may be at an increased risk of MSDs. Research on the MSD risk factors of forklift operators is scarce, particularly in quantifying body posture.

**Methods.** In this study, the ShapeTape system by Measurand Inc. was used to monitor trunk and neck rotation during forklift operations at two manufacturing plants in Ohio, United States. The ShapeTape system consisted of a fiber optic tape and two gyroscopes, capable of measuring the Cartesian coordinates (x, y and z) of the various segments of the tape. Due to the limitation of data collection capacity, posture data were measured in 53 trials on 18 subjects. Data were collected at a 97 Hz sampling rate in various collection periods (mean  $\pm$  standard deviation = 32  $\pm$  9.7 minutes).

**Results.** Results showed that on average, the 50th percentile and 95th percentile neck rotation levels were 19° and 62°, respectively. Subjects' neck rotation was in the non-neutral position (>15° or < -15°) for about 60% of the time. Approximately 19% of the time, the subjects rotated their neck in the extreme positions (>45° or <-45°). Their trunk was in the non-neutral position for 11% of the time.

**Discussion.** The objective quantifications of the body posture for forklift operations confirmed the awkward neck posture observed by a previous study and indicated a need for continuous monitoring of extreme neck posture commonly required for forklift operations.

## Biomechanical evaluation of hotel luxury bed making while using a mattress-lift tool and fitted sheets

Carisa Harris Adamson (presenter), Emma Lam, Stephen Hill, Andrew Smith

**Background.** The deployment of luxurious bed mattresses in hotels has been implicated as a source of physical exposure associated with musculoskeletal disorders (MSDs) in hotel room cleaners. The purpose of this study was to quantify biomechanical and cardiovascular exposure while making beds — with and without interventions (tool and fitted sheet).

**Methods.** 16 female hotel room cleaners with at least six months' experience and no severe pain over the prior week participated in this laboratory-based study of multi-factorial crossover design. Information concerning personal data, work experience and discomfort (NPS) was collected at baseline and fatigue (BORG-CR10) was collected after each condition. Participants made a queen size bed eight times, randomizing the order of interventions (tool and sheet). Muscle activity of the flexor digitorum superficialis (FDS), extensor digitorum (ED), biceps brachii (BB) and deltoid (DL) was quantified using surface electromyography (Delsys Trigno, Natick, MA) and summarized reporting median (APDF 50%) and peak (APDF 90%) amplitude probability distribution functions. Heart rate (HR) (Garmin, Olathe, KS) was collected continuously to assess cardiovascular load. Data were analyzed using a repeated measures ANOVA and a tukey post-hoc test.

**Results.** 11 of 16 individuals were Hispanic and 25% (n=4) had a BMI $\geq$ 30kg/m<sup>2</sup>. Discomfort over the past year was moderate in the hands/wrist (X=4.3,SD=3.4) and low back (X=5.0,SD=3.4). 50% reported taking medication for pain, and up to 25% reported days off or having difficulty maintaining their work pace due to pain. The average % relative HR (32%) and fatigue in the upper extremity (<2) and back (<3) was consistently lower following tool and fitted sheet use (p<0.05). Average mean ED (X=35%,SD=23) and peak FDS muscle activity (X= 60%, SD=25) was lower with tool use (p<0.05).

**Discussion.** Hotel room cleaners are exposed to high cardiovascular and biomechanical loads when making beds. Interventions such as a mattress lift tool used with fitted sheets reduced some muscle loads and fatigue.

## Full-shift and task-specific ergonomic exposure assessment of posture and muscle activity among U.S. dairy parlour workers in large-herd operations

David Douphrate (presenter), Nathan Fethke, David Gimeno, Matthew Nonnenmann, Robert Hagevoort

**Background.** The U.S. dairy industry has experienced a transformation from small-herd farms to large-herd operations. During the last 30 years, the number of U.S. dairies has decreased while herd sizes and milk production has increased. This transformation has led to significant changes in work tasks and created ergonomic challenges because of the highly repetitive nature of the work involved in the milking process. Minimal research has addressed ergonomic issues in these mass-production environments. Field-based direct measures of physical exposures have been limited in these challenging work environments. The purpose of this study was to evaluate full-shift and task-specific exposures to muscle forces and postures among large-herd dairy parlour workers.

**Methods.** Study participants were recruited from large-herd dairy operations in four Western U.S. states. Shoulder elevation angles and movements were estimated using inertial measurement units (IMUs), and muscle activity was measured using surface electromyography (EMG). Data collection took place during an entire work shift (8-12 hours) while workers performed milking tasks. Digital marking enabled the identification and analysis of task specific exposures.

**Results.** Results suggest that parlour workers are exposed to extreme exposures (awkward postures, high movement velocities, high repetition, high muscle forces and inadequate rest). These physical exposures are often associated with the development of upper limb pathology. Specific milking tasks were identified as being associated with higher exposures as well.

**Discussion.** These findings suggest the need for continued research. Investigation into these working environments may facilitate the development of cost-effective intervention strategies such as engineering and administrative controls. Several strategies to reduce physical exposures have been developed and are currently being evaluated for effectiveness.

SESSION 12, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 202B

## Different autonomic responses to occupational and leisure time physical activity among blue-collar workers

Tatiana Sato (presenter), David Hallman, Jesper Kristiansen, Jørgen Skotte, Andreas Holtermann

**Background.** There is a well-established relationship between high physical activity at leisure time and decreased mortality risk. On the other hand, high physical demands at work seem to increase this risk. However, the underlying mechanism behind this effect remains unknown. Heart rate variability (HRV) measurements may bring some insight into the mechanism. Thus, the aim of this study was to determine whether or not HRV differs between work and leisure time among blue-collar workers.

**Methods.** This study was based on data from the cross-sectional NOMAD study among blue-collar workers from seven workplaces in Denmark. 138 blue-collar workers, who had at least seven recorded hours during work and leisure time were included in the analysis. Data from physical activity and HRV were obtained over four days using tri-axial accelerometers (Actigraph GT3X+) and heart rate monitor (Actiheart), respectively. Parametric (paired t test) and nonparametric (Wilcoxon signed-ranks test) tests for pairwise comparisons were applied to compare mean HRV indices in time and frequency domains between work and leisure time.

**Results.** The mean age of the workers was 45.2 years, 51% were females, 42% were smokers, 18% reported lifetime occurrence of hypertension and 45% reported performing lifting and carrying tasks for more than half of their work time. A significant, higher overall HRV was found during leisure time compared to work. Leisure time showed higher parasympathetic nervous system (PNS) measures of HRV ( $p < .05$ ), while sympathetic nervous system (SNS) related indices ( $p < .05$ ) were reduced in comparison to work.

**Discussion.** Leisure time showed high HRV and PNS indices and work time showed high SNS-related indices. The higher SNS modulation during work can be related to a greater risk of developing heart diseases among blue-collar workers.

## Muscle fatigue assessment in leather-cutting tasks: a comparison between manual and machine-assisted operations

J Nieves Serratos Perez (presenter), Juan Luis Hernandez Arellano, Carmen Negrete Garcia

**Background.** Historically, the cutting of leather used in the production of shoes was performed manually. However, in recent years leather-cutting machines with features of advanced manufacturing technology (AMT) have been incorporated into that stage of the production of footwear. This research report presents a comparison of results from muscle fatigue assessment (MFA) methodology between the traditional manual procedure and the semi-automated procedure. The study was conducted in a shoemaking company in Leon, Guanajuato, Mexico.

**Methods.** Task analysis was applied to identify the main tasks in the two styles of leather-cutting operations. MFA modelling, developed by Suzan Rodgers, was applied to predict the risk of developing work-related musculoskeletal disorders (MSDs) for the workers engaged in both procedures. This method looks into the intensity of effort placed on joints and relates it to the need for changes in the assessed situation.

**Results.** According to the assessment results, the manual procedure involves very high levels of change priority in hand/wrist; high levels in shoulders, arm/elbow and legs; and, medium levels in neck and back. Semi-automated process is associated with very high levels of change priority in hand/wrist; medium levels in back and legs; and, low levels in neck, shoulders and arms.

**Discussion.** The application of MFA methodology shows that physical load has been diminished after the introduction of cutting machines, especially in shoulders and legs. However, this is not the case for the hand/wrist area, since the level of change priority is very high in both procedures. On the other hand, recent research has found that while the introduction of new technologies diminishes the physical load, it increases the mental load. Therefore, it is necessary to perform a cognitive task analysis in order to compare the mental load between both modalities of the leather-cutting task.

## Physical workload of garbage collectors in two organization modes: one loader vs. two loaders

Kévin Desbrosses (presenter), Bastien Adam, Mélissa Vieira

**Background.** Garbage collection is physically demanding work and is usually performed by a crew composed of one driver and two loaders (two-loader organization, “TL”). French companies have recently introduced a new work organization mode, reducing the workforce to one driver and just one loader (one-loader organization, “OL”). The aim of this field study was to compare the physical workload of garbage collectors between the one-loader mode and the two-loader mode.

**Methods.** 22 loaders (10 in OL and 12 in TL) and 15 drivers (9 in OL and 6 in TL) participated in this study conducted on 16 usual collection rounds (10 in OL and 6 in TL). Physical activity, using the GT3X monitor (ActiGraph) and Acti4 software (NRCWE), and heart rate (Polar Team<sup>2</sup>) were recorded continuously during the working time.

**Results.** Garbage collection time was on average  $434 \pm 90$  minutes in OL and  $401 \pm 48$  minutes in TL. The mean weight of garbage collected by each loader was  $9.6 \pm 2.2$  tons and  $4.5 \pm 0.7$  tons, respectively in OL and in TL. Mean arm elevation was similar in OL and in TL for loaders. Number of steps performed by loaders was significantly higher in OL ( $16599 \pm 4865$ ) than in TL ( $12238 \pm 3702$ ). Mean heart rate (in % of heart rate reserve) was significantly higher in OL ( $35.6 \pm 9.7$  %) than in TL ( $26.5 \pm 9.2$  %) for loaders. No significant difference was found for drivers between OL and TL for time sitting and heart rate.

**Discussion.** Physical workload of loaders was found to be considerably higher in OL than in a typical TL organization mode, resulting in an excessive increase in heart rate. Thus, the one-loader organization mode currently used should be discontinued or else substantially improved for the occupational safety and health of garbage collectors.

## Sustained low physical exposure in a lean process plant

Malin Håkansson (presenter), Mikael Forsman, Teresia Nyman

**Background.** Earlier research on lean production and its effects on employees shows mixed results, but it points in the direction of increased workload. Research concerning lean production and physical ergonomics is limited, and studies that focus on associations between changes in physical exposure due to transformations to lean production and musculoskeletal pain are lacking. The aim of this study was to evaluate the impact of more standardized work on work postures and movements, physical fatigue, prevalence of musculoskeletal pain and disability among operators in a lean process industry.

**Methods.** Two units (process work and line work) were investigated at baseline (2011) and at follow-up (2013). Inclinometry and goniometry were used to assess work postures and movements (n=20) in the upper extremities during a typical work day. Questionnaires concerning musculoskeletal pain, disability and physical fatigue were distributed 2011 (n=81) and 2013 (n=98).

**Results.** For both units, the time percentage of work with arms elevated  $>60^\circ$  did not differ between baseline and follow-up (process work Mn=5-7%; line work Mn=3%). Wrist angular velocity was kept low at baseline and at follow up, (process work p50=10 °/s; line work p50=11 °/s). At follow up, self-rated physical fatigue had decreased significantly for line workers. However, for process workers, fatigue had increased, but not significantly so. The prevalence of musculoskeletal pain in the neck, elbow and hand during the last seven days increased in process work. In line work there was an increase in pain in the shoulder and hand. However, none of the differences were significant ( $p > 0,05$ ).

**Discussion.** Despite several years of experience with lean production, with a gradual standardization of work and increased productivity, the mechanical exposure was maintained at a low level and there was no significantly increased prevalence of musculoskeletal pain. The company's systematic focus on health and safety alongside ergonomic interventions may have contributed to these conditions.

## Use of activity monitors to understand falls

Tiffany Poole Wilson, Kermit Davis (presenter), Susan Kotowski

**Background.** Falls in long-term care facilities occur at alarming rates with 50% to 70% of residents falling each year, accounting for more than 180,000 falls per year. Current falls investigations rely on self-reporting by patients and on reconstructions of the underlying conditions contributing to the falls generated by nurses. The current study investigated the physical activities prior to falls using objective measurement to attempt to identify potential activities that lead to falls.

**Methods.** 14 frequent fallers were monitored with an activity monitor (ActivPal) to quantify the amount of standing, sitting/laying, and walking during a one-week period.

**Results.** Non-fallers were more active than fallers. Non-fallers had five minutes less per hour of laying or sitting and five minutes more of standing. The non-fallers also walked 15 steps per hour more. Objective activity levels indicated durations of lying flat or standing without walking was a precursor to a fall (90% of falls fell into these categories).

**Discussion.** Although the results should be considered preliminary due to the low number of falls (n=9), the quantitative data provides an interesting view of the conditions prior to a fall. However, there appeared to be distinct patterns of activities that happen prior to the fall as compared to the activities for non-fallers. More activity appears to be one key factor in limiting the occurrence of falls in frequent fallers. This type of technology may be employed to understand how falls occur in the workplace.

SESSION 13, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 204C

## Effects of artifacts in a repetitive light assembly task on muscular activity according to age and work rate constraints

Laurent Claudon (presenter), Kévin Desbrosses, Pascal Wild, Olivier Remy, Martine Gilles, Pichené-Houard Anne

**Background.** Time constraints can be particularly stressful for older workers in repetitive work. Opportunities for work rate regulation could offer a way of dealing with production variations. The aim of this laboratory study was to investigate the effects of occurrence of artifacts on muscular activity under two work rate conditions for a repetitive task completed by both younger and older participants (YPs and OPs).

**Methods.** 14 YPs (25-35 years) and 14 OPs (55-65 years) performed an assembly task (with a theoretical cycle time (TCT) of 22s) under two conditions: C1, a forced work rate with a production penalty (PP) if the task was not completed within the TCT; and C2, a more flexible work rate with a PP inflicted if three consecutive cycle times were greater than three TCT (66s). For each condition, participants made 136 assemblies with 15% of them being artifacts assemblies (AAs) which required supplementary operations within the same TCT. Assembly time (ATime) and EMGs of the right flexor digitorum superficialis (FDS-R), extensor digitorum communis (EDC-R), biceps brachii (BB-R), triceps brachii (TB-R), and right and left deltoid (DEL-R/L) and trapezius (TRA-R/L) muscles were recorded.

**Results.** ATime was greater for AAs than for non AAs for all participants under C1 only ( $p < 0.001$ ). Under C1, EMGs of all muscles, except TRA-R/L, were greater for AAs than for non AAs for all participants ( $p < 0.001$ ). In C2, EMGs of FDS-R, EDC-R, BB-R, TB-R and DEL-R were greater for AAs than for non AAs for OPs only ( $p < 0.001$ ). The number of PPs was greater under C1 than under C2 ( $p < 0.001$ ).

**Discussion.** Giving leeway in time made it possible to improve performance and to reduce muscular activity. However, older workers needed to pay special attention when coping with artifacts since their muscular strains remained higher than for standard assemblies.

## Effect of time constraint on performance speed of a repetitive assembly task according to age

Martine Annie Gilles (presenter), Pascal Wild, Olivier Remy, Laurent Claudon, Kévin Desbrosses, Anne Pichené-Houard

**Background.** Repetitive work at required pace, as observed on assembly lines, is often characterized by reduced amounts of temporal margin of maneuver (TMM). Various epidemiological studies have shown that working under time constraints is particularly difficult for ageing workers. The aim of this study is to use movement analysis to improve characterization of the effect of having possible TMM during performance of a repetitive task.

**Methods.** This laboratory study was conducted on 28 subjects distributed into two age groups (younger participants 25-35 years, and older participants 55-65 years). They performed repetitive work for 50 minutes either at an imposed pace or at pace with TMM. At both work paces, assembly with additional tasks (options) occurred randomly without increasing the allotted assembly time. The speed of the right wrist was analyzed using 3D modeling of the movements, based on the recordings by an optokinetic system.

**Results.** The preliminary results show, for both groups, a significant increase ( $p < 0.001$ ) in the speed of the right wrist during assembly with options. Moreover, with or without option, the speed of the right wrist was significantly lower ( $p < 0.001$ ) at the TMM pace than at the imposed pace in the younger participants, whereas no change was observed in the older participants between the two paces. At the imposed pace, the older participants were significantly slower ( $p < 0.01$ ) than the younger participants.

**Discussion.** This study shows that, in terms of regulating the speeds of movement, TMM seems to benefit younger workers, whereas older workers appear to be able to take less advantage of it.

## Does increased automation influence the physical workload of the hands during repetitive manual work?

Francisco Locks Neto (presenter), Gert-Ake Hansson, Lothy Granqvist, Helen Cristina Nogueira, Henrik Enquist, Andreas Holtermann, Ana Beatriz Oliveira

**Background.** Industrial production rate has been increasing due to the introduction of new technology, which leads towards more mechanized, rationalized and automated production processes. This is usually followed by lower physical exposure levels, but less opportunity for micropauses and variation during the workday — features assumed to be risk factors for developing musculoskeletal disorders. This study aims to investigate the physical workload during natural work in manual (ML) and semi-automated (SL) production lines.

**Methods.** 19 male workers from an automotive parts industry (SL = 10, ML = 9) had their wrist posture, movements and muscular load (goniometry and electromyography for forearm extensor muscles) bilaterally recorded. The same component (auto clutch disc – 1.2 kg) was assembled at both lines. Data were analyzed for the whole work (approximately seven hours) and presented as percentiles [APDF – mean (standard deviation)].

**Results.** Workers' characteristics were similar regarding age [ML – 30.2 (5.5); SL – 31.4 (8.5) – years], BMI [ML – 27.1 (3.3); SL – 24.7 (3.0) – kg/m<sup>2</sup>] and seniority [ML – 85.4 (43.6); SL – 80.5 (39.3) – months]. Wrist angles (°) and angular velocities (°/s) from both wrists were similar in the two production lines. However, workers from the SL spent less time with their hands still (% time < 1°/s) than workers from the ML [right wrist: SL – 1.5 (0.8); ML – 3.5 (2.4)]. The same pattern was observed for muscle rest (% time) [right forearm: SL – 3.1 (1.9); ML – 10.8 (7.6)]. Moreover, for the right forearm muscles, the load (% maximal capacity) was higher on the SL [50<sup>th</sup> percentile: 13.1 (4.9); 90<sup>th</sup> percentile: 31.5 (11.0)] than on the ML [50<sup>th</sup> percentile: 7.2 (5.3); 90<sup>th</sup> percentile: 18.3 (12.5)].

**Discussion.** The SL implied a higher muscular load and lower rest than the ML, which can be associated with an increased risk of musculoskeletal disorders in hands from working in the SL.

## Feasibility study of creating a harmonized approach for MSD hazard assessment and engineering tools

Amin Yazdani (presenter), Richard Wells

**Background.** The lack of common assessment tools could be a barrier for the integration of musculoskeletal disorder (MSD) prevention activities into a company-wide approach or management system. The main purpose of this study was to explore the possible integration of MSD hazard assessment tools into tools used to address other risks at an organizational level.

**Methods.** A comprehensive review of observational biomechanical assessment techniques (30 techniques) and risk analysis methodologies for industrial settings (62 methodologies) was conducted. In addition, a framework was used to categorize these techniques based on their common features. Then, using a content analysis approach, the possibility of integrating these techniques was systematically assessed to recommend opportunities for integration.

**Results.** The results of this study revealed that the integration of observational techniques for MSD hazard assessment into methodologies that are widely used by engineers and other stakeholders could be possible. This is more feasible for tools that have common features and use the same type of methodology, input data and output data. More specifically, this study suggests that failure mode, effects and critical analysis (FMECA) and the NIOSH equation for MSD risk assessment in manual materials handling could be used together beneficially for integrative risk assessment purposes.

**Discussion.** By reviewing both observational tools for MSD hazard identification and assessment and the wide range of hazard assessment tools used in organizations for other risk factors (including quality, health and safety, and engineering) integration was feasible in a few cases. Such integration could create the opportunity to use a harmonized approach to identify, assess and evaluate MSD hazards within management systems. However, other factors need to be taken into account to select an appropriate tool for integration, including ease of use, training, time commitment, technology required, cost, expertise required, prevalence and preference of use.



## Epidemiology of work-related MSDs

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SESSION 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 203B

## Epidemiological differences between localized and non-localized low-back pain

David Coggon, Karen Walker-Bone (presenter), Ntani Georgia

**Background.** Low-back pain (LBP) often occurs in association with pain at other anatomical sites, and has similar psychological and psychosocial risk factors, suggesting a shared underlying predisposition. It seemed possible that pain, which is confined entirely to the low back (localized LBP), might be epidemiologically distinct from that which is accompanied by pain elsewhere.

**Methods.** To test this hypothesis, we analyzed data from a cohort study of musculoskeletal pain and associated disability in 47 occupational groups from 18 countries (the CUPID study).

**Results.** Among 12,197 subjects at baseline, 609 (4.9%) reported localized LBP in the past month, and 3,820 (31.3%) reported non-localized LBP. Non-localized LBP was more frequently associated with sciatica in the past month (48.1% vs. 30.0% of cases), occurred on more days in the past month and past year, was more often disabling for everyday activities (64.1% vs. 47.3% of cases), and had more frequently led to medical consultation and sickness absence from work. It was also more often persistent when participants were followed up after a mean of 14 months (65.6% vs. 54.1% of cases). In adjusted Poisson regression analyses, non-localized LBP was differentially associated with female sex, older age, somatising tendency, poor mental health and report of time pressure at work. There were marked differences between occupational groups in the overall prevalence of LBP, and in their relative prevalence of localized and non-localized LBP.

**Discussion.** Large international variations in the prevalence of low-back pain appear to be driven by differences in general propensity to musculoskeletal pain rather than by factors specific to the spine. Future epidemiological studies should distinguish, where possible, between pain that is limited to the low back, and that which occurs in association with pain at other anatomical sites.

## Use of multiple data sources for surveillance of work-related chronic low-back pain and low-back spinal damage in a French region

Natacha Fouquet (presenter), Julie Bodin, Emilie Chazelle, Alexis Descatha, Yves Roquelaure

**Background.** The objective of this study was to compare the data of the French workers' compensation system and those of three monitoring networks to determine if it is possible to identify industry sectors and occupational categories at risk of chronic low-back pain (LBP).

**Methods.** This study compared four data sources: (1) French workers' compensation system (radiculalgia due to herniated disc caused by vibration or handling of materials); (2) surveillance of lumbar disc surgery (LDS) in the general population; (3) surveillance of musculoskeletal symptoms and their risk factors in the workplace (LBP and sciatica); and (4) surveillance of uncompensated work-related diseases (LBP and sciatica). People aged 20-59 were studied. The prevention index (PI) was used to rank industries and occupational categories according to the number of cases and the prevalence or incidence rate as in the SHARP program.

**Results.** Considering all data sources, manufacturing (for both genders), construction (for men) and health and social work activities (for women) ranked among the top sectors with respect to the PI. For men, skilled, blue-collar workers were found in the occupational categories that ranked first in the PI. For women, unskilled, industrial blue-collar workers, government employees and other workers in public services (including cleaners, caretakers, nurses' aides, personal care workers) ranked first in the PI. However, in examining the surveillance system for LDS in the general population, the first ranking occupational category in terms of the PI was personal services occupations dominated by women (including waitresses, nursery school assistants, child care workers and housekeepers). This result differed from other data sources that rely on occupational physicians' networks.

**Discussion.** This study showed coherence between all data sources. However, the workers' compensation system is not able to describe the phenomenon accurately. A surveillance network for the general population seems to be the appropriate method to more accurately assign work-related LBP or sciatica according to categories and sectors, especially for those not covered by the occupational health system.

## Are different mechanisms a potential reason for contrasting evidence on relationships between sedentary work and low-back symptoms?

Leon Straker (presenter), Pieter Coenen, Peter O'Sullivan, Genevieve Healy, David Dunstan

**Background.** Sedentary work is considered a risk factor for musculoskeletal symptoms, despite current evidence being inconclusive regarding the strength and direction of any relationship. The aim of the current paper was to examine the cross-sectional associations between sedentary work exposure and low-back musculoskeletal symptoms in the context of potential mechanisms.

**Methods.** Baseline data from a cluster RCT that aimed to reduce sitting at work<sup>1</sup> was used. Participants were desk-based office workers; those unable to sit/stand for 10 minutes were ineligible. Sedentary time was assessed by activPAL3 monitors (thigh worn; 24hr/day, 7-day protocol), with diaries kept for wake and work times. Low-back symptom presence was self-reported. Regression analyses, adjusted for potential confounders, assessed the bi-directional, non-linear association of workplace sedentary time and usual sedentary bout duration with low-back symptoms.

**Results.** Data from 216 (150 female) workers aged 45.4±9.3 years was available. Mean (SD) sitting time at work (standardized to an 8-hour work day) was 379.7 (44.4) minutes; mean usual sitting bout duration was 33.1 (14.9) minutes. 168 (68%) reported low-back symptoms. The odds of low-back symptoms were approximately half in those with high vs. low sitting time or usual sitting bout duration (tertile 3 vs. 1; OR 0.52, 95%CI 0.20 to 1.37; OR 0.55, 0.33 to 0.93 respectively). The mean sitting time and usual sitting bout duration of those with low-back symptoms with impact vs. those without symptoms were not different (383min, 95%CI 366 to 400 vs. 387min, 376 to 398; 33min, 27-39 vs 35min, 32 to 38 respectively).

**Discussion.** The contrasting relationships observed suggest that there are potentially a number of different and interacting mechanisms underlying the association between sitting and low-back symptoms. A better understanding of the mechanisms will help inform interventions to reduce work-related symptoms in office workers.

## Multidimensional factors associated with low-back pain in adolescence

Leon Straker (presenter), Darren Beales, Anne Smith, Peter O'Sullivan

**Background.** While low-back pain is traditionally considered an adult problem, it is now well established that, for most people, their initial episode occurs during adolescence. Given the importance of prior history in predicting future work-related, low-back pain, a more detailed understanding of the development of low-back pain over adolescence is important to assist with better prevention. Therefore, the aim of this study was to examine the multidimensional factors associated with the development of low-back pain in adolescence.

**Methods.** This longitudinal study used data gathered as part of the Raine Study ([www.rainestudy.org.au](http://www.rainestudy.org.au)). Mothers were recruited during pregnancy with offspring followed for 25 years. Data for the current study were collected around the time of the offsprings' 14<sup>th</sup> and 17<sup>th</sup> birthdays. Low-back pain with impact on health-care utilisation and daily life was assessed at 17 years of age; biological, psychological, social, lifestyle and other factors were assessed at 14 years of age. Binary logistic regression was used to examine the association of risk factors at 14 years of age with low-back pain and with impact at 17 years of age.

**Results.** 1,088 participants had data available at both 14 and 17 years of age. Low-back pain with at least two impacts was reported by 16%, with one or less impacts by 17% at 17 years of age (68% reported no low-back pain in the last month). Physical (body mass index, standing and sitting posture, muscle power, flexibility and aerobic capacity), psychological (self efficacy, somatic complaints, aggressive behaviour), social (carer back pain, life stress events, neighbourhood), and lifestyle (exercise) at 14 years of age predicted low-back pain with two or more impacts at 17 years of age.

**Discussion.** The multidimensional factors in early adolescence that predicted low-back pain in late adolescence highlights the importance of an early preventive approach that addresses multiple risk factors.

SESSION 3, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 203B

## Is there an exposure-response relationship between the NIOSH lifting index and low-back disorders?

Ming-Lun Lu (presenter), Vern Putz-Anderson

**Background.** The revised National Institute for Occupational Safety and Health (NIOSH) lifting equation (RNLE) is one of the most widely used job analysis methods for assessing the risk of low-back pain (LBP). The lifting index (LI) for single lifting task or the composite lifting index (CLI) for multiple lifting tasks is the product of the RNLE. The value of LI or CLI  $\leq 1.0$  is recommended as the guideline for safe manual lifting. Since the inception of the RNLE in 1991, there have been many epidemiological studies validating this recommended value in relation to LBP in the workplace. However, no systematic review of the epidemiological studies has been found.

**Methods.** A systematic review was conducted to summarize the state of the epidemiological work associated with the exposure-response relationship between the LI/CLI and LBP outcomes.

**Results.** The review identified 13 studies that investigated the LI/CLI with regard to various LBP outcomes. Different study designs (prospective,  $n=5$ ; cross-sectional,  $n=6$ ; retrospective,  $n=2$ ) were employed for the investigation. Most studies ( $n=11$ ) were carried out in the manufacturing and wholesale and retail trade sectors. The current state of the literature suggests an exposure-response relationship between the LI/CLI and LBP outcomes, particularly in the range from LI/CLI=1.0 to 3.0.

**Discussion.** The threshold of the LI/CLI for most LBP response is likely to fall within the range between 1.0 and 2.0. However, complete validation of the risk function of the LI/CLI variable and its relationship with different LBP outcomes remains elusive. Future studies are needed with a balanced distribution of physical and non-physical risk exposures to determine accurate and generalizable risk estimates.

## Low-back pain and potential work-related factors among home care aides

Chuan Sun (presenter), Laura Punnett, Margaret Quinn, Bryan Buchholz, Pia Markkanen, Catherine Galligan, Susan Sama, Rebecca Gore

**Background.** The home care aide workforce is often exposed to high physical workloads such as client handling and housework, tasks that might contribute to the development of low-back pain. The home is a unique work environment where the aides usually have no help. Often there are no assistive devices for client handling. The aim of this study was to investigate the associations between physical workload, work arrangements, home environment and low-back pain among home care aides.

**Methods.** Data from 1,249 aides with 3,484 recent client visits, collected from a self-administered cross-sectional survey, were analyzed. The analysis was performed at both the worker level and the client visit level. Dependent variables include client-handling related injuries, low-back pain and its characteristics expressed as the proportion affecting all aides. Independent variables include client visit characteristics that were summed up and expressed as proportions of all visits made in the previous week. Bivariate analysis and trend tests were performed to investigate the association between physical workload risk factors and the probability of having low-back pain symptoms in the past 12 months.

**Results.** About one-third of the aides had low-back pain in past year. Number of years working for current employer was positively associated with the probability of having low-back pain. Low-back pain was also associated with a higher number of client visits and with any client handling activities, all client visits involving direct care tasks, and always facing unfavourable home conditions during visits.

**Discussion.** Exposure to demanding physical workloads such as frequent client-handling activities, other direct-care activities, and unfavourable home conditions is associated with low-back pain for home care aides. Interventions that aim to reduce lifting and unfavourable home condition are worth pursuing.

## Association between neck pain and working postures among forklift operators

Charlotte Wåhlin (presenter), Ulf Flodin, Krapl Blerim, Håkan Löfgren, Fredrik Nyqvist, Bo Rolander

**Background.** There is conflicting evidence in the scientific literature concerning whether or not high exposure to strenuous working postures for the neck can be a cause of neck pain. The aim of this study was to analyse if there are associations between neck pain and working with extreme neck postures among forklift operators. Employees' needs for workplace adjustments were also analyzed.

**Methods.** A retrospective cohort study was conducted at a large warehouse in Sweden. All salaried employees, including warehouse staff and administration were eligible to participate. A questionnaire was sent to 429 employees with questions on demographic variables, neck pain, work conditions, work postures, work load, and the need for workplace adjustments. Risk factors for neck pain were calculated in a multivariate binominal regression model (risk ratios) with work exposure time from the start of first employment. Calculations with person years were performed in a Poisson regression model (incidence risk ratios).

**Results.** 94 employees responded to the questionnaire and 87 employees stated that they had suffered from neck pain (45%). Employees that operated forklifts were three times more likely to suffer from neck pain (RR=3.11;  $p<0.05$ ). Three ergonomically unnatural neck positions in work were associated with neck pain. Rotation (RR=2.52;  $p<0.01$ ), Lateral flexion (RR=2.12;  $p=0.001$ ) and Extension (RR=2.34;  $p=0.001$ ). Time of exposure was also essential and results suggest that first five years of exposure are the most critical for neck pain occurrence. Employees reported the need for several workplace interventions like adjustment of work tasks, schedule and new equipment.

**Discussion.** This study shows that there is an increased risk of neck pain among fork lift operators who work with unnatural neck positions; rotation, extension and lateral flexion. This study indicates a pressing need for ergonomic interventions and workplace adjustments in order to prevent work-related neck pain.

SESSION 4, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 204A

## Is coxarthrosis an occupational disease by law?

Bernd Hartmann (presenter), Karin Praefke

**Background.** Coxarthrosis is a degenerative musculoskeletal disease that occurs approximately in the last decade of working life and may limit the ability to work. The load-related causes are not clearly understood. On the basis of announcements of occupational diseases by doctors at the German Social Accident Insurance (DGUV), the situation shall be characterized.

**Methods.** From January 1, 2005 until December 31, 2011, 172 cases (157 men, 15 women) of suspected work-related coxarthroses were filed with the DGUV. The cases are organized according to the occupations and industries represented; figures from the agricultural sector are unknown.

**Results.** The mean age of cases was 48.4 years, where 100 were younger than 50 years, 17 (10%)  $\geq$  60 years old. Annual reporting indicates that the peak was in 2007 (with 36 cases), when osteoarthritis (OA) of the knee was included in the list of occupational diseases in Germany. Since then, reported incidences have steadily decreased. Information showing the possible relationships between coxarthrose and physical workload is indicated by the distribution of cases among the various sectors. The listed cases, by sector and in descending order of frequency, include: the construction industry (35%); the metal industry (18%); trade and administration (12%); mining (9%); and health services. By the numbers, the activities most often linked to coxarthrosis are bricklayers (17), workers in underground mining (11), tilers (9), drivers (8) and construction workers (7).

**Discussion.** The reported incidences show inconsistent associations between the coxarthrose and certain work-related stress. Professions and activities that feature high degrees of physical stress, kneeling and squatting are prominent. Age distribution differs significantly from the typical age of onset. These cases cannot be completely explained by longer work-related loads. There is no greater risk of work-related coxarthrose compared with gonarthrosis. Professions that require kneeling and squatting — and a strong flexed hip — likely present less of a risk of work-related coxarthrose compared to the risk of OA of the knee.

## Kneeling as occupational risk in the etiology of the knee osteoarthritis: secondary analysis of the Danish DWECS cohort study

Falk Liebers (presenter), Hermann Burr, Ute Latza

**Background.** Knee osteoarthritis is a common musculoskeletal disease with a high public health impact. Occupational risk factors, like kneeling at work, are considered as causally related. However, there is a lack of evidence from cohort studies regarding the dose-response relationships. The aim is to analyze the dose-response relationship between cumulative occupational kneeling and the risk of knee osteoarthritis using a population-based cohort study design.

**Methods.** The study is based on four waves of the Danish DWECS cohort study conducted in 1990, 1995, 2000 and 2005. The follow-up time of the dynamic cohort with linkage to national registers runs from 1991 to 2010. Employees aged 18 to 59 years are included (6,288 men; 6,494 women). Indicator events are primary cases of hospitalization due to knee osteoarthritis. Self-reported working hours of kneeling activities per week are considered as exposure. Hazard ratios (HR) with 95% confidence intervals (CI) based on multivariate Cox-regression are calculated using different models.

**Results.** Overall, 163,529 person years and 262 indicator events are observed. The HRs are elevated in the highest exposure categories in the prior-to-interpret model [kneeling 0 hours per week: HR 1 (reference); >0-2.5h/week: HR 0.80 CI 0.55-1.15; >2.5-5h/week: HR 1.13 CI 0.76-1.66; >5-10h/week: HR 1.43 CI 0.92-2.22; >10h/week: HR 2.28 CI 1.46-3.57]. This model is adjusted for age, gender, knee pain at entry, body-mass index, year of entry, occupational lifting, and occupational sitting. A further adjusted model shows a trend in the exposure-response relationship with a HR up to 2.7 in the highest exposure category.

**Discussion.** The open cohort study provides a dose-response relationship between occupational kneeling and incident knee osteoarthritis. Measures of prevention seem to be useful if knee-demanding work lasts at least 2.5 hours per week. Prevention measures are required if kneeling at work lasts longer than five to 10 hours per week.

## Non-traumatic upper extremity musculoskeletal pain, physical and psychosocial/organizational work exposures and psychological distress: a path analysis of mediated and moderated effects

Nektaria Nicolakakis (presenter), Susan Stock, Rex Kline

**Background.** The relationships between biomechanical and psychosocial/organizational work exposures, psychological distress and personal factors in work-related musculoskeletal disorder (MSD) aetiology remain largely uncharacterized. Stock and colleagues postulated that psychological distress mediates the association between work-related MSD and certain psychosocial/organizational work factors, and that some of these factors can moderate biomechanical exposures. Focusing on non-traumatic upper extremity musculoskeletal pain (UEMSP), we sought to test these hypotheses among Quebec workers.

**Methods.** Data was from the cross-sectional 2007-2008 Quebec Survey on Working and Employment Conditions and Occupational Health and Safety. Analyses were gender-stratified (1,289 men; 1,189 women). Given the many theoretically plausible and empirically-supported risk factors for work-related MSDs risk factors, we first used multivariable logistic regression with manual backward stepwise elimination to identify variables associated with UEMSP. We then evaluated hypothesized mediated and moderated associations using nested path models of UEMSP, and the likelihood ratio test for model selection.

**Results.** In men, high physical demands, emotionally demanding work, contradictory demands, low co-worker support, low job security and unemployment increased likelihood of UEMSP — both through direct and indirect effects mediated by psychological distress. The indirect effect of emotionally demanding work increased UEMSP odds by 25%. In women, duration of occupational computer use, lack of promotion prospects and means to do high-quality work, exposure to high physical and quantitative work demands, emotionally demanding work, noise, tense situations with clients and sexual harassment increased pain likelihood. For the latter six exposures, we hypothesized that effects were partially mediated by psychological distress, and confirmed a clinically important additional increase in odds of pain through these indirect effects for all exposures but physical demands. We also confirmed an interaction between high quantitative and physical demands.

**Conclusion.** Results highlight the complexity of the associations between work exposures and UEMSP, as well as gender differences, which, if confirmed in longitudinal studies, could guide UEMSP prevention.

## Demographic, clinical and work-related factors associated with return-to-work trajectories for musculoskeletal disorders

Eline Reiff, Ute Bultmann, Chris Mcleod (presenter)

**Background.** The purpose of this study was to investigate the association between key demographic, clinical and work characteristics and different types of return-to-work (RTW) trajectories for workers on sickness absence with a work-related musculoskeletal disorder (MSDs).

**Methods.** This study used administrative workers' compensation data to identify accepted time-loss MSD claims with an injury date between 2010-2012 in British Columbia, Canada. Using validated calendar measures of four RTW statuses (RTW, modified RTW, sickness absence and non-RTW), 2,132 unique RTW trajectories (i.e. the sequence of RTW statuses) spanning a one-year period were derived for a cohort of 81,677 claims. RTW trajectories were clustered using a set of decision rules that identified a shared trajectory structure. Poisson regression with robust standard errors was used to estimate risk ratios with 95% confidence intervals between the six main RTW trajectory clusters and demographic, clinical and work characteristics.

**Results.** Workers with back strains (reference category) were the most likely to have early sustained RTW trajectories, while workers with fractures or dislocations were consistently more likely to have longer durations of sickness absence (RR ranging between 4.9-10.2) or to have a non-RTW trajectory (RR ranging between 1.5-5.8). Older age (RR ranging between 1.6-4.5), small firm size (reference category), physically demanding occupations or industries (RR ranging between 1.3-3.6) were associated with delayed RTW, sickness absence and non-RTW trajectories. Being female (RR ranging between 1.2-1.3) or having a lower wage was associated with trajectories then ended in non-RTW.

**Discussion.** Using population-based data and RTW trajectories, this study provides an in-depth look at RTW as a process. The study found that a variety of demographic, clinical and work-related factors were associated with different types of RTW trajectories. Policy-makers and researchers can use these findings to focus interventions and research on groups at higher risk of non-RTW or complex RTW trajectories.

SESSION 5, MONDAY, JUNE 20, 3:30PM – 5:00PM, ROOM 203B

## Physical risk factors for the development of neck pain in office worker: a systematic review

Deokhoon Jun (presenter), Zoe Michaleff, Venerina Johnston, Shaun O'Leary

**Background.** Identification of factors associated with the development of work-related neck pain is necessary prior to the development of programs aimed at reducing this prevalent and costly health problem. To date, the majority of epidemiological studies have focussed on psychosocial factors associated with the development of work-related neck pain, mostly in office personnel. The aim of this systematic review was to identify individual (e.g. leisure activity) and workplace physical (e.g. ergonomics) factors associated with the development of non-specific neck pain in office workers.

**Methods.** Studies were identified by an electronic search of Pubmed, CINAHL, EMBASE, PsychInfo and Proquest databases. Two authors independently screened search results, extracted data, assessed risk of bias using the epidemiological appraisal instrument (EAI). Based on methodological quality assessment, the level of evidence for physical risk factors was assessed by defining five levels of evidence.

**Results.** 18 papers described the findings of the 10 prospective cohort studies and one prospective randomized control trial. No ergonomic factors were identified as risk factors due to a lack of evidence. Self-reported long duration of mouse use was found to be a predictor in the development of neck pain. Physical leisure activities did not show a cause-effect relationship with development of neck pain. Several physical factors such as non-adjusted chair, keyboard placement, and low task variation during work, were identified as related with the development of neck pain, but the findings were inconsistent.

**Discussion.** Inconsistencies in the literature for most physical factors is potentially due to a high dependency on self-report outcomes. Further prospective studies using valid objective measures are needed to improve our understanding of the association between physical factors and development of neck pain.

## Is work a risk factor for lumbosacral radicular syndrome? A systematic review and meta-analysis of clinical studies

Paul Kuijer (presenter), Jos Verbeek, Andreas Seidler, Carel Hulshof, Monique Frings-Dresen, Henk Van der Molen

**Background.** Lifting, whole body vibration and bending of the trunk are established work-related risk factors for non-specific, low-back pain. Knowledge of threshold limits for these risk factors enables prevention. However, for a specific cause of low-back pain, lumbosacral radicular syndrome (LRS), often referred to as lumbar herniated disc disease, no systematic review of work-related risk factors is present.

**Methods.** A systematic review was performed in PubMed and Embase until January 16, 2015 and registered by the international prospective register of systematic reviews with number CRD42015025763. Inclusion criteria were that LRS was diagnosed by a clinician and a risk estimate was reported for work-related characteristics. A quality assessment of evidence and a meta-analysis was performed.

**Results.** The search resulted in 5,015 studies, and 23 studies from 12 countries were included. The median number of participants per study was 200 (interquartile range 124-445). The following work-related characteristics were reported: job description, physically demanding work, and work-related activities like lifting and carrying, bending of the trunk, sitting, driving a vehicle/whole body vibration and kneeling. The meta-analysis revealed significant pooled ORs for heavy physically demanding work (OR 2.0, 95%CI 1.5-2.8), bending of the trunk (OR 2.4, 95%CI 1.7-3.6), and bending of the trunk combined with lifting and carrying (OR 3.2, 95%CI 1.5-5.6). No significant increased risk was found for driving a vehicle/whole body vibration, without lifting, carrying or bending of the trunk.

**Discussion.** Work is a risk factor for LRS and therefore should be addressed in the patient history to understand the etiology. When work-related risk factors are present, appropriate preventive measures can be selected. The assumption that exclusively driving a vehicle/whole body vibration is a risk factor for LRS was not supported by the pooled clinical data.

## Analysis of ergonomic risk factors in a seafood processing company

Deepak Sharan (presenter), Joshua Samuel Rajkumar, Jerrish A Jose, Rajarajeshwari Balakrishnan, Nimmu Roy

**Background.** The aim of this study was to estimate postural, positional risk factors and associated work-related musculoskeletal disorders (MSDs) among a group of workers in a seafood industry and to provide appropriate recommendations to prevent work-related MSDs. No studies are available reporting the results of an ergonomic workplace analysis (EWA) in the seafood processing industry.

**Methods.** A team of ergonomists conducted a prospective EWA in a multinational seafood company located in a developing country. Ergonomic risk factors considered to predispose workers to work-related MSDs were identified by an initial inspection of workstations. Task areas were visited and a detailed workplace assessment of the three tasks (unloading of raw material from the truck, batching and dumping raw material into a feeder, and packaging of the finished goods) was performed. Workstation information consisted of duration of work, intensity of work, breaks, working postures, working surface, weight of the object, force exertion, etc. Tasks were recorded in photographs and with video. Key Indicator Method (KIM), Rapid Entire Body Assessment (REBA), Revised NIOSH Lifting Equation (RNLE) and Rodgers Muscle Fatigue Analysis (RMFA) were used to identify risks in the respective tasks.

**Results.** Workers performing all three tasks were found to adopt hazardous postures and have improper work stations. All three tasks involved high risk of work-related MSD involving neck, back, knees, ankle, arm, elbow, hands and fingers. Some tasks involved most body parts on RMFA. Scores of REBA also showed a very high postural risk. Hazardous postures were also recorded among workers working at computer desks due to improper workstation setup.

**Discussion.** A high prevalence of ergonomic risk factors for work-related MSDs was reported among workers in the seafood industry based on the evaluation. Appropriate recommendations were given to help in the prevention of work-related MSDs.

## Ergonomic risk factors in an electrical equipment manufacturing company

Deepak Sharan (presenter), Joshua Samuel Rajkumar, Jerrish A. Jose, Rajarajeshwari Balakrishnan, Nimmu Roy, Amruta Kulkarni

**Background.** Work-related musculoskeletal disorders (MSDs) are common in workers in the manufacturing sector. However, few studies have investigated the risk factors for the development of work-related MSDs in electrical equipment manufacturing companies. The aim of this study was to identify the ergonomic risk factors among a group of workers in an electrical equipment manufacturing company.

**Methods.** A team of ergonomists conducted a prospective ergonomic workplace analysis (EWA) at four locations of an electrical equipment manufacturing company. The selected locations were in the south (2) and in the west (2) of a developing country. At each location, experts identified tasks that might predispose workers to work-related MSD. The selected tasks varied in different locations with 17 tasks in South Zone A, nine tasks in South Zone B for LPCP, one task in West Zone A for panel testing and five tasks in West Zone B for intelligent electronic device manufacturing. Borg RPE scale (BRPE), RULA, REBA and Rodgers Muscle Fatigue Analysis (RMFA) were used to identify the risk.

**Results.** All the evaluated tasks involved high risk of work-related MSD involving neck, back, knees, ankle, arm, elbow, hands and fingers. Some tasks involved most body parts on RMFA in all the four zones. Postural and movement risk analysis using RULA and REBA in South Zone A had mean scores of 7 and 13, respectively. South Zone B had mean scores for REBA and BRPE of 11 and 13, respectively. West Zone A had mean scores = for REBA and BRPE of 13 and 11, respectively.

**Discussion.** Based on the evaluation, a high prevalence of ergonomic risk factors for work-related MSDs was reported among workers at this electrical equipment manufacturing company.

SESSION 6, TUESDAY, JUNE 21, 10:30AM – 12:00PM, ROOM 204A

## Diagnosis of work-related lumbar disc diseases: results from a case list of a public occupational health clinic

Angela Carta (presenter), Michela Crippa, Barbara Bellina, Stefano Porru

**Background.** Occupational risk factors are relevant in the etiology of lumbar disc diseases (LDD). Our aim was to analyze an eight-year case list and to elaborate on etiological diagnosis assessments.

**Methods.** Over the period 2007-2014, LDD cases attended the occupational health clinic of a public general hospital located in a very industrialized Italian area. A detailed clinical report was available, including lifetime occupational and clinical history, imaging and instrumental assessments. All clinical diagnoses were formulated after imaging. Risk assessment information was collected from various sources, whenever possible. Attribution to occupation was based on occupational history, risk assessment, objective clinical data and scientific literature.

**Results.** 574 LDD were assessed, representing about 28% of all cases attending the clinic over 2007-2014. 91% (n=528) were sent by general practitioners; 64% were male, 19% were immigrants. Mean age of all cases was 48 years (20-74); mean total job length was 28 years (3-55); mean job length with biomechanical overload was 15 years (1-55). 28% cases had usable risk assessment data. L4-L5 was the most affected disc (n=464), followed by L5-S1 (n= 414); 15% had had surgery, 7% multiple surgeries. 63% LDD were attributed to occupation: manual material handling (79%), patient handling (21%), whole body vibration (19%) and posture (14%) were the major risk factors. Overall, extra-occupational factors for LDD were not relevant.

**Discussion.** A relevant number of cases satisfied criteria of etiological attribution to occupation. However, occupational LDD cases were probably underestimated, considering LDD cases expected to arise from such an industrialized area. Underestimation of occupational LDD could be reduced referring possible cases to occupational health clinics. LDD related disability and relevant role of biomechanical risk factors should be taken into account to implement preventive strategies in workplaces. Further studies should be oriented to improve preventive strategies based on reliable and accurate risk assessment data.

## Prognosis after surgery for subacromial impingement syndrome: negative influence of high preoperative occupational shoulder exposures

Susanne Wulff Svendsen (presenter), Annett Dalbøge, Johan Hviid Andersen, Poul Frost

**Background.** In Denmark, one to two per 1,000 persons of working age undergo first-time surgery for subacromial impingement syndrome (SIS) each year. This study evaluated the hypothesis that high pre-operative occupational shoulder exposures have a negative influence on post-operative prognosis.

**Methods.** We conducted a follow-up study of 3,000 persons who were randomly selected from among persons who had first-time surgery for SIS 2007-2008. The study group was born in Denmark 1933-1977 and had what amounted to  $\geq 5$  years of full-time employment since 1993. In 2010-2011, we collected questionnaire information on job history, job strain, body mass index, smoking, pre-operative physical activity, comorbidity and outcome scores. To obtain individual estimates of shoulder load accrued over 10 years until one year before surgery, we combined job histories with a job exposure matrix based on expert ratings of force, upper arm elevation  $>90^\circ$  and repetitive shoulder movements. We trichotomized the cumulative shoulder load estimates, dichotomised the outcome scores, and used multivariable logistic regression analysis to calculate adjusted odds ratios ( $OR_{adj}$ ) with 95% confidence intervals (CI).

**Results.** 1,873 persons responded (62%), of whom 53% were women; mean age 54 years (SD 8.1). 28% were categorized with an Oxford Shoulder Score  $<35$  (range 0 (worst) to 48), 41% with a Work Ability Score  $<6$  (range 0 (worst) to 10), and 25% with no change or worsening of Patients' Global Impression of Change ( $>3$ ; range 1 (much improved) to 7 (much worse)). A high cumulative shoulder load was associated with a low Oxford Shoulder Score:  $OR_{adj}$  1.74 (95% CI 1.27-2.38), a low Work Ability Score:  $OR_{adj}$  2.12 (95% CI 1.57-2.86), and no change or worsening of Patients' Global Impression of Change:  $OR_{adj}$  2.21 (95% CI 1.60-3.04).

**Discussion.** These preliminary results corroborated our hypothesis that high preoperative occupational shoulder exposures have a negative influence on postoperative prognosis.

## The content validity of the Work-Related Questionnaire for Upper extremity disorders (WORQ-UP)

Bas Aerts, Paul Kuijer, Annechien Beumer, Denise Eygendaal, Monique Frings-Dresen (presenter)

**Background.** Upper extremity musculoskeletal disorders are responsible for limitations in work and form a reason for a large part of the working population to report sick from work. Currently, there is a lack of attention to the factor of work in daily orthopaedic practice. It is important to identify work-related limitations that patients experience in order to apply appropriate interventions in order to enhance or support work participation. The aim of this study is to develop a patient-reported outcome measure (PROM) specific for work-related limitations due to upper extremity musculoskeletal disorders and to assess its content validity.

**Methods.** The first version of the questionnaire was developed following the evaluation of existing PROMs and consensus within the research team. The content validity was assessed in three steps: (1) interviews with patients (n=14) from the target population were held to discuss the clarity and possible adaptation of the items; (2) 48 experts from the field were approached to participate in an interview to discuss the clarity, relevance and missing items; and (3) patients (n=12) were interviewed to discuss the final version.

**Results.** The first version of the Work-Related Questionnaire for Upper extremity disorders (WORQ-UP) consisted of 18 items based on the criteria: exertion, dexterity, handling tools and equipment, and mobility. Patients indicated that most of the items (44%) were not easy enough to understand. 21 experts participated in the interviews (physiotherapists, insurance physicians, occupational health physicians, rehabilitation physicians and orthopaedic surgeons) and adaptations were made: items or examples were added, and items were deleted. The final version of the WORQ-UP consisted of 17 items. Patients reported all items as being easy to understand (100%).

**Discussion.** A PROM specific to work-related limitations in patients with upper extremity musculoskeletal disorders was developed. The content includes four categories: exertion, dexterity, handling tools and equipment and mobility. According to patients and experts, it has sufficient content validity.

## Long-term prolonged standing: the silent risk factor for lower extremity health outcomes

Susan Kotowski, Kermit Davis (presenter), Kari Dunning, Amit Bhattacharya

**Background.** In many manufacturing facilities, standing continually in one place while working on the product or task is commonplace. However, prolonged standing has the potential to have a negative impact on workers, although it is not routinely identified as a serious risk factor in most industrial settings. The study objective was to quantify the impact of cumulative prolonged standing on the health outcomes of seasoned workers.

**Methods.** 637 workers (100% male) at a medium/heavy duty truck manufacturing facility completed a survey that inquired about demographics, employment history, medical history and standing and walking exposure. The average age of the workers was 57.3 years, with 35.3 years of experience and exposure to prolonged standing.

**Results.** A total of 29% of workers reported standing without walking at least 50% of the time, with 37% of those individuals reporting standing without walking more than 75% of the time. More cumulative exposure to standing without walking (less than 50% vs. more than 50%) was found to be related to many adverse health effects: swelling in legs (7% increase), pain in calf (12% increase), fatigue in legs (14% increase), pain in hips (8% increase), pain in the legs (7% increase), and herniated disc (6% increase).

**Discussion.** The study was a unique opportunity to evaluate a large cohort that was employed at a company for many years (63% had more than 35 years of experience at the facility). Overall, prolonged standing appears to be correlated to adverse health outcome in the lower extremities. Other, more critical outcomes such as osteoarthritis and vascular issues in the legs had an increasing, but not significant, trend with increased prolonged standing. The findings show that prolonged standing should be considered a potential risk factor for lower extremity musculoskeletal issues, although further research is necessary to determine the injury mechanism.

SESSION 7, TUESDAY, JUNE 21, 1:30PM – 3:00PM, ROOM 204A

## Physical work demands and risk of long-term sickness absence in the general working population and among blue-collar workers: Prospective cohort study

Lars Andersen (presenter), Nils Fallentin, Sannie V. Thorsen, Andreas Holtermann

**Background.** Although the physical work environment has improved substantially, preventing work-related musculoskeletal disorders and sickness absence remain a challenge in the 21<sup>st</sup> century. This study determines the prospective association between physical demands at work and long-term sickness absence (LTSA).

**Methods.** Using cox-regression analyses, we estimated the risk of register-based incident LTSA (+3 consecutive weeks) from self-reported physical demands among 11,908 wage earners from the general working population (Danish Work Environment Cohort Study year 2000 and 2005).

**Results.** Incident LTSA was 8.9% during follow up. Spending 25% or more of the total work time with a bended or twisted back (HR 1.59 [95%CI 1.39-1.83]), arms above shoulder height (HR 1.35 [95%CI 1.14-1.59]), squatting or kneeling (HR 1.30 [95%CI 1.09-1.54]), pushing/pulling or lifting/carrying (HR 1.40 [95%CI 1.22-1.62]), and standing in the same place for 50% or more of total work time (HR 1.19 [95%CI 1.00-1.42]), were risk factors for LTSA when adjusted for age, gender, psychosocial work environment, lifestyle, musculoskeletal and mental disorders and socioeconomic status. HRs increased from 1.25 [95%CI 1.04-1.51] for one to 1.94 [95%CI 1.56-2.41] for four physical demands. Results largely remained stable in subgroup analyses including only blue-collar workers (n=5,055). Population attributable risks were 23% and 40% in the general working population and among blue-collar workers respectively.

**Discussion.** Several of the investigated physical work demands were risk factors for long-term sickness absence when exceeding 25% of the work time. A higher number of combined physical demands were associated with progressively increased risk. Our study underscores the importance of physical work demands as risk factors for LTSA in the general working population as well as among blue-collar workers.

## Work-related musculoskeletal disorders in the U.S. construction industry, 1992-2013

Xiuwen Sue Dong (presenter), Xuanwen Wang, Julie Largay

**Background.** Work-related musculoskeletal disorders (MSDs) are commonly associated with the workplace. This study examines trends and patterns of work-related MSDs among construction workers in the U.S.

**Methods.** Work-related MSDs were identified from the 1992-2013 Survey of Occupational Injuries and Illnesses – a survey conducted by the U.S. Bureau of Labor Statistics. Risk of Work-related MSDs was measured by number of work-related MSDs per 10,000 full-time equivalent workers (FTEs). FTEs were calculated from the Current Population Survey. The risk of work-related MSDs was stratified by major demographic and employment sub-groups. Time series analysis was performed to examine the trend of work-related MSDs in construction over time.

**Results.** From 1992 to 2013, work-related MSDs accounted for 27% of injuries involving days away from work in construction. Following the overall injury trends, the number of work-related MSDs dropped by 65% from 1992 to 2010, but increased 16% between 2010 and 2013. In 2013, the rate of work-related MSDs in construction was 25% higher than in all industries combined. Within construction, plumbing, heating and air conditioning contractors had a higher rate of work-related MSDs than other subsectors over time. Among occupations, helpers, heating and air conditioning mechanics, and cement masons had the highest rates of work-related MSDs. Construction workers aged 35-44 had a higher risk than average, but the work-related MSDs shared by those aged 55 and older increased from 2.8% in 2003 to 13.3% in 2013, corresponding to the increasing proportion of workers in this age group during this time period. The rate of work-related MSDs for Hispanic construction workers was significantly lower than their white, non-Hispanic counterparts, suggesting injury underreporting among Hispanic workers. In addition, 43% of work-related MSDs in construction were back injuries.

**Discussion.** Construction workers continue to face a higher risk of work-related MSDs. Ergonomic solutions that reduce overexertion—the primary exposure for work-related MSDs, should be adopted extensively on construction sites, particularly for workers with a higher risk of work-related MSDs.

## Evaluation of ergonomic risk factors in an interconnector manufacturing company

Deepak Sharan (presenter), Joshua Samuel Rajkumar, Jerrish A Jose, Rajarajeshwari Balakrishnan, Nimmu Roy

**Background.** Workers in the manufacturing sector are highly predisposed to work-related musculoskeletal disorders (MSDs). An on-site ergonomic workplace analysis (EWA) was conducted on the premises of a company that manufactures electronic, electrical and fibre optic interconnectors to switches and application tooling. The aim of this study was to find out the postural and movement risk factors for work-related MSDs among a group of workers in an interconnector product manufacturing company.

**Methods.** A team of ergonomists conducted a prospective EWA at an interconnector product manufacturing factory in a developing country. Initially there was a floor-by-floor visit by the experts to identify tasks that might be considered to predispose workers to work-related MSD. A total of 33 tasks that had risks related to posture, movement and improper workstation were selected for further detailed evaluation. Workstation information was gathered from employees involved in each task with respect to duration of work, breaks, frequency, sub tasks, work station set up, etc. Borg RPE scale (BRPE), Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA) and Rodgers Muscle Fatigue Analysis (RMFA) were used to identify the risk factors.

**Results.** All the 33 tasks involved high risk of work-related MSD involving neck, back, knee, ankle, arm, elbow, hands and fingers and some task involving most body parts on RMFA. Scores of REBA and RULA has mean value of 6-7 and 10-11 for all tasks respectively which suggested the presence of high to very high postural risks. BRPE showed a mean value of 15 which suggested that the tasks were very hard to perform.

**Discussion.** A high prevalence of ergonomic risk factors for work-related MSD was reported among workers in an interconnector product manufacturing company. The recommendations include frequent stretch breaks, task modification, workstation modification, job rotation and frequent breaks during working hours.

## Declining incidence of work-related musculoskeletal disorders in Ontario, 2004-2011

Cameron Mustard (presenter), Andrea Chambers, Selahadin Ibrahim, Jacob Etches, Peter Smith

**Background.** In the developed economies, there has been intermittent surveillance of work-related musculoskeletal disorders (MSD). These disorders are the leading cause of work disability, representing economic costs of \$500 million per million workers. The objective of this study was to describe trends in the incidence of musculoskeletal disorders attributed to work exposures in Ontario over the period 2004-2011.

**Methods.** An observational study of work-related morbidity obtained from three independent sources for a complete population of approximately six million occupationally-active adults aged 15-64 in the largest Canadian province. We implemented a conceptually-concordant case definition for work-related non-traumatic musculoskeletal disorders in three population-based data sources: emergency department encounter records, lost-time workers' compensation claims, and representative samples of Ontario workers participating in consecutive waves of a national health interview survey.

**Results.** Over the eight-year observation period, the annual percent change (APC) in the incidence of work-related MSDs was -2.3% in emergency departments' administrative records, -6.8% in lost-time workers' compensation claims and -4.6% among participants in the national health interview survey. Corresponding APC measures for work-related disorders due to traumatic causes and occupational illness were -4.3%, -5.6% and -5.0% respectively. Incidence rate declines were substantial in the economic recession following the 2008 global financial crisis.

**Discussion.** The three independent population-based data sources used in this study documented an important reduction in the incidence of work-related morbidity attributed to non-traumatic musculoskeletal disorders. The results of this study are consistent with an interpretation that the burden of non-traumatic musculoskeletal disorders arising from work exposures is declining among working-age adults.

SESSION 8, TUESDAY, JUNE 21, 3:30 – 5:00PM, ROOM 204A

## Long-term symptomatic, functional and work outcomes of CTS among carpenters

Alfred Franzblau (presenter), Bradley Evanoff, Bethany T. Gardner, Jaime R. Strickland, Skye Buckner-Petty, Ann Marie Dale

**Background.** The aim of this study was to describe the long-term natural history of carpal tunnel syndrome (CTS) among carpenters.

**Methods.** We used health insurance claims data from a carpenters' union insurance fund to identify active workers with a claim for CTS from 2003-2010, and we age-matched control workers without a CTS claim. We collected administrative data on work hours from union payroll records and conducted structured telephone interviews with cases and controls to assess symptoms, hand function, work ability, and hours worked.

**Results.** We interviewed 234 workers with CTS claims and 249 matched controls from two to nine years following the index CTS claim (mean of five years). Workers with a past medical claim for CTS were more likely to report recurring hand symptoms in the past year (OR 2.24, 95% CI 1.54- 3.24), decreased production or quality of work performed (OR 2.37\*, 95% CI 1.52- 3.68), decreased ability to perform physical demands of work (OR 1.59\*, 95% CI 1.13-2.24), and decreased functional status of the upper extremity as measured by the Levine Functional Status Scale and by the *QuickDASH* Work and Hobby Modules. (\*=OR expressed as one point decrease in measurement scales.) Workers who underwent surgery showed significantly larger improvements on multiple outcomes. Workers with CTS claims worked fewer hours following the claim.

**Discussion.** Claims for CTS outside of the workers' compensation system were associated with long-term increased hand symptoms, decreased functional status and decreased work hours. Among carpenters who were diagnosed with CTS, those who had surgery appear to have had better outcomes than those who did not. Overall, the findings suggest that available national data underreport the morbidity, costs and disability consequences of work-related chronic MSDs such as CTS.

## Musculoskeletal disorders and total occupational exposure in commercial lobstering

Scott Fulmer (presenter), Bryan Buchholz, Paul Jenkins, Melissa Scribani

**Background.** The main objective of this study was to collect data for estimating the denominator or full-time equivalent (FTE) for calculating the rates of morbidity and mortality in the American Lobster harvesting industry in the United States. Secondary objectives were to calculate incidence densities for acute injuries and to report on prevalence of non-acute injuries within this population. This is the first study to estimate these rates for this industry.

**Methods.** A randomly selected cohort of lobstermen licensed to fish in Maine and Massachusetts was followed prospectively. Data on work exposure and acute injuries that occurred on the boat were collected using a survey administered quarterly via phone interview with the captain. This survey assessed parameters of total occupational exposure and relevant data on acute injuries. A second questionnaire, based on the Nordic Musculoskeletal Questionnaire, assessed pain having non-specific or non-acute onset. It was administered in-person with the captain and crew.

**Results.** A total of 395 individuals participated from 287 boats. The average annual FTE calculated for the lobstermen (2,453 days) is higher than all American fisheries except Alaskan salmon (3,429 days). As expected, the summer months had the highest FTE and the winter the lowest FTE. The incidence density for all injuries (49.7/100 FTE) and for injuries requiring treatment (15.0/100 FTE) was much higher than reported in other commercial fisheries and higher than general industries reported to the U.S. Occupational Safety and Health Administration (OSHA). Half of respondents reported low-back pain. Low-back pain was prevalent and attributed to or exacerbated by lobstering. Sternmen reported more hand/wrist pain than captains. Multiple locations for pain were common in individual subjects.

**Discussion.** Equipment to assist material handling ought to be a priority for intervention, as the body segments with high prevalence of pain (back, hand/wrists, shoulders, knees) are all affected by the repetitive and forceful handling of the lobster traps.

## Neck and upper extremity pain in sonographers: associations with occupational factors

Jenny Gremark-Simonsen (presenter), Anna Axmon, Catarina Nordander, Inger Arvidsson

**Background.** Biomedical scientists working as sonographers have a high risk of musculo-skeletal disorders. The scanning involves static postures and exact motions.

The aims of this study were (1) to explore associations between physical and psychosocial working conditions, and pain in the neck and upper extremities, and (2) to develop recommendations for improved working conditions for sonographers.

**Methods.** Sonographers in clinical physiology and cardiology departments in hospitals throughout Sweden were included in this cross-sectional study.

A questionnaire on personal, physical and psychosocial factors and general working conditions was answered by 291 female sonographers. The echocardiographers also answered a detailed questionnaire about working techniques. Outcome measures were pain in neck/shoulders and elbows/hands based on frequency and intensity of complaints during the past year. Poisson regression was used to assess associations on neck/shoulder and elbow/hand pain. Prevalence ratios (PR) were calculated and adjusted for possible confounders, i.e. personal factors that showed associations with p-values  $\leq 0.20$ .

**Results.** A high seniority in sonography, physical factors i.e. a higher score in Mechanical Exposure Index (MEI) and dissatisfaction with the computer work station were associated with *pain* in the neck/shoulders, as were high job demands and high sensory demands. The possibility to adjust keyboard and chair were protective factors. To perform echocardiography, a high MEI, eye complaints and high job demands and sensory demands were associated with *pain* in the elbows/hands. A moderately high transducer time and a transducer grip with the wrist bent backwards were associated with elbow/hand pain in the echocardiographers. However, a two-handed grip was protective.

**Discussion.** Improved working conditions, optimal visual conditions and health screening for early detection and prevention of pain related to the working environment are recommended. Also, other techniques for handling the transducer in echocardiography should be developed in light of the prevalence of hand pain in this group.

## Exposure–response relationships for work-related neck and shoulder musculoskeletal disorders: an analysis of pooled, uniform data sets

Gert Hansson, Catarina Nordander, Kerstina Ohlsson, Inger Arvidsson (presenter), Istvan Balogh, Ralf Rittner, Staffan Skerfving

**Background.** There is a lack of quantitative data regarding exposure-response relationships between occupational risk factors and musculoskeletal disorders in the neck and shoulders. We explore such relationships in pooled data from a series of our cross-sectional studies.

**Methods.** The prevalence of complaints/discomfort (Nordic Questionnaire) and diagnoses (physical examination) were recorded in 33 groups (24 female and nine male) within which the subjects had similar work tasks (3,141 subjects, of which 817 were males). Postures and velocities of the head (n=299) and right upper arm (inclinometry; n=306), right wrist postures and velocities (electrogoniometry; n=499), and muscular activity in the right trapezius muscle (n=431) and forearm extensors (n=206) were recorded in representative sub-groups (electromyography). The psychosocial work environment was also assessed (Job Content Questionnaire).

**Results.** Uni- and multivariate linear meta-regression analysis revealed several statistically significant group-wise associations. Neck disorders were associated with head inclination, upper arm elevation, muscle activity of the trapezius and forearm extensors and wrist posture and angular velocity. Right-side shoulder disorders were associated with head and upper arm velocity, activity in the trapezius and forearm extensor muscles and wrist posture and angular velocity. The psychosocial work environment (low job control, job strain and isostrain) was also associated with disorders. Women exhibited a higher prevalence of complaints and diagnoses than men in the same occupation, who were subject to the same physical and psychosocial exposures.

**Discussion.** In conclusion, quantitative exposure-response relationships were found between neck and shoulder disorders and objective measures of the physical workload on the arm. Such information can be used for risk assessment in different occupations/work tasks, to establish quantitative exposure limits, and for the evaluation of preventive measures.

## Association between sitting time at work and favorable changes in neck-shoulder pain among blue-collar workers

David Hallman, Marina Heiden, Nidhi Gupta, Mette Korshøj, Svend Erik Mathiassen, Marie Birk Jørgensen, Andreas Holtermann (presenter)

**Background.** Previous studies suggest that prolonged sitting at work is a risk-factor for neck-shoulder pain (NSP). However, a majority of studies on the association between occupational sitting and NSP have relied on cross-sectional designs and self-reported measurements of sitting time. Our aim was to determine the extent to which occupational sitting time, assessed using accelerometry, is associated with the 1-year time course of NSP intensity among blue-collar workers.

**Methods.** Our study included 494 Danish workers (female n=220) from three occupational sectors: cleaning (n=96), manufacturing (n=356) and transportation (n=42). At baseline, sitting was monitored continuously for several working days (mean (SD) wear time: 2.6 (0.9) days) using accelerometers attached to the thigh and trunk. During the following 12 months, data on self-reported NSP intensity (NRS scale, range 0-10) were collected on a monthly basis using SMS tracking. Repeated measures ANOVA adjusted for gender, occupational sector, seniority, and pain at baseline was used to examine the association between per cent time spent sitting (at work and leisure) and changes in NSP across time.

**Results.** We found a significant interaction between occupational sitting at baseline and the time course of NSP ( $F(11,491)=6.37$ ,  $p=0.01$ ), which remained significant with adjustment for covariates ( $F(11,464)=6.64$ ,  $p=0.01$ ). We found no main effect of occupational sitting on NSP ( $p>0.05$ ). Categorizing sitting time revealed that more sitting at work was accompanied by larger reductions in NSP over time. The effect of time on NSP was stronger in the high sitting group ( $F(11,162)=30.4$ ,  $p<0.0001$ ) than in the low ( $F(11,162)=4.9$ ,  $p=0.05$ ) and moderate ( $F(11,167)=5.10$ ,  $p=0.02$ ) sitting groups. We found no association between leisure-time sitting and NSP ( $p>0.05$ ).

**Discussion.** In contrast to previous studies, our results indicate that prolonged sitting is associated with a favourable prognosis of NSP across one year in workers. The clinical significance of this result needs to be examined further.

SESSION 9, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 204A

## Musculoskeletal symptoms and physical exposures of dental hygiene students during transition into practice: a two-year prospective cohort study

Jennifer Garza (presenter), Jeff Dussetschleger, Martin Cherniack

**Background.** There is a high prevalence of musculoskeletal symptoms among dental hygienists. Dental hygienists experience high physical exposures when performing dental work, which may affect their development of musculoskeletal symptoms. Experiences of dental-work related physical exposures may begin while students are training to be dental hygienists. The objective of this study was to characterize musculoskeletal symptoms and physical exposures of dental hygiene students during dental hygiene school and after transitioning into practice.

**Methods.** A questionnaire was distributed to dental hygiene students who were verbally recruited by faculty at three dental hygiene schools in Connecticut during their clinical year of dental hygiene school (Time 1) and again after graduation approximately two years later (Time 2). The prevalence and incidence of neck, shoulder, elbow, forearm, and back pain symptoms, as well as frequency of dental-work related neck, arm, forearm and repetition physical exposures were assessed.

**Results.** 66 dental hygiene students participated in the study at Time 1, and 29 participated at Time 2. 43%, 17%, 9% and 38% of participants reported neck, shoulder, forearm and lower back symptoms at Time 1, and 72%, 28%, 45%, and 66% reported these symptoms at Time 2. 48%, 24% and 38% of participants reported incident neck, shoulder and forearm pain in the past two years. At Time 1, 87%, 45%, 82% and 84% of participants reported experiencing high neck, arm, forearm and repetition exposures often or very often, and at Time 2, 97%, 67%, 85% and 94% reported experiencing these exposures often or very often.

**Discussion.** Many dental hygienists develop musculoskeletal symptoms early in their career. The high and increasing physical exposures that dental hygienist students experience during school and after transitioning to practice may contribute to the high prevalence and incidence of musculoskeletal symptoms observed among dental hygienists.

## Musculoskeletal disorders in physical and occupational therapists in long-term care work

Rajashree Kotejoshyer, Laura Punnett (presenter),  
Alicia Kurowski, Bryan Buchholz, Gerard Dybel

**Background.** Performing patient handling is associated with low-back and shoulder symptoms among nurses. Physical and occupational therapists perform similar tasks, but therapists typically avoid using patient lift equipment as it may compromise functional independence among patients. The aim of this study is to compare the frequency and cost of musculoskeletal disorders (MSDs) and their risk factors between therapists and other nursing home employees.

**Methods.** We used cross-sectional survey data of workers from 18 nursing homes to compare therapists, nurses, nursing aides, and other workers on musculoskeletal health, lifting equipment use, and physical and psychological job demands. Workers' compensation claims (WCC) data for years 2012-2013 were used to compute injury rates by body region, nature and cause of injury, and costs per full-time equivalent (FTE).

**Results.** Nursing aides and therapists reported the highest prevalence of low-back pain (LBP) (both 48%) and shoulder symptoms (about 30%). LBP was "mild" with a chronic onset in therapists, and "severe/extreme" pain with more recent onset in nursing aides. About half of therapists reported "never/rarely" using patient lift equipment. Physical demands were rated highest by therapists — nearly twice as high as office workers (the lowest scores). Perceived psychological demands were highest among nurses and therapists. WCC back injury rates were similar in therapists and nurses, while only one-third of the rate in nursing aides. Upper extremity claims rates were highest in each job group except therapists, who reported having high back injury claims. Total cost (medical and indemnity) towards musculoskeletal injury was highest among nursing aides, housekeeping/maintenance/dietary, and therapists. Ergonomic injury-related costs were highest among therapists and technicians.

**Discussion.** Rehabilitation jobs have MSD frequencies high enough to deserve more attention. A comprehensive, safe patient-handling program should address the particular needs and clinical goals of therapists, and should include ergonomic analysis of their work.

## Lower extremity symptom persistence and recovery of nursing home workers

Alicia Kurowski (presenter), Laura Punnett

**Background.** Work-related, low-back pain of health-care workers has been widely reported on, but less attention has been paid to symptoms of the lower extremity (LE). This study aims to characterize self-reported knee and ankle pain symptoms of nursing home workers and examine symptom persistence and recovery.

**Methods.** Surveys on general health, health behaviours, and physical and psychosocial working conditions were distributed to employees at 24 nursing homes (2012-2013). Follow-up surveys were distributed two years later. Knee and ankle symptoms in the past three months were examined, and for participants in both surveys, pain persistence, recovery, and incidence of new pain were examined.

**Results.** Of the 2,465 participants at baseline, 22% reported knee symptoms and 20% reported ankle symptoms in the previous three months. There were 1,242 workers who participated in both surveys. Of the 297 who reported knee pain symptoms at baseline, symptoms persisted for 54%. Of the knee pain-free individuals at baseline, 16% developed knee symptoms at follow up. Of the 251 individuals reporting ankle pain symptoms at baseline, symptoms persisted for 41%. 13 % of pain-free individuals at baseline reported ankle symptoms at follow-up. A larger percentage of those with persistent knee and ankle pain reported higher than average physical exertion at baseline. Additionally, new reports of knee and ankle pain at follow-up were slightly more likely to have reported higher than average physical exertion at baseline.

**Discussion.** About one-fifth of nursing home workers in this study reported knee and ankle pain. Among clinical staff, safe handling equipment may help to address some LE exposures, but interventions to address other tasks and reduce exposures to the LE are crucial. Non-clinical jobs such as housekeepers and dietary staff also have high work exposures, and it is important to include these workers when considering interventions.

## Relationship between social support and upper limb pain in employed and self-employed health-care therapists in Ireland

Dervla Hogan (presenter), Sheilah Nolan, Leonard O'Sullivan, Birgit Greiner

**Background.** Within the current literature, self-employed workers appear to be more at risk of suffering work-related musculoskeletal disorders (MSDs) compared to their employed counterparts. High levels of work-related social support can compensate for work-related strain which workers have to contend with. It is hypothesised that self-employed workers suffer low work-related social support and are, therefore, more susceptible to upper limb (UL) pain. The main objective of this study was to estimate the adjusted odds of developing work-related UL pain based on exposure to work-related social support among both employed and self-employed therapists in Ireland.

**Methods.** The HITS study was a cross sectional study investigating work-related MSDs in chartered physiotherapists and physical/athletic therapists in Ireland (n=347). The social support scales (supervisory and peer support) of the Copenhagen Psychosocial Questionnaire (COPSOQ) were used for employed therapists and modified to allow for use by self-employed therapists. The questions on 12-month prevalence of UL pain were part of the Nordic Questionnaire on MSDs.

**Results.** Self-employed therapists have a significantly higher prevalence of UL pain (86.4%) compared to their employed counterparts (76.5%) ( $p=0.03$ ). The logistic regression models, which adjusted for socio-demographic and physical work factors, indicated that employed therapists with high and medium supervisor support were significantly less likely than those with low supervisor support to have UL pain [OR 0.12, 95% CI (0.02-0.68)] and [OR 0.14, 95% CI (0.02-0.90)] respectively. No significant associations were found between UL pain and work-related social support in self-employed therapists.

**Discussion.** This study indicates that self-employed therapists have a higher prevalence of UL pain compared to their employed counterparts. This higher prevalence could not be explained by work-related social support levels. Further research is needed to explain the higher prevalence of UL pain in the self-employed therapists which are an under-researched group.

SESSION 10, WEDNESDAY, JUNE 22, 10:30AM – 12:00PM, ROOM 204C

## Trajectories of low-back pain with impact from adolescence to adulthood

Pieter Coenen (presenter), Anne Smith, Markus Paananen, Peter O'Sullivan, Darren Beales, Leon Straker

**Background.** Low-back pain (LBP) is highly prevalent and creates a substantial burden on our (working) society. However, there is a limited understanding of the development of disabling LBP during the transition from adolescence to adulthood. In this study, we aimed to identify and profile trajectories of LBP and associated negative impact (occupational activity modification, health-care utilization) among a general population sample followed from adolescence to adulthood.

**Methods.** LBP and its impact on daily life were obtained from 17, 20 and 22 years of age follow-up assessments of the Western Australian Pregnancy Cohort (Raine) Study (n=1,249). Latent class analysis was used to identify clusters of LBP and associated impacts during this period. Identified clusters were profiled on sex, waist circumference, diagnosed co-morbid pain and health related quality of life.

**Results.** Four clusters of the prevalence and impact of LBP were identified: a cluster with consistently low prevalence and impact of LBP (n=661, 53%), a cluster with an increase in prevalence of LBP and impact of LBP (n=272, 22%), a cluster with a decrease in prevalence of LBP and impact of LBP (n=192, 15%); and a cluster with consistently high prevalence and impact of LBP (n=124, 10%). These clusters differed substantially with respect to sex, waist circumference, diagnosed co-morbid pain and health related quality of life.

**Conclusion.** The identification of four clusters of LBP and LBP impact with different multi-dimensional profiles provided unique and important information on the transition of LBP in adolescence and early adulthood. Consideration of these trajectories may be important for the design of effective early (workplace) prevention and management strategies.

## Multi-site musculoskeletal pain among young technical school students entering working life

Therese Nordberg Hanvold (presenter), Lars-Kristian Lunde, Markus Koch, Morten Wærsted, Kaj Bo Veiersted

**Background.** There is a need to investigate the occurrence of multi-site pain in young adults and to determine potential factors contributing to the early course of multi-site musculoskeletal pain. The aim of this prospective study was to assess the change of prevalence in the number of pain sites. In addition, the study sought to identify work-related and individual risk factors associated with the number of musculoskeletal pain sites.

**Methods.** Musculoskeletal pain from four body regions (neck/shoulder, low back, arm-wrist-hand, hip-knee-leg) was monitored on 21 occasions over a 6.5-year period. We also monitored individual and work-related factors. We studied 420 technical school students (mean age 17.5 ( $\pm 1.2$ )) entering working life. Data were analyzed by generalized estimating equations (GEE).

**Results.** Pain from more than one body site was prevalent in a cohort of young adults entering working life (69% at baseline). The number of body sites in pain was found quite stable over the 6.5-year follow-up period. Women had higher numbers of pain sites compared with men and gender specific risk factors were identified. Perceived muscle tension was the only factor which was significantly associated with increased number of pain sites in both genders. Mechanical workload, quantitative demands and socioeconomic status were associated with number of musculoskeletal pain sites among women, while among young men, tobacco use was found as a risk factor.

**Discussion.** The current study supports earlier findings and show that pain from multiple body sites are frequent also among young workers. The identification of gender specific risk factors in our study is important and may facilitate practical prevention and future research.

## Occupational influences on progression of spondylolysis and spondylolisthesis in young adults

Shlomo Moshe (presenter), Oren Zack Zack, Yair Barak Aharon S. Finestone, Dan Slodownik

**Background.** The aim of our study was to examine the risk of spondylolysis/spondylolisthesis progression as a function of initial severity and of occupational strain as represented by various military professions in new military recruits.

**Methods.** In this controlled historical prospective study, all male Israel Defense Forces (IDF) soldiers drafted between the years 1998-2006 were followed for a period of three years. Subjects were categorized according to disease severity and the following occupational categories: combat, maintenance, driving administrative professions. Using initial disease severity as an individualized baseline, we compared the disease progression rates amongst the different occupational groups.

**Results.** Statistically significant progression to grade II spondylolisthesis or higher was found in the administrative professions only with a rate of 2.2%. The relative risk for progression between painful spondylolisthesis and non-painful spondylolisthesis was  $RR=4.7$  ( $p<0.02$ ) amongst administrative profession soldiers.

**Conclusion.** Among subjects with grade I spondylolisthesis, symptomatology is a risk factor for the progression of the listhesis to grade II or higher among administrative professions in young adults. Spondylolysis and non-painful spondylolisthesis were not found as a risk factor for the development of symptomatic grade II or higher spondylolisthesis.

## Influence of physical and psychosocial work environment throughout life and cognitive capacity in midlife for labour market attachment among senior workers

Emil Sundstrup (presenter), Otto Melchior Poulsen, Lars Louis Andersen

**Background.** In the future, elderly will account for an increasing proportion of the total population in Denmark and in the European Union. Thus initiatives to achieve a stronger retention of senior employees to the labour market are needed. The present study will investigate the influence of physical and psychosocial work environment throughout working life and physical and cognitive capacity in midlife for labour market attachment among senior workers.

**Methods.** 5,000 participants (aged 50-60 years) from the Copenhagen Aging and Midlife Biobank (CAMB) will be followed prospectively through the DREAM register which contains information on all types of transfer payments on about five million Danes on a weekly basis. Cox regression will be used to model the risk of labour market attachment within a three-year period from the baseline measurement as a function of the following predictors: (1) physical work environment throughout working life (questions on physical work demands); (2) psychosocial work environment throughout working life (questions from the Copenhagen Psychosocial Questionnaire); (3) physical capacity in midlife (e.g. muscle strength, jump height, aerobic performance, postural balance); and (4) cognitive capacity in midlife (Intelligenz - Struktur-Test; I-S-T 200R). The following variables will be controlled for in the analyses: age, BMI, social class, chronic disease, musculoskeletal disorders and long-term sickness absence at baseline.

**Results.** Preliminary results will be presented at PREMUS 2016.

**Discussion.** The project will contribute significantly to knowledge on risk factors and protective factors for labour market attachment. The results will add to the scientific knowledge on which factors should be targeted in future interventions for maintaining a longer and healthier working life among senior employees.

SESSION 11, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 204A

## Contribution of individual, physical, work-related and psychosocial variables to work ability in office workers

Venerina Johnston (presenter), Alyssa Welch, Leon Straker, Gisela Sjøgaard, Tracy Comans

**Background.** The intensity of musculoskeletal symptoms, flexibility of the spine and age are among the factors shown to have a negative effect on work ability in office workers. Individuals with poorer work ability may be at greater risk of sick leave and early retirement. This study investigates the relationship between several individual, physical, psychosocial and work-related variables with self-reported work ability in a sample of Australian office workers.

**Methods.** An online survey was used to obtain data from office-based employees participating in a randomized trial (#ACTRN12612001154897). Included questions were about the individual (age, gender, body mass index, income, education); work (daily computer use, self-reported job performance); workplace psychosocial environment (job strain, job satisfaction); and health-related (musculoskeletal symptom severity and location; mental health status, health-related quality of life, number of co-morbidities, physical activity levels). Physical measures of neck range of motion, neck muscle strength and endurance using reliable and validated methods were also collected. Self-reported work ability was evaluated with one question scored on an 11-point scale from 0 (totally unable to work) to 10 (work ability at its best).

**Results.** A subsample of participants' recruited [n = 342; mean age, 42 years; 192 (55.8%) females] completed the question on work ability. Mean work ability was 8.4 (SD = 1.3). Eight factors explained 40% (Adjusted R<sup>2</sup> = 0.399, p < 0.05) of the variance in work ability. In descending order of strength of association these factors were: better self-reported job performance, health-related quality of life, job satisfaction, mental health status, greater neck flexion range of motion, female gender, older age and less severe low-back pain.

**Discussion.** Intensity of low-back pain is one of several factors related to the work ability of Australian office workers and should be considered when organisations plan interventions to enhance worker capacity.

## The role of individual and organizational factors in completion of two workplace-based health promotion programs among office workers

Alyssa Welch (presenter), Venerina Johnston

**Background.** Research suggests that workplace-based health interventions are more effective with greater participation; organizational factors contribute to the effectiveness of recruitment in workplaces. We investigated the individual and organizational factors associated with participation in a 12-week health program.

**Methods.** 763 office-based employees from 14 organizations (4 private, 8 government, 2 other) were randomly allocated to weekly health promotion (HP, n=382) or supervised weekly specific exercise training (SET, n=381) arms of a RCT (Trial Registration ACTRN12612001154897).

A consistent recruitment strategy was used across all organizations, with incentives offered to six organizations. Individual and organizational data (e.g. age, gender, Kessler 6 for psychological distress, Job Content Questionnaire, daily computer use, occupational category – manager, professional, associate professional, administrative, personal service/ other) were collected through an online survey.

Linear regression was used to identify the variables associated with high participation rates (attendance at sessions) for each intervention arm separately. Variables with a significance of  $p < 0.2$  were included in the final models.

**Results.** 744 participants completed the baseline survey (mean age = 42.6 years, 60.9% female). Mean attendance at SET was 58.2%. Mean attendance at HP was 56.2%. Factors associated with greater participation ( $p < .05$ ) in both interventions were occupational category and psychological distress. Industry type, job control and daily computer use were significantly associated with SET participation, while organisational participation rate and age were associated with HP attendance. The adjusted  $R^2$  value for participation in SET and HP was 0.1262 and 0.1759 respectively.

**Discussion.** Many of the organizational factors commonly associated with high recruitment rates were not associated with individual participation, suggesting that external factors may influence the decision to start a workplace-based health promotion activity, but individual characteristics determine the extent of participation. These factors differ depending on the nature of the health promotion activity.

## The risk for work-related carpal tunnel syndrome by occupational type in the U.S. controlling for related comorbidities

Nancy Baker (presenter)

**Background.** Carpal tunnel syndrome (CTS) has been associated with high-repetition, forceful jobs in small samples. In this study, we used data from the National Health Information Survey (NHIS), which is representative of the U.S. civilian non-institutionalized population, to determine the risk for CTS in people in five major occupational types: management, professional and related; service; sales and office; natural resources, construction and maintenance; and, production, transportation and material moving. We examined the risk for CTS in these occupations in combination with four co-morbidities associated with increased risk of carpal tunnel: arthritis, diabetes, obesity and smoking.

**Methods.** We analyzed the 2010 survey data for all adults (ages  $\geq 18$  years) in the NHIS Sample Adult Core who were 65 or less to determine the population level of risk for CTS from occupational type. We obtained odds ratios (OR) by completing five logistical regressions with CTS status as the outcome, and each occupational type as a predictor. Covariates were age, sex, race/ethnicity, education, employment status, and the four comorbidities.

**Results.** Of our sample of 22,012 adults under 65, 7.5% (95%CI: 7.0, 7.9) had CTS. Working in a management job was significantly protective (OR: 0.85, 95%CI: 0.74, 0.98), while working in production was a significant risk factor (OR: 1.29, 95%CI: 1.10, 1.51). No other occupational type was significant (OR: service 1.06, 95%CI: 0.91, 1.23; sales 1.11, 95%CI: 0.97, 1.26; construction 1.12, 95%CI: 0.89, 1.42). All four comorbidities were significant risk factors for CTS, with arthritis the strongest (approximately 3.1), and diabetes, obesity and smoking at similar risk (approximately 1.4).

**Discussion.** While occupational type plays a role in the development of CTS, comorbidities, particularly arthritis, are greater risk factors for CTS.

## Task precision and time-dependent changes of motor variability during a sustained bimanual reaching task

Alessia Longo (presenter), Ruud Meulenbroek

**Background.** Decreasing movement variability during cyclical work has been supposed to increase the risk of musculoskeletal disorders (MSDs).

**Methods.** In the present study, we tested the hypothesis that in repetitive movements — such as those that occur in typing — healthy people tend to increase their movement variability in order to avoid monotonous sensorimotor processing, fatigue and risky co-contraction levels. To this end, we studied in a cyclical bimanual reaching task the effects of time-on-task (early and late in 20-minute intervals) and precision demands on the mean and standard deviation of movement duration and end-point variability. In addition, we analyzed approximate entropy (ApEn) to capture any systematicity in the variability of the participants' sustained, cyclical task performance. A group of asymptomatic subjects ( $n = 17$ ) performed a tapping task with their index fingers, moving back and forth between two target areas of varying sizes and representing different indices of difficulty (ID).

**Results.** Time-on-task showed decreasing movement duration, increasing end-point variability and increasing ApEn values. Higher IDs elicited, as expected, contrasting effects, viz. increased movement duration, decreased end-point variability and decreased ApEn values.

**Discussion.** The results suggest that healthy subjects apply diverse strategies to compensate for time-on-task effects. The observed higher ApEn confirms the hypothesis that time-on-task increases movement variability — probably to avoid movement rigidity. Increased precision demands clearly resulted in a more regular motion pattern reflected by low ApEn values. Collectively, the findings support the hypothesis that precision demands in sustained motor tasks may increase the likelihood of acquiring work-related MSDs by reducing movement variability, which people try to compensate for during sustained task performance.

SESSION 12, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 204A

## The impact of gender on surgical decision-making following workplace musculoskeletal injury

Andrea Marie Jones (presenter), Mieke Koehoorn, Chris B McLeod

**Background.** Gender has been shown to influence physician recommendations for elective orthopedic surgery in the general population, with fewer women recommended for surgery compared to men controlling for injury characteristics. The current study examined whether or not these gender differences persist among a workers' compensation population with musculoskeletal injuries in the Canadian province of British Columbia.

**Methods.** The study sample included all workers with an accepted first time workers' compensation, lost-time claim from 2008 to 2010 for knee meniscal tear, thoracic/lumbar disc displacement, or rotator cuff tear (n=1,721). Two outcomes were examined within one year of injury: surgery (yes/no) and, among those who received surgery, number of days from injury to surgery. The relationship between gender and surgery was assessed using the risk ratio while the relationship between gender and time to surgery was assessed using the Wilcoxon two-sample test. Analyses were stratified by injury type.

**Results.** For each injury type, a smaller proportion of women received surgery compared to men with the same injury (knee: 72.9% vs. 78.3%; back: 15.0% vs. 19.9%; shoulder: 10.7% vs. 23.45%). Using men as the reference category, the 95% confidence interval for the risk ratio included one for the knee (RR=0.93, 95% CI:0.83-1.04) and back groups (RR=0.75, 95% CI:0.50-1.13), but not the shoulder group (RR=0.46, 95% CI:0.32-0.66). Among those who received surgery, the median wait time was longer for women with knee (107.5 vs. 94 days,  $p<0.05$ ) and shoulder injuries (202 vs. 170 days,  $p<0.10$ ), but not for women with back injuries (147 vs. 149 days,  $p<0.6$ ), compared to men with the same injury.

**Discussion.** Women were consistently less likely to receive surgical treatment than men for knee, back, and shoulder injury, and waited longer for knee and shoulder surgery. Future research will include survival models and adjustment for potential confounders.

## Factor analysis affecting the knee symptoms and diseases of farmers in South Korea

Donghee Shin (presenter), Sanghyuk Im

**Background.** Knee diseases are common among farmers in South Korea. Most farm work in Korea is done by hand and the farmers work in awkward or improper postures and rely on repetitive movements; e.g., squatting, repetitive kneeling. This study analyzes factors such as the demographic characteristics, working conditions and crop type affecting knee diseases among Korean farmers.

**Methods.** The subjects were 15,204 Korean farmers ( $\geq 19$  years old) selected through a sample design. We sent investigators to the farms where they examined the demographic characteristics, agricultural activities, knee symptoms and hospital visits by farmers attributed to knee disease.

**Results.** We conducted a multiple logistic regression analysis with risk factors that can affect hospital use due to knee diseases and the complaints of knee symptoms in farmers.

A significant increase was observed in knee symptoms in farmers with these identified risk factors: growing of low-floor crops (odds ratio (OR), 1.13; 95% CI 1.042-1.226), female (OR, 1.762; 95% CI 1.643-1.889), 70s compared to less than 60 years old (OR 2.149; 95% CI 1.903-2.427), 40-60 years compared to 0-20 years in agriculture-engaged period (OR 1.594; 95% CI 1.415-1.796), and improper kneeling motion (OR 1.364 ; 95% CI 1.209-1.539).

A significant increase was observed in ratio of hospital use due to knee disease in farmers with these risk factors: female (OR, 1.737; 95% CI 1.583-1.906), 70s compared to less than 60 years (OR 2.084; 95% CI 1.752-2.479), and 40-60 years compared to 0-20 years in agriculture-engaged period (OR 1.615; 95% CI 1.364-1.911).

**Discussion.** We conducted a standardized sampling of about 15,204 people in the study group supplemented with research visits conducted by trained researchers to improve the accuracy of response. However, there were limitations that may occur due to the study design through a cross-sectional study.

## Rural agriculture as a biopsychosocial context for low-back health: preliminary results of the Saskatchewan Farmers Back Study

Catherine Trask (presenter), Aaron Kociolek, Muhammad Khan, Xiaoke Zeng, Bath Brenna

**Background.** Back pain occurs within a social and environmental context and is influenced by both biological and psychological phenomena. Rural Canadians and those working in agriculture not only have higher rates of back disorder, but also higher prevalence of several comorbidities and lower access to health care. A recent population-based study identifies low-back pain as the most common musculoskeletal disorder among farmers; however, not much is known about the impacts of back health on rural farmers. The goal of this pilot study was to explore quantitative measures of the back health of Saskatchewan farmers and interpret their experience within a biopsychosocial framework.

**Methods.** Farm workers from 22 Saskatchewan farms were invited to complete a comprehensive back health questionnaire. The questionnaire included items on working exposures, back health and health care utilization/access, including several standardized tools covering a range of biopsychosocial domains. The questionnaire was completed on the farm in the presence of a researcher, who was available to clarify questions.

**Results.** A total of 32 farmers from 22 farms completed the questionnaire; 94% were male and the majority were over 50 years of age. Preliminary analyses show high levels of reported back pain, with more than half describing pain in the last year and nearly a quarter describing impact on their work. Comorbidities were common as were unfavourable scores on standardized psychosocial tools.

**Discussion.** Although this pilot study did not yield a representative or generalizable sample, it gives insight into the context of back pain in an at-risk rural farming population. The combination of high physical workloads, older age, comorbidities and limited health care access make this a vulnerable population in terms of back health. Results of this pilot study will be useful in planning tailored interventions for back pain in this population.

SESSION 13, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 202A

## MSDs in Sweden: an analysis of sickness benefit applications to a non-profit insurance company

Michel Normark (presenter), Anna Weigelt

**Background.** AFA Insurance is a non-profit insurance company jointly and equally owned by the Swedish labour market parties: the Swedish Employers Confederation and the Swedish Trade Union Congress (Landsorganisationen). The company gives complementary sick benefits to employees who are covered by collective agreements. Approximately 90% of all blue-collar workers in the private sector and all public-sector employees in the local authorities and municipalities are covered by this scheme (approximately 2.7 million employees). When a sick person makes an application for benefits, AFA Insurance registers the following information: age, gender, occupation, employer, diagnosis (according to ICD 10), length of absenteeism and degree of absenteeism.

**Methods.** During the period 2005-2014, we studied 176,409 cases with long sick-leave periods due to musculoskeletal disorders (MSDs) and 112,975 cases with shorter periods of absenteeism due to MSDs. Since the female participation in the labour market is very high in Sweden, we can draw conclusions based on gender at both macro and micro levels.

**Results.** Women are at a higher risk of MSDs. The most common diagnosis among men is back pain. Joint diseases and diseases in the soft tissues, especially fibromyalgia, are more common among women. In future, we will also be able to report on the occupations at the highest risk for MSDs, the development for MSDs over time, and the risk of permanent economical disability due to MSDs.

**Discussion.** We will discuss the reasons for MSDs in the Swedish context, the policy implications and AFA Insurance's recommendations to the labour market parties. We will also present R&D projects that AFA Insurance has financed.

## A follow-up study of the importance of occupational and personal factors for neck-shoulder pain among females

Inger Arvidsson (presenter), Catarina Nordander, Jenny Gremark Simonsen, Jonas Björk

**Background.** Musculoskeletal neck-shoulder pain is assumed to be associated with both the physical workload and the psychosocial work environment, as well as with personal and lifestyle factors. This study aims to determine which factors at baseline predicted pain at follow-up.

**Methods.** A questionnaire on 18 areas of physical, psychosocial and individual factors was answered by 1,079 females in five occupations at baseline and after mean 28 months (follow up). Outcome measures were neck-shoulder *pain*, based on frequency and intensity of complaints in the neck and/or shoulders during the past year. The study population was stratified into four categories: (1) no pain at baseline, no pain at follow-up (NP-NP, n=354), (2) no pain at baseline, pain at follow-up (NP-P, n=150), (3) pain at baseline, no pain at follow-up (P-NP; n=128), and (4) pain at baseline, pain at follow-up (P-P; n=447). The groups were compared with respect to occupational and personal factors at baseline; i.e. pairwise NP-NP vs. NP-P and P-P vs. P-NP, using the Kruskal Wallis test.

**Results.** Preliminary results show that NP-P reported higher physical workload than NP-NP; mechanical exposure index (MEI, score 18.6 vs. 17.6;  $p=0.007$ ) and physical exposure index (score 12.3 vs. 11.7;  $p=0.04$ ). Further, NP-P reported lower job control (scores 2.9 vs. 3.0;  $p=0.04$ ), higher emotional demands (scores 2.2 vs. 2.0;  $p=0.04$ ) and were younger (mean age 47 vs. 49;  $p=0.03$ ), than NP-NP. The P-P reported higher MEI-score (20 vs. 18.5;  $p<0.001$ ) and higher sensory demands (score 3.1 vs. 2.9;  $p=0.03$ ), than P-NP. No other conditions at baseline predicted outcome.

**Discussion.** Among females without pain at baseline, the perception of a high physical workload was the strongest predictor of neck-shoulder pain at follow-up. Further, among females with pain at baseline, the perception of lower physical workload and lower sensory demand increased the chance for recovery.

## Disability pensions and musculoskeletal disorders in men and women after long-term exposure for heavy physical workload

Katarina Kjellberg (presenter), Andreas Lundin, Daniel Falkstedt, Peter Allebeck, Tomas Hemmingsson

**Background.** Heavy physical workload has been associated with early exits from the labour market through disability pensions (DP) in a number of studies. However, the association may be confounded by early life factors, level of education and psychosocial working conditions. The aim of this study was to investigate the association between long-term, heavy physical workload in middle age and DP before 61 years of age with adjustments made for early life factors, education and psychosocial working conditions.

**Methods.** The study is based on cohorts of 21,809 Swedish men and women born in 1948 and 1953, with data on physical workload estimated with a job exposure matrix based on occupational titles in 1985 and 1990 and follow up data on diagnosis-specific DP in the years 1991-2009. Data on paternal education and intelligence were collected in primary school. Data on level of education were taken from administrative records. Job control was estimated with a job exposure matrix based on occupational titles in 1990.

**Results.** Long-term exposure to heavy physical workload measured five years apart at around age 40 was strongly associated with DP due to musculoskeletal disorders up to the age of 61 among both men and women. The increased risks remained, but were clearly attenuated after adjustment for fathers' education, IQ in childhood, achieved education and job control.

**Discussion.** Exposure to heavy physical workload is strongly associated with long-term risk of DP due to musculoskeletal disorders. Early life factors, level of education and level of control at work partly explain the association, implying a selection of individuals with lower intelligence and low level of education into heavy physical jobs. Also, early exits from heavy physical jobs may partly be explained by low control in these jobs, possibly involving low possibilities to adjust work to reduced health.

SESSION 14, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 202B

## Frequency of compensation claims for carpal tunnel syndrome according to occupational category in a cohort of patients from surgical centers in the Paris region

Emilie Chazelle (presenter), Cédric Girault, Marie Pascual, Catherine Ha Laurence Chérié-Challine, Loïc Garras, Julie Plaine, Thierry Dubert

**Background.** Carpal tunnel syndrome (CTS) is the most frequently compensated occupational disease in France. The aim of the study was to evaluate whether or not the frequency of claims for compensation for CTS was different according to occupational categories.

**Methods.** Patients who had undergone surgery for CTS were enrolled in the study from six surgical centres in the Paris-region hand prevention network. Before surgery (n=880), patients were sent a questionnaire about work, physical and psychosocial exposures, and were asked if they had claimed compensation for their CTS as a work-related disease; the questionnaire was also sent to patients six months after surgery (n=420). Patients were categorized according to the occupational category of their most recent job. Associations between occupational category and compensation claim were tested by multivariate logistic regressions adjusted for sex, age and work physical exposure level to CTS.

**Results.** Before surgery, 18% of patients had claimed compensation for their CTS. A gradient was observed in the frequency of compensation claims according to occupational category ( $p < 0.001$ ): 5% of managers and professionals respectively (reference category), 7% of associate professionals (OR=1.0, CI95% [0.4-3.0]), 21% of clerks and service workers (OR=3.4, CI95% [1.5-9.3]) and 44% of manual workers (OR=8.5, CI95% [3.6-23.3]) had made claims for compensation. Similar results were observed six months after surgery with higher frequencies of compensation claims. Compensation claim was strongly associated with work physical exposure but differences between occupational categories remained among moderate/high exposed workers (OR manual workers=5.4, CI95% [2.1-16.8]). Besides, a high proportion of patients who had claimed were exposed to high job demand (79%) or low job control (69%).

**Discussion.** Manual workers made more frequent claims for compensation for their CTS as an occupational disease than other workers, even taking into account work physical exposure level. Other work factors such as psychosocial work factors are being studied too as a motivation for compensation claim.

## The relationship between median nerve latency, biomechanical risk factors and work disability from carpal tunnel syndrome: a pooled prospective study

Carisa Harris Adamson (presenter), Ellen Eisen, Jay Kapellusch, Arun Garg, Kurt Hegmann, Matthew Thiese, Ann Marie Dale, Bradley Evanoff, Stephen Bao, Barbara Silverstein, Fred Gerr, David Rempel

**Background.** This analysis examined the relationship between median nerve latency, pain, biomechanical exposure and work disability from carpal tunnel syndrome (CTS).

**Methods.** 4,321 workers were evaluated and followed up to seven years with repeated symptom surveys and nerve conduction studies to identify prevalent and incident cases of CTS (n=318). Among those with CTS, work disability was defined as symptom driven: (1) change in work pace/quality, (2) lost time or (3) job change, derived from SF12 and *Quick-DASH* questionnaires. Individual job-level biomechanical exposures (peak hand force, HAL repetition scale, total repetition rate, forceful repetition rate, % time all hand exertions, % time in forceful hand exertions, ACGIH-TLV for HAL) were time weighted averages of task level exposures. Adjusted hazard ratios were estimated using Cox proportional hazards models.

**Results.** Of the 318 workers with prevalent or incident CTS, 57.5% (n=183) reported a work disability. The most common disability was a change in work pace/quality (n=124), followed by job change (n=71) and lost-time (n=56). Median sensory latency ( $HR_{upper}=1.83$ ; 95%CI:1.06-3.16) and pain ( $HR_{upper}=1.64$ ; 95%CI:1.03-2.62) were associated with increased changes in work pace/quality. The biomechanical factors associated with any type of work disability were the HAL repetition scale ( $HR_{middle}=1.79$ ; 95% CI: 1.23-2.63;  $HR_{upper}=1.32$ ; 95% CI: 0.83-2.10), total repetition rate ( $HR_{middle}=1.45$ ; 95% CI: 0.96-2.19;  $HR_{upper}=1.61$ ; 95% CI: 1.07-2.43) and the % time in forceful exertions ( $HR_{middle}=1.50$ ; 95% CI: 1.02-2.21;  $HR_{upper}=1.38$ ; 95% CI: 0.89-2.12).

**Discussion.** These results indicate that median sensory latency and hand/wrist pain were associated with increased change in work pace/quality from CTS, but were not associated with other more severe measures of work disability such as lost time or job change. Contrary to prior analyses, these analyses indicate that measures of forceful hand activity and hand repetition were associated with work disability from CTS.

## Working with multisite chronic pain: findings from the (MUSCLE) MUsculoskeletal Study of Construction workers' Longitudinal Exposures

Alberto Caban-Martinez (presenter), Samuel Huntley, Xuan Yang

**Background.** Population-based studies have shown that multisite (i.e. two or more joint sites) musculoskeletal pain can be more common than single anatomic site pain. Little is known, however, about what factors influence multisite musculoskeletal chronic pain (i.e. pain lasting  $\geq 3$  months) severity over time in workers, and particularly in construction workers who are exposed to strenuous mental and hazardous physical work environments. In the present study, we use baseline data from the recently completed longitudinal MUSCLE cohort study to: (1) characterize the multisite musculoskeletal chronic pain location and severity; and (2) examine the association between multisite chronic pain severity and occupational risk factors in a cohort of construction workers.

**Methods.** Commercial construction workers ( $n=518$ ) employed at worksites in Florida, Virginia, Maryland, Massachusetts and Washington, D.C. completed a paper-based baseline survey at their jobsite during their lunch break. The baseline survey collected measures on musculoskeletal pain location and severity (primary outcome), as well as covariates including absenteeism and presenteeism, physical workload, ergonomic use, organizational/worksites policies and practices and non-occupational risk factors (i.e. worker health behaviours and demographics, health conditions and psychosocial factors).

**Results.** Over 42% of the cohort reported working with multisite chronic pain of which the top three joint locations include: low back (66%), wrist/forearm (50%) and shoulder (47%) at baseline. For workers with multisite chronic pain, the average pain severity score ( $3.69 \pm$  standard deviation, 1.34) compared to workers with only one site anatomic pain ( $2.54 \pm 1.46$ ). At baseline, workers' perceived company support of ergonomic tools was inversely correlated ( $r=-0.65$ ,  $p=0.000$ ) while average hours slept in a 24-hour period was positively correlated ( $r=0.712$ ,  $p=0.000$ ) with self-reported multisite chronic pain.

**Discussion.** Musculoskeletal pain at multiple sites is a common and persistent phenomenon among construction workers suggesting that the prevention of severe occupational outcomes for this group must have a wide multidisciplinary focus.



## Health disparities and globalization

Session 1 358

SESSION 1, MONDAY, JUNE 20, 10:30AM – 12:00PM, ROOM 204C

## Towards understanding relationships between social inequalities, gender and working conditions associated with work-related musculoskeletal disorders

Susan Stock (presenter), Hicham Raiq, Nektaria Nicolakakis, Karen Messing

**Background.** Reducing health inequalities is a worldwide public health priority. The objectives of this study are to characterize social inequalities related to work-related musculoskeletal disorder (MSD) exposures and how they differ by gender/sex.

**Method.** Study data were from the 2007-2008 Quebec Survey on Working and Employment Conditions and OHS. Gender/sex stratified multivariable analyses were performed in three steps: (1) logistic regression models to identify work exposures associated with work-related MSDs; (2) calculation of multivariate risk scores (MRS) based on the sum of workers' exposures weighted by the magnitude of the exposure's association with work-related MSDs (i.e. its logistic regression coefficient from step 1); and (3) linear regression models of the relationships between MRS and three measures of socioeconomic status (SES).

**Results.** In both genders, work-related MSDs were significantly associated with high physical and quantitative work demands, emotionally demanding work, lack of promotion prospects and unemployment. Additionally, in women, work-related MSDs were associated with exposure to sexual harassment, psychological harassment, tense situations with clients, noise, and  $\geq 16$  hours computer work/week; in men, work-related MSDs were associated with low co-worker support and contradictory work demands. In both genders, MRS was significantly associated with lower education and the two lowest socio-occupational classes; in men, it was also associated with lower household income and technical occupations and, in women, with professional occupations.

**Discussion.** The MRS quantified, in a single statistic, the combined work exposures associated with work-related MSDs. Lower occupational classes and educational categories have higher MRS. In women, this relationship is more complex, with both less-qualified and professional occupational groups associated with higher MRS. Variations in relationships between SES and specific work exposures explain some of these differences. In both genders, the strongest association of MRS was to elementary occupations. Low paid, vulnerable workers in such occupations often have less access to adequate occupational health and safety and labour standards protection. These results have implications for targeting preventive interventions.

## Lifestyle and work-related factors and the health of Australian long-distance commute and residential miners: evidence from a cross-sectional survey

Venerina Johnston (presenter), Frazer Ryan, Bronwen Otto, Asad Khan

**Background.** There is currently mixed evidence regarding the impact of working arrangements involving a long distance commute (LDC) on the health of mining employees, and the need for comprehensive research into the health of these workers is well recognized. This study provides the first step towards understanding the health risks associated with specific work-related, lifestyle and biomedical factors in mining workers by comparing these LDC workers to their residential counterparts to establish the most relevant factors for each of these groups. The objective of this study was to determine the relative contribution of work-related, lifestyle and biomedical factors to the presence of chronic health conditions in a sample of LDC and residential miners.

**Methods.** A comprehensive cross-sectional survey was administered to employees of one mining company in Australia. LDC (n=1,056) and residential mine workers (n=435) responded (68% response rate). Multinomial logistic regression was used to determine the relative risk ratio (RRR) of having one or multiple Australian National Health Priority Area (NHPA) health conditions in the presence of certain variables.

**Results.** LDC workers reporting excessive alcohol consumption (RRR= 2.56) and obesity (RRR=2.46) were significantly more likely to have multiple NHPA health conditions. Conversely, LDC workers reporting high levels of physical activity (RRR=0.56) and residential workers reporting high job satisfaction (RRR=0.38) and moderate (RRR=0.28) to high (RRR=0.22) levels of social support were less likely to report single or multiple NHPA health conditions. High blood pressure, dayshift fatigue and high psychological job demands were consistent risk factors for poor health across both the LDC and residential populations.

**Conclusions.** Our findings suggest that lifestyle factors may be more relevant for the health of LDC miners and work-related factors more important for the health of residential miners. The results of this study suggest that current health campaigns should target the identified health needs of LDC and residential miners.

## The effect of union membership on lost-time and MSD claim rates in construction in Ontario

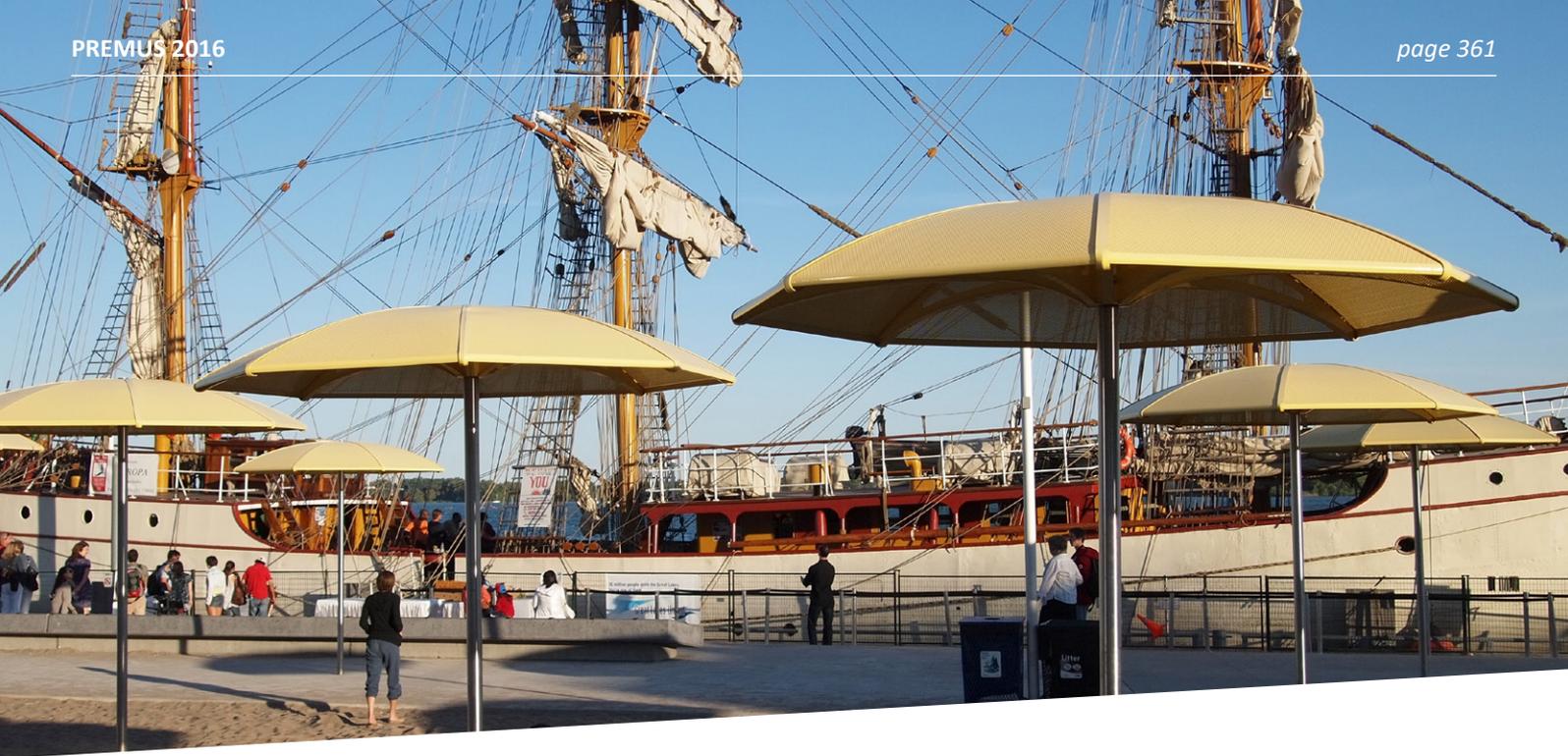
Ben Amick (presenter), Sheilah Hogg-Johnson, Ron Saunders, Desiree Latour-Villamil

**Background.** Do Ontario unionized construction firms in the industrial, commercial and institutional (ICI) sector have lower lost-time workers' compensation claims rates and lower rates of musculoskeletal injuries compared to non-union firms?

**Methods.** Building trade and construction trade association lists of union contractors were linked to Workplace Safety and Insurance Board claims data for 2006 to 2012. Data were pooled for 2006-2012 and negative binomial regressions conducted with adjustment for size, type of work, region and business complexity to estimate a union-safety effect.

**Results.** The sample included 5,797 unionized and 38,626 non-union construction firms. The rate of lost-time claims was 14% lower (0.86, 0.82-0.91), while the rate of MSD claims was 8% lower (0.92, 0.86-0.99).

**Conclusions.** Unionized compared to non-unionized construction firms have lower lost-time claims rates and lower rates of MSD claims. This research is a first step in understanding how collaborative partnerships between unions and employers create safer and less hazardous construction work places. This research is being extended into construction workplaces to better understand differences in organizational behaviour.



## Economic burden of work-related MSDs

Session 1 362

Session 2 367

SESSION 1, MONDAY, JUNE 20, 1:30PM – 3:00PM, ROOM 204C

## Costs of work-related musculoskeletal disorders in Colombia 2009-2012

Martha Isabel Riaño Casallas (presenter)

**Background.** Morbidity and mortality related to the workplace not only result in suffering for the worker and his or her family, but also generate an economic loss due to increased use of health resources and loss of productivity. Companies protect their workers with insurance policies against workplace hazards, but there are also indirect costs, which can affect productivity and competitiveness. For this reason, the objective of this work is to estimate the costs of work-related musculoskeletal disorders (MSDs) in Colombia during the period 2009-2012. This study evaluates productivity loss from the perspective of human capital because these disorders are the major cause of occupational disease in the country.

**Methods.** The literature was reviewed and cases were identified from information contained in the Second Survey on Working Conditions and Health (because Colombia does not have a source of public information for these cases). The average cost of medical expenses for these events, and days absent from work, were established for each MSD. Total (direct and indirect) costs were estimated. Data were adjusted due to inflation.

**Results.** A regression model that shows the relationship between direct and indirect costs of MSDs to days absent from work was developed. Indirect costs correlate directly with total costs. This work advances the estimation of the burden of occupational disease because there are no studies of this kind focussing on the Latin American region. It is also necessary to continue the study of this topic in order to develop more precise estimations.

**Discussion.** Indirect costs of MSDs are unknown to employers. While this approach only estimated loss of productivity, there are also other costs that affect companies. Ultimately, however, it is necessary for employers to become more knowledgeable about occupational disease costs in order to direct more investments to preventive measures.

## Economic burden of occupational musculoskeletal disorders in the wholesale and retail trade sectors and subsectors

Anasua Bhattacharya (presenter)

**Background.** The incidence of nonfatal occupational injuries and illnesses requiring days away from work was 109.4 cases per 10,000 workers in 2013 in the U.S. Musculoskeletal disorders (MSDs) accounted for 33 per cent of these cases. The total number of reported MSDs in the wholesale and retail trade (WRT) sector was 131,060 in 2013. Workers sustaining MSDs took a median of 11 days away from work, above the median of eight days for all cases. In wholesale trade, the rate of MSDs was 37 cases per 10,000 workers, with a median of 12 days away from work. In retail trade, it was 42 cases per 10,000 workers, with a median of 11 days away from work. The objective of this study was to estimate the costs of occupational MSDs in WRT subsectors in 2013 and rank these subsectors by costs, cases and rates. Data from the Bureau of Labor Statistics (BLS) were used to estimate MSD cases by WRT subsector, age group and gender, and MarketScan data were used to estimate workers' compensation costs.

**Methods.** MSD cases were multiplied by the average medical and indemnity costs of MSDs to estimate total medical costs and lost earnings in 2013. Other cost components, including fringe benefits and home production losses, were estimated using previous findings.

**Results.** Preliminary results suggested that the costs of MSDs in WRT was \$19.9 billion in 2013. Among subsectors, food and beverage (\$503 million), retail trade and merchant wholesalers nondurable goods (\$396 million) and wholesale trade had the highest costs.

**Discussion.** This study ranked WRT subsectors by the economic burden of occupational MSDs. Policies targeting MSD prevention in high-cost WRT subsectors would improve worker safety and health and help to reduce the societal economic burden of MSDs.

## The increasing burden of work-related musculoskeletal disorders (MSDs) in Sweden

Adnan Noor (presenter), Mats Hagberg

**Background.** The costs of sickness absence (SA) are increasing in Sweden, and musculoskeletal disorders (MSDs) are accounting for a large fraction of SA — especially for long-term SA. The purpose of this study is to estimate and investigate trends in the burden of work-related musculoskeletal disorders in Sweden.

**Method.** Every even-numbered year, Statistics Sweden performs a survey on work-related disorders on a representative sample from the Swedish workforce. In 2014, 16,455 participated (92 % participation) in this telephone-interview survey. Respondents were asked questions about work-related disorders, health, sickness absence and rehabilitation experienced during the previous 12 months.

**Results.** One in seven workers reported work-related MSDs. They also reported 5.9 million days SA due to these work-related MSDs. That was 60% of total SA due to all types of work-related disorders. There was a substantial gender difference; men accounted for 47%, while women for 53% of these SA days. Interestingly, both men and women were absent from work an average of nine days due to these disorders. Workers 50-64 years old averaged 15 days SA, while workers 16-49 years old averaged six days absent from work due to these work-related MSDs. There has been an increase in the burden of work-related MSDs since 2009. Since 2009, one in eight workers reported work-related MSDs, accounting for 5.3 million days sickness absence due to these disorders. In 2009, men were absent for an average eight days, while women averaged 11 days absent from work due to these disorders.

**Discussion.** In Sweden, the burden of work-related MSDs has increased since 2009. The gender differences have decreased; men and women were nearly equally accounted for in the SA days counted in 2013. The age differences in reporting work-related MSDs, and sickness absence attributed to work-related MSDs, have not changed.

## Body mass index (BMI), musculoskeletal symptoms and health-related job loss in older workers

Catherine Linaker (presenter), Stefania D'angelo, Karen Walker-Bone, Clare Harris, David Coggon, Keith Palmer

**Background.** The workforces of Western countries are aging at a time when obesity is becoming more common. There is a need for older people to work longer, but obesity may limit work capacity. In particular, it is a risk factor for musculoskeletal complaints. Using baseline data from a cohort study of health and work in later life, we assessed relationships between body mass index (BMI), persistent musculoskeletal pain and health-related job loss (HRJL).

**Methods.** Some 8,000 50-64 year-olds from 24 British GP practices completed a questionnaire about employment circumstances, weight, height and health. We used logistic regression to explore cross-sectional associations between BMI and persistent musculoskeletal pain (lasting >1 month over the past 12 months in the back/neck, arms or legs); also between these two and HRJL, with adjustment for age, sex and low mood (CES-D score).

**Results.** Almost one third of participants were out of work, 11% leaving for a health reason (4.5% cited a musculoskeletal problem); 26% reported persistent musculoskeletal pain. Obesity was significantly associated with musculoskeletal pain (OR 2.5 95% CI 2.2 to 2.9), and particularly with leg pain (OR 4.1 95% CI 3.4 to 4.9). Significant associations were also seen with low BMI (<18.5). These associations remained after adjustment for low mood. Musculoskeletal pain and high BMI were both risk factors for HRJL (ORs 3.3 and 1.9). However, HRJL was only marginally higher in obese people without musculoskeletal pain (OR 1.2) whereas it was substantially higher in obese people with pain (OR 4.5), and even higher if pain involved the lower limb (OR 5.9).

**Discussion.** Obesity contributes importantly to musculoskeletal-related HRJL, underscoring the importance of weight control in older workers with musculoskeletal disorders.

## The monetary value of productivity losses due to musculoskeletal disorders in office workers

Michelle Pereira (presenter), Venerina Johnston, Leon Straker, Gisela Sjøgaard, Markus Melloh, Shaun O'Leary, Tracy Comans

**Background.** Up to 70% of office workers report musculoskeletal disorders (MSDs). MSDs have been linked to diminished productivity, creating an economic burden for employers. Importantly, the monetary value of MSDs for employers of office-based workers is unknown. This study evaluated the economic burden of MSDs in office workers from an employer's perspective.

**Methods.** A cross-sectional study was performed using baseline data from a two-arm RCT conducted in Australia (interventions delivered from June 2013 – October 2015) that compared a workplace program of ergonomics, plus specific exercise regime to another program that combined ergonomics and health education (ACTRN#12612001154897). Data collected included age, gender, income and comorbidities.

The Health and Work Performance Questionnaire was used to estimate productivity loss from absenteeism and presenteeism using individual salary data. One question assessed the presence of self-reported MSDs in the preceding week using a body diagram with nine anatomical regions. Severity of MSD was recorded on a 10-point scale with symptomatic status defined as a score of  $\geq 3$  in a particular region. The number of symptomatic regions was calculated for each participant.

Analysis of variance determined between-group differences in the means of productivity loss. Linear regression investigated the relationship between productivity loss and MSDs (adjusted for age, gender and comorbidities).

**Results.** 763 office workers from 14 organizations were allocated to either arm of the RCT. Annual productivity loss due to MSDs was valued at \$3,612 AUD per worker (95% C.I.=1068 – 6157), or approximately 4.15% of individual yearly salary. Productivity loss and the number of symptomatic MSDs were significantly related ( $p=0.026$ ), with every additional symptomatic MSD region increasing productivity loss by an average of \$638 AUD annually per worker.

**Discussion.** MSDs in office workers have a negative monetary impact due to productivity loss. These findings demonstrate for employers the possible financial benefit of workplace health interventions targeting MSDs in this population.

SESSION 2, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 201A

## The cost-effectiveness of therapeutic ultrasound versus application of corticosteroids in the management of moderate carpal tunnel syndrome in Colombian working population

Francisco Palencia (presenter)

**Background.** Carpal tunnel syndrome (CTS) is a common disease that is subject to different approaches; however, management with therapeutic ultrasound is not a common option in clinical practice in Colombia.

**Methods.** The aim of the study was to evaluate the cost effectiveness of medical treatments for CTS using therapeutic ultrasound versus local application of corticosteroids in the Colombian working population. The study was conducted over a six-month time horizon and from the perspective of a third-party payer.

**Results.** In TreeAge Pro 2011, analytical decision models are generated in accordance with the recommendations for clinical practice guidelines for the care and treatment of musculoskeletal disorders associated with repetitive upper limb movement and supported by an informal consensus among experts.

**Discussion.** The use of ultrasound is not cost for treatment of workers with moderate CTS effective based on a six-month time horizon.

## Costs of work-related low-back disorders: a huge but unappreciated burden on Mexico's health systems

Nieves Serratos-Perez (presenter), Juan Francisco Vela-Roa, Martha Angelica Gasca-Barajas, Carmen Negrete-Garcia, Jose Guadalupe Ochoa-Tirado

**Background.** It is well established that damage to the musculoskeletal system is nowadays a common and unwanted effect of work on people.

The scope of the problem must also be considered in light of the huge monetary costs associated with compensating this group of disorders. A significant consideration, of course, is also the potential of these disorders to render workers completely unable to perform labour, which entails substantial human and social costs.

Even though the issue of costs for work-related musculoskeletal disorders (MSDs) has been widely addressed, this is not true for every country in the world. In the case of Mexico, very little is known about the real extent of the problem. We looked into the issue of low-back disorders and associated costs for the Instituto Mexicano del Seguro Social (IMSS), the provider of health and social security services for workers in Mexico. The IMSS is funded by government, employers and workers.

**Methods.** The research was conducted in one of the seven hospitals run by IMSS in the city of Leon, located in the center of the country. We reviewed the records for the year 2012, looking for cases of low-back disorders that fully qualified as work-related. For these, we had access to data showing the cost of social security benefits; the costs associated with medical attention are not easily traceable.

**Results.** We found 118 cases; 79 males, 39 females. For these, IMSS paid a total subsidy of 4,017 days of salary; 787 of them corresponded to relapses. The money involved was \$625,411.55 MXN (\$47,563 USD). The number of cases also included five that eventually qualified as permanent partial disability, costing a total of \$53,565.12 MXN (\$4,074 USD).

**Discussion.** Of course, this is only the tip of the iceberg. It is assumed that medical treatment costs are six times these sums. IMSS runs 2,294 hospitals.

## Whole body vibration exposures: using low-back and neck claims to assess the cost and health effects of different bus driver seats

Kat Gregersen (presenter), Peter Johnson, June Spector, Shan Liu, David Veenstra

**Background.** Whole body vibration (WBV) is a risk factor for low-back pain in professional vehicle operators. Using a 15-year workers' compensation claim database from a regional bus municipality, a predictive cost-utility analysis (CUA) was performed to determine whether or not there were bus driver seating alternatives that would be effective in reducing WBV-related workers' compensation claims.

**Methods.** A CUA was conducted in which three seating alternatives were compared with the current industry-standard practice of using a passive, air-suspension seat: (1) installation of an active-suspension driver seat that would reduce WBV exposures by up to 50%; (2) replacement every five years of the industry-standard bus driver seat to prevent an increase in WBV exposures; and (3) installation of a static, suspension-less driver seat that would not alter WBV exposures but would reduce seat maintenance costs. The CUA applied a decision-analytic Markov model to simulate a driver filing a low-back or neck claim. Accumulated claim costs and health outcomes were determined over the 15-year life of a bus. Model inputs were based on expert feedback from the bus municipality, the epidemiologic literature and previous research on seating interventions.

**Results.** The active-suspension seat was estimated to lower WBV exposures and to reduce driver claims costs by \$4.8 million over a 15-year life of the municipality's bus fleet; the static seat saved \$2.0 million over the same period through reduced maintenance costs; and the periodic replacement of seats was not cost-effective.

**Discussion.** These findings indicate that the adoption of active-suspension seats may both improve driver health and reduce a bus municipality's claims costs. Given differing vehicle costs, claims costs and vehicle service life, care should be taken when generalizing these findings to other industries in the transportation sector.

## A cost-benefit analysis of peer coaching for overhead lift use in the long-term care sector in Canada

Emile Tompa (presenter), Roman Dolinschi, Hasanat Alamgir, Anna Sarnocinska-Hart, Jaime Guzman

**Background.** To reduce the hazard of high physical demands associated with patient handling, overhead (ceiling) lifts have been introduced in many jurisdictions in Canada. Training and coaching have the potential to enhance the effective use of overhead lifts, which can translate into reduced injury incidence and severity associated with patient handling and transfer. This study aimed to evaluate whether or not a peer coaching program for patient-lift use in British Columbia, Canada was beneficial and cost effective.

**Methods.** We used monthly panel data from 15 long-term care facilities from 2004 to 2011 to estimate the number of patient-handling injuries averted by the peer-coaching program using a generalized estimating equation model. Facilities that had not yet introduced the program served as concurrent controls. Accepted lost-time claim injuries related to patient handling were the outcome of interest. A cost-benefit approach was used to estimate the net monetary gains at the systems level.

**Results.** The coaching program was found to be associated with a reduction in the injury rate of 37% during the program and 50% after the program concluded, with an estimated 66 lost-time injury claims averted. Two other factors were associated with changes in injury rates: the more floor-lifts per bed the higher the injury rate; and the more nursing hours per bed the lower the injury rate. We calculated monetary benefits to the system of \$800,500 and costs of \$894,000 with a benefit-to-cost ratio of 0.90. The benefit-to-cost ratio was -0.02 in the worst case scenario and 2.44 in the best case scenario. The largest cost item was coaches' time. A simulation of the program continuing for five years with the same coaching intensity would result in a benefit-to-cost ratio of 0.83.

**Discussion.** In summary, peer-coaching program to increase effective use of overhead lifts prevented additional patient-handling injuries incurring minor extra cost to the system.



## Management of work-related MSDs and sustainable employment

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SESSION 1, MONDAY, JUNE 20, 3:30PM – 5:00PM, ROOM 204A

## Does the addition of a vocational advice service to best current care improve work outcomes in patients with musculoskeletal pain? The SWAP trial

Gwenllian Wynne-Jones (presenter), Majid Artus, Annette Bishop, Sarah Lawton, Martyn Lewis, Chris Main, Gail Sowden, Simon Wathall, Kim Burton, Danielle van der Windt, Elaine Hay, Nadine Foster

**Background.** Musculoskeletal pain commonly causes work absence, and early intervention is advocated to prevent longer term absence. The SWAP trial tested the addition of a vocational advice service to best current care for adults with musculoskeletal pain.

**Methods.** A cluster randomized controlled trial in six U.K. general practices randomized to intervention (n=3) or control (n=3). Intervention practices referred adults reporting musculoskeletal pain who were either absent from work  $\leq 6$  months, or struggling at work, to a new, brief intervention provided by a vocational advisor located in the practice. The primary outcome measure was days off work over four months. Secondary outcomes included self-reported time off work, self-efficacy to return-to-work, current pain intensity (0–10 rating scale) and bothersomeness (1–5 rating scale) at four and 12 months follow up. Analysis was by intention-to-treat.

**Results.** 348 participants (162 intervention arm; 186 control arm) were recruited. Baseline characteristics were comparable between arms; four-month follow-up rates were 72% (intervention) and 79% (control). Participants in the intervention arm had significantly fewer days off work over four months (mean 9.3 days, SD 21.6) compared to control (mean 14.4, SD 27.7); adjusted incidence rate ratio (IRR) 0.51 (0.26, 0.99),  $p=0.048$ . This difference was predominantly due to fewer GP certified absent days [mean 8.4 days (SD 20.9) in intervention arm, compared to 13.5 days (SD 27.5) in control]. Self-efficacy to return-to-work [mean difference -0.27 (-7.09, 6.55)  $p=0.938$ ], current pain intensity [mean difference -0.46 (-1.41, 0.49)  $p=0.339$ ] and bothersomeness [OR 1.69 (0.69, 4.42)  $p=0.286$ ] were not significantly different between arms at four months.

**Discussion.** The addition of a brief vocational advice intervention to best current primary care for adults with musculoskeletal pain leads to fewer days absent over four months. However, there was no between-group difference in a range of secondary outcomes at four or 12 months follow-up.

## The reporting of low-back pain by Korean firefighters

Jangwhon Yoon (presenter)

**Background.** There is a significant gap between complaints about low-back pain (LBP) and reported incidences of LBP as a work-related musculoskeletal disorder (MSD). The aim of this survey was to ask firefighter applicants for workers' compensation for their opinions about difficulties associated with reporting LBP and about the prevention of work-related MSDs.

**Methods.** 227 applicants were contacted and 146 agreed to participate. 96 (nine female) participants responded to the questionnaire and provided anonymous opinions about reporting, reviewing and the settlement processes for addressing LBP, and obstacles to preventing work-related MSDs.

**Results.** The majority of applicants were between 40-45 years old. Common diagnoses were herniated disc (48%), lumbar sprain (29%), fracture (11%) and others (12%). Injuries occurred in the course of providing emergency medical services (42%), fire fighting (28%), rescue (11%), and during training and other activities (19%). 48% of all claims were accepted as work-related MSDs, 25% partially accepted, 19% declined and 8% unknown. Only 3% reported the injury on the day of the incident, 27% reported within a week, and 54% made a report more than a month after injury. Applicants delayed reporting or inquiring about work-related MSDs until the end of treatment; they were unsure of the procedure for reporting, and they worried about raising the incidence rate for their departments. 94% of participants responded that they did not report their pain or discomfort prior to their current case. 61% of participants were unsatisfied with the result of evaluation because the work-relatedness of their condition was considered weak or the nature of problem was considered degenerative.

**Discussion.** The firefighters said they did not have sufficient training about work-related MSDs and reporting procedures. Moreover, because of the difficulty in establishing work-relatedness, non-specific LBP cases are rarely reported. Participants highlighted the need for sufficient staffing levels in the field, improvements in equipment with respect to quality and quantity, and more generous reviewing of policies and procedures.

## Prevalence of low-back pain in Danish office workers and the effect of Intelligent Physical Exercise Training: a randomized controlled trial.

Tina Dalager (presenter), Just Bendix Justesen, Mike Murray, Gisela Sjøgaard

**Background.** Low-back pain is common among office workers. Physical exercise training at the workplace may reduce the prevalence and result in additional health benefits. The aim this study was to assess the effect of individually tailored Intelligent Physical Exercise Training (IPET) on musculoskeletal health.

**Methods.** Office workers were randomized 1:1 to a training group, TG (n=194) or a reference group, REF (n=195). TG received one-hour supervised high intensity IPET every week within working hours for one year and asked to exercise for 30 minutes with moderate intensity six days weekly during leisure time. The IPET training program was based on health-check measures of muscle strength, musculoskeletal pain (self-reported on a 0-9 numeric box scale), cardiorespiratory fitness, health-risk indicators, and functional capacity. Trial registration was in ClinicalTrials.gov, number: NCT01366950.

**Results.** Baseline mean±SD was for low-back pain over the past three months: 3.2±1.8 and seven days: 2.4±1.7, muscle strength /back extension: 535±161 N and abdominal flexion: 459±143 N. In total, 54% (3 month) and 24% (7 days) were categorized as pain cases (pain intensity ≥ 3) at baseline. An intention-to-treat analysis using ANCOVA analysis demonstrated significant improvements for TG compared with REF in low-back pain past seven days of -1.2±1.6 and in muscle strength with ~ 8% increases (back extension: 7.0±19.6%; abdominal flexion: 8.6±14.6%). In addition, the proportion of employees who were categorized as pain cases at baseline but not at follow-up was significantly decreased in TG (3 months: 39%; 7days: 18%) compared to REF (3 months: 14%; 7days: 7%).

**Discussion.** IPET has the potential to reduce prevalence and intensity of musculoskeletal pain and increase muscle strength among office workers, providing them a lower relative workload on the low back. Of note is the large proportion of employees in TG who shifted from being a pain case at baseline to a no-pain case at follow up.

SESSION 2, MONDAY JUNE 20, 3:30PM – 5:00PM, ROOM 204C

## Age as a factor affecting repetitive manual-handling technique

Mark Boocock (presenter), Steve Taylor, Grant Mawston

**Background.** Older workers have been shown to control the detrimental effects of fatigue associated with repetitive lifting and limit maximum lumbar flexion. To determine how older workers might affect these changes, this study investigated differences in the kinematics and kinetics throughout a repetitive handling task (lifting and lowering) between a group of younger and older participants.

**Methods.** 28 participants were grouped according to age: 14 younger (mean 24.4 yr) and 14 older males (mean 47.2 yr). They were required to lift and lower a box (13kg) at 10 lifts/min for a maximum of 20 minutes. Motion analysis was used to record postural kinematics (joint angles and angular velocities). Two force plates enabled joint reaction forces and net joint moments to be estimated throughout the lifting task. Electromyography measured the muscle activity of eight major muscle groups of the spine, abdomen and lower limbs.

**Results.** The younger participants moved their trunk and lumbar spine through a greater range of movement towards the end of the lifting task when compared to the older group. The younger group increased peak extension and flexion velocities during the task, which differed significantly between age groups. Normalized peak lumbar spine and hip moments were consistently lower in the older group and changed little during the lifting task. There was no significant difference between age groups for the length of time the load was held or the peak lumbar extension. Increased muscle fatigue was evident in the younger group compared to the older group.

**Discussion.** Younger participants appeared to be at greater risk of musculoskeletal injury compared to older participants when performing a repetitive lifting task. Understanding the strategies adopted by older participants may assist in the development of approaches to improve lifting techniques in younger workers, which may reduce the risk of manual handling injuries.

## Lifting during pregnancy: provisional guidelines

Stephen Hudock (presenter), Leslie MacDonald

**Background.** Over the past 30 years, proportionally more women in the U.S. have entered the industrial workforce than previously. These women have also remained longer on the job during pregnancy due, in part, to a lack of adequate prenatal leave programs and no federal regulation requiring such leave.

**Methods.** Empirically-based lifting criteria established by the National Institute for Occupational Safety and Health (NIOSH) to reduce the risk of overexertion injuries in the general U.S. working population were evaluated for application to pregnant workers performing manual material handling tasks. The evaluation included an extensive review of the literature linking occupational lifting to maternal and fetal health. The Revised NIOSH Lifting Equation (RNLE) was adapted to derive recommended weight limits for female workers at early and mid-term points of their pregnancy.

**Results.** The resulting lifting thresholds are levels that most pregnant workers with uncomplicated pregnancies should be able to perform without increased risk of adverse maternal or fetal health consequences. Except for restrictions involving lifting from the floor and overhead, the provisional guidelines presented are compatible with NIOSH lifting recommendations for the general working population.

**Discussion.** Clinical guidelines for primary care physicians, obstetricians and gynecologists are proposed to update guidance on the issue that is quite dated. Implementation of these provisional guidelines could protect millions of female workers from fetal and maternal lifting-related health problems.

## Interventions to promote work participation in older workers with musculoskeletal disorders: results from a systematic review

Ivan Steenstra (presenter), Kimberly Cullen, Emma Irvin, Dwayne Van Eerd, Mohammad Alavinia, Dorcas Beaton, Judy Geary, Monique Gignac, Doug Gross, Quenby Mahood, Martine Puts, Heather Scott-Marshall, Amin Yazdani

**Background.** Workforce health is receiving increased attention as a critical driver of the economy. Aging is an important demographic trend that affects worker health and work disability. While the number of older workers wanting, or needing, to participate in the workforce after injury or chronic disease is increasing, knowledge on their specific needs and circumstances has not been summarized in a systematic way. The review objective was to synthesize the evidence on effectiveness of interventions promoting work participation in older workers.

**Methods.** The team of researchers and stakeholders followed a systematic review process developed by the IWH: research question formulation; literature search; relevance review; quality appraisal; data extraction; and, evidence synthesis. Our evidence synthesis methods were adapted from the Cochrane Collaboration for RCTs. Synthesis of the evidence is ranked on a scale from strong evidence, through moderate, and limited, down to insufficient evidence. Various stakeholders were involved at multiple times during the review process.

**Results.** The search yielded 6,176 non-duplicate references. We found 14 relevant studies from six countries in three languages. Eight studies were classified as health-care interventions, one as workplace accommodation and five as combined interventions (also including service coordination). One article reported on return to work (RTW) and stay at work (SAW), four studied RTW and nine studied SAW. Five studies were in populations with a musculoskeletal disorder. 10 studies reported a positive effect of intervention.

**Discussion.** Preliminary results indicate that work accommodations are consistently effective across populations. Chronic disease management should be considered as a part of interventions to promote work participation in older workers. Levels of evidence will be presented. Implications for practise will be discussed.

SESSION 3, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 201C

## The experiences of stakeholders of a primary care based vocational advice service: qualitative interviews within the SWAP trial (ISRCTN 52269669)

Gwenllian Wynne-Jones (presenter), Tom Sanders, Majid Artus, Bie Nio Ong, Nadine Foster

**Background.** Most U.K. patients consult their general practitioner (GP) for advice about work, yet GPs report struggling to manage these consultations. The Study of Work and Pain (SWAP) cluster randomized trial tested the addition of an early access vocational advice service to usual primary care. In qualitative interviews, we explored experiences of the new service with key stakeholders: clinicians, including GPs and nurse practitioners (NPs); vocational advisors (VAs); and patients.

**Methods.** Semi-structured interviews focused on experiences of the new early-access vocational advice service, and the enablers and barriers to adopting the service. Purposive sampling identified 13 GPs and four NPs interviewed at baseline and 12 months, three VAs interviewed prior to service start and at one, six and 12 months, and 20 patients interviewed at discharge from the service.

**Results.** GPs/NPs felt the vocational advice service could help manage patients with complex work-related difficulties. However, their engagement with the new service was limited as a result of normative assumptions of how patients “ought” to be managed. The VAs felt that many patients were referred too early in their episode of work absence and, as a result, many patients were self-managing their condition and their return-to-work. VAs also reported that, when they felt unable to help patients with their work difficulties, they tended to resort to their more traditional role as a physiotherapist. Patients also viewed the service as “too early” and, therefore, not required. However, in cases where the timing of the service was appropriate, patients found it to be useful.

**Discussion.** A vocational advice service in primary care was generally acceptable to all stakeholders. Timing of the service was paramount to acceptance. While early intervention is advocated, the qualitative data highlighted that our vocational advice service, on the whole, focused on patients too early in their episode of work absence.

## Do prognostic factors for receiving wage replacement benefits differ between older and younger workers?

Fahad Algarni (presenter), Doug Gross, Ambikaipakan Senthilselvan Senthilselvan, Michele Crites-Battie

**Background.** Older workers often require more recovery time than younger workers due to various considerations (i.e. comorbidities), which may result in prolonged work disability. Work disability and its negative consequences may be reduced by identifying injured workers who are at increased risk of developing work disability. The question of whether or not older injured workers have the same characteristics and prognostic factors as younger injured workers, however, requires more investigation. The objective of this study was to identify prognostic factors for wage replacement and determine whether or not they are similar between younger and older workers.

**Methods.** A secondary analysis was conducted using a database containing administrative and clinical data for claims from the Workers' Compensation Board of Alberta. This database provided information about injured workers who had incurred work-related musculoskeletal injuries in Alberta and underwent a comprehensive return-to-work (RTW) assessment. The database also included many variables (i.e. demographic and social, occupational, health/injury, and health care utilization). The study participants consisted of three age groups (25-54, 55-64, and  $\geq 65$  years). Variables were compared between age groups. Logistic regression analysis was used to determine prognostic factors for work disability, as indicated by the receipt of wage-replacement benefits. The hypothesis that prognostic factors were the same across age groups was tested by examining the interaction effect between each factor and the categorized age variable.

**Results.** Differences in prognostic factors were observed across the three age groups based on the unadjusted odds ratios. Interactions between health-care factors and the categorized age variable were statistically significant, with more physician and physical therapy visits predictive of delayed recovery only in younger workers.

**Discussion.** There appear to be differences in prognostic factors for wage replacement across different age groups, especially related to physician and physical therapy visits, suggesting that age group should be considered when predicting return to work.

## Determinants of work participation in older workers with musculoskeletal disorders: results from a systematic review of prognostic studies

Ivan Steenstra (presenter), Kimberly Cullen, Emma Irvin, Dwayne Van Eerd, Douglas Gross, Algarni, Mohammed Alavinia, Dorcas Beaton, Judy Geary, Monique Gignac, Quenby Mahood, Matine Puts, Heather Scott-Marshall, Amin Yazdani

**Background.** Workforce health is considered a critical driver of the economy. Aging is an important demographic trend that will affect worker health. While the number of aging workers who wish or need to participate in work after injury or chronic disease is increasing, knowledge of their specific needs and circumstances has not been summarized in a systematic way. The review objective was to describe the factors associated with work participation of older workers.

**Methods.** The team of researchers and stakeholders followed a systematic review process developed by the Institute for Work & Health (IWH): research question formulation; literature search; relevance review; quality appraisal; data extraction; and evidence synthesis. All relevant electronic databases were searched from inception to the present. Review steps were completed with two independent reviewers coming to consensus for each reference. An adapted QUIPS tool (Hayden) was used for quality assessment. Our best evidence synthesis methods will be adapted from other IWH reviews of prognostic studies. The strength of evidence will be ranked on a scale from strong evidence, through to moderate, to limited and down to insufficient evidence. Determinants will be classified based on a modified Work Functioning Conceptual Framework (Sandqvist and Henriksson).

**Results.** The comprehensive search yielded 6,176 non-duplicate references. From these, we found 103 studies that were relevant to our objective. Over 400 determinants were extracted from these publications. 21 studies looked specifically into the role of musculoskeletal disorders on work participation in older workers.

**Discussion.** We will present the state of the evidence on the role of musculoskeletal disorders in work participation of older workers. We will discuss development of interventions based on these findings.

## Role of occupational health clinics in the prevention of work-related musculoskeletal disorders in an information technology company

Deepak Sharan (presenter), Joshua Samuel Rajkumar, Rajarajeshwari Balakrishnan, Jerrish A Jose, Sunu Jerrish

**Background.** The aim of this study was to find out the role of occupational health clinics in the prevention and treatment of work-related musculoskeletal disorders (MSDs) among the employees working in an information technology (IT) company.

**Methods.** From 2011 to 2015, a retrospective analysis was conducted among 6,588 employees of a multinational IT company with software development centres in an industrialized developing country. The subjects were 4,760 males and 1,828 females between 20 and 55 years of age who reported musculoskeletal pain in a specific region. All subjects reported pain in one or more body parts following extended computer use and were diagnosed with a work-related MSD by an experienced orthopaedic and rehabilitation physician. All participants were then referred to an on-site physiotherapist-cum-ergonomist for ergonomic workplace analysis and treatment by protocol-based manual/physical therapy.

**Results.** A total of 69% of employees worked for at least 5-9 hours per day and 21% for 10-14 hours per day. Both populations had eye strain and increased fatigue in common. 87% had overall body pain, 64.9% had neck pain, 56.5% had low-back pain and 42.1% had shoulder and other upper arm, thigh, knee and foot pain. 49% were diagnosed with myofascial pain syndrome, 43% with thoracic outlet syndrome, 35% with fibromyalgia and 8% with other problems. After rehabilitation following a sequenced protocol, the VAS scale showed significant reduction in pain levels in all the workers ( $p < 0.01$ ). 95% of workers reported complete resolution of symptoms and 5% reported partial resolution of symptoms, but were able to work without restriction. No employee had to take leave for more than seven days or leave the job due to a work-related MSD.

**Discussion.** The on-site occupational health clinic was effective in providing ergonomic evaluations, recommendations and rehabilitation to prevent and treat work-related MSDs in an IT company.

SESSION 4, TUESDAY, JUNE 21, 3:30PM – 5:00PM, ROOM 202A

## The persisting benefit of early or immediate return to work on back pain and function after controlling for multiple confounds

William Shaw (presenter), Candace Nelson, Mary Jane Woiszwilllo, Glenn Pransky

**Background.** Early return to work (RTW) for musculoskeletal conditions is commonly recommended in order to maintain physical and occupational functioning, and to prevent long-term disability. However, few studies have evaluated the longitudinal health benefits of early RTW while controlling for important baseline covariates and potential confounds.

**Methods.** In a prospective, inception cohort study, 557 workers (65% male) consulting for a new onset of work-related low-back pain (LBP) (< 14 days) completed an assessment of pain, circumstances of pain onset, and psychosocial risk factors. At one and three months' follow up, participants completed measures of pain, function and work status. Individuals were classified as having an immediate RTW (0 days off), early RTW (1-7 days off), or later RTW (8 or more days of sickness absence) based on one-month recall. Multiple regression analyses assessed longitudinal group differences in three-month outcomes after controlling for demographic, occupational, health and psychosocial variables.

**Results.** Over three months, median pain intensity ratings decreased from 6 to 2. Participants were approximately equally divided between immediate RTW (30.7%), early RTW (36.8%), and later RTW (32.5%). After controlling for a number of probable confounds (age, gender, income, type of injury, job tenure, baseline pain, and an index of psychosocial disability risk factors), three-month outcomes of pain and function were still superior for those with an immediate or early RTW compared with a late RTW ( $p < .05$ ). There were no significant interactions to suggest an immediate or early RTW was beneficial for only a select group of patients.

**Discussion.** While it is impossible to control for all possible sources of confounding in observational studies of return to work, health benefits of an immediate or early RTW persisted in our analyses after controlling for multiple potential confounds. We conclude that facilitating an early RTW has positive health consequences in addition to reducing disability costs.

## The association of low physical exposure at work with excellent work ability in workers with neck pain

Stefan Oliv (presenter), Adnan Noor, Ewa Gustafsson, Mats Hagberg

**Background.** Reduced self-reported work ability is a predictor of future sick-leave or worklife absence. The aim of this study was to investigate which physical and psychosocial exposures were associated with excellent work ability in individuals with neck pain, and to investigate age and gender differences in these associations.

**Methods.** The material for this study was obtained from the Statistics Sweden (SCB) cross-sectional Work Environment survey from 2007 and 2009. The study sample consisted of workers who reported experiencing neck pain after work at least twice per week over the last three months (n=3,212). Self-reported exposure to physical and psychosocial work demands was compared with workers' self-reported work ability.

**Results.** The findings showed an association between excellent work ability and self-reported low exposure to lifting, twisted work posture, working with hands at shoulder level or higher, and leaning forward without support (prevalence ratio (PR) ranging from 1.15 to 1.71). The associations were present only in the two older age groups and were generally stronger for men than for women. Self-reported low exposure to seated work showed a reversed association with excellent work ability for men and women aged 50-64 years (PR 0.55 and 0.71, respectively) and also for those aged 30-49 years (0.86 and 0.87).

With respect to psychosocial variables, an association was found with self-reported high support for both men and women in the 30- to 49-year age group and self-reported high control for women in the same age group. We also found a reversed association between self-reported low demands for men and women in the 50- to 64-year age group (PR 0.61 and 0.88) and self-reported excellent work ability.

**Discussion.** To promote excellent work ability, older workers with neck pain might benefit from having less physically demanding jobs.

## The risk for low-back pain caused by driving professions in a young adult population

Shlomo Moshe (presenter), Oren Zack, Regina Levin

**Background.** The aim of this study was to assess the relationship between the incidence and exacerbation of low-back pain (LBP) in young professional drivers

**Methods.** In this controlled historical prospective study, we included all-male Israel Defense Forces (IDF) soldiers drafted between the years 1997-2006. We followed them for three years and categorized them into three groups: administrative, light-duty vehicle drivers and heavy vehicle drivers. The incidence and recrudescence of LBP was calculated for soldiers with or without a medical history of LBP in either professional group accordingly.

**Results.** The incidence rates for LBP were 0.7%, 0.34% and 0.43% for the combined administrative and light vehicle driver groups, heavy vehicle driver and total driver groups, respectively (averagely 0.65%). The relative risk (RR) for severe LBP exacerbation for soldiers with a history of LBP without clinical findings was 1.4 ( $p < 0.001$ ) and for soldiers with a history of LBP with mild clinical/radiographic findings was 3.8 ( $p < 0.01$ ). Examination of RR exacerbation rates within different severity tiers yielded a similar trend amongst all professions.

**Discussion.** The crude incidence rate for LBP was found to be 0.65% — lower than literature-reported rates, possibly attributable to our more stringent variable definition of severe LBP. The most prominent risk factors identified in our study include: a history of LBP and multiple complaints of LBP at recruitment. Driving professionally at a young age is not a risk for LBP.

## Workplace-based interventions for neck pain in office workers: a systematic review and meta-analysis

Xiaoqi Chen (presenter), Brooke Coombes, Gisela Sjogaard, Deekhoon Jun, Shaun O'Leary, Venerina Johnston

**Background.** Neck pain is a chronic and prevalent condition in office workers. While workplace-based interventions can be efficacious, there is no consolidated evidence on the prevention and reduction of neck pain in office workers. This review investigates the effectiveness of workplace-based interventions on neck pain in office workers and extends on previous reviews by doing subgroup analysis of symptomatic office workers and the general office-worker population (with or without neck pain).

**Methods.** A systematic search of randomized controlled trials (RCTs) of workplace-based interventions evaluating neck/shoulder pain intensity or incidence/prevalence was conducted. A modified PEDro scale was used to assess methodological quality. Standardized mean differences (SMDs) for pain intensity, and relative risks (RR) for pain incidence/prevalence were calculated for intervention and comparator groups.

**Results.** 27 RCTs (4,993 participants) met the inclusion criteria. Meta-analysis found strong evidence for reducing neck pain by using neck/shoulder strengthening exercises in symptomatic office workers, but no effect on the general office-worker population. The greatest benefits were found for studies with the highest adherence to exercise. Meta-analysis also found strong evidence for the efficacy of general fitness training in symptomatic office workers but effect size was smaller than for neck/shoulder strengthening exercise intervention. There was strong evidence for the ineffectiveness of multi-component ergonomic interventions in the general office-worker population, but only limited evidence on symptomatic office workers.

**Discussion.** This review has important implications for employers and policy-makers. Neck/shoulder strengthening exercises were effective in reducing neck pain in symptomatic office workers and adherence was an important factor influencing the effectiveness of exercise. General fitness exercises were also beneficial but effect size was larger for neck/shoulder strengthening exercises in symptomatic office workers. More research is needed to consolidate the evidence for prevention of neck pain and on the impact of ergonomic interventions on symptomatic office workers.

SESSION 5, WEDNESDAY, JUNE 22, 1:30PM – 3:00PM, ROOM 204C

## Effectiveness of two different modes of onsite ergonomic intervention to prevent work-related musculoskeletal disorders

Deepak Sharan (presenter), Joshua Samuel Rajkumar, Rajarajeshwari Balakrishnan, Amruta Kulkarni

**Background.** The aim of this study was to compare the effectiveness of two types of onsite ergonomic intervention programs in preventing work-related musculoskeletal disorders (MSDs) among employees working at two different information technology (IT) companies.

**Methods.** A retrospective analysis was conducted among employees at two different IT companies in an industrially developing country: IT(A) and IT(B). A total of 1,470 employees reported musculoskeletal pain. 780 employees were from IT(A) — 642 males and 138 females, with a mean age of 38. 690 employees were from IT(B) — 546 males and 144 females, with mean age of 35. All subjects reported pain in one or more body part following extensive computer use. All subjects were examined and diagnosed with work-related MSDs. IT(A) employees received an ergonomic assessment and recommendations on one-time basis from a physiotherapist-cum-ergonomist. IT(B) employees received an assessment and diagnosis from an orthopedic and rehabilitation physician and an ergonomic-assessment with recommendations and protocol-based manual/physical therapy from a physiotherapist for up to two weeks, if needed. Both groups of employees were observed for a recurrence of symptoms.

**Results.** Both groups were analyzed for specific and non-specific MSDs. Myofascial pain syndrome was the most common disorder in both groups: 35% in IT(A) and 30% in IT(B). In IT(A), the body regions affected were neck (13%), shoulder (55%), back (42%) and other areas (15%). By comparison, IT(B) subjects reported neck (11%), shoulder (41%) and back (25%) symptoms and other affected areas at (25%). 18% of IT(A) employees reported recurrence of symptoms that necessitated at least one repeat medical visit compared to IT(B), where only 6% of employees reported at least one repeat medical visit.

**Discussion.** The addition of assessment and diagnosis by an orthopedic and rehabilitation physician and onsite manual physical therapy, along with ergonomic workplace analysis and recommendations, for the employees at IT(B) proved more effective at preventing the recurrence of work-related MSDs.

## Effectiveness of an ergonomics intervention program for reducing work-related musculoskeletal disorders for community nurses in Hong Kong

Billy So (presenter), Edwin Lee, Sheung Wai Law, Grace Szeto

**Background.** Community nurses are at risk as they must carry a heavy backpack and travel to work onsite with patients in their homes. This work often involves awkward postures and exposes community nurses to high physical demands and the risk of musculoskeletal disorders. The objective of this study was to determine the effectiveness of an ergonomic intervention program aimed at reducing work-related musculoskeletal symptoms of community nurses in Hong Kong.

**Methods.** 50 community nurses working in four local hospitals participated in the study. The full intervention program consisted of participatory group ergonomic training, individual onsite ergonomic supervision, a daily exercise program, equipment modification, computer workstation assessment and typing training. The intervention program lasted for about three months and nurses were evaluated at pre-intervention (T1), post-intervention (T2) and post-intervention at one year (T3). The outcome variables included musculoskeletal symptom scores, functional outcome measures (NPQ, CODI DASH and IKDC), rate of perceived exertion (RPE), perceived physical and psychosocial risk factors of work, flexibility and grip-strength measures.

**Results.** Comparing the pre- (T1) and post-intervention data (T2), musculoskeletal symptom scores were significantly reduced in major body regions such as neck, back and shoulders ( $p < 0.001$ ). Four outcome measures were also significantly improved (neck: -44.32%,  $t = 3.82$ ,  $p = 0.000$ ; low back: -33.89%,  $t = 2.57$ ,  $p = 0.013$ ; upper limb: -46.61%,  $t = 2.66$ ,  $p = 0.011$ ; knee: -7.58%,  $t = -3.01$ ,  $p = 0.004$ ). Physical and psychosocial risk factors as well as RPE also reported significant declines after the intervention program. Comparing the post-intervention (T2) and one-year follow-up (T3) data, the four functional outcomes and both perceived physical and psychosocial risk factors showed no significant differences. Many of these variables maintained the significant difference comparing pre-intervention (T1) to one-year follow-up (T3).

**Discussion.** The intervention program was effective in reducing the musculoskeletal symptoms of community nurses, and the results support the positive benefits, both short- and long-term, of the ergonomic intervention program for community nurses.

## Effects of ergomotor intervention on motor control in the neck and shoulder region during functional movements in people with work-related neck-shoulder disorders

Grace Szeto (presenter), Billy So, Leung Kim Hung, Sheung Wai Law

**Background.** Work-related neck and shoulder disorders are common health problems affecting workers in many different occupations in office and industrial settings. A new intervention approach that combines ergonomics intervention and motor control training has been investigated in a randomized controlled trial with a one year follow up. The “ergomotor” approach consists of a 12-week intervention program that integrates the ergonomic interventions with the clinical approach of motor-control training. Participants allocated in the control group received 12 weeks of conventional physiotherapy.

**Methods.** 50 subjects were recruited in each of the ergomotor (EM) and control (CO) groups. Participants were from different occupations who reported more than three months’ history of work-related neck and shoulder pain. Each participant underwent a detailed biomechanical assessment involving surface electromyography (EMG) and 3D kinematics measurement of the neck and shoulder region at both pre- and post-intervention. Participants were required to perform three repetitions of lifting a weighted object (2 kg) in a forward-backward (F-B) functional task.

**Results.** Results of preliminary analysis with seven subjects in each group showed some apparent changes in muscle activity of the upper trapezius (UT) and lower trapezius (LT) during functional tasks. For example, in the FB test, UT showed a reduction from 46.3% of the EMG recorded in reference voluntary contraction (RVC) to 35.3% RVC in the EM Group, whereas the CO group decreased by about 5% from 51.4%. When this task was repeated with scapular retraction, the EM Group showed even greater reduction in UT activity (from 45.5% to 32.7%) and corresponding increase in LT activity (from 70.6% to 98.7%) at the post-intervention assessment.

**Discussion.** The results suggest an improved motor-control strategy in the functional movement pattern of workers who received ergomotor intervention. This effect can contribute to more sustainable reductions in work-related musculoskeletal symptoms in the long term.

## A systematic review of onsite fitness programs in the prevention of work-related musculoskeletal disorders

Deepak Sharan (presenter), Joshua Samuel Rajkumar, Rajarajeshwari Balakrishnan, Amruta Kulkarni

**Background.** Onsite fitness programs are becoming more widespread, testing the premise that fit and healthy employees tend to be happier and more productive. Such fitness programs range from simple offerings of information to workers, to subsidizing healthy lunches, to fitness education and the provision of a company gym. The aim of this study is to present a systematic review of the role of onsite fitness programs in the prevention of work-related musculoskeletal disorders (MSDs).

**Methods.** This systematic review examined published articles between the years of 1995 to 2015 in online database search engines including MEDLINE, Cochrane Library, CINAHL, PEDro and Google Scholar. Appropriate keywords were used to extract maximum studies. Three reviewers conducted the systematic review based on PRISMA criteria. The reviewers analyzed the studies for inclusion and excluded the studies that were duplicated. The studies were reviewed and summarized for research design, methodological quality, onsite fitness program regimen, results and conclusions.

**Results.** Overall, 99 studies met the inclusion criteria of which 71 studies were selected for the review. Although a number of the studies published found onsite fitness programs to be effective, only eight were RCTs. A majority of the studies on onsite fitness programs for preventing work-related MSDs were focused on computer professionals, construction workers, musicians, industrial workers and a few on health-care workers. Onsite fitness programs included ergonomic modifications, stretching and strength-training exercises, injury prevention and awareness counselling and pain reduction techniques. The outcome of randomized and non-randomized trials support the effectiveness of onsite fitness programs in both preventing and treating of work-related MSDs. Apart from this, onsite fitness programs also reduced stress and sickness absenteeism among workers in various sectors.

SESSION 6, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 201C

## What's new in return-to-work (RTW) for musculoskeletal, pain-related and mental health conditions?

Kim Cullen (presenter), Emma Irvin, Alex Collie, Fiona Clay, Ulrik Gensby, Peter Jennings, Sheilah Hogg-Johnson, Vicki Kristman, Marie Laberge, Donna McKenzie, Sharon Newnam, Andrew Palagyi

**Background.** The primary objective of this review was to update and synthesize evidence on the effectiveness of workplace-based RTW interventions that assist workers with musculoskeletal and pain-related (MSD) and mental health (MH) conditions with RTW and recovery after a period of work absence.

**Methods.** We followed a systematic review process developed by the Institute for Work & Health and an adapted best evidence synthesis. Synthesis of the evidence was ranked as strong, moderate, mixed, limited or insufficient. Seven electronic databases were searched from January 1990 until April 2015. This comprehensive search yielded 8,898 non-duplicate references.

**Results.** Our synthesis identified 36 studies examining three RTW outcomes (lost time, work functioning and associated costs) and four recovery outcomes (pain, psychological functioning, physical functioning and quality-of-life). These studies examined 12 types of interventions that were classified into three broad domains: health-care provision, service delivery and workplace modifications. Our review identified that, in most cases, interventions were multi-faceted and included multiple intervention components, sometimes operating across multiple domains. There is strong evidence that interventions encompassing multiple domains are effective in improving RTW outcomes in workers with MSD or MH conditions. In contrast, most interventions that are primarily focused on a single domain have mixed or limited evidence to support their effectiveness. There is also strong evidence that MH multi-domain interventions can improve psychological functioning after illness. However, there is moderate to strong evidence that most workplace-based interventions have no effect on improving recovery after injury or illness regardless of condition.

**Discussion.** We recommend implementing multi-domain interventions to help improve RTW outcomes for both MSD and MH conditions. Evidence for the impact of single-component interventions suggests that certain programs may reduce lost time, but the effect of most single-component interventions on RTW or recovery outcomes was less encouraging.

## Returning to work in spite of conflicts: an exploration of different types of decision-making in work rehabilitation after a chronic musculoskeletal disorder

Marie-Michelle Gouin (presenter), Marie-France Coutu, Marie-José Durand

**Background.** Return to work for disabled workers is a complex social process that involves numerous stakeholders with divergent concerns. The decision-making process could be a key to return to work (RTW), at least, in a work rehabilitation context. Concerted, negotiated or imposed decision making can be observed in RTW, but the influence of those types of decision making on sustainable RTW is not known. This study explores the influence of the type of decision making on RTW following a work rehabilitation program for chronic pain due to a musculoskeletal disorder.

**Methods.** A retrospective analysis of a multiple-case study (n=20) was carried out; each case corresponding to the decision-making process between RTW stakeholders (e.g. the worker, and representative(s) of the employer, the insurance board and the health care system). Individual semi-structured interviews with stakeholders (two to six individuals, in each case) were performed at the end of the program. Inductive analyses were performed for each case, followed by an inter-case analysis to identify, for each subject of decisions, the types of decision making. Moreover, sociograms were created.

**Results.** RTW was successful for 11 cases (out of 20). Concerted, negotiated and imposed decisions were documented, but could not help differentiate RTW status. Two characteristics of the decision-making seem to be important for RTW: (1) stakeholders should agree on a socioprofessional goal (at least for a short time), and (2) decisions reached by the stakeholders should respect workers' (physical and psychological) capabilities. In some cases, those characteristics can be encountered despite conflicts between stakeholders. However, in other cases, a conflict can hinder the reach of those decisions and this can hinder RTW.

**Discussion.** Understanding the decision-making process and acting strategically to reach a decision in favour of sustainable RTW seems important. Effort to facilitate the decision-making process should take into account the possibility of conflicts that can lead

## Which patients do not return to work after total knee arthroplasty?

Paul Kuijer (presenter), Arthur Kievit, Thijs Pahlplatz, Truus Hooiveld, Marco Hoozemans, Leendert Blankevoort, Matthias Schafroth, Rutger van Geenen, Monique Frings-Dresen

**Background.** Total knee arthroplasty (TKA) is highly effective in treating pain and loss of function caused by knee osteoarthritis (OA). Historically, TKA has mostly been performed on older retired patients. Now, an increasing number of TKA patients are of working age. However, two out of 10 working patients do not return to work (RTW) after TKA. To enhance an appropriate and timely diagnosis for additional work-directed care, knowledge about the characteristics of these TKA patients is needed. This study investigates patient characteristics associated with no RTW after TKA.

**Methods.** A multi-centre retrospective cohort study was performed among working patients having undergone a primary TKA during 2005-2010. The following pre-operative characteristics were assessed: age at surgery, sex, comorbidity, body mass index (BMI), preoperative sick leave duration, patient-reported work relatedness of knee symptoms and physical job demands. In addition, the Knee Injury and Osteoarthritis Outcome Scores (KOOS) after TKA were assessed. Backward stepwise logistic regression analyses were performed to predict no RTW.

**Results.** 167 patients met the inclusion criteria: 46 (28%) did not return to work. A pre-operative sick leave duration of more than two weeks was most strongly associated with no RTW (OR=12.5, 90%CI=5.0-31.5). Other associations found were: female sex (OR=3.2, 90%CI=1.3-8.2), BMI of 30 or more (OR=2.8, 90%CI=1.1-7.1), patient-reported work relatedness of the knee symptoms (OR=5.3, 90%CI=2.0-14.1) and a physically knee-demanding job (OR=3.3, 90%CI=1.2-8.9). Age and KOOS were not associated with no RTW.

**Discussion.** Given the estimated increasing number of working TKA patients, more prognostic studies on RTW are required to understand the disease-specific mechanisms for no RTW after TKA. Meanwhile, patients at risk for no RTW— especially obese female workers — with a preoperative sick leave duration of two weeks or more, and who perform knee-demanding work and indicate that their knee symptoms are work related, should actively be referred for work-directed care.

## Exploring the diagnostic value of heart rate variability for sustained employability

Marianne Six Dijkstra (presenter), Remko Soer, André Bieleman, Marielle Behrmann, Rollin McCraty, Frits Oosterveld, Doug Gross, Michiel Reneman

**Background.** Sustained employability (SE) is a trending topic in Western countries. Consequently, the focus on sickness and absence has shifted towards enabling future health and performance during work. A promising psychophysiological concept related to SE is heart rate variability (HRV), which has proved to be a strong independent predictor of future health issues in a number of studies. There is, however, insufficient knowledge about the additional value of HRV in the occupational context. The purpose of this study was to explore (1) the added diagnostic value of HRV for a worker's health assessment (WHA), and (2) the association between Work Ability Index (WAI) and HRV.

**Method.** In a cross-sectional study, the primary diagnostic outcome HRV was plotted in cross tabs with a cardiovascular, musculoskeletal, mental and work-related profile of 120 workers. Measurements were performed by an occupational therapist. HRV, expressed as MHRR, was assessed with a one-minute-forced-breathing protocol. Diagnostic aspects were analysed and the association between WAI and MHRR was determined with step-wise regression analyses.

**Results.** Preliminary results (n=51) show a high specificity (0.7-1.0) and positive predictive value (PP+) (0.7 -1.0) and a weak sensitivity (0.1-0.2) and negative predictive value (PV-) (0.1-0.4) of MHRR compared to most of the health profile indicators. Only MHRR and WAI showed a different pattern, with high PV- (0.8) and specificity (0.8) and weak PV+ (0.2) and sensitivity (0.2). The association between WAI and MHRR, controlled for age, was negative and weak:  $\beta$ [-0.26]; p [0.016]; 95%CI [-0.48/-0.05].

**Discussion.** HRV measurement could be valuable for a WHA. HRV values below an age-adjusted cut-off value can be interpreted as a valid indication for referral to a physician. The prediction of future employability could not be explored with the current study design. Therefore, a longitudinal study will be performed to validate HRV as a screening tool for SE.

## A novel chamber lid removal tool reduces spinal and shoulder loading

Mohammad Abdoli-Eramaki (presenter), Cale Templeton

**Background.** Removing chamber lids (manhole covers) has been identified as a contributor to the development of back pain and musculoskeletal disorders (MSDs) in workers who access underground chambers and vaults. The objective of this research was to compare a new tool for the removal of chamber lids with standard removal devices. The tool tested was a compact and light chamber lid remover tool (CLRT) designed to reduce spine and shoulder loading.

**Methodology.** Using a handheld force meter and an inertial motion capture system, the CLRT was compared to standard pickaxe and J-hook removal on two types of chamber lids. Kinetic and kinematic data were combined in a simulation model to estimate joint moments at the L4/L5 spine and left and right shoulders.

**Results.** At L4/L5, resultant moment was significantly lower when removing the lids with the CLRT compared to the pickaxe (mean decrease: 457.3 Nm,  $p < 0.0001$ ) or J-hook (mean decrease: 173.0 Nm,  $p = 0.001$ ). Significant ( $p < 0.05$ ) decreases in resultant moment were observed for the left and right shoulder when using the CLRT. The CLRT also puts the worker in a more favourable posture when peak force is applied, resulting in lower moment production at the spine.

**Discussion.** The lower resultant moment when using the CLRT may indicate decreased likelihood of shoulder and back injuries when removing the lids with this tool.

SESSION 7, WEDNESDAY, JUNE 22, 3:30PM – 5:00PM, ROOM 204C

## Participatory organizational intervention for improved use of assistive devices for patient handling: a single blinded cluster randomized controlled trial

Markus Due Jakobsen (presenter), Emil Sundstrup, Birgit M. Aust, Jeppe N. Ajslev, Lars L. Andersen

**Background.** Epidemiological studies have shown that patient handling is a risk factor for back pain, back injuries and long-term sickness absence; whereas consistent use of assistive devices during patient handling is associated with reduced risk of back injury. Consequently, Danish hospitals have made great efforts to increase awareness about the risks associated with patient handling and the use and availability of assistive devices for reducing work-related physical strain due to patient handling. Notwithstanding these efforts, a recent survey of more than 300 nurses and nurses' aides showed that two thirds rarely uses assistive devices during patient handling. Therefore it seems relevant to investigate the barriers, opportunities and practical solutions for increasing the use of assistive devices among healthcare workers. The purpose of this study is to evaluate the effectiveness of a participatory organizational intervention designed to increase the use of assistive devices.

**Methods.** This study was designed as a cluster randomized controlled trial performed at five hospitals in Denmark. During 2016, approximately 300 health-care workers from 30 departments (clusters) located at five different hospitals will be assigned to a participatory intervention or a control group. Surveys, interviews and observations will be performed prior to the intervention in order to gain knowledge about barriers and opportunities for use of assistive devices. The participatory intervention will subsequently consist of workshops involving leaders and selected participants from each department who will discuss these barriers and develop solutions for increasing the use of assistive devices. These solutions will, thereafter, be implemented for the entire department. Objectively measured (using accelerometers) use of assistive devices (primary outcome), average pain intensity (VAS scale 0-10) of the back, neck and shoulder, physical exertion during work, social capital and work ability (secondary outcomes) is assessed at baseline and at one-year follow up.

**Discussion.** The present study will provide documentation on how to improve the use of assistive devices for patient handling among hospital health-care workers.

## Musculoskeletal disorders among hospital cleaning staff and prevention measures

Michael Holbach (presenter)

**Background.** Much of the cleaning work in hospitals consists of monotonous, repetitive movements and includes working at heights and in ergonomically unfavourable positions. Lower education levels, increasing work intensity due to staff cuts and generally low levels of recognition further contribute to the unfavourable working conditions for this group.

**Methods.** A 2014 employee survey revealed that 27 female cleaners at a psychiatric hospital reported significantly more work-related musculoskeletal disorders (back and joints) than the other occupational groups [odds ratio, adjusted by age and sex, 4.4 (back pain) and 2.8 (joint pain) respectively].

An external, specialist trainer provided a one-day training session featuring the following main contents: ergonomic features and use of mops and other handled cleaning equipment; cleaning machines, suitable work positions; and, lifting and carrying loads. Eight affected employees were trained with the intention that they should act as multipliers. In addition, gymnastic exercises targeted to specific workloads were offered. A few months after the ergonomic training, the majority of the course participants reported a slight improvement of work-related motion sequences or a low relief of physical workloads.

**Discussion.** Choosing equipment with reference to ergonomic criteria, staff knowledge and input from trained ergonomists and professionals was the appropriate method for making physiological adaptations to the physical workload demand in the identified jobs. In addition, specific exercises may be useful for workers in some jobs. Accordingly, such measures should be broadly propagated and implemented. However, these recommendations are derived from a small group of cleaning staff. In order to estimate effects on morbidity, or to be able to develop interventional studies, larger groups from this occupational class are required.

## Systematic review of prognostic factors for return to work in workers with subacute and chronic low-back pain

Ivan Steenstra (presenter), Claire Munhall, Nelson Oranye, Steven Passmore, Emma Irvin, Dwayne Van Eerd, Sheilah Hogg-Johnson

**Background.** We assessed the evidence on factors that predict duration of sick leave in workers after six weeks of low-back pain (LBP) related sick leave. We hypothesized that different factors affect the duration of the leave depending on the time away from work.

**Methods.** Our review had seven phases: (1) developing the central question; (2) conducting the literature search; (3) identifying relevant publications; (4) quality appraisal; (5) data extraction; (6) evidence synthesis; and (7) knowledge translation. We searched for studies that reported on episodes of LBP and sick leave that lasted more than six weeks. All included studies had to have at least one prognostic factor where return to work (RTW) was the outcome.

**Results.** We identified 22 relevant publications. Workers' recovery expectations are important in later phases; the impact of pain, functional status and radiating pain seems to change with duration of work disability. Modified duties are rarely considered in later phases of work disability, although workplace physical factors remain important. Claim-related factors are supported by strong evidence in the chronic phase; however, depression/mental health did not appear to be an important factor in later phases. There is insufficient evidence that pain catastrophizing and fear avoidance are predictive factors in later phases. Age did not seem to play a role in RTW in the later phases.

**Discussion.** Physical demands in the workplace are preventing workers from getting back to work in a timely fashion across all phases of work disability. The psychosocial work environment is understudied in later phases.

## Does the difficulty of a memory task interspersed between bouts of repetitive work influence recovery?

Susanna Mixter, Svend Erik Mathiassen (presenter), Helena Jahncke, David Hallman, Petra Lindfors

**Background.** Controlled experiments suggest that active breaks with mental activity interspersed between physical work bouts can lead to more effective recovery from fatigue than passive rest. However, most of these studies investigated a highly stereotyped physical task until exhaustion. Research investigating the effects of mental breaks in tasks of higher occupational relevance is limited. The aim of this study was to evaluate the extent to which a working memory task performed at three difficulty levels would enhance recovery of perceived fatigue after a repetitive physical work task.

**Methods.** 12 women (mean age 26.4) performed 10 work cycles each comprising seven minutes of pipetting (to model repetitive work) followed by three minutes devoted to a working memory task. Three difficulty levels (MT1, MT2, MT3) of the memory task were tested on three different days in a randomized order across participants. During the last minute of pipetting and after the memory task, participants rated fatigue on the Borg CR-10 scale. Before, during and after each experiment, salivary  $\alpha$ -amylase was measured.

**Results.** Perceived fatigue in the right shoulder during the last minute of pipetting increased with time ( $p < 0.001$ ) but did not significantly differ between types of MT ( $p = 0.314$ ). Perceived fatigue in the right shoulder just after the memory task also increased with time ( $p < 0.001$ ), and in a pattern differing between MT types (time\*MT:  $p = 0.042$ ), while MT type showed no significant main effect ( $p = 0.169$ ). Post-hoc tests showed that MT3 led to better recovery than MT1 (effect of MT:  $p = 0.041$ ; time\*MT:  $p = 0.025$ ). Salivary  $\alpha$ -amylase increased with time ( $p = 0.001$ ) but showed no significant effects of MT type ( $p = 0.214$ ).

**Discussion.** Our results indicate that recovery of perceived fatigue after a repetitive task was better when performing a difficult — as compared to an easy — memory task. This effect was not accompanied by any differences in  $\alpha$ -amylase response.

SESSION 8, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 201A

## A method for the estimation of workers' risk of developing MSDs in early stages of process planning

Nadia Rego-Monteil, Steven Fischer (presenter)

**Background.** When making strategic decisions about a work system (i.e. hiring to increase capacity, a potential increase in demand, etc.), process managers often have difficulties in quantifying the exposures that these decisions may have on the workers involved. A discrete event simulation model is proposed to estimate the injury potential of workers under different operational scenarios.

**Methods.** A case study based on the Hastings-Quinte (Ontario) Paramedic Service served as an illustrative example. In the model, the emergency service was represented by a collection of entities that simulate the tasks (driving, patient handling, patient care, etc.) that paramedics perform when a call arrives to the system. Process parameters including, inter-arrival call times and task cycle times are introduced as probability distributions and are used to estimate low-back compression for workers. The configuration of the variables is set up to estimate workers' peak, cumulative and day-to-day variation of low-back compression, simultaneously to system efficiency results. Input data were characterized from questionnaires, call reports, self-reported data describing the tasks required during urgent and non-urgent calls and 20 observed calls. Low-back compression was introduced as a function of patient weight, and efficiency was measured with average call waiting time (different of zero if paramedics cannot respond immediately).

**Results.** Compression cumulative exposure ranged from 200 to 1400 N·h and peak values exceeded NIOSH limits 0.5 to 3.3 times a day, depending on the paramedic service location and shift. Paramedics from stations with lower call volumes were likely to experience lower cumulative spine exposures, but greater inter-day variation.

**Discussion.** Experimentation suggested that an increase in call volumes would have the greatest effect on increasing the spine load exposures of paramedics, opposed to increases in patient weight. The connection of biomechanical variables with operational characteristics through simulation opens an opportunity to assist decision-makers in process design and management.

## Building on good ideas: developing MSD interventions with residential builders

David Tappin (presenter), Bevan Catley, Darryl Forsyth, Tim Bentley, Liz Ashby, Clare Tedestedt-George, Ronny Tedestedt

**Background.** Boom-and-bust cycles in residential construction are the industry norm, with competition and customer demand creating pressure to complete work on time and to budget. Weather, terrain and dynamic worksites further complicate the sustainability of construction work, leading to a high prevalence of musculoskeletal disorders (MSDs). Injury data for 2009–2013 indicates that MSDs were responsible for around 40% of industry claims. This presentation reports on a two-stage study aimed at documenting measures used by residential builders to address MSDs, and considerations for enlisting participative development for industry support and implementation of prevention measures.

**Methods.** In stage one, 61 residential builders from three cities were interviewed at their worksite to identify potential MSD prevention measures along with their ideas for further changes. Approximately 160 measures were identified and organized into 26 groups broadly relating to the organization of work, building practices and work equipment. Each measure was accompanied by frequency data, degree of research support, and the researchers' views on its prevention potential. Significantly, many builders stated that they applied the measures primarily because they were of benefit to the business through gains in productivity, with reduced MSD risk a secondary consideration.

Following the release of an industry report, stage two focused on participative development and refinement of the measures. After an introductory meeting, a sample of builders rated each measure on its implementation feasibility before reconvening to discuss their findings. A short list was developed comprising those measures rated highest by the builders and the researchers. This list is currently being considered by the builders, with further workshops planned to develop targeted implementation strategies for each measure.

**Results/Discussion.** The presentation will outline major findings from the two stages of research, focusing on the measures themselves, benefits and drawbacks of a participative approach to MSD intervention, the importance of stakeholder support, and considerations for undertaking industry-level initiatives to address MSD.

## Analysis of worker strategies: a comprehensive understanding for a sustainable prevention of work-related musculoskeletal disorders

Marie-Eve Major (presenter), Nicole Vézina

**Background.** It is widely recognized that a multi-dimensional approach is needed in order to understand work-related musculoskeletal disorders (MSDs). At the same time, the establishment of corresponding prevention strategies remains a difficult task. The goal of this study was to examine how the analysis of worker strategies to manage pain could contribute to our understanding of the complex interaction between individual and organizational factors. More specifically, the aims were (1) to analyze strategies developed by workers to manage their pain in order to remain on the job, and (2) to construct a framework for studying workers' strategies that could be used for the prevention of work-related MSDs.

**Methods.** Based on a mixed methods approach (Creswell and Plano Clark, 2011), an ergonomic study centred on work activity analysis (St-Vincent et al, 2011) combined with a multiple case study (Yin, 2009) was conducted. Data were collected in two seafood-processing plants in two provinces in Canada. 16 seafood-processing workers were followed over two consecutive years using a range of interviews, as well as observations of work activity and work organization over the course of the entire study. The mixed methods analysis was performed through a qualitative content analysis and descriptive statistics.

**Results.** Overall, 818 strategies were identified. The results show that workers use a large variety of musculoskeletal pain management strategies to remain on the job. This identification, and the process of categorizing the strategies, led to the development of a framework for studying worker strategies.

**Discussion.** By revealing how the body is mobilized to achieve goals, strategies disclosed the difficulties encountered by workers with respect to their own activity (competences, awareness, etc.) and to the work organization (workstation layout, work organization, work tools, time factor, teamwork, supervisors, etc.). This understanding led to the identification of problematic situations to target for a sustainable prevention of work-related MSDs.

## Workplace barriers to reducing incidence of musculoskeletal disorders

Jodi Oakman (presenter)

**Background.** Musculoskeletal disorders (MSDs) are a large and complex workplace problem. Despite evidence that supports the role of work-related psychosocial hazards, and the broader psychosocial work environment in the development of musculoskeletal disorders, little is known about current workplace risk-management procedures. This research explores managers' — and other employees' — beliefs and attitudes about MSD causal factors and current workplace risk-management practices. Evidence will be presented on the types of strategies needed to achieve effective workplace implementation of a new evidence-based risk management procedure to reduce MSDs.

**Methods.** 75 interviews with managers, supervisors and employees across 20 organizations were undertaken in two sectors: aged care and logistics. Interview questions and structure were developed using "barrier analysis" methodology. In addition, during the interview, participants were provided with information about new ways to manage MSD and asked about potential barriers and enablers to the implementation of the process.

**Results.** Policies and procedures for workplace risk management of MSDs were largely focused on physical hazards with minimal reference to psychosocial hazards. Many participants acknowledged an awareness of links between psychosocial hazards and MSDs but they were not routinely identified and controlled in their organisations. Many participants reported that existing risk management processes could be expanded to include psychosocial hazards.

**Discussion.** To effectively manage MSDs, workplaces need to address all relevant hazards and risks including psychosocial and physical. Improved translation of research evidence into practice is required which takes into account relevant barriers to ensure successful uptake of new processes. Guidance material provided by regulators needs to ensure that coverage of hazard and risk factors associated with MSDs is comprehensive and reflects contemporary evidence.

SESSION 9, THURSDAY, JUNE 23, 10:30AM – 12:00PM, ROOM 203A

## Computer vision-based postural ergonomic evaluation

Joonoh Seo, Meiyin Liu, Sanghyun Lee (presenter), Tom Armstrong

**Background.** Workers in occupations that involve physically demanding and repetitive manual handling tasks suffer from work-related musculoskeletal disorders (MSDs) that account for about 33% of nonfatal occupational injuries and illnesses. Several ergonomic methods for evaluating workers' postural stresses through observations (e.g. OWAS, PATH or RULA) have been applied to identify the risks of work-related MSDs during work tasks. However, these methods are constrained by time-consuming procedures, observer bias and the need for a well-trained analyst.

**Method.** We propose vision-based posture classification to classify postures on video sequences by learning a classifier image pixel pattern according to different postures. Classified postures of images are then used to identify the level of ergonomic risks. To test the feasibility of this proposed approach, we conducted a case study. We recruited five male subjects and recorded videos from different viewpoints (e.g. left, left-diagonal and back) while they simulated several occupational tasks (e.g. bending, twisting, reaching or squatting). The video images were processed to classify postures according to different body parts (e.g. back, upper and lower limbs).

**Results.** By comparing classified postures with direct observation, we achieved over 90% of accuracy (# of correctly classified images / total # of images). The video sequences from the left-diagonal view showed the lowest accuracy, implying that this view is not recommended for posture classification in practice. In addition, postures involving upper limb movements had higher errors as arms were frequently overlapped in the front of the body.

**Discussion.** Vision-based posture classification has the potential to automate current ergonomic evaluation methods, even though the proposed approach needs to be further validated for more complex postures. The proposed approach enables practitioners to identify the risk of work-related MSDs through automated ergonomic postural evaluation only by recording videos at sites, which can help to prevent work-related MSDs for workers in a range of occupations.

## A critical review of the literature on the effectiveness of ergonomic interventions in preventing work-related musculoskeletal disorders

Massiagbè Diabaté, Susan Stock (presenter), Nicole Vézina, Marie Laberge, Valérie Albert, Katherine Sinden, Louis Gilbert

**Background.** The prevention of work-related musculoskeletal disorders (MSDz) is a priority in many jurisdictions. Systematic reviews of the effectiveness of ergonomic interventions in preventing work-related MSDs have arrived at contradictory conclusions, for reasons that remain unclear. We sought to clarify discrepancies in the evaluation of the evidence by conducting a critical review of existing systematic reviews of effectiveness of ergonomic interventions to reduce work-related MSDs.

**Methods.** We searched nine medical, psychology, business and occupational health databases from inception for English- and French published systematic reviews. The search strategy combined terms from five concepts: ergonomic interventions, evaluation of effectiveness, musculoskeletal disorders, work-related and review. Two independent reviewers screened each systematic review for relevance, assessed it for bias with the “Assessing the Methodological Quality of Systematic Reviews” (AMSTAR) tool, and summarized its selection criteria, methodologic quality assessment criteria, nature of interventions evaluated and conclusions. Two high quality reviews with contradictory conclusions were selected for more in-depth analysis of the reviews and each of their primary studies. Each study was also evaluated with respect to presence of eight key elements of an ergonomic intervention derived from the theoretical framework and definition of ergonomic intervention proposed by St-Vincent et al (2011).

**Results.** 22 systematic reviews meeting selection criteria were retained for evaluation and detailed description. Reviews by Rivilis et al (2008) and Driessen et al (2011) were selected for in-depth analysis. Review conclusions were influenced by differences in selection and quality appraisal criteria and the nature of the interventions reviewed. Reviews that were limited to randomized controlled trials were more likely to include studies that evaluated pieces of equipment rather than complex ergonomic interventions.

**Discussion.** Inclusion, exclusion and quality appraisal criteria for systematic reviews of the effectiveness of complex workplace-based interventions need to be adapted to the realities of workplace-based research while maintaining scientific rigour.

## Proposal for exercise resistance training for industrial workers

Rosimeire Padula (presenter), Hélio Gustavo Santos, Luciana Dias Chiavegato

**Background.** The physical overload of work is a triggering factor for muscle fatigue. The main causes are related to work postures and the duration of static muscle contraction necessary to implement tasks. In addition, lack of breaks, rest and ergonomic adaptations are ways of compounding this overload. However, nothing can replace the physical fitness of the worker, which is essential in the control of fatigue. This study proposes individual resistance exercise programs to assist with muscle fatigue management at the workplace.

**Methods.** This is a descriptive study. The intervention protocol consists of individual resistance exercises with progressive loads three times a week for 20 minutes. The resistance exercises are prescribed for workers of both sexes, aged 18-65. Workers at a medium-sized dairy plant will perform these exercise after receiving instruction on health self management, breaks, adjustments to workstations and the benefits of physical exercise. The program will run for four months.

**Results.** The training program will focus on muscle resistance, starting at 30% of one maximum repetition (1MR). The speed of the exercise will be moderate, with progressive loading according to each worker's adaptability and physiological characteristics. The exercise program will focus on the large muscle groups such as elbow flexors, elbow extensors, trunk flexors, trunk extensors, knee flexors, knee extensors, thigh adductors, thigh abductors, and ankle dorsal and plantar flexors. All exercises will be carried out in three sets of 10 repetitions each, with a 30-second rest interval between sets. A room equipped with dumbbells, ankle weights, weight plates and bars will be prioritized for the development of the exercises.

**Discussion.** There is evidence that resistance exercises are important for the control of fatigue. It is hoped that with a workplace-based program, that it will be possible to maintain the results with a shorter exercise exposure time (20 minutes, three times a week) .

## Are organizational or psychosocial work interventions effective in preventing work-related musculoskeletal disorders? A systematic review of the literature

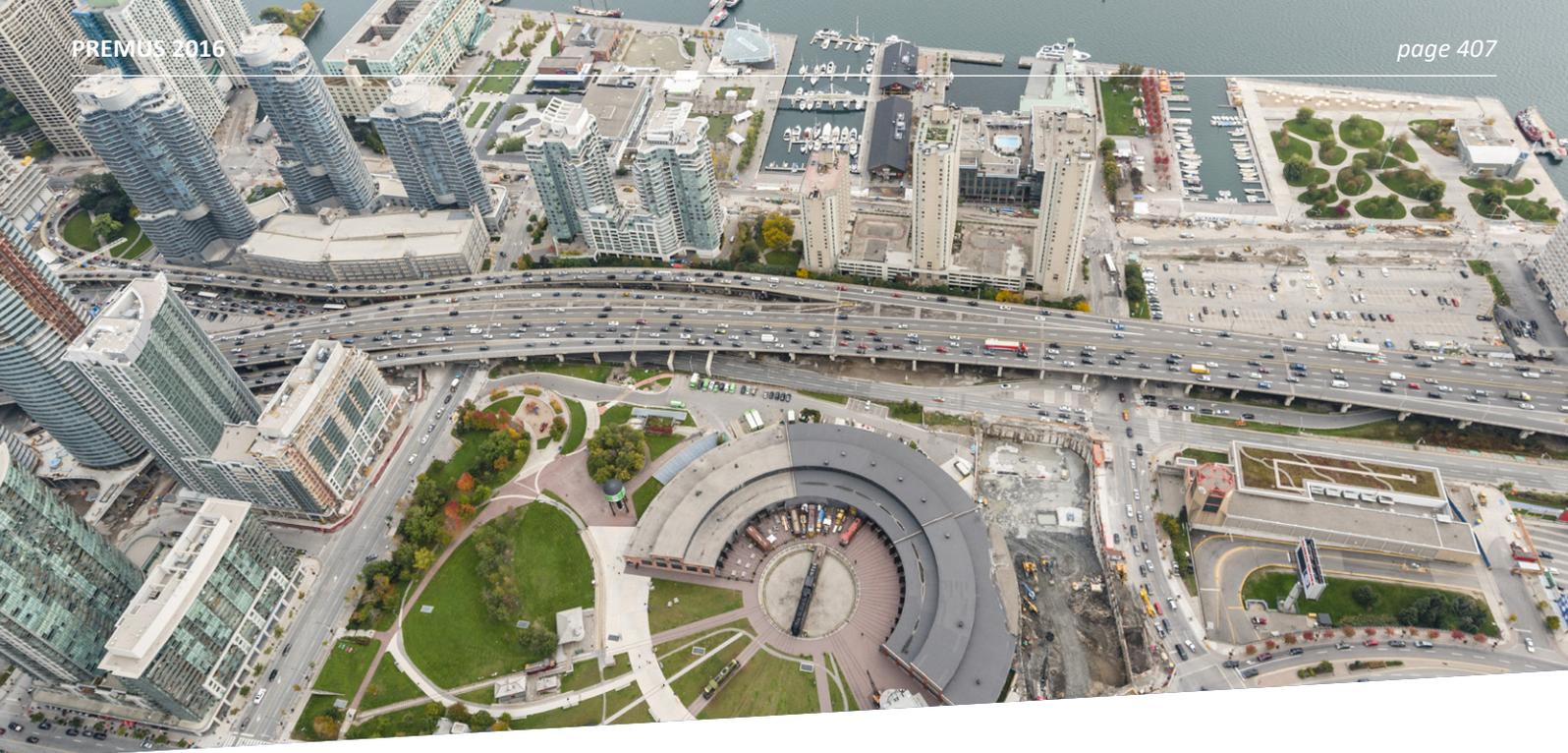
Susan Stock (presenter), Nektaria Nicolakakis, Systematic Literature Review Working Group on Musculoskeletal Disorders and Psychosocial Workplace Risk Factors, Clément Beaucage, Céline Delga, Marie-Agnès Denis, Louis Gilbert, Kathryn Sinden, Hélène Sultan-Taieb, Alice Turcot, Michel Vézina, Nicole Vézina

**Background.** Psychosocial and organizational work factors have been shown to contribute to onset of work-related musculoskeletal disorders (MSDs). But it is unknown whether or not interventions targeting such factors can prevent work-related MSDs. Our goal is to review the intervention literature between 2000 and 2015 to answer the question: Are interventions that target organizational or psychosocial factors in the workplace effective in the prevention of work-related MSD?

**Methods.** We are conducting a systematic review of English- and French-language peer-reviewed scientific articles, with searches in 12 bibliographic databases (medical, psychology, sociology, business, occupational health). The search strategy combines terms from four concepts: psychosocial/organizational interventions, evaluation of effectiveness, musculoskeletal disorders and workplace. Relevance is evaluated by two independent reviewers using the following inclusion criteria: (1) the study evaluated the effectiveness of an intervention; (2) the intervention targeted psychosocial/organizational aspects of the workplace to prevent work-related MSD; and (3) the outcome assessed was a musculoskeletal health outcome or psychosocial/organizational work exposure(s). We exclude rehabilitation/return-to-work interventions, individual strategies to reduce anxiety or to improve physical fitness and studies with >50% loss to follow up. Selected studies are assessed for bias according to 16 methodological quality criteria by two independent reviewers. Information is extracted from medium- and high-quality studies. Evidence is classified as very strong, good, mixed, limited or insufficient, based on methodological quality, quantity of studies and consistency of evidence across studies.

**Results.** The review will be completed by March 2016 and presented at PREMUS. Findings will inform the design of a pilot intervention of Québec's Public Health Network in Occupational Health and influence the methods used to evaluate effectiveness of work-related MSD prevention interventions carried out by the Network.

**Discussion.** Our findings may allow psychosocial and organizational workplace risk factors to be better addressed in ergonomic practice, and may be of relevance to other stakeholders interested in workplace work-place MSD prevention.



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## EPIDEMIOLOGY OF WORK-RELATED MSDS

# Burden of carpal tunnel syndrome (CTS) in active economic population in Colombia

Francisco Palencia (presenter), Martha Isabel Riano

**Background.** Musculoskeletal disorders are a leading cause of chronic pain and sick leave. The musculoskeletal disorders related to work mainly affect the upper limbs. It is believed that 1.5% out of 9.4% of musculoskeletal disorders occur in the wrist and hands. It is further believed that carpal tunnel syndrome (CTS) represents 1.5% of wrist and hand MSD cases. Carpal tunnel syndrome is an expensive and common disorder that affects working-age adults, and its prevalence could be between 1-5% in the general population and up to 14.5% in some groups of workers. There are two main methods for calculating the burden of one disease: the prevalence and the incidence approach. The objective of this study was to determine the burden of CTS in adults working in Colombia.

**Methods.** We performed a systematic review of studies found in the regional databases Scielo and Biblioteca Virtual en Salud (BVS), and in Google Scholar. We used the following search strategy without restrictions: "burden of carpal tunnel syndrome in working population in Colombia." We also performed this search in English and Spanish. Finally, we performed a deep search in grey literature.

**Results.** Our research articles showed that the prevalence of CTS among Colombia's working adults depended on the economic sector in which they worked. The prevalence of CTS among odontologists could be between 15.8%-40%. In contrast, the prevalence of CTS among white-collar workers could be around 4.5%, and the incidence within the pain unit of a hospital could be 10.7%.

**Discussion.** The burden of CTS in working adults needs to be studied within the context of each particular sector of the economy in order to estimate the burden of these disorders without bias.

## Estimated and self-reported workloads and lower extremity symptoms for nurses and nursing aides

Alicia Kurowski (presenter), Laura Punnett

**Background.** In U.S. nursing homes, nursing assistants are responsible for direct care and resident handling, while nurses are primarily responsible for medication distribution and administrative duties. This study examines differences between nurses and nursing assistants in observed and self-reported workloads and self-reported knee and ankle symptoms.

**Methods.** Clinical staff's postures and handling were observed at fixed time intervals using the PATH method. An additive physical workload index (PWI) was computed to compare lower extremity (LE) workload of nursing assistants and nurses. The PWI combined observed frequencies of postures and handling with their associated forces on the knee and ankle derived from the University of Michigan's 3D Static Strength Prediction Program. Additionally, surveys on health and working conditions were distributed to employees at 24 nursing homes. Knee and ankle symptoms in the past three months and physical demands were examined by clinical job type.

**Results.** Frequencies of postures and handling input into the PWI were based on observations of 275 nursing assistants and 40 nurses. The analysis of PWI for the LE demonstrated higher physical exposures on both the knee and ankle for nursing assistants, especially while performing resident handling, compared to nurses. Among survey participants ( $n = 1,467$ ), nursing assistants reported higher mean physical exertion scores than nurses. They also reported higher frequencies of knee and ankle symptoms ( $p=0.0076$ ) than nurses during the previous three months.

**Discussion.** In this study, both estimated and self-reported physical workloads were higher among nursing assistants compared to nurses. LE symptoms were also more common among nursing assistants than nurses. Safe handling equipment helps reduce some LE exposures for nursing assistants, but interventions for other strenuous tasks should be considered to reduce LE pain symptoms, such as introducing lighter food carts, which are often pushed by nursing assistants, and limiting the number of dirty linens bagged before they are transported to the soiled linen drop-off.

## The Italian network MAREL and musculoskeletal disorders

Stefano Mattioli, Stefania Curti (presenter), Pierluigi Cocco, Alfonso Cristaudo, Marco Dell'omo, Giovanni Mosconi, Giuseppe Campo.

**Background.** Occupational health surveillance is an important issue in many countries since working conditions and occupational exposures are rapidly changing. We aim to create a network of occupational disease consultation centres in Italian university hospitals to which patients are referred for potential work-related diseases.

**Methods.** The pilot network, namely MAREL (MALattie e Rischi Emergenti sul Lavoro), will include five occupational disease consultation centres at university hospitals located in central-northern Italy. Patients are referred to these consultation centres by their general practitioners, occupational physicians or other specialists for the investigation of the putative occupational origin of the disease. Each centre will collect cases of putative occupational origin through a structured and standardized data collection form. An online database platform will be developed collecting data on diagnosis, personal habits, occupational history, exposure assessment for potentially associated risk factors, and the physician's opinion on the possible causal relationship between disease and occupation. The data will be coded according to national and international classifications. To detect emerging musculoskeletal disease-exposure associations, we intend to apply the proportional reporting ratio used in pharmacosurveillance and adopted by the French occupational disease surveillance system (RNV3P).

**Results.** The data collection is going to start in 2016. Preliminary data will be available in due course. However, we expect to collect a high proportion of musculoskeletal disorders among the reported cases of putative occupational diseases. The detection of new musculoskeletal disease-exposure associations is an important public health issue, especially as large numbers of new technologies, products and duty cycles are regularly introduced.

**Discussion.** The Italian network MAREL will contribute to surveillance systems (i.e. MAL-PROF) through the detection of new and emerging musculoskeletal disorders and risks. A prompt detection of emerging disease-exposure associations can contribute to the development of preventive measures and can stimulate research on new occupational risks and musculoskeletal diseases.

## Perceived muscular tension in healthy subjects: a cross-sectional study

Tina Borg (presenter), Martin Björklund, Mats Djupsjöbacka, Anders Wänman, Fredrik Hellström

**Background.** Perceived muscular tension (PMT) has been suggested to predict development of neck/shoulder pain. It has been hypothesized to be an early sign of musculoskeletal disorder and a possible mediator of stress on symptoms. However, the content of the concept of PMT is not clear. This study examined the association between PMT and physical and psychosocial factors and physical activity in a group of healthy students.

**Methods.** This cross-sectional study was conducted on the baseline measurements of an ongoing longitudinal case-control study. A total of 63 healthy university students without complaints of neck/shoulder pain were included (21 males, 42 females, mean age 24 years). PMT was measured by asking the question “Have you, during the past month, experienced muscular tension (for example, wrinkled your forehead, ground your teeth, raised your shoulders)?” with the following response options: never, a few times, a few times per week, or one or several times per day. Self-reports on symptoms in the neck, anxiety, depression, stress, mental health, physical health, sleep and physical activity were collected with questionnaires, as well as by tenderness on palpation of neck muscles and trapezius pressure pain threshold. This produced a total of 15 variables. The relationship between these variables and PMT were analyzed using Spearman’s rank correlation coefficient.

**Results.** Positive correlations were found between PMT and temporomandibular complaints ( $\rho = .34$ ,  $p < .001$ ), neck crepitus ( $\rho = .33$ ,  $p < .001$ ), anxiety ( $\rho = .33$ ,  $p < .001$ ), depression ( $\rho = .31$ ,  $p < .05$ ), tenderness on palpation ( $\rho = .25$ ,  $p < .05$ ). There was a negative correlation between PMT and mental health ( $\rho = -.26$ ,  $p < .05$ ).

Frequent experience of PMT had weak to moderate correlations with frequency of symptoms and higher psychosocial strain, but not with stress. This suggests some covariance between PMT and both physical and psychosocial factors.

## Ergonomics factors and low-back pain among office workers in a private university in Colombia: a cross-sectional study.

Adriana Angarita Fonseca (presenter), Adriana Marcela Jacome Hortua, Mayra Patricia Gonzalez Bonilla, Eliana Vanesa Silva Guerra, Ruth Mayerly Suarez Hernández

**Background.** The prevalence of low-back pain (LBP) has been associated with physical exposures. In Colombia, however, this relationship has not been addressed sufficiently. The aim of this study was to investigate the relationship between ergonomics factors and LBP among office workers in a private university.

**Methods.** A cross-sectional study was conducted among 119 office workers with computer workstations. A structured questionnaire, which included demographic and work-related questions, and the Standardized Nordic Questionnaire were used to collect data. The Rapid Upper Limb Assessment (RULA) technique was utilized to characterize postures adopted by the workers. The dependent variable was LBP in the last 12 months. Prevalence ratio (PR) and 95% confidence interval (95%CI) between the main predictors and LBP were calculated using simple and multivariate binomial regression.

**Results.** The prevalence of LBP during the previous seven days and previous 12-month period was 14.3% (95% CI = 9.0-21.9) and 47.9% (95% CI=38.79- 57.00), respectively. From multivariate analysis, the posture adopted by workers was significantly associated with LBP (further investigation vs. acceptable posture PR=1.15, 95% CI=1.11-1.86; investigate and implement change vs. acceptable posture PR = 1.79, 95% CI= 0.63-5.13), adjusted by education level, using reclining chair, using portable base support, using mouse pad and having a support on their feet.

**Discussion.** Our study confirmed the associations between LBP and ergonomics factors. This report may be used as a guideline for implementing an intervention program focusing on trunk and shoulder posture changes in office workers.

## Work-related musculoskeletal disorders of Korean firefighters

Jangwhon Yoon

**Background.** Reported cases of work-related musculoskeletal disorders (MSDs) are increasing among Korean firefighters. Acceptance rates and applicants' satisfaction with the reviewing procedure are still main issues among Korean firefighters with work-related MSDs. The aim of this study was to analyze firefighters who applied for public workers' compensation benefits due to work-related MSDs.

**Methods.** Data for 579 applicants for work-related MSDs from 2011 to 2013 were collected by reviewing the compensation records for public workers of the National Emergency Management Agency. The cases were analyzed by gender, age, tasks, region, part of body injured and type of work-related MSD.

**Results.** Females made up 7.8% of the applicants, and the greatest percentage of applicants were 40-45 years old. In terms of work experience, less than five years was the most common category among the applicants, followed by 20-25 years. Injury happened while performing the following job duties: emergency medical service (38%), fire extinguishing (38%), rescue (12%), and training and others (12%). There was a significant difference (from 0 to 88.2) in prevalence per 10,000 by region. Out of 513 cases, 193 were in lumbar spine, 79 in knee, 54 in cervical spine, 54 in ankle, 33 in shoulder, and 32 in hand. Frequent types of injury were sprain and strain (49%), disc herniation (20%), fracture (17%), and others (14%).

**Discussion.** The incidence of work-related MSDs among firefighters was 0.96% in 2011, 0.76% in 2012, and 0.74% in 2013, which is 48% higher than 0.65% among all workers' compensation applicants. Work experience at reporting injuries and regional distribution suggest organizational factors are associated with reporting work-related MSDs.

## Upper extremity musculoskeletal pain among office employees in Costa Rica, Nicaragua and Spain

Adriana Campos-Fumero (presenter), David Gimeno, David I. Douphrate, Sarah A. Felknor, Sergio Vargas-Prada, Consol Serra, George L. Delclos

**Background.** The aim of this study was to estimate the prevalence and incidence of upper extremity musculoskeletal pain (UEMP) and associated disabling pain among office workers in two Spanish-speaking middle-income economies, Costa Rica and Nicaragua, and compare them to a Spanish-speaking high-income economy, Spain.

**Methods.** A secondary analysis of office workers in Costa Rica, Nicaragua and Spain using data collected as part of CUPID (Cultural and Psychosocial Influences on Disability), an international longitudinal multi-country study, was conducted at baseline (n=947; 93%) and followed up 12 months later (90%). Multivariate logistic regression was used to estimate the association (odds ratio [OR] and corresponding 95% confidence intervals [95%CI]) between country and six outcomes. These outcomes included three at baseline—(1) pain in the last 12 months, (2) pain in the past month and (3) disabling pain—and three at the 12-month follow-up— (4) pain in past month, (5) disabling pain and (6) persistence of pain. We adjusted for socio-demographic, job-related and health-related covariables.

**Results.** UEMP prevalence in the previous 12 months was higher in Nicaragua (69%) and Costa Rica (67%) than in Spain (51%). Compared to Spain, the UEMP incidence was 60% in Nicaragua (OR=3.15; 95% CI. 2.05-4.83) and 50% in Costa Rica (OR=2.17; 95% CI. 1.36-3.47). The incidence of disabling UEMP was 22% in Nicaragua (OR=2.39; 95% CI. 1.35-4.22) and 19% in Costa Rica (OR=2.21; 95% CI. 1.20-4.04).

**Discussion.** UEMP prevalence and incidence in Costa Rica and Nicaragua were two to three times higher than in Spain. These differences were mostly independent of demographic indicators, health-related factors, and employment and working conditions. Future research will be needed to study additional work-related factors, such as ergonomics conditions, and cultural differences that may explain between-country UEMP variability.

## Decrease of work-related low-back pain prevalence in drivers in France

Stéphanie Riviere, Hélène Prouvost, Brigitte Sobczak, Julie Plaine, Loïc Garras, Corinne Pilorget, Madeleine Valenty, Emilie Chazelle (presenter)

**Background.** Work-related low-back pain (LBP) is often reported in drivers, especially due to whole body vibrations. The evolution of LBP in drivers was analyzed by using the data of the French surveillance programme for uncompensated work-related diseases (UWRDs) from 2007 to 2012, following the implementation in France in 2005 of the EU vibration directive, which aimed to evaluate and decrease exposition in particular to whole body vibrations.

**Methods.** The French surveillance programme for UWRDs relies on a network of occupational physicians who volunteer to report all UWRDs diagnosed during a biannual two-week observation period. Each physician also completes a chart that lists, anonymously, each employee seen during the period, to serve as the denominator for calculating UWRD prevalence rates. The evolution of LBP prevalence in drivers was first compared to those of LBP in the other workers, and second to drivers' prevalence of neck and thoracic spine pain and prevalence of shoulder pain.

**Results.** Among the 553,191 workers seen between 2007 and 2012, 37,298 were drivers. Low-back pain prevalence in drivers decreased significantly from 2.0% to 1.5% between 2007-08 and 2011-12, whereas it was stable in the other salaries (1.1% vs. 1.1%). During the same period, prevalence of neck and thoracic spine pain and prevalence of shoulder pain remained stable in drivers (0.3% to 0.4% and 0.6% to 0.7% respectively).

**Discussion.** The decrease of LBP prevalence in drivers could reflect the implementation of preventive measures taken to limit whole body vibrations (EU vibration directive and improvements in drive cabs), even if no direct conclusion can be drawn. It could also reflect, in theory, an increase of compensated occupational diseases, but between 2007 and 2012, the annual number of compensated LBP cases only increased by around 100 for the whole of France. Our observations are nevertheless limited by the absence of data before 2005.

## Work-related MSDs in physical therapists

Edgar Vieira (presenter), Denis Brunt, Bruno da Costa

**Background.** Few studies have investigated work-related MSDs among American physical therapists (PTs) and none have investigated work-related MSDs among physical therapists in Florida. In addition, potential differences in the rates of work-related MSDs among specialties and settings need further evaluation. The purpose of this study was to evaluate the rate and characteristics of work-related MSDs in a sample of PTs practicing in Florida based on their specialty and setting.

**Methods.** Participants completed an online questionnaire that included 15 demographic questions, seven work-related questions, and eight injury-related questions for nine different body parts. The survey questions were based on the Nordic Musculoskeletal Questionnaire and other questionnaires used in studies of work-related MSDs in PTs.

**Results.** Complete responses were obtained from 121 PTs. Of these PTs 96% reported MSD symptoms during the previous 12 months, and 64% reported MSD symptoms affecting at least three body parts. The body parts with the highest prevalence of symptoms were the low back (66%) and the neck (61%). For PTs that specialized in acute care, geriatrics and pediatrics, the body part most commonly affected was the low back, while for PTs that specialized in orthopedics and neurology, the body part most commonly affected was the neck. Regarding work settings, the low back was most commonly affected among PTs working in skilled nursing facilities, outpatient clinics and hospitals, and the neck was most commonly affected among PTs working in academic and home health-care settings.

**Discussion.** MSDs are common among PTs. The body parts most often affected are the low back and neck. The prevalence and body parts affected varies by practice setting and specialty area. Rehabilitation of injured PTs needs to address the symptoms of the multiple body parts that are usually affected (e.g. back, wrists and hands), and take into consideration their job demands, practice setting and specialty area. These findings can help inform the design of evidence-based rehabilitation, prevention, training and educational programs.

## Work-related musculoskeletal disorders among nurses in a tertiary referral hospital

Charuwan Manmee (presenter), Kanya Janpol, Wannakorn Homsuwan, Sinjai Invichai

**Background.** Musculoskeletal disorders (MSDs) are a major concern for nurses because of their impact on health and work productivity. The prevalence of MSDs among nurses has not been well documented or taken seriously in Thailand. This study aims to determine the prevalence of MSDs and factors associated with MSDs among nurses working in Rajavithi Hospital (RJH), a tertiary referral hospital in Bangkok, Thailand.

**Methods.** A cross-sectional study was conducted in 485 nurses. Data were collected using the Standardized Nordic Questionnaire. The questionnaire was divided into two parts. Part I included socio-demographic data and Part II contained information on work-related MSDs and locations of MSDs during the previous 12-month period and past seven days in nine body areas. Binary logistic regression assessed the associations between variables and MSD-related risk factors. The study was approved by the Rajavithi Hospital's Ethics Committee.

**Results.** The mean  $\pm$ SD of participants' ages was  $40.5 \pm 11.1$  years. Most participants were female. The results revealed that 62.3% of nurses had MSDs in at least one out of nine body parts in the past 12 months. MSDs were most prevalent in the shoulder (41.9%), neck (33.8%) and low back (32.4%). Binary logistic regression analysis showed that lifting (OR 1.44, 95% CI 1.06-1.97) was strongly associated with MSDs ( $p=0.021$ ).

**Discussion.** The prevalence of MSDs in this study is consistent with the literature. Musculoskeletal disorders in the shoulder, neck and lower back were associated with the length of time spent working in static standing postures and improper neck postures. Lifting was also a factor related to MSDs. Lifting patients in bed and lifting patients from the floor were the activities commonly associated with MSDs in nurses. These findings are consistent with previous reports indicating manual patient lifting, handling, transferring or moving are important predictors of MSDs among nurses.

## Associations between self-reported CTS and the co-exposure to neurotoxic chemicals and physical constraints for male agriculture workers in France in 2010

Xavier Pascal, Julie Bodin (presenter), Natacha Fouquet, Ronan Garlantezec, Yves Roquelaure

**Background.** This study aimed to assess the associations between carpal tunnel syndrome (CTS) and the co-exposure to neurotoxic chemicals and physical constraints in male agricultural workers covered by a French health insurance fund.

**Methods.** In 2010, about 10,000 workers were randomly selected from the health insurance database of five French administrative areas. Data were collected by a self-administrated questionnaire (participation rate was 24%). This study included 744 men, aged 18-65 years, actively working in the agriculture, forestry and fishing sectors at the time of the study.

Co-exposure was assessed by reporting at least one of the eight physical constraints studied (repetitive movement, using of vibrating hand-tools, handling heavy load, twisting of the wrist, holding tools or objects in a pinch grip, using a keyboard, pressing with the base of the palm, working in low temperature) and reporting an exposure to at least one of the nine neurotoxic chemicals studied (pesticides, gasoline, white spirit, cellulosic thinner, other solvents, glue, paint, ink, trichloroethylene) in the last 12 months. Statistical associations between self-reported CTS and co-exposure were analyzed using logistic regression, adjusted for personal factors.

**Results.** A total of 32 men declared CTS in the last 12 months, and 25.5% (95% CI 21.7-29.2) reported co-exposure to neurotoxic chemicals and physical constraints. Men co-exposed more often declared CTS in the last 12 months than men without co-exposure: 6.6% (95%CI 2.8-10.3) vs. 2.8% (95%CI 1.3-4.2),  $p=0.001$ . Adjusted for personal factors, co-exposure to neurotoxic chemicals and physical constraints was associated with CTS (OR=5.0 95%CI 4.0-6.2).

**Discussion.** This study found an association between self-reported CTS in the last 12 months and co-exposure to neurotoxic chemicals and physical constraints in men. The declarative nature of CTS is a limit of this study, and health insurance data documenting CTS will be used to confirm this result.

## Prevalence and associated factors of suspected carpal tunnel syndrome among hospital personnel

Kanya Janpol (presenter), Charuwan Manmee, Wannakorn Homsuwan, Sinjai Invichai

**Background.** Carpal tunnel syndrome is a condition affecting the hand and wrist resulting in health impacts and reduced productivity at work. This study aimed to assess prevalence of suspected carpal tunnel syndrome (CTS) and associated factors among personnel working in Rajavithi Hospital, Bangkok, Thailand.

**Methods.** A cross-sectional study was conducted of 1,580 personnel. Eligible participants that had worked in their current position at least one year were recruited. Data were collected using a symptom questionnaire (the Katz hand diagram). Sex, age, years of working, shift work, health status and behaviour and employment history were collected. Binary logistic regression was performed to assess the associations between suspected carpal tunnel syndrome and associated risk factors. The Rajavithi Hospital Ethics Committee approved this study.

**Results.** The mean standard deviation of participants' ages was  $39.3 \pm 11.6$  years. The majority of personnel were female. Almost 35% of participants were nurses and support staff. The results revealed that 34.9% of personnel had suspected carpal tunnel syndrome. Multivariate analysis revealed that tea and coffee consumption (OR 1.59, 95% CI 1.15-2.20), drug use (OR 1.41, 95% CI 1.02-1.95), poor sleep quality (OR 1.41, 95% CI 1.05-1.88), longer computer use (OR 1.20, 95% CI 1.02-1.41) and heavy work activities for hand and arm (OR 1.30, 95% CI 1.08-1.56) were significantly associated with suspected CTS ( $p < 0.05$ ). Of 270 suspected CTS cases, 106 had CTS confirmed by clinical examination.

**Discussion.** The prevalence of suspected CTS is likely to be high, consistent with previous studies. Tea and coffee consumption, drug use, quality of sleep, working at a computer for long periods, and heavy work activities are factors associated with suspected CTS. The use of hand diagrams may be used for early screening and may contribute to physical and clinical examination in the risk group.

## Capacity for work and occurrence of musculoskeletal symptoms in women

Dernival Bertencello (presenter), Isabel Aparecida Porcatti de Walsh, Shamyry Sulyvan Castro, Maria Cristina Cortez Carneiro Meireles, Nara Paula Carvalho

**Background.** The number of females in Brazil's labour force who are older, married and with children has increased. Several factors affect the Work Ability Index (WAI) making life unsatisfactory. The aim of this study was to evaluate the WAI to identify the body regions with musculoskeletal symptoms and to analyze the associations between these variables in working women over 18 years of age in the city of Uberaba, Minas Gerais, Brazil.

**Methods.** This was a cross-sectional population-based study of probability sampling, carried out through home interviews. The ability for work was assessed using the WAI. The evaluation of musculoskeletal symptoms was performed by the Nordic Musculoskeletal Questionnaire (NMQ). Data were analyzed by descriptive analysis. We used the chi-square test and the Pearson's product-moment correlation with a statistical significance level of 5% to analyze the relationship between our variables.

**Results.** We evaluated 500 women with a mean age of 43 ( $\pm 13.87$ ) years. , with 212 of these women (42.40%) were considered homemakers. Musculoskeletal symptoms were present in the following body regions: 34.2% lower back; 29% wrist/hand; 28% dorsal region; 26.4% shoulder; 23.6% ankle/foot; 23.4% knee; 21.4% hip/thigh; 20.6% neck; and 12.6% elbow. The WAI had an average score of 38.92 ( $\pm 6.4$ ) with participants falling in the following categories: low capacity 5.8%; moderate capacity 24.8%; good capacity 42.2% ; and optimum capacity 27.2% . The WAI results were significantly and negatively influenced by participants' age, but were not statistically influenced by years of study ( $p=0.599$ ;  $r=0.024$ ) and family incomes ( $p=0.081$ ;  $r=0.079$ ).

**Discussion.** The presence of musculoskeletal symptoms in all body regions were significantly associated with decreased WAI scores. It is important to know the commitment to WAI for a better knowledge in characterizing the causal nexus to propose preventive measures involving training, guidelines and ergonomic adjustments in the workplace.

## An exaggerated initial pain report bias in field studies?

Morten Waersted (presenter), Therese N Hanvold, Kaj Bo Veiersted

**Background.** When recording musculoskeletal pain in a group of workers over time, it is important to have a reliable baseline pain level. This is especially important in intervention studies in which changes in pain level is a main outcome. Observations in earlier studies have suggested that a subject may tend to report higher levels of pain in their initial report on pain level (Steingrimsdóttir 2004; Hanvold 2014). In an ongoing intervention study with daily reports on pain level, we thus analyzed the first five pain reports to look for signs of an “exaggerated initial pain report”.

**Methods.** In this nine-month follow-up study on physical workload, 24 hairdressers give daily pain reports from seven body regions (head, neck, right/left shoulders, right/left lower arms and low back) on an 11-point scale going from zero (no pain at all) to 10 (the worst imaginable pain). In the preliminary analysis presented here, we used both the first five days and the first three days of pain reports. We analyzed each body region separately using multilevel mixed-effect regression (STATA version 12).

**Results.** These preliminary analyses showed no sign of an increased pain score in the first pain report, compared to the following days of pain reporting.

**Discussion.** The data from this study do not support the notion of an “exaggerated initial pain report”. However, such an effect may occur in specific circumstances that were not present in this study. In our dataset, the subjects gave their pain reports daily, compared to monthly reports (Steingrimsdóttir, 2004) or reports every fourth month (Hanvold, 2014) in the earlier studies that raised this question. The two earlier studies asked for the intensity and duration of pain during the last four weeks, whereas the present study asked for pain intensity on the actual day of reporting.

## Personal support worker (PSW) safety in the community: a prospective cohort study

Emily King (presenter), Paul Holyoke, Robin Hurst, Tara Kajaks, Kenneth Hutchinson, Seham Rabaa, Tilak Dutta, Susan Jaglal

**Background.** Community-based personal support workers (PSWs) provide 70-80% of paid home care. Unfortunately, they sustain work-related injuries at more than twice the rate of the general working population. Most of these injuries are musculoskeletal, cumulative, affect the low back, and relate to client handling. While the presence of general risk factors (heavy loads, awkward postures, cramped spaces, working alone, limited access to functional equipment) is well-acknowledged, specific information on the activities and circumstances that pose the greatest risks is lacking. The purpose of this project is to identify high-impact risk factors for work-related injuries and lost-time claims on community-based PSWs.

**Methods.** All PSWs employed by the participating community care agency in selected geographic areas (>900 individuals) will be followed for one year. The primary outcomes are reported injuries, lost time at work and injury-related costs. Independent variables from the administrative data include: hours worked, care activities performed, client characteristics (assistance required, unsteadiness, dementia/delirium, resistance to care), and the PSWs' age and sex.

Epidemiology of work-related MSDs in the cohort will be invited to participate in a series of surveys. A baseline survey will ask about demographics, personal history, health-related quality of life, aches, pains and prior injuries. Baseline and closing surveys will also address job satisfaction, job demands, control over work, available supports and perceptions of organizational policies and practices. Weekly surveys will ask about other jobs, fatigue, pain, work-related violence or abuse, whether respondents did extra work for their clients, and whether they received promised support.

Regression models will be used to identify the risk factors with the greatest influence on reported injuries, lost time, and related costs.

**Results.** Data collection starts early in 2016. Preliminary findings will be presented.

**Discussion.** The study will inform the development of evidence-based interventions to reduce the rate of musculoskeletal injuries.

## Work-related risk factors for incidence of neck pain in a large working population

Audrey Petit, Julie Bodin, Angélique Delarue, Natacha Fouquet (presenter), Yves Roquelaure

**Background.** Non-specific neck pain (NP) is a prevalent issue in occupational health, and all its work-related determinants are not yet known. The aim of this study was to evaluate the incidence of NP in the workplace and to identify its work-related factors.

**Methods.** Between 2002 and 2005, 3,710 workers were randomly included in a French surveillance system of work-related musculoskeletal disorders. In 2007, 2,332 subjects responded to a follow-up questionnaire. The questionnaire assessed musculoskeletal symptoms (Nordic questionnaire) and individual and work-related risk factors. Incident NP was reported by subjects who were free of NP at baseline and complained of NP lasting more than eight days during the 12 preceding months at follow-up. Analyses were performed on workers. Associations between incident NP and risk factors at baseline were studied using logistic regression modeling, stratified by gender.

**Results.** Among the 1,510 workers (914 men and 596 women) still active at follow-up and free of NP at baseline, 10.4% [IC95%=[8.4-12.4] of men and 14.6% [11.8-17.4] of women declared NP at follow-up. Among men, work-related factors associated with incident NP were work pace dependent on permanent controls or surveillance (OR=2.1 [1.3-3.3]), work pace dependent on demand of customers (OR=1.8 [1.2-2.9]) and low co-worker support (OR=1.8 [1.1-3.0]). Among women, sustained or repeated arm posture in abduction and high perceived physical demand (RPE Borg scale $\geq$ 14) (OR=3.5 [1.7-7.2]), paced work (OR=2.1 [0.97-4.6]) and age (OR=2.3 [1.1-4.6] for 40-49) were associated with incident NP.

**Discussion.** This study, conducted in a large sample of workers, confirms the high incidence of NP in the workplace and its multifactorial nature. It also emphasizes the differential impact of risk factors by gender. Aside from biomechanical factors in women, this study highlights the impact of workplace organizational and psychosocial factors on the incidence of NP in both genders.

## Example of using a job-exposure matrix: carpal tunnel syndrome and computer exposure at work in two large complementary cohorts

Alexis Descatha (presenter), Zakia Mediouni, Julie Bodin, Ann Marie Dale, Matthieu Carton, Annette Leclerc, Natacha Fouquet, Christian Dumontier, Yves Roquelaure, Bradley Evanoff

**Background.** The boom in computer use and concurrent high rates in musculoskeletal complaints and carpal tunnel syndrome (CTS) among users has led to a controversy about a possible link. The present study used longitudinal data from two large complementary cohorts to evaluate a possible relationship between CTS and the performance of computer work, assessed by questionnaire in one, and by a job exposure matrix in the other one.

**Methods.** The Cosali cohort is a representative sample of a French working population that evaluated CTS using standardized clinical examinations and assessed self-reported computer use. The PrediCTS cohort study enrolled newly hired clerical, service and construction workers in several industries in the United States, evaluated CTS using symptoms and nerve conduction studies (NCS), and estimated exposures to computer work using a job exposure matrix. During a follow-up of three to five years, the association between new cases of CTS and computer work was calculated using logistic regression models adjusting for sex, age, obesity and relevant associated disorders.

**Results.** In the Cosali study, 1,551 workers (41.8%) completed follow-up physical examinations; 36 (2.3%) subjects were diagnosed with CTS. In the PrediCTS study, 711 workers (64.2%) completed follow-up evaluations; 31 (4.3%) had new cases of CTS. The adjusted odds ratio for the group with the highest exposure to computer use was 0.39 [0.17; 0.89] in the Cosali cohort and 0.16 [0.05; 0.59] in the PrediCTS cohort.

**Discussion.** Data from two large cohorts in two different countries showed no association between computer work and new cases of CTS among workers in diverse jobs with varying job exposures. Job exposure matrices might be used in such purposes.

## Prevalence and risk factors associated with thumb pain from smartphone use in secondary school students at Khlong-Luang, Pathumthani

Santhanee Khruakhorn (presenter), Siriluck Kanchanomai, N. Jetjongjai, C. Kumkong, N. Nanon, K. Kaewlek, S. Kanchnomai, S. Khruakhorn

**Background.** Today, smartphones are very popular and widely used. Many studies have found smartphone use associated with thumb pain or fatigue. The objective of this study was to determine the prevalence of thumb pain among lower secondary school students who use smartphones, and to determine the risk factors associated with thumb pain.

**Methods.** An analytic cross-sectional study was conducted. Participants were secondary school students age 12-15 years in Khlong-Laung District. Data were collected by online questionnaires that assessed smartphone use and risk factors associated with thumb pain. Two video cameras recorded thumb movements while students used smartphones for five minutes. Grip strength was also measured using a hand grip dynamometer.

**Results.** 820 students returned questionnaires, a 100% response rate. Out of 753 students, 202 (26.83%) reported thumb pain from smartphone use. Playing sports and using smartphones with large screens were protective factors against thumb pain from smartphone use (OR=0.71, 95% CI 0.51-0.98 and OR=0.30, 95% CI 0.09-0.91 respectively) after adjusting for sex, hobbies such as playing sports, playing music, reading, forearm pain, and smartphone screen size.

**Discussion.** Thumb pain from smartphone use was associated with many internal and external factors. We suggest that playing sports and using smartphones with large screens may help prevent thumb pain.

## Prevalence and risk factors associated with neck pain from smartphone use in secondary school students at Khlong-Luang, Pathumthani

Siriluck Kanchanomai (presenter), Paphonkan Boonyarit, Thitima Rammayan, Irin Pinsanoh

**Background.** Today, smartphones are very popular and widely used. A literature review revealed that the use of smartphones may be associated with neck pain or fatigue. Therefore, this study examined the prevalence and relationship between neck pain and smartphone use factors in lower secondary school students, ages 12-15 years.

**Methods.** An analytic cross-sectional study was conducted. Participants were secondary school students ages 12-15 years in Khlong-Laung District. Data were collected by online questionnaires that examined smartphone use and risk factors associated with neck pain. Craniovertebral angle (CV angle) was evaluated by lateral photograph and neck range of motion was measured by Myrin goniometer.

**Results.** 820 students returned questionnaires, a 100% response rate. Among 753 respondents, 258 reported neck pain from smartphone usage (34.26%). Also, students who used a smartphone for more than 165 minutes per day were at significant risk of experiencing neck pain (adjusted OR= 5.26, 95%CI. 1.11-24.79) after adjusting for body mass index, right neck rotation range of motion, and left neck rotation range of motion.

**Discussion.** The prevalence of neck pain from smartphone use in this study was high. Using a smartphone more than 165 minutes per day was also an important risk factor for predicting neck pain.

## Factors related to upper limb musculoskeletal pain among office workers

Kiook Baek (presenter), Insung Chung, Miyoung Lee

**Background.** Office workers face a number of risk factors for work-related musculoskeletal pain. Psychosocial and ergonomics factors are main risks of work-related MSDs. The aim of this study was to investigate the risk factors for upper limb musculoskeletal symptoms among office workers.

**Methods.** A cross-sectional study was conducted among 101 office workers and 339 subway drivers. Subway drivers were selected for the control group because they spend the majority of their time sitting during work. Field investigations were carried out by an industrial hygienist. RULA and ART tools were used to conduct ergonomics assessments, by picture and sample interview data. Self-administered questionnaires, including the Nordic Musculoskeletal Questionnaire, Korean Occupational Stress Scale (KOSS), Psychosocial Well-being Index(PWI), and Pittsburgh Sleep Questionnaire(PSQI), were given to all workers. Descriptive statistics, chi-square analysis and logistic regression analysis were used to compare the two groups.

**Results.** Among office workers, repetitive hand movement was considered a risk factor. Among drivers, awkward neck posture and pushing with force were considered risk factors. The ART score was higher in the office worker group, and the RULA score was higher in the driver group. The prevalence of musculoskeletal pain in hands (18.8% vs. 9.4%) and arms (12.9% vs. 4.4%) were significantly higher among office workers ( $p < 0.05$ ). No difference in neck, shoulder and knee pain was evident between the two groups. The overall KOSS score was significantly higher among office workers. Among subscales of KOSS, subway drivers reported more stress due to the physical environment while office workers reported higher stress due to job demands and insufficient job control. No significant differences on PSQI scores and PWI scores were found. In multivariable analysis, job demand was independently associated with upper limb work-related MSDs.

**Discussion.** Repetitive hand movement and job demands should be indicated as risk factors for work-related MSDs among office workers. Both ergonomics risks and psychosocial conditions should be considered to prevent work-related MSDs among office workers.

## Work related lower limb disorders: lessons learned from a case list of a public occupational health clinic

Angela Carta (presenter), Michela Crippa, Barbara Bellina, Stefano Porru

**Background.** An increasing number of studies highlight the role of occupational risk factors for lower limb disorders (LLDs), which are largely underestimated. Our aim was to analyze a case list of LLDs and to assess and discuss etiological diagnostic criteria.

**Methods.** LLD cases attended, over 2007-2014, the occupational health clinic of a public general hospital located in one of the most industrialized Italian areas. A detailed clinical report (lifetime occupational and clinical history, imaging) was available; diagnosis reported whether the LLD was work-related or not. Risk assessment information was collected from various sources. Data were compared with those retrieved from the regional compensation authority (INAIL). Attribution to occupation was based on occupational history, risk assessment, objective clinical data and scientific literature.

**Results.** 111 LLDs were assessed, about 5 % of all cases evaluated over 2007-2014. 90% (n=101) were sent by general practitioners; 68% were male; 62% of LLD cases were assessed over the last four years. 70% were knee disorders (49% meniscus; 21% gonarthrosis), followed by hip (15%) and foot-ankle (5%); 11% involving multiple sites. 24% of LLD cases were attributed to occupation: all males, working in construction, with knee or hip disorders. Manual material handling, awkward postures > 5 years (meniscus disorders) or > 10 years (gonarthrosis) were the major risk factors. Extra-occupational factors for LLD were not relevant. Comparison with INAIL data showed our case list represented about 8% of all 304 LLD reported cases.

**Discussion.** A limited number of cases satisfied criteria of etiological attribution to occupation. Lack of risk assessment data for biomechanical overload was a major limiting factor. More LLDs were shown over the last four years. Underestimation of occupational LLD could be reduced by referring possible cases to occupational health clinics. Further studies should better characterize dose-response relationships for occupational risk factors and LLD.

## Risk factors for hip osteoarthritis (coxarthrosis): results from a systematic review and meta-analysis

Bernd Hartmann (presenter), Rainer Schiele, Marcus Schiltewolf, Gunther Hofmann, Michael Kaiser, Gunther Spahn

**Background.** Coxarthrosis can be caused by different endogenous factors. Exogenous factors can influence their occurrence. Above all, these factors are biomechanical: hip injuries or biomechanical overload in occupations or sports. This review was performed to identify significant or possible risk factors for hip osteoarthritis.

**Methods.** The PRISMA guidelines for systematic reviews and meta-analyses were strictly followed. Articles for this systematic review were obtained from the following databases: PubMed, Medline, Cochrane, EMBASE and WebofScience.

**Results.** A total of 8,442 abstracts were initially identified. From these, 81 papers (longitudinal studies n=31, cross-sectional studies n=50) were included in the meta-analysis.

The crude prevalence of hip osteoarthritis independent of any adjustments was 7.9%. The mean crude incidence was 20.1 (95% CI 14.3 – 26.7) / 10,000 person years. The prevalence and incidence tended to be higher in surveys or clinical studies than in radiological studies. The lowest incidences were identified in studies which addressed the requirements of a hip replacement.

Age is the most important risk factor for hip osteoarthritis [OR=1.8 (95% CI 1.6-1.8; p<0.001)]. No significant differences were seen between men and women.

Other significant risk factors for hip osteoarthritis are overweight or obesity [OR=2.3 (95% CI 1.9-2.6; p<0.001)], hip dysplasia [OR = 2.2 (CI 1.8 – 2.7; p<0.001)] and hip injuries (OR = 3.5 [CI 1.7-7.3; p=0.001]).

**Discussion.** Despite a large number of identified studies, there is limited evidence about risk factors for hip osteoarthritis. The prevalence of hip osteoarthritis rises significantly as patients age. Being overweight as well as the presence of hip dysplasia and injuries are significant risk factors for hip osteoarthritis in longitudinal studies. A number of other factors are also possible risk factors (based on results from cross-sectional studies): femoro-acetabular impingement, ethnic factors and occupational load.

The pathogenesis of hip osteoarthritis isn't clearly understood. Therefore, further investigations (e.g. prospective studies, clear definitions for hip osteoarthritis and large populations) are urgently needed.

## MANAGEMENT OF WORK-RELATED MSDS AND SUSTAINABLE EMPLOYMENT

### Aging among building and construction workers: effects of deteriorating respiratory and neuromuscular functions

Gitte Kær Jeppesen (presenter), Jakob Hjort Brønløkke, Pascal Max Madeleine

**Background.** In January 2012, the Danish Parliament raised the retirement age. For persons born after 1966, the retirement age will be at least 69 years, and it is expected to increase further. We lack knowledge about the consequences of the aging work force. Age-related reduced work capacity such as loss of muscle mass and decreased respiratory function will make it more difficult to honour work-related physical requirements and thus counter the goal to retain people in the labour market longer. This is probably especially true in trades with high physical demands, for example craftsmen in building and construction jobs.

**Methods.** 100 male craftsmen aged 50-70 will be invited to a clinical examination at Aalborg University to examine the physiological aging processes. The craftsmen will be recruited based on a questionnaire with an expected participation of 2,000 Danish construction workers. The following methods will be applied in order to evaluate the effect of aging on the muscle-skeleton system and on lung function. We will implement neuromuscular and biomechanical measurements (force, tracking with cognitive load and surface electromyography) and measurements of lung function (spirometry).

**Discussion.** This study will enable us to benchmark changes due to aging among workers 50 years of age and up, and it will delineate deteriorations of both musculoskeletal systems and lung function.

## Prevention of musculoskeletal disorders among computer workers

Karin Reinhold (presenter), Viive Pille, Piia Tint

**Background.** Work-related musculoskeletal disorders (MSDs) develop slowly and stealthily; therefore, it is important to pay attention to early diagnosis of work-related MSDs, as well as to their preventive measures and treatment. Intensive use of computers can contribute to health problems such as tissue damage, blood flow imbalance, and the formation of carpal tunnel syndrome. The majority of diagnosed occupational disorders in Estonia are associated with MSDs, which often occur in computer workers. The aim of the current research is to reduce the late-stage diagnosis of MSDs among computer workers and, thus, increase the length of time they can work.

**Methods.** Myotonometer “MYOTON-3” (developed at Estonia’s University of Tartu) was used to diagnose the functional state of the skeletal muscles. The device exerts a local impact on the biological tissue by means of a brief mechanical impulse. Additionally, an integrated questionnaire based on the Nordic, WAI and Kiva questionnaires was compiled to study workers’ perceptions of their physical working conditions. The survey was given to 295 office workers (96 men and 197 women).

**Results.** According to the results, the majority of respondents reported the existence of two or more local pain points. The main registered complaints were neck, shoulder, wrist and back pain. The results of the measurements with a myotonometer for frequency and stiffness of *m.add pollicis brevis* did not show any statistically significant decrease; the decrease was stated in the *m.abd pollicis brevis*. Thus, it can be concluded that static muscle tension causes increased muscle tone. It is important to find the organizational measures that would ensure regular breaks and exercises and to possibly combine them.

**Discussion.** The main conclusion of this study is that MSDs in employees who work at computers can be prevented by using proper intervention programs such as regular breaks and exercises.

## Does dental staffing matter for perceived health and work demands?

Charlotte Wåhlin (presenter), Bo Rolander, Ulrika Lindmark

**Background.** Swedish County Councils have started to implement changes in dental health organization to ensure they are able to meet community needs with a higher share of older people tending to retain their own teeth and requiring ongoing dental care. This requires an equal or larger number of dental hygienists relative to dentists at many clinics, as well as a shift of tasks from dentists to dental hygienists. The shared responsibilities between dental hygienists and dentists may impose different and new physical and psychosocial work demands on both parties. The aim of this study was to compare workplaces with an equal or greater proportion of dental hygienists than dentists (HDH) with workplaces with a greater proportion of dentists (HD) with regard perceived physical and psychosocial workload, health and work ability, and sickness presence.

**Methods.** In 2012 and 2014, all 486 and 510 dental staff members, respectively, in the Public Dental Service in a Swedish County Council were invited to complete a web-based questionnaire consisting of questions about workplace physical and psychosocial conditions and personal health. 192 staff members answered the questionnaire on both occasions.

**Results.** Between 45-50% of dental health professionals reported a poor psychosocial work environment, particularly dentists in HDH workplaces (93%) in 2012. In 2014, there was a marked deterioration with poorer perceived psychosocial work environment (18%) and work control (43%) for employees in HD workplaces, but results still showed a poor psychosocial environment for both HDH and HD workplaces. Poor workability and musculoskeletal pain were unchanged for the two groups during 2012-2014.

**Discussion.** Dental professionals, and dentists in particular, reported a considerably poorer psychosocial working environment in workplaces with the same number or more of dental hygienists than dentists, thereby suggesting that redistribution of work tasks negatively affects dentists' health.

## Age differences in prediction of occupational disability three months after functional restoration

Fahad Algarni (presenter), Doug Gross, S. Ambikaipakan, Michele Crites-Battie

**Background.** Older age has been reported to be a risk factor for failure to return to work (RTW) following functional restoration (FR). Such findings prompt the question as to why older workers, in comparison with younger workers, experience worse outcomes after FR programs. This study aimed to identify prognostic factors for occupational disability and determine whether they are similar among younger and older injured workers undergoing occupational rehabilitation.

**Methods.** An historical cohort design was used. Secondary analysis of demographic, social, occupational, health/injury, health-care utilization and other factors was conducted on a database of 2,602 injured workers taking part in functional restoration programs. . Logistics regression analysis was used to determine whether prognostic factors were the same in the younger (25-54 years) and older ( $\geq 55$  years) age groups by considering the interaction between each prognostic variable and a dichotomous variable indicating age group.

**Results.** Older workers were more likely to be male, live with their partner, work in white-collar jobs, have  $\geq 91$  days between the accident and comprehensive assessment, and have undergone  $\geq 25$  physical therapy visits (26% vs. 19%). No significant interactions were observed between age group and any of the prognostic factors. In the final prognostic model, older age group, lesser SF-36 physical role functioning, more comorbidity, more physician visits, unavailability of modified duties and working in a health-related job were associated with greater occupational disability after three months..

**Discussion.** Despite important differences between younger and older workers on descriptive characteristics, there were no significant differences in prognostic factors for occupational disability, as indicated by wage replacement, between younger and older age groups undergoing occupational rehabilitation. Given that older workers are more likely to experience work disability after work-related injuries, these findings suggest that other factors may need to be investigated.

## Drilling, counter-sinking, and riveting; the risks of MSDs in aviation assembly work

Maud Gonella, Denys Denis (presenter)

**Background.** The goal of this project was to evaluate the possibilities of implementing workstation rotation to reduce MSD occurrence in the aviation sector. Workers in this sector are known to be at risk and constitute a large part of the manual labour force in Québec. However, changing work situations is complex due to the aviation sector's high quality requirements.

**Methods.** A series of general interviews (n=16) were conducted, as well as specific interviews on learning (n=19) and risk factors (n=23). A questionnaire on the musculoskeletal health of cockpit assemblers was carried out (n=22), as were work activity observations at the various department workstations (> 320 hours of video).

**Results.** The diverse results show the demanding requirements for assembly work. Assemblers are exposed to numerous risks factors: repetitive work, awkward postures, high work rate, vibrations and psychosocial factors. For a fairly low average age (39 yrs), more than three quarters of the workers (n=17/22) reported a MSD in at least one area of the body (especially the upper limbs). Moreover, 27.3% of the workers were exposed to a combination of high psychological demand and low decision latitude, an at-risk combination, as compared to 17% of the general population of Québec workers.

The interviews and observations highlighted the workers' hyper-specialization, which is useful in minimizing the risk of errors, but also has an impact on MSD development (i.e. due to greater overexposure to effort, repetition, and vibrations).

**Discussion.** The assemblers constitute a population at high risk of developing MSDs. There are, however, limited possibilities for changing work situations to protect workers given the sector's regulatory framework. The results show some hope regarding training, which could be quite useful in preventing risks and integrating prudence-related knowhow.

## Using a job exposure matrix on physical exposure as a decision tool for helping in social compensation and retirement benefits: a preliminary study in France

Alexis Descatha (presenter), Thomas Despreaux, Emmanuelle Peris, Ann Marie Dale, Sabirna Pitet, Yves Roquelaure, Bradley Evanoff

**Background.** The French social security system allows workers to receive compensation and early retirement for certain work-related disorders. Evaluation of qualifying work exposures is difficult in this system, requires expensive consultation, and causes many delays. We performed a feasibility test of evaluating qualifying exposures based on an existing American job exposure matrix (JEM).

**Methods.** We coded French job titles to match the American Standard Occupational Classification (SOC) System of job codes. Using existing transcoding tools,<sup>1</sup> we coded French job titles into the ISCO 1988 classification, then into the American SOC codes via correspondence to ISCO 2008. SOC codes were linked to the American O\*NET database<sup>2</sup> to obtain measures of workplace physical exposures for each job title. These exposures were compared to consensus exposures from 10 simulated patients used for teaching exposure assessment to French occupational medicine physicians, and to 11 anonymized files from real patients applying for early retirement. We compared agreement between O\*NET derived exposures and those made by physicians reviewing these training files and actual cases.

**Results.** The 10 simulated patients had 18 jobs. 11 jobs (seven patients) fitted the compensation list for work-related disorders, and six patients met criteria for an early retirement. Area-under-curve statistics from receiver-perative-characteristic curves were between 0.7 and 0.8 for three variables tested (handling objects, no computer use, and dynamic strength). Based on real patient compensation files where 10 of 11 were awarded an early retirement, two patients were misclassified by the JEM.

**Discussion.** It may be feasible to use a JEM to streamline the process of physical exposure assessment during evaluation for social compensation and retirement benefits. However, development of larger validation studies are needed before developing a decision tool that might help social security systems give quicker and more uniform answers for workers.

### References.

<sup>1</sup>Caps tools (<https://ssl3.isped.u-bordeaux2.fr/CAPS-FR/Rechercher.aspx>, InVS)

<sup>2</sup>O\*Net (<https://www.onetonline.org/>, U.S. Department of Labor)

## MEASURING EXPOSURES IN A NEW WORLD OF WORK

# Validation of an ambulatory approach to estimate lumbar back loadings

Alain Delisle (presenter), François Thénault

**Background.** Low-back loadings related to manual lifting have been recognized as a cause of low-back pain. Until recently, very few methods were available to reliably and continuously assess low-back loading during working tasks. This study aimed to validate such an approach combining trunk posture and trunk muscle activity through an artificial neural network.

**Methods.** Four women and two men volunteered for the study. The model to be validated used two inertial sensors, one on the trunk and one on the pelvis, to assess trunk postures. The electromyography (EMG) of three trunk muscles was recorded bilaterally. For training the artificial neural network, that is establishing the lumbar moment – EMG – trunk posture relationship, inertial sensors were added to both arms and forearms as well as an instrumented box to measure hand forces. This relationship was established while the subjects lifted and lowered the instrumented box. The artificial neural network's net lumbar moment predictions were compared to the net lumbar moment computed from a validated bottom-up 3D dynamic model, using an optoelectronic system for measuring segments orientation and position along with force-plates to measure ground reaction forces. The lifting task used to validate the model involved repeated lifting for a prolonged period of time in order to generate muscle fatigue.

**Results.** The artificial neural network's prediction explained on average 50% of the variance of the golden standard. However, for some subjects, over 70% of the variance was explained. Some signal processing methods implemented were able to reduce the impact of muscle fatigue, limiting the increase in the error observed over the development of muscle fatigue.

**Discussion.** The approach described shows great potential for estimating the lumbar moment during lifting tasks of short duration during real work, although further refinements of the artificial neural network are needed.

## Occupational health care as a measure to prevent work-related musculoskeletal disorders: trigger criteria for health care and estimation of employees concerned

Patrick Serafin (presenter), Ann Kathrin Waldminghaus, Christoph Muehlemeyer, André Klussmann

**Background.** In Germany, as it is in many other countries, there is a legal requirement to assess employees' working conditions and to arrange, if necessary, measures to eliminate or reduce excessive workloads. These measures should be prioritized, so that technical measures are preferred over organizational measures, which are preferred over personal measures. High physical exposures may lead to musculoskeletal disorders and diseases. The German legislation implemented this aspect in a specific occupational health care ordinance in 2013. The employer is obliged to offer this health care for employees with work tasks with substantially increased physical exposures. These increased exposures include (1) lifting, holding and carrying, (2) pulling and pushing, (3) manual materials handling, (4) kneeling/squatting, (5) bending forward, (6) working above shoulder height, (7) assuming awkward sitting postures, and (8) permanent standing.

**Methods.** There is little systematic data about which physical exposures occur and how often they occur. We analyzed the data of a large industrial company with 40 plants and more than 50,000 employees, including 20,000 manufacturing employees. Data were obtained using the Exposure-Documentation System – BDS (Klussmann et al., 2013).

**Results.** Almost one third of 20,000 production employees met at least one criterion to get the health care. The most common of these criteria were physical exposures to load handling (~ 22%), followed by manual work processes (~ 8%) and work above shoulder height (~ 6%).

**Discussion.** The empirical analysis shows the relevance of physical exposures at work. Even if the data cannot be considered as representative for all employees, it can be deduced that the number of employees with substantially increased physical exposures is considerable. The assessment of working conditions is as important as taking further steps to reduce increased physical exposures and to offer occupational health care.

## Manual handling of loads; types, amount and frequencies of typical load handling in a large-scale industrial company

Patrick Serafin (presenter), André Klussmann, Christoph Muehlemeyer, Joerg Nimoth, Klaus-Dieter Wendt, Peter Dolfen

**Background.** Physical exposures like manual handling of loads (i.e. lifting, carrying, pushing and pulling of loads) still describe an important factor at work. The aim of this study was to provide information about typical distributions of load weights, handling frequencies (number of repetitions) and distances covered in manual load handling tasks in industry.

**Methods.** Data from a large-scale industrial company with 40 plants and approximately 20,000 employees in manufacturing were analyzed. Data were obtained using the Exposure-Documentation System – BDS (Klussmann et al., 2013). Overall, the data set consisted of more than 38,000 single work tasks, 5,186 work tasks that included lifting and carrying (LC), and 4,407 work tasks that included pushing and pulling (PP).

**Results.** About 60% of the PP loads weighed up to 10kg, 35% of these loads weighed between 11kg and 25kg, and 5% of these loads weighed more than 25kg. In 74% of the work, LC tasks occurred up to 50 times per shift. The single distance covered in LC was up to 2m in 80% of the work tasks; in 19%, the distance ranged between 2m and 20m. In about 40% of PP tasks, the load was 50kg or less; in 42% the load was between 50kg and 300kg. The number of repeated PP actions was up to 50 times per shift in 89%. The single distance covered in PP was up to 5m in 43% of the work tasks; in 52%, the distance ranged between 5m and 50m.

**Discussion.** Even if the data cannot be considered representative for all employees, the analysis shows a typical distribution of load weights, handling frequencies and distances in load handling tasks. This can be seen as valuable information for the scaling of assessment methods for physical exposures at work.

## Challenges in measuring fatigue: task parameters and their differential influence on measures

Richard Wells (presenter), Marcus Yung

**Background.** Mechanisms underlying fatigue may be influenced by the task, the environment, and an individual's physical characteristics. Of particular interest are task-specific influences, such as the intensity, duration and type of contraction. The aim of this study was to investigate the task dependency of fatigue using a complementary set of fatigue measures, representing mechanisms central and peripheral in origin.

**Methods.** The responsiveness of a test battery of fatigue measures was documented in two conditions representing changes to the type of contraction (intermittent isometric vs. sustained isometric). Seven measures were included in the test battery, including perceived fatigue, physiological resting tremor, postural tremor, action tremor, surface electromyography (EMG), mechanomyography (MMG), and maximum voluntary handgrip contraction. Measures were taken at 10-minute intervals until volitional fatigue or until the end of 60-minutes of exercise.

**Results.** 16 participants (8 male, 8 female) demonstrated significant changes in maximum handgrip contraction and rating of perceived fatigue over time in both conditions. The sustained isometric condition led to increases in action tremor of the hand and MMG. The intermittent isometric condition resulted in increases in EMG amplitude of the flexor carpi radialis. These results suggest that measures, which predominantly reflect peripheral changes, were responsive in both conditions. Generally, in the intermittent condition, the first 20 minutes of exercise were primarily loaded by peripheral fatigue indicators and later by central fatigue indicators. The sustained condition, however, led to an inverted trend. A general increase in peripheral fatigue followed by involvement of central fatigue indicators.

**Discussion.** This study supports previous research on the dependency of the type of contraction on the pattern of fatigue development. Additionally, it identifies possible complementary fatigue measures for inclusion into a test battery in order to provide a comprehensive picture of fatigue development in different work or exercise tasks.

## Fatigue in a light precision micropipetting task: responsiveness of a test battery of measures over an eight-hour period

Marcus Yung, Richard Wells (presenter)

**Background.** Fatigue is linked to human performance outcomes, including work quality and productivity, and is possibly a precursor to work-related musculoskeletal disorders (MSDs). Since fatigue is a multidimensional construct, which consists of a complex interaction between central and peripheral mechanisms, there are a considerable number of measures and measurement parameters. Previous studies have shown inconsistent or null fatigue responses during light or sedentary work. Therefore, detecting fatigue in light precision work might benefit from a test battery of complementary fatigue measures. The objective of this study was to investigate the responsiveness of a set of fatigue measures, during simulated light precision work, over a period of eight hours, and to identify possible measures for inclusion in a test battery.

**Methods.** 11 participants performed a light precision micro-pipetting task for an eight-hour period at a predetermined psychophysically frequency-adjusted pace. Rating of perceived fatigue (VAS), maximum voluntary force, electromyography, postural tremor of the hand and shoulder, and eye blink frequency were recorded at hourly intervals. Three break times were scheduled: two, 15-minute breaks in the morning and afternoon, and a 30-minute mid-day lunch break.

**Results.** A mixed model repeated measures analysis revealed significant change over time in rating of perceived fatigue, postural tremor of the hand and shoulder, and eye blink frequency. Generally, responses increased mid-morning (i.e., two hours from the beginning of the task), decreased towards mid-day, significantly decreased after the lunch break, and increased significantly towards the end of the eight-hour task. Maximum voluntary force and electromyography did not exhibit marked fatigue changes over time.

**Discussion.** The findings of this study show that centrally mediated indices appear to demonstrate stronger indications of fatigue over an eight-hour light precision task. The study also supports the need of a complementary set of fatigue measures, representing both physical and cognitive mechanisms.

## Assessment of physical exposures of housekeepers in a hotel chain

Rosimeire Padula, Maryanne Martins Gomes de Carvalho (presenter), César Ferreira Amorim

**Background.** The rate of occupational disorders among hotel housekeepers exceeds that of average workers in other sectors as evidenced by high rates of absenteeism. Muscle fatigue can also be a cause of musculoskeletal disorders and affects the quality of life of millions of workers. This study evaluated the strength and surface electromyography (EMG) signal of housekeepers' upper limb and cervical muscles.

**Methods.** 22 housekeepers (female) participated in the study. The volunteers performed the maximum force with lumbar dynamometer synchronized to EMG equipment to record the electrical signals (upper trapezius and middle deltoid), measured twice a day (i.e. in the morning and at the end of the day). Three questionnaires were used to analyze personal data, body region with pain and pain intensity. The Borg Rating of Perceived Exertion (BRPE) scale and block notes were used to record housekeepers' daily work activities.

**Results.** 15 housekeepers (68.2%) reported pain in one region of the body, and five housekeepers (33.3%) reported pain in more than one body region: upper and lower back, knees and ankles. The BRPE scale indicated moderate effort at the end of the workday. The EMG of the deltoid muscle right before and after the workday showed statistically significant differences with values  $74.80 \mu$  (43.11-87.33) and  $52.55 \mu$  (28.24- 78, 52), with  $p = 0.009$ . The left deltoid muscle had values  $62.32 \mu$  (57.05 to 79.20) and  $48.55 \mu$  (39.41 to 68.35) with  $p = 0.001$ . The right trapezius muscle showed differences with  $110.91 \mu$  (52.84-150.85) and  $44.21 \mu$  (23.24-89.61) with  $p = 0.020$ .

**Discussion.** The surface electromyography and dynamometry results showed less muscle activity at the end of the day. This equipment was also a reliable and effective tool in recognizing muscular work and evaluating workers' functionality.

## Measuring exposure: the scoring method for assessment of repetitive tasks

Marija Bubaš, Marina Mihalinač Bolanča (presenter), Ana Bogadi Šare

**Background.** This paper describes the development and evaluation of a new tool—a scoring method for numerical assessment of manual tasks, making it possible to measure and evaluate both “new” tasks with high repetition and “old” manual work. It is aimed at surveillance and detection of occupational health risks causing occupational musculoskeletal disorders.

**Methods.** A comprehensive and critical review of the literature was conducted prior to designing the tool, together with follow-up evaluations of our own studies.

**Results.** The new tool includes an objective description of tasks, repetition, force and body posture. Demands of work are presented with scores, each in an individual scale that corresponds to the conditions encountered in practice. The classification of these scales and their final numerical quantification gives an indication of overload and of load bottlenecks. The total numerical score is obtained by multiplying the scale value for the daily duration by the sum of other scale values. The end result is a total score, with numerical value, describing the risk of physical overload. The numerical value is explained in an explanatory table, which contains four ranges of numerical values, also coloured in green, yellow, orange and red according to the risk level. The method used was the Scoring Method for Assessment of Repetitive Tasks (SMART).

**Discussion.** The draft method was tested on 98 workers at 32 different workplaces with comparative evaluation of the same workplaces using four additional existing assessment methods. The newly developed tool is easier to handle in the field, with fair correlation of results when assessing strains compared to results of other tested tools, providing easy numerical quantification of manual tasks with high repetition, occasional force exertion and awkward body postures together with their interaction. The draft is now in the process of being field tested and scientifically evaluated.

## Vibration exposures of operators of pallet trucks during internal transport of goods

Frank Rokosch

**Background.** To help commerce and product logistics companies with implement the provisions of the Noise and Vibration Occupational Safety and Health Regulation, the German Social Accident Insurance Institution for trade and logistics (BGHW) executes vibration measurement projects and helps to evaluate and reduce stress of the musculoskeletal system.

To protect workers against risks arising from noise and vibration, the Directive 2002/44/EC of the European Parliament reacted on the minimum requirements of safety and health hazards caused by vibrations by passing this into German law in 2007. The regulation defines action values and limits to employee stress from vibrations. The BGHW helps their members with the implementation of measurement projects in identifying and evaluating these risks.

**Methods.** The project was conducted in modern logistic centres. Extensive vibration measurements were taken on pallet trucks. These relatively light and agile devices are operated by the driver who stands on a platform that is mainly used for loading and unloading trucks onto loading docks.

The usual operating time of these pallet trucks is about five hours per work shift. During these shifts, the drivers are exposed to noise and vibration levels that are above the values ruled safe by the Noise and Vibration Occupational Safety and Health Regulation. Accordingly, these levels need to be reduced to decrease stress on drivers' musculoskeletal systems.

**Results.** The practical measuring methods are shown and the measured values of about 50 individual measurements, with a total measurement time of about 40 hours, are represented and compared with the regulation's requirements. Practical ways to reduce the stress on employees are identified and evaluated.

**Discussion.** The results of the project will help companies to identify and evaluate hazards to the musculoskeletal system as well as provide ways to reduce vibration exposures to drivers in modern business practices.

## Correlation of daily walking steps among three measurement tools: smartphone application, wearable device and pedometer

Ekalak Sitthipornvorakul (Presenter), Prawitl Janwantanaku, Rattaporn Sihawong, Vitool Lohsoonthorn

**Background.** When daily physical activity, is performed at low to moderate levels, it is widely known that this has important health benefits.<sup>1</sup> New wearable devices that measure daily physical activity levels have been developed that have wide consumer appeal. The valid assessment of daily physical activity is necessary to advance the relationship between health benefits and increased daily physical activity. The aim of this study was to evaluate the correlation between smartphone application, wearable device and pedometer on daily walking steps measurement.

**Methods.** This study is a cross-sectional study using convenience sampling from participants aged 20-55 years from workplaces in Bangkok, Thailand. Office workers were included if they were healthy and were free of neck pain in the previous three months. For daily physical activity measurement, each participant was given a pedometer, fitbit flex, and? A smartphone application (Accupedo) to measure daily walking steps for seven consecutive days (Monday to Sunday). The researcher explained how to operate the instruments and participants were asked to carry the pedometer (on the belt), fitbit flex (on left hand) and smartphone (Accupedo application) from the time they got up in the morning until they went to bed at night, except when their body was immersed in water.

**Results and Discussions.** Data analysis is currently underway and the results, discussion and conclusion will be presented at the conference.

**References.** Ainsworth BE, Youmans CP. Tools for physical activity counseling in medical practice. *Obes Res.* 2002.; 10. 69S–75S.

## A pilot study of the SLUMP questionnaire for assessing musculoskeletal pain and laptop use in students

Chelsea D'Silva (presenter), Pierre Côte

**Background.** Musculoskeletal pain is a significant burden in university students. Laptop use is believed to be associated with the incidence of musculoskeletal pain in this population. However, the measurement of laptop use (frequency, duration, purpose and posture) has not been standardized for epidemiologic studies. Therefore, there is a need for a reliable questionnaire to measure laptop use in undergraduate students.

The objective of this study was to develop an online questionnaire to measure laptop use in university students and to test the feasibility of its administration in a sample of university students

**Methods.** We developed an online version of the self-administered Student Laptop Use and Musculoskeletal Pain (SLUMP) questionnaire. The items included in the SLUMP questionnaire focus on laptop use related to school, work and recreational activities. We tested the feasibility of administering the SLUMP questionnaire in a class of 44 kinesiology undergraduate students at the University of Ontario Institute of Technology. Participants were asked to complete the questionnaire and make recommendations to improve its administration and completion. All participating students provided informed consent.

**Results.** 33/44 (75%) students completed the questionnaire (64% female and 36% male). The mean age was 19.8 (SD=1.7). 22 out of 33 students (67%) reported experiencing pain in the neck, back, shoulder, arms, wrists or hand. It took students between 10-12 minutes to complete the SLUMP questionnaire. There was no missing data. Two students suggested altering questions inquiring about the duration of "breaks" while using a laptop. We addressed this by refining response options in this section. Moreover, one student suggested emphasizing the section headings for academic, recreational and employment laptop use. We capitalized these headers to ensure that the titles were distinguishable.

**Discussion.** The SLUMP questionnaire is appropriate for "in-class" measurement of laptop use in university students. Our future research will evaluate the test-retest reliability of the SLUMP questionnaire.

## BIOLOGY OF WORK-RELATED MSDS

### Relative phase changes during lifting fatigue protocol within a middle-aged population

Wayne Albert (presenter), Matt Cochran, Robin Hampton, Madji Sultan, Steven Fischer

**Background.** Lifting tasks have been highly associated with musculoskeletal disorders (MSDs) in the workplace. Few fatigue-related studies have been conducted with middle-aged working population.

**Purpose.** The primary goal of this study was to assess changes in lifting coordination of the back and shoulder resulting from prolonged symmetrical lifting in a middle-aged working population.

**Methods.** 11 healthy males ( $47.1 \pm 7.2$  years old) and 14 healthy females ( $49.7 \pm 6.6$  years old) were recruited. The task consisted of a 75-minute sagittal lift of a box, weighing 10% of the participant's maximum lifting capacity, from floor to shoulder height at a rate of six lifts per minute. To measure lifting kinematics, electromagnetic motion tracking sensors defined each upper body and trunk segment. Myoelectric signals were collected for arm and back musculature using an eight-channel electromyography system. Relative phase was determined between the forearm and upper arm and the upper arm and trunk, respectively. Kinematic differences were compared pre- and post-fatiguing task, using an ANOVA and a cross-correlation analysis.

**Results.** In terms of fatigue, perceived exertion increased in both males and females, while maximum voluntary contractions (MVC) decreased in both the shoulder and back musculature. Kinematic data showed significant pre/post changes over time. During lifting, females increased upper extremity angular velocity. Males significantly increased ROM of trunk lateral bend and decrease elbow flexion. Relative phase plots showed pre/post coordination changes over time. Although there was no correlation coefficient difference during lifting for any relative phase waveforms, lag time was different with females exhibiting an earlier pattern of coordination in forearm to upper arm relative phase.

**Discussion.** With prolonged lifting, there was a shift in the lifting coordination, with males exhibiting changes focused on trunk motion while females altered arm coordination patterns.

## Effect of repetitive work on intramuscular calcium release and uptake rates: implications from a rat model of work-related muscle disorders

Jenny Hadrevi (presenter), Mary F. Barbe, Eleanor Boyle, Gisela Sjogaard, Niels Ortenblad, Karen Sogaard, Ulrik Frandsen

**Purpose.** Repetitive movements are considered to be a risk factor for the development of work-related muscle disorders. Previous studies hypothesize cytosolic calcium ( $\text{Ca}^{2+}$ ) accumulation to be one of the underlying mechanisms. This is supported by human studies showing altered abundance of proteins connected to the calcium regulation in human chronic work related pain. The present study evaluates the hypothesized effects of muscle over-use on skeletal muscle sarcoplasmic reticulum (SR)  $\text{Ca}^{2+}$  kinetics.

**Methods.** Rats ( $n=6$ ) exposed to 6 weeks of repetitive reach and grab movements and unexposed food restricted control rats ( $n=6$ ) were used. The supraspinatus, trapezius, extensor digitorum and flexor digitorum muscles were dissected post mortem from both reach and non-reach limbs, and then proximal, middle and distal portions of each muscle were collected and homogenized separately. Sampling was performed two days after the cessation of the last task session to avoid acute effects of muscle activity. The SR  $\text{Ca}^{2+}$  release and uptake rates were measured in SR vesicles fluorometrically using Indo-1 and normalized for total protein concentration. Linear mixed models and non-parametric statistics were conducted to determine if the SR  $\text{Ca}^{2+}$  release and uptake properties differed by location.

**Results.** There were significant differences ( $p>0.01$ ) in SR  $\text{Ca}^{2+}$  release rates between muscles exposed to repetitive movements and controls. Associations show that the exposed rats had significantly higher SR  $\text{Ca}^{2+}$  release rates, compared to the control rats. The location of the collected muscle (e.g. proximal versus distal) was not significantly associated with the outcome.

**Conclusion.** The present results show that six-weeks of performing a repetition reaching and grasping task lead to altered  $\text{Ca}^{2+}$  release rates in forearm muscles, verifying previous indications of  $\text{Ca}^{2+}$  having a role in pathophysiological mechanisms. The altered calcium release may play an essential role in the pathophysiology of accumulated cytosolic  $\text{Ca}^{2+}$  and development of chronic work related disorders.

## Biomechanical demands of bricklaying concrete masonry blocks using one-handed technique

Wayne Albert (presenter), Tiffany McKinley, Emily Taylor, Usha Kuruganti

**Background.** Many masons handle lighter concrete masonry units with only one hand—a factor that is not considered in published lifting guidelines. As of 2010, masons had the highest rates of back injuries resulting in lost time from work among all the construction trades and a cumulative lifetime prevalence of 87% for low-back pain.<sup>1</sup>

**Purpose.** The purpose of this study was to determine the biomechanical demands in terms of joint loading and postural requirements of one-handed lifting of pre-apprenticeship bricklaying students over the course of an hour-long concrete wall-building session.

**Methods.** Five male pre-apprenticeship bricklaying students (average age 22 years) constructed a wall using 13kg 6x8x16-inch concrete blocks while employing a one-handed lifting technique. Standard video captured the entire work session. Custom software (3D Match, University of Waterloo) was used to identify body posture frame-by-frame to determine percentage time spent in non-neutral postures and to calculate peak and cumulative spinal and shoulder loading.

**Results.** During the one hour of building the six-course wall, the students assumed trunk postures that were non-neutral over 80%, 20% and 20% for flexion, lateral bend and twist, respectively. Similarly the shoulders were flexed more than 50% of the time. Although peak compression and shear loads on the back and shoulders did not reach published limits the cumulative joint loads represent values associated with increased risk of musculoskeletal injury.

**Recommendations.** Education of pre-apprentice students would be valuable in promoting safe lifting techniques and postures with an aim at reducing the cumulative exposure to musculoskeletal risk associated with masonry work.

<sup>1</sup> Jørgensen, K., Jensen, B., & Kato, M. (1991). Fatigue development in the lumbar paravertebral muscles of bricklayers during the working day. *International Journal of Industrial Ergonomics*, 8(3), 237-245.

## A case-control study of back muscle fatigue in younger and older adults with and without chronic low back pain

Edgar Vieira (presenter), Rubens da Silva, Marcos Cabrera, Leandro Altimari, Andreo Aguiar, Alexandre Nowotny, Adriana Carvalho, Marcio Oliveira

**Background.** Poor back muscle endurance has been associated with chronic low back pain (CLBP). Given the high prevalence of CLBP and the aging working population, understanding fatigue responses of younger and older adults with and without CLBP is important for the management and prevention of chronic low-back pain. Few studies have compared the effects of back pain on muscle fatigue in younger and older adults. Therefore, the purpose of this study was to compare back muscle fatigue of younger and older adults with and without CLBP.

**Methods.** 20 participants without CLPB and 20 with nonspecific CLBP participated in this study. Each group contained 10 younger (50% males with a mean age of  $31 \pm 6$  years) and 10 older (50% males with a mean age of  $71 \pm 7$  years) adults. Participants were randomly assigned to one of two isometric fatigue protocols: (1) to maintain the unsupported trunk at the horizontal position while on a 45 Roman chair for a minute, and (2) to maintain a 10% of body weight box close to the trunk in the upright position for a minute. Surface electromyography (EMG) signals from the back (multifidus and iliocostalis) and one hip (biceps femoris) muscles were recorded bilaterally, and the median frequency fatigue estimate from linear regression slopes of the EMG time-series was computed.

**Results.** There were no significant ( $p > 0.05$ ) age effects nor group-by-age interaction effects in either the isometric or functional fatigue tasks. However, both younger and older adults with CLBP displayed more back muscle fatigue than those without CLBP for both fatigue protocols ( $p < 0.01$ ; effect size ( $d$ ) from 17% to 32%).

**Discussion.** Both younger and older adults with CLBP presented significantly more back muscle fatigue than people without CLBP. These results have significant implications for the management and prevention of low-back pain in both younger and older workers.

## Seat pressure distribution characteristic during one-hour sitting in office workers with and without chronic low-back pain

Prawit Janwantanakul (presenter), Nipaporn Nipaporn Akkarakittichoke

**Introduction.** Low-back pain (LBP) is common among office workers. Occupational groups exposed to poor postures while sitting for longer than half a day have a considerably increased risk of experiencing LBP (OR=9.0, 95% CI 4.9-16.4). In sitting, LBP subjects placed their spines closer to the end range than their healthy counterparts. Subjects with LBP also assumed more static posture and had large, infrequent rather than subtle, regular spinal movements while sitting. Sitting is dynamic and short-duration investigations of sitting posture may not completely represent time-dependent biological responses to prolonged exposure. Seat pressure distribution measurement is one of the methods for studying sitting for a long period. The purpose of this study was to describe seat pressure distribution characteristics and body perceived discomfort (BPD) during 60-minute sitting in office workers with and without chronic LBP.

**Methods.** This study is a cross-sectional study, in which 46 (10 male, 36 female) full-time office workers were recruited. Participants were divided into two groups: chronic LBP (n=23) and a healthy group (n=23). Age, gender and body mass index were matched between groups. For testing, each participant was asked to sit on the adjustable office chair with a pressure mapping device placing over the seat pan and continuously typed a standardized text passage at their normal pace for an hour. During the one hour of sitting, the BPD level was rated at the 10th, 20th, 30th, 40th 50th, and 60th minute. The seat pressure distribution was determined through three variables: the average pressure, peak pressure and dispersion index.

**Discussion.** Data analysis is currently underway and the results, discussion and conclusion will be presented at the conference.

## EMERGING ISSUES IN THE PREVENTION AND MANAGEMENT OF WORK-RELATED MSDS

### Protection of workers

#### Ayres Carollo (presenter)

**Background.** This work has been prepared by a law professional in Brazil who deals with social security issues, including work-related injuries among people suffering from repetitive strain injuries (RSIs) and work-related musculoskeletal disorders (MSDs).

He is a member of the Public General Lawyers (AGU) and defends the National Institute of Social Security (INSS), a government agency that deals with social security issues.

In Brazilian law, there is the concept of typical work accident, which is an act or violent act caused by an external agent resulting in injury to the worker and/or in an occupational disease, subdivided into professional and work disease, without having the characteristic of being abrupt.

RSIs/MSDs are considered occupational diseases, characterized by disorder of multifactorial origin and not specific symptoms.

Progress enables the improvement of the means of production and the introduction of new technologies. It also gives workers psychological pressures in the face of new professional challenges, as well as mental burdens in carrying out the service and uncertainties of unemployment.

This issue concerns everyone, since the drama of workplace accidents is to maintain the subsistence of the worker and his/her family, if he/she is unable to do his/her work and receive payment.

The importance of this work lies in the novelty of this theme, as RSIs/MSDs affect millions of workers worldwide.

The goal is to understand if and how each country effectively protects the worker when unemployed because of disease and fails to receive a salary.

**Discussion.** This work shows the need to formulate a global policy to tackle this problem and to find solutions in order to eliminate, or at least decrease, cases of RSI/MSD diseases.

## Self-adjustment of occupational activities: a principle for the prevention of musculoskeletal overload

Matthias Jaeger (presenter), Alwin Luttmann, Claus Jordan

**Background.** Musculoskeletal complaints and diseases can be induced substantially by overloading muscular or skeletal structures, if the work requirements surpass the performance capacity of the working person. Therefore, adaptation of the workload to the current capability represents an effective overload prevention measure. Two principles are supposed: (1) reduction of workload by ergonomic work design, and (2) self-adjustment of workload by changing the behaviour of the working person. Shop-floor studies were used to examine whether self-adjustment can be identified which limits the current workload and prevents muscular or skeletal overload.

**Methods.** EMGs of 13 office workers of the German tax authority were recorded during total working days, and musculoskeletal complaints were documented using a questionnaire. Skeletal load was studied on eight people working in occupations with object-handling activities (surface construction, metal work at a drop hammer, industrial meat processing, and dustbin removal). Posture and action forces were estimated for all situations with object handling or non-upright postures and the mechanical forces acting in the lumbar spine of the workers were calculated for total working shifts using 3-D biomechanical simulations.

**Results.** EMG changes observed during the working day were compared with the occurrence of complaints. Persons with decreasing myoelectrical activity of shoulder muscles reported less frequently on shoulder complaints than persons with increasing or rather constant muscular activity. For the persons with object-handling jobs, lumbar load was cumulated for subsequent one-hour sections, and a decrease during the day was observed.

**Discussion.** The decrease in muscular or skeletal load is interpreted as self-adjustment. It is induced by the working person to adapt the workload to the current performance capacity, which presumably decreases in the course of the working day. Self-adjustment is supposed to represent an effective strategy to prevent musculoskeletal overload and complaints.

## Interprofessional medical collaboration in the care of work-related MSDs

Cyril Begue, Clara Bernege, Isabelle Fernandes, Anne-Claire Leboucher, Frantz Henry-Duret, Sandrine Hüge, Yves Roquelaure; presenter—Natacha Fouquet

**Background.** Musculoskeletal disorders (MSDs) are associated with three types of risk factors: biomechanical, psychosocial and individual. Their consideration requires interprofessional cooperation, which does not seem optimal. The objective was to study how general practitioners (GPs) collaborate with occupational physicians (OPs) and social insurance physicians (SIPs) within the framework of the care of MSDs.

**Methods.** This qualitative study included semi-structured interviews with GPs from a town and surrounding area in Brittany, France. Interviews were the object of a double open coding followed by thematic analysis.

**Results.** 34 interviews were conducted. GPs reported problems in the care of MSDs: late consultations, limited possibilities of adapting workstations, the important risks of chronicity and professional exclusion. They seemed to know the functions of OPs: prevention and improvement of working conditions. Despite the overlap between GPs' needs and the radius of action of OPs, contacts were infrequent. GPs asked for a real collaboration with OPs, but doubted their independence and considered that they had little room for maneuver. SIPs who could also participate in the fight against professional exclusion were limited to a control role and were seen as "guardians of the stock exchange," answering to Social Security.

**Discussion.** Few qualitative studies question relations between GPs, OPs and SIPs. These relations could be improved by allowing GPs, OPs and SIPs to strengthen their interprofessional confidence; for example, by means of common training. Contacts could be also simplified by the implementation of a common platform.

## Interactions with clients and physiological responses related to musculoskeletal disorders and stress-related outcomes among call centre workers

Richard Wells (presenter), Sophia Berolo

**Background.** This study aimed to demonstrate relationships between call centre agents' appraisal of their interactions with clients and physiological responses monitored over a work shift. The hypothesis was that interactions appraised as overwhelming would result in greater trapezius muscle activity and sympathetic nervous system activity compared to baseline interactions.

**Methods.** 24 call centre agents were recruited from two Ontario call centres. Participants used a touchscreen tablet placed beside their workstation to appraise every call they took over their shift. Each participant's call log (including start and end time of every call) was matched to his/her call ratings. Trapezius electromyography was collected using a belt-worn data-logger, heart rate was collected using a lightweight wireless monitor, and skin conductance was collected using a wrist-worn device; all three were collected continuously. A video recorder was used to document standing/walking time. All data was imported into The Observer® XT 8.0, which allowed integration of observational data (call logs and video recordings) and raw physiological signals so data could be synchronized, coded, and exported for analysis. The Office of Research Ethics at the University of Waterloo approved this study.

**Results.** Findings demonstrated that there was greater activation of the trapezius muscle and sympathetic nervous system when calls were perceived to be overwhelming compared to when calls were perceived to be non-straining. Observed physiological changes across both the physical and psychosocial domain suggest the presence of a common workplace risk factor for MSD and stress-related outcomes among call centre workers: overwhelming calls.

**Discussion.** Findings highlight the importance of both the physical and psychosocial work environment when considering worker health.

## Prevention of work-related musculoskeletal disorders and disability management using holistic risk assessment data about physical exposures at work

Peter Dolfen, Klaus-Dieter Wendt, Karl Heinz Lang, Andre Klussmann (presenter)

**Background.** In Germany, as in many other countries, occupational rehabilitation and inclusion of disabled people at work is an important topic. Due to demographic changes, disability management is an emerging issue. A systematic workplace assessment is necessary to find a suitable workplace for disabled people or workers that are returning to work after receiving musculoskeletal system rehabilitation.

**Methods.** For many years, Continental Corporation has used the ergonomic assessment tool "Exposure Documentation System" (BDS, Klussmann, et al, 2013) to assess its production work areas. Detailed assessments of physical exposures of workplaces of all 19,000 employees in all production areas were carried out at the German company. The results were displayed in bar charts using traffic light colours: green bars to represent no risk of physical overload expected; yellow bars to represent work situations that may be critical for people with reduced resilience but work tasks are usually executable; and red bars to represent when there is a serious risk of physical overload. The original idea was "only" to use this system to identify workplaces with risk of physical overload to prioritise ergonomic measures systematically. Between the years 2011 and 2015, a significant improvement for approximately 3,000 employees from "red" to "green" workplaces was achieved.

**Results.** Criteria were defined by an expert group that described which physical exposures could be managed by employees with specific disabilities. First results and practical experiences with this new kind of analysis will be presented at the conference.

**Discussion.** A structured and systematic evaluation of workplaces with a focus on physical exposures may help to systematically a) prioritise ergonomic measures to prevent MSDs, and b) match workplaces with low physical load to employees with specific disabilities. The system is planned to roll out in additional plants worldwide.

## FIELD EVALUATIONS OF MSD PREVENTION POLICIES, PROGRAMS AND PRACTICES

### Assessing the impact of a training intervention within the electric utility industry

Madiha Ahmed (presenter), Naira Campbell-Kyureghyan

**Background.** Administrative controls, such as training programs, are commonly used as an injury prevention countermeasure in the utility sector. The training programs are typically used to teach how to identify and mitigate risk factors observed in the field in efforts to provide a safer workplace. The aim of this study is to assess the impact and effectiveness of a training intervention on preventing injuries due to overexertion within the electric utility field.

**Methods.** Three utility companies were recruited for this study. The impact of the training intervention targeting awkward postures and lifting techniques was assessed via tests, onsite observations, interviews and a review of injury records. Tests identical in content and format were administered to assess knowledge levels at baseline (t1), immediately after training (t2) and 12 months post-training (t3). Deltas describe the difference in scores between the three time points. Measures of impact were compared prior to training and 12 months post-training.

**Results.** A positive delta in scores between t1 and t2 indicated a gain in safety knowledge. Twelve months post-training, 97% and 66% of the trainees retained knowledge on awkward postures and lifting techniques, respectively. Onsite observations revealed workers adopting safer work practices for lifting (i.e. using equipment to lift a 200-lb item as opposed to manual efforts), but still working in awkward postures due to a lack of corporate involvement. The study examines several examples of success and failure that are based on objective assessments.

**Discussion.** Results of the training show that a gain in safety knowledge does not automatically translate to “problem solved.” The topics where training was supplemented with other controls yielded positive impact results. Impact assessments should be done on a per-hazard topic basis to truly assess the effectiveness of the intervention.

## Step by step to job rotation implementation in textile manufacturing industry

Rosimeire Padula, Maria Luiza Caires Comper(presenter), Jack T. Dennerlein

**Background.** Job rotation implementation depends on knowledge of several factors such as workers' exposure to different risk factors and production aspects. This study aimed to report the strategies for the implementation of a job rotation program in a textile industry.

**Methods.** A job rotation program was deployed in a large Brazilian textile industry. First, the researchers met the production managers to understand the characteristics and particularities of each sector, the required level of training, and possible difficulties in carrying out the job rotation. After, an ergonomic analysis of the tasks performed was carried out to identify: (1) the main physical demand; (2) predominant posture adopted; (3) body regions with higher overhead; and (4) the intensity of exposure level (low, moderate, high or very high). All this information was used for classification of tasks and definition of job rotation scale. The completion of the rotation will take place at intervals of two hours. In the third phase, the workers were trained for two months and the job rotation was implemented.

**Results.** Job rotation was successfully deployed in two production departments (finishing socks and finishing underwear) with 266 workers. We had some difficulty implementing job rotation when there were few workers. There was resistance by workers when they were allocated to tasks with lower risk who didn't want to exchange with workers with higher risk. During the job rotation program, most workers stayed in the bathroom and did not want to return to the jobs, which generated lost productivity.

**Discussion.** A large number of workers fulfilled the proposed job rotation schedule. However, some low-risk activity workers who were assigned to higher risk activities boycotted their assigned job rotation. This result showed that even when a job rotation is planned, and workers are trained and accept their new positions, some workers may not fit their new jobs.

## Functional profile of preparation program workers for a Brazilian university retirement

Dernival Bertoncello (presenter), Isabel Aparecida Porcatti de Walsh, Marina Donzeli

**Background.** Retirement preparation programs in organizations are important to ensure a smoother transition from work to retirement. The objective of this study was to develop a profile of participants in the retirement reparation program at a Brazilian public institution and to offer participants guidance and referrals, according to their presented needs.

**Methods.** This was a cross-sectional study, exploratory, descriptive and quantitative, using a population of 29 people expected to retire in the next five years. The evaluation was conducted using the following questionnaires: the International Physical Activity Questionnaire (IPAQ) to assess physical exercise; the Nordic Musculoskeletal Questionnaire (QNSO) to assess musculoskeletal symptoms; and the Ability Index for Work (AIW) to assess work capacity. Flexibility was assessed using the Sit and Reach test and functional mobility was assessed using the Timed Up and Go (TUG) test.

**Results.** Ages of volunteers ranged from 50 to 68 years. Evaluation of physical activity indicated that 14 participants were sedentary. The Nordic questionnaire showed that the participants pointed to musculoskeletal symptoms in the lower back, knee and neck as the main causes of contact with a health professional during the past 12 months. The average time on the TUG test was 7.52 seconds, which indicated a low risk of falling. The capacity index for work revealed that 48% of the individuals had moderate ability, 34% good capacity and only 17% optimum capacity. The flexibility test performed showed that 60% were classified as weak, associated with IPAQ, which indicated that approximately 50% were sedentary.

**Discussion.** This research indicates the need for stimulation and guidance on the practice of regular physical activity as well as stretching and gymnastics, during the period in which participants are still working before retirement.

## Proposal of a prospective multisite evaluation approach to understand the mechanisms of action underlying complex ergonomic interventions

Valerie Albert (presenter), Nicole Vezina, Henriette Bilodeau

**Background.** Recent systematic reviews concluded that ergonomic interventions are not effective in reducing workers' musculoskeletal symptoms. However, the interventions assessed in randomized controlled trials appear to be extremely simplified. They greatly differ from real-life interventions performed by ergonomists who carry out a complex participatory change process closely adapted to an organization's context. In real-life ergonomic interventions, numerous actions precede the implementation of changes. These actions are part of the development phase of the ergonomic intervention aimed at generating an action plan tailored for a given organisation. This phase is crucial to improve work situations, but is almost never mentioned in evaluation studies. The objective of this study is to design a novel evaluation approach focussing on the development phase of real-life ergonomic interventions.

**Methods.** A prospective multiple-case study of four ergonomic interventions each taking place in a different organization will be performed. Evaluation research questions are: (1) Which contextual factors influenced the action plan and the ergonomist's actions that led to its adoption? (2) Which specific actions and/or information transmitted to key stakeholders contributed to changes in their representations and to the action plan? Data will be collected in real time through the review of documents produced during the intervention (logbook of actions performed and progress reports) and semi-structured interviews with emerging ergonomists and key stakeholders. A process-centred analysis will be performed, first with in-depth case analyses, then with inter-case comparisons.

**Results.** Logic models will illustrate results obtained in the evaluation. Such an evaluation will provide substantial knowledge on the actions that led to changes in specific contexts, which could be transferred to future interventions performed in similar contexts.

**Discussion.** Performing an evaluation of the development phase of complex interventions may also provide useful insights to select relevant and site tailored pre-post variables to be documented in a subsequent implementation or effectiveness evaluation.

## Multifaceted workplace intervention: managing musculoskeletal disorders in workers at a medium-sized company

Denise Harari, Raquel Aparecida Casarotto, Rosimeire Simprini Padula (presenter)

**Background.** Ergonomic programs might not be sufficient to control work-related musculoskeletal disorders (MSDs). Since MSDs are multifactorial, refractory cases might need an additional rehabilitation focus. The present study established the effectiveness of a workplace multifaceted intervention consisting of participatory ergonomics, physical exercises and acupuncture/physical therapy orientation for work-related MSDs.

**Methods.** The program was conducted for one year and ten months with 126 workers at a medium-sized company that manufactures hearing aids in Sao Paulo, Brazil. Musculoskeletal disorders in different parts of the body were the outcomes and were measured by the Nordic Musculoskeletal Questionnaire.

**Results.** Participants were included in one of three study groups. Analyses were performed according to intention to treat in three different scenarios. The first group included all eligible participants in the study (SC1). The second group included only the workers with MSDs pre-intervention (SC2). The third group included only the workers without MSDs pre-intervention (SC3). The exact statistical test based on the binomial distribution showed significant effects on MSDs when considering musculoskeletal complaint in at least one region of the body ( $p = 0.001$ ), in the neck region ( $p = 0.0026$ ) and in the hand/wrist region ( $p = 0.032$ ) for all the participants (SC1). When evaluating only the workers with MSDs pre-intervention (SC2), the improvement was significant for all body regions except for the finger region. Additionally, the prevention of new cases of MSDs was achieved in 70% of all body regions for the workers without MSDs pre-intervention (SC3).

**Discussion.** This study demonstrated that a multi-faceted workplace intervention consisting of participatory ergonomics, physical exercises and acupuncture/physical therapy orientation can effectively help manage work-related MSDs among workers of a medium-sized company. Thus, multi-faceted interventions may be relevant for reducing musculoskeletal complaints in a working population.

## The influence of adherence to job rotation in control of musculoskeletal complaints

Rosimeire Padula (presenter), Patricia Rodrigues da Silva, Cristiana Caroline Villas Boas, Maria Luiza Caires Comper

**Background.** Job rotation has been an organizational strategy to optimize work. There is much evidence suggesting that job rotation is effective in reducing physical overload and in preventing musculoskeletal diseases. This study evaluated the influence of job rotation adherence with musculoskeletal complaints control.

**Methods.** An observational study was developed at an international automotive manufacturer with 432 employees. The company had a rotation job culture for its production strategy. The workers were distributed in five assembly lines: assembly of seat 1, 2 and 3, assembly components and factory foam. All employees were interviewed about job rotation participation and musculoskeletal complaints (Nordic Questionnaire). Exposures to biomechanical risk factors were evaluated using the Quick Exposure Check (QEC). The data analyses were descriptive and qualitative.

**Results.** The following summarizes each assembly line's job rotation adherence: 100% for seat assembly 2, 86% for seat assembly 1, and 25% for factory foam. There were no job rotations in seat assembly 3 or in assembly components. Seat assembly 2 had worse results to biomechanical risk followed by assembly 3, assembly 1, assembly components and factory foam. Musculoskeletal complaints were more prevalent in shoulder (100% seat assembly 1, 78.6% seat assembly 2, 57.2% seat assembly 3, 60% assembly components, and 40% factory foam workers). Musculoskeletal complaints in the spine were more than 60% in factory foam workers. Considering body pain scale, it was reported higher in employees of seat assembly 1, with mean (SD) 6.1 (1.3) points, followed by seat assembly 3 with mean (SD) 4.5 (1.1) points, factory foam with mean (SD) 3.6 (0.8), assembly components with mean (SD) 3.2 (1.2) points, and seat assembly 2 with mean (SD) 1.8 (0.7) points.

**Discussion.** Production lines with greater adherence to job rotation are at greatest risk of biomechanical overload, and workers report more complaints, especially in the upper limbs.

## HEALTH DISPARITIES AND GLOBALIZATION

### Sociodemographics and health determinants among older adults workers: a population-based study

Rosimeire Padula, Renata Dantas (presenter), Monica Perracini

**Background.** Population aging has had a global effect on the workforce with a gradual increase in the number of older adults in the labour market. However, little is known about which sociodemographic and health factors allow workers to continue working. Thus, the objective of this study was to identify the factors that enable older workers to stay at work.

**Methods.** This is a cross-sectional, population-based study conducted in four Brazilian cities with similar human development indexes in the FIBRA Network Study (Frailty in Brazilian Older Adults). Participants included 1,762 older adults, aged 65 or above, both genders, community-dwelling. A multidimensional questionnaire was used to interview older adults to determine their sociodemographic, physical/mental health, physical/functional capacities and performance restriction in advanced and instrumental activities of daily living. Physical tests were applied. The dependent variable of this study was dichotomous and self-reported: "Do you actually work?" The answers were "yes" or "no". The variables were categorized to univariate analysis and logistic regression with enter the blocks of variables hierarchically using SPSS 23.0 program.

**Results.** 295 participants with a mean age of  $71.4 \pm 5.5$  years reported they were working, while 1,467 participants with a mean age of  $73.5 \pm 6.3$  years reported they were not working. The full regression model showed an association between less likelihood of working and participants' age ( $>75$  years), gender (female), medications ( $>4$ ), visual perception (visual good), handgrip strength ( $<24,6\text{kg/f}$ ) and comorbidities ( $>3$  diseases). The association factors explained 67.1% of the reason older adults did not stay at work.

**Discussion.** Older adults that stay at work are male, younger, have less disease, use fewer medications and have higher handgrip strength.

OTHER

## Short term Zhan Zhuang, Bauduanjin and segmental stabilization exercises to improve capacity in adults with low-back pain: a pilot study

Sheila Silva, Dernal Bertoncello (presenter), Marina Donzeli, Victor Alves

**Background.** The World Health Organization (WHO) estimates that 65-80 % of the population has LBP (Sahin, 2011). In 40% of cases, the initial pain tends to become chronic low-back pain (CLBP) (Ferreira, 2010).

LBP is the most common musculoskeletal disorder in industrialized countries (Carita et al., 2012), generating high costs in healthcare because of the constant demand for services, and high costs related to disability at work because thousands of people are away from their work activities (Marcondes, Lodovichi, Cera, 2010).

Qigong consists of a series of exercises and meditation that contribute to the health and welfare of the practitioner, regulating the energy flow. The exercises and associated breathing are performed in a slow, continuous manner (Chen et al., 2008). Among Qigong systems are Baduanjin and Zhan Zhuang (Jwing-Ming, 1997).

Our aim was to evaluate the effectiveness of Baduanjin and Zhan Zhuang associated with segmental stabilization exercises to see if they resulted in improved capacity in adults with CLBP.

**Methods.** We evaluated 11 patients, four men and eight women with a specific clinical diagnosis of chronic LBP that was confirmed by imaging. We administered two questionnaires: the Oswestry Index (OI) measuring disability and the PHQ 9 depression screening tool. Most patients worked as general service assistants.

**Results.** Patients had a mean age of  $46 \pm 5$  years, a BMI of  $29 \pm 3.6$ , and a duration of pain from one to 15 years. We conducted a univariate analysis of the data and obtained initial and final scores of the IO ( $34.8 \pm 15.8$  and  $14.7 \pm 14.7$ ); start and end of the PHQ 9 ( $7.55 \pm 4.3$  and  $4.64 \pm 5.28$ ) for  $p \geq 0.05$ . We found a positive association between the IO and PHQ9 variables.

**Discussion.** Symptoms improved with respect to capacity and depression in both groups, plus there was a positive association between initial and final IO and PHQ 9 variables and initial and final Spearman test,  $p \geq 0.05$ .

## Depression and work limitation trajectories in injured workers with musculoskeletal disorders: two-year follow-up study

Selahadin Ibrahim (presenter), Ute Bültmann, Benjamin Amick, Hogg-Johnson Sheilah, Selahadin Ibrahim

**Background.** Depression has implications for both return to work (RTW) and work limitations (WL) in injured workers with musculoskeletal disorders. The aims of the study were to identify trajectories of depression and WL in injured workers with musculoskeletal disorders over a two-year follow-up and to determine factors associated with trajectory group membership.

**Methods.** We used data from 632 workers with back or upper extremity musculoskeletal disorders, who filed a lost-time claim injury in Ontario in 2005. Data were collected at baseline, and at six, 12 and 24 months follow-up. Depressive symptoms were measured with the 20-item CES-D. The 16-item version of the Work Limitations Questionnaire (WLQ) was used to assess WL due to injury or associated treatment. We used latent growth modelling to identify parallel trajectory groups of depression and WL and factors associated with group membership.

**Results.** A four-class trajectory was chosen as the best fitting and substantively meaningful model. Group 1 (37.7%) presented with the lowest scores for depression and WL, and both scores decreased over time; Group 2 (12.8%) had both very high depression and WL scores that almost stayed constant over the two-year follow-up period; Group 3 (15.0%) consisted of workers with medium scores of both depression and WL, and Group 4 (34.0%) had high scores of WL, which decreased dramatically (from 80 to 20) during two-year follow-up and depression that also decreased significantly, but not as much as WL. Return-to-work, self-efficacy, SF-12 mental and physical health scores showed significant differences between some of the groups.

**Conclusion.** Distinct trajectories of depression and WL were identified. Return to work and health characteristics predicted trajectory group membership. Health-care providers should be aware of the course of depression and WL over time in injured workers, and may want to monitor both concepts closely after injury.

## Quantitative assessment of shoulders postures: preliminary application of a real-time monitoring system in a grocery store setting

Francesca Graziosi, Roberta Bonfiglioli (presenter), Matteo Di Lello, Elena Severi, Francesca Buganè, Gabriele Casadio

**Background.** The aim of the study was to test in the field a portable system that monitors shoulder movements in real time. Several methods, very often questionnaire based and/or observational, have been used for assessing biomechanical hazards in the field. Our equipment was low-cost and easy to wear, allowing a more accurate measurement of shoulder posture in contrast to traditional biomechanical assessment methods.

**Methods.** Two female workers employed in a deli department grocery store were recruited during working hours. They performed usual tasks wearing three small inertial sensors (3D accelerometer plus a gyroscope) simply secured with a strap, one for each upper arm and one for the trunk. Sensor signals were recorded at 50 Hz on a smartphone. We estimated shoulder measurements for flexion-extension, abduction-adduction and internal-external rotation.

**Results.** One subject performed, with the dominant arm, flexion movements (from 0° to 60°) for 65% of the working time, exceeding 90° of flexion for 10% of the work shift; the abduction-adduction (-20° to +20°) movements were performed, for both arms, for 70% of the working time. The second subject performed, with the dominant arm, flexion movements (from 0° to 60°) for 78% of the working time, exceeding 90° for 5% of the work shift; the abduction-adduction (-20° to +20°) movements were performed for 80% of the time for both arms.

**Discussion.** Our system allows real-time measurement of shoulder angles during work activity. It records extreme angles and the duration of sustained postures in the sagittal, frontal and horizontal planes. Large group samples and different settings are needed to test and validate this easy-to-wear and low-cost device.

## Fragility fractures in the workplace: analysis of patient survey data from Ontario, Canada

Chamila Adhietty (presenter), Dorcas Beaton, Nooshin Rotondi, Sheilah Hogg-Johnson, Susan Jaglal

**Background.** A fragility fracture (FF) may be defined as a fracture that is caused by minimal trauma, such as a fall from standing height or less (i.e. forces that would not normally fracture healthy bone). Due to the aging population and increasing labour market participation of older individuals, many workers are at risk for FFs. Evidence is required to determine where efforts should be targeted to prevent FFs in the workplace. The objective of this study was to examine FFs that occur at work with respect to the characteristics of the workers who sustain these fractures and the circumstances leading to fracture.

**Methods.** Participants aged 50 years and older were recruited from an Ontario post-fracture care program. Patients who had sustained a FF and were employed at the time of fracture were mailed a survey; 275 eligible participants completed the survey. This study focused on FFs at work (as opposed to elsewhere, e.g. home). A descriptive quantitative analysis was used to examine patient characteristics (demographic and occupational traits, health beliefs) and fracture circumstances (time, place, hazards). Open card sorting with consensus groups was used to cluster respondents' occupations and fracture circumstances to identify patterns that might suggest avenues for prevention.

**Results.** Of the 275 participants, 47 (17.1%) had sustained a FF at work. This group was mostly female (66.0%) with an average age of 59.6 years. Respondents who fractured at work tended to be employed in sales/service occupations (31.9%) and engaged in full-time permanent employment (66.0%). Less than 10% believed that their fracture was caused by poor bone strength. Prevention recommendations included (1) need for improved workplace housekeeping practices and safety culture, and (2) bone health education to be incorporated into workplace health/training.

**Discussion.** These findings will inform efforts to prevent FFs in the workplace, such as interventions directed toward particular occupations and/or worker demographics.

## Assessment of physical workload: muscular activity vs. resultant external force

Clarisse Gaudes, Laurent Claudon (presenter)

**Background.** Physical workload is often evaluated in ergonomics by measuring muscular activity, whereas standards recommend assessing resultant external force or posture.

**Methods.** We compared muscular activity and resultant external force measurements during a clip fitting activity. A clip is a small component used to secure two parts together. This activity is present in automotive assembly process.

11 right-handed males inserted eight clips on eight supports with two methods: (1) with their bare hands and (2) with a pneumatic tool. The 90th percentile for the force was measured using a force platform located under the supports. It was compared with the values recommended by CEN 894-3 (2008). The 10th, 50th and 90th percentiles for the right flexor digitorum superficialis (FDS), extensor digitorum communis (EDC) and trapezius pars descendens (TRA) activity were compared with thresholds proposed by Jonsson (1978) in relation to preventing muscular fatigue. The data were analyzed based on a two-way mixed-effects ANOVA.

**Results.** When fitting clips with the bare hand, the 90th percentile for the force was higher than the thresholds recommended by the standard. The force was higher with the bare hand than when using the tool.

The 10th percentile for EDC and TRA activity when using the tool exceeded the Jonsson's recommended values. With the bare hand, these values were not exceeded. The tool required higher 10th percentiles for FDS, EDC and TRA activity and a higher 50th percentile for FDS activity than the bare hand. The bare hand generated a higher 90th percentile for the EDC activity than the tool.

The results showed that neither of these two clip-fitting methods led to lower physical workload.

**Discussion.** Our conclusions would have been different if only force or muscular activity had been used. This study highlights the risk of a wrong conclusion when only a single method is considered (Gaudes et al., 2015).

## Effects of dual monitor workstation on visual and neck-shoulder muscular and proprioceptive outcomes associated with a 90-minute computer task in men and women

Amanda Farias (presenter), Julie N. Côté

**Purpose.** Work-related musculoskeletal disorders (MSDs) are common among computer (especially female) users. Although working with multiple monitors has become increasingly popular, few studies have provided objective evidence on how this affects the neuromusculoskeletal system in both genders. Thus, our objective was to measure the effects on healthy young male and female adults of performing a 90-minute computer task with a single monitor versus a dual monitor setup.

**Methods.** 27 participants completed two sessions of a 90-minute computer task in either of the two setups, assigned in random order. The standardized computer task involved a combination of reading, typing and search-and-find tasks. Electromyography (EMG) from eight upper body muscles, and visual strain from a visual analog scale (VAS) were measured every nine minutes. Neck proprioception was tested before and after the computer task using a head-repositioning test. EMG amplitude (RMS), variability (CoV), normalized mutual information (NMI), and head repositioning overshoot and accuracy were computed.

**Results.** Reductions in right cervical erector spinae RMS ( $p = .04$ ) and cervical NMI, and more degrees of overshoot (mean =  $4.15^\circ$ ) and end position error (mean =  $1.26^\circ$ ) were observed in using a dual monitor setup. Right middle trapezius CoV, visual strain ( $p < 0.00$ ) and right upper trapezius (RUT) RMS ( $p = 0.03$ ) increased significantly over time, independently from the workstation condition. Overall, workstation effects on proprioception were more pronounced in females (significantly higher for a dual monitor setup) whereas time effects on muscle activity were more pronounced in males.

**Discussion.** Results suggest that dual-monitor work is effective in reducing cervical muscle activity, dissociating cervical connectivity, and maintaining more typical neck repositioning patterns, suggesting some health protective effects. In addition, computer workstation layout and time effects, and underlying pathways, seem to differ for men and women. This evidence could be considered when deciding on the use of dual monitor office workstations.

## Pain intensity and pain thresholds after a dynamic physical load in persons with chronic neck pain

Anna Grimby-Ekman (presenter), Mats Hagberg, Björn Gerdle, Britt Larsson, Christina Ahlstrand, Helena Sandén

**Background.** Chronic pain is common and leads to great human suffering and societal costs and consequences in terms of function loss, reduced participation in society and increased sick days. There are some studies showing increased pain and increased pain sensitivity in patients with fibromyalgia syndrome during and immediately after exercise. Also, our clinical experience has shown that some patients with chronic musculoskeletal pain experience increased pain the day after light physical exercise. This may suggest a dysfunction of exercise-induced pain inhibitory mechanisms or perhaps the facilitation of pain excitatory mechanisms. To our knowledge, there are no research studies that highlight pain intensity and pain sensitivity the day after light physical exertion in this patient population.

**Methods.** The aim of this study was to investigate load-induced prolonged pain in a group with chronic neck pain by studying the development of pain thresholds during the 24 hours after a light dynamic physical load compared to a control group.

**Results.** The present study contributes to increased understanding of the mechanisms in chronic pain, pain sensitization and prolonged load-induced pain, which is crucial for understanding chronic pain patients' clinical situations, for tailoring rehabilitation and for optimizing assessments of work ability.

**Discussion.** These issues are emphasized in a Swedish Governmental work ability report from 2009, which states, "How much pain is acceptable, how focused you can be, how tired you become; these are all issues that have to be left to professional medical considerations."

## Knee biomechanics in obese female during walking

Chitchanok Nutalaya (presenter), Montakarn Chaikuman

**Background.** The purpose of this study was to compare knee biomechanics such as gait tempo-spatial, kinematic, and kinetic (external knee adduction moment) between obese and healthy-weight female subjects during walking.

**Method.** 20 Thai females ages 18-40 years participated in this study and were categorized into four groups by BMI level: normal, overweight, obese I and obese II (World Health Organization in the Western Pacific Region, WPRO). The anthropometric parameters were measured before gait analysis. The biomechanical parameters were measured during walking, with self-selected velocity (Frode) and constant velocity obtained from the Motion Analysis System.

**Results.** The gait biomechanics of both healthy overweight and obese participants showed changes during walking in all types of velocity when compared to normal participants. Increased peak knee flexion angle was found in the higher BMI group for absorbing the external force that helps to reduce risk of joint injury. The knee adduction moment was higher in obese participants possibly representing the higher knee joint load and the joint cartilage damage of osteoarthritis.

**Discussion.** The slower self-selected velocity in obese females may help maintain a magnitude of normal knee joint loading. We recommend future studies examine the use of orthotics to reduce biomechanical load, joint cartilage damage, and osteoarthritis of the knee in females with high BMIs.

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