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Zhiying Cui, Jintu Fan & Yuenshing Wu. *A comparative study on the effects of air gap wind and walking motion on the thermal properties of Arabian Thawbs and Chinese Cheongsams*. Pages 999-1008.

This paper reports on an experimental investigation on the effects of air gap, wind and walking motion on the thermal properties of traditional Arabian thawbs and Chinese cheongsams. Total thermal resistance (I_t) and vapour resistance (R_e) were measured using the sweating fabric manikin – ‘Walter’, and the air gap volumes of the garments were determined by a 3D body scanner. The results showed the relative changes of I_t and R_e of thawbs due to wind and walking motion are greater than those of cheongsams, which provided an explanation of why thawbs are preferred in extremely hot climate. It is further shown that thermal insulation and vapour resistance of thawbs increase with the air gap volume up to about 71,000 cm³ and then decrease gradually. Thawbs with higher air permeability have significantly lower evaporative resistance particularly under windy conditions demonstrating the advantage of air permeable fabrics in body cooling in hot environments. **Practitioner Summary:** This paper aims to better understand the thermal insulation and vapour resistance of traditional Arabian thawbs and Chinese cheongsams, and the relationship between the thermal properties and their fit and design. The results of this study provide a scientific basis for designing ethnic clothing used in hot environments.

- **Keywords:** Thawb, cheongsam, air gap, thermal insulation, vapour resistance

Gemma J. M. Read, Paul M. Salmon & Michael G. Lenné. *When paradigms collide at the road rail interface: evaluation of a sociotechnical systems theory design toolkit for cognitive work analysis*. Pages 1135-1157.

The Cognitive Work Analysis Design Toolkit (CWA-DT) is a recently developed approach that provides guidance and tools to assist in applying the outputs of CWA to design processes to incorporate the values and principles of sociotechnical systems theory. In this paper, the CWA-DT is evaluated based on an application to improve safety at rail level crossings. The evaluation considered the extent to which the CWA-DT met pre-defined methodological criteria and aligned with sociotechnical values and principles. Both process and outcome measures were taken based on the ratings of workshop

participants and human factors experts. Overall, workshop participants were positive about the process and indicated that it met the methodological criteria and sociotechnical values. However, expert ratings suggested that the CWA-DT achieved only limited success in producing RLX designs that fully aligned with the sociotechnical approach. Discussion about the appropriateness of the sociotechnical approach in a public safety context is provided. **Practitioner Summary:** Human factors and ergonomics practitioners need evidence of the effectiveness of methods. A design toolkit for cognitive work analysis, incorporating values and principles from sociotechnical systems theory, was applied to create innovative designs for rail level crossings. Evaluation results based on the application are provided and discussed.

- **Keywords:** Cognitive work analysis, sociotechnical systems, rail level crossings, safety, design

Chris Dijksterhuis, Ben Lewis-Evans, Bart Jelijs, Oliver Tucha, Dick de Waard & Karel Brookhuis. *In-car usage-based insurance feedback strategies. A comparative driving simulator study. Pages 1158-1170.*

Usage-Based Insurances (UBI) enable policyholders to actively reduce the impact of vehicle insurance costs by adopting a safer and more eco-friendly driving style. UBI is especially relevant for younger drivers, who are a high-risk population. The effectiveness of UBI should be enhanced by providing in-car feedback optimised for individual drivers. Thirty young novice drivers were therefore invited to complete six experimental drives with an in-car interface that provided real-time information on rewards gained, their driving behaviour and the speed limit. Reward size was either displayed directly in euro, indirectly as a relatively large amount of credits, or as a percentage of the maximum available bonus. Also, interfaces were investigated that provided partial information to reduce the potential for driver distraction. Compared to a control no-UBI condition, behaviour improved similarly across interfaces, suggesting that interface personalisation after an initial familiarisation period could be feasible without compromising feedback effectiveness. **Practitioner Summary:** User experiences and effects on driving behaviour of six in-car interfaces were compared. The interface provided information on driving behaviour and rewards in a UBI setting. Results suggest that some personalisation of interfaces may be an option after an initial familiarisation period as driving behaviour improved similarly across interfaces.

- **Keywords:** Intelligent speed advisor, Pay-As-You-Drive, driver distraction, behavioural feedback, intelligent transport system

Leah S. Hartman, Irfan Kil, Christopher C. Pagano & Timothy Burg. *Investigating haptic distance-to-break using linear and nonlinear materials in a simulated minimally invasive surgery task. Pages 1171-1181.*

Accurate detection of mediated haptic information in minimally invasive surgery (MIS) is critical for applying appropriate force magnitudes onto soft tissue with the aim of minimising tissue trauma. Force perception in MIS is a dynamic process, with surgeons' administration of force into tissue revealing information about the remote surgical site which further informs the surgeons' haptic interactions. The relationship between applied force and material deformation rate provides biomechanical information specifying the deformation distance remaining until a tissue will fail: which is termed distance-to-break (DTB). The current study demonstrates that observers can detect DTB while deforming simulated tissues and stop before reaching the tissues' failure points. The design of training simulators, control devices and automated robotic systems for applications outside of MIS is discussed. **Practitioner Summary:** In MIS, haptic information is critical for applying appropriate forces onto soft tissue to minimise tissue trauma.

Observers used force information to detect how far they could deform a virtual tissue before it would break. The design of training simulators, control devices and automated robotic systems is discussed.

- **Keywords:** Medical simulation/training and assessment, haptic/touch, perception-action

Pieter Coenen, Marjolein Douwes, Swenneke van den Heuvel & Tim Bosch. *Towards exposure limits for working postures and musculoskeletal symptoms – a prospective cohort study.* Pages 1182-1192.

Occupational postures are considered to be an important group of risk factors for musculoskeletal pain. However, the exposure-outcome association is not clear yet. Therefore, we aimed to determine the exposure-outcome association of working postures and musculoskeletal symptoms. Also, we aimed to establish exposure limits for working postures. In a prospective cohort study among 789 workers, intensity, frequency and duration of postures were assessed at baseline using observations. Musculoskeletal pain was assessed cross-sectionally and longitudinally and associations of postures and pain were addressed using logistic regression analyses. Cut-off points were estimated based on ROC-curve analyses. Associations were found for kneeling/crouching and low-back pain, neck flexion and rotation and neck pain, trunk flexion and low-back pain, and arm elevation and neck and shoulder pain. The results provide insight into exposure-outcome relations between working postures and musculoskeletal symptoms as well as evidence-based working posture exposure limits that can be used in future guidelines and risk assessment tools. **Practitioner Summary:** Our study gives insight into exposure-outcome associations of working postures and musculoskeletal symptoms (kneeling/crouching and low-back pain, neck flexion/rotation and neck pain, trunk flexion and low-back pain, and arm elevation and neck and shoulder pain). Results furthermore deliver evidence-based postural exposure limits that can be used in guidelines and risk assessments.

- **Keywords:** Exposure assessment, musculoskeletal pain, work postures, occupational health

Carolyn M. Sommerich, Steven A. Lavender, Kevin Evans, Elizabeth Sanders, Sharon Joines, Sabrina Lamar, Radin Zaid Radin Umar, Wei-Ting Yen, Jing Li, Shasank Nagavarapu & Jennifer A. Dickerson. *Collaborating with cardiac sonographers to develop work-related musculoskeletal disorder interventions.* Pages 1193-1204.

For more than two decades, surveys of imaging technologists, including cardiac sonographers, diagnostic medical sonographers and vascular technologists, have consistently reported high prevalence of work-related musculoskeletal discomfort (WRMSD). Yet, intervention research involving sonographers is limited. In this study, we used a participatory approach to identifying needs and opportunities for developing interventions to reduce sonographers' exposures to WRMSD risk factors. In this paper, we present some of those needs. We include descriptions of two interventions, targeted for cardiac sonographers, that were developed, through an iterative process, into functional prototypes that were evaluated in pilot tests by practicing sonographers. One of these interventions is now in daily use. We would like other engineers and ergonomists to recognise this area of opportunity to apply their knowledge of biomechanics and design in order to begin to address the high prevalence of WRMSDs in sonographers, by working with sonographers to develop useful and usable interventions. **Practitioner Summary:** This paper discusses needs, opportunities and methods for working with sonographers in order to develop interventions to reduce their exposure to risk factors

for work-related musculoskeletal discomfort. Results from field tests of two novel interventions targeting cardiac sonographers are also presented.

- **Keywords:** Sonography, engineering controls, musculoskeletal injury, ultrasound

Ryan J. Marker, Jaclyn E. Balter, Micaela L. Nofsinger, Dan Anton, Nathan B. Fethke & Katrina S. Maluf. *Upper trapezius muscle activity in healthy office workers: reliability and sensitivity of occupational exposure measures to differences in sex and hand dominance. Pages 1205-1214.*

Patterns of cervical muscle activity may contribute to overuse injuries in office workers. The purpose of this investigation was to characterise patterns of upper trapezius muscle activity in pain-free office workers using traditional occupational exposure measures and a modified Active Amplitude Probability Distribution Function (APDF), which considers only periods of active muscle contraction. Bilateral trapezius muscle activity was recorded in 77 pain-free office workers for 1–2 full days in their natural work environment. Mean amplitude, gap frequency, muscular rest and Traditional and Active APDF amplitudes were calculated. All measures demonstrated fair to substantial reliability. Dominant muscles demonstrated higher amplitudes of activity and less muscular rest compared to non-dominant, and women demonstrated less muscular rest with no significant difference in amplitude assessed by Active APDF compared to men. These findings provide normative data to identify atypical motor patterns that may contribute to persistence or recurrence of neck pain in office workers. **Practitioner Summary:** Upper trapezius muscle activity was characterised in a large cohort of pain-free workers using electromyographic recordings from office environments. Dominant muscles demonstrated higher activity and less rest than non-dominant, and women demonstrated less rest than men. Results may be used to identify atypical trapezius muscle activity in office workers.

- **Keywords:** Occupational exposure, electromyography, amplitude probability distribution function, activity monitoring, reliability

David C. Kingston, Liana M. Tennant, Helen C. Chong & Stacey M. Acker. *Peak activation of lower limb musculature during high flexion kneeling and transitional movements. Pages 1215-1223.*

Few studies have measured lower limb muscle activation during high knee flexion or investigated the effects of occupational safety footwear. Therefore, our understanding of injury and disease mechanisms, such as knee osteoarthritis, is limited for these high-risk postures. Peak activation was assessed in eight bilateral lower limb muscles for twelve male participants, while shod or barefoot. Transitions between standing and kneeling had peak quadriceps and tibialis anterior (TA) activations above 50% MVC. Static kneeling and simulated tasks performed when kneeling had peak TA activity above 15% MVC but below 10% MVC for remaining muscles. In three cases, peak muscle activity was significantly higher (mean 8.9% MVC) when shod. However, net compressive knee joint forces may not be significantly increased when shod. EMG should be used as a modelling input when estimating joint contact forces for these postures, considering the activation levels in the hamstrings and quadriceps muscles during transitions. **Practitioner Summary:** Kneeling transitional movements are used in activities of daily living and work but are linked to increased knee osteoarthritis risk. We found peak EMG activity of some lower limb muscles to be over 70% MVC during transitions and minimal influence of wearing safety footwear.

- **Keywords:** EMG, knee, occupational ergonomics, footwear, kneeling

Steven Visser, Henk F. van der Molen, P. Paul F. M. Kuijer, Judith K. Sluiter & Monique H. W. Frings-Dresen. *Stand up: comparison of two*

electrical screed levelling machines to reduce the work demands for the knees and low back among floor layers. Pages 1224-1231.

Electrical screed levelling machines are developed to reduce kneeling and trunk flexion of sand-cement-bound screed floor layers. An observational intervention study among 10 floor layers was performed to assess the differences between a self-propelled and a manually moved machine. The outcome measures were work demands, production time, perceived load, discomfort and applicability. Compared to the self-propelled machine, the duration of kneeling ($\Delta 13$ min; $p = 0.003$) and trunk flexion ($\Delta 12$ min; $p < 0.001$) was shorter using the manually moved machine, and the duration of pushing and pulling increased ($\Delta 39$ min; $p < 0.001$). No significant or relevant differences were found for production time, perceived load and discomfort. Nine out of ten floor layers found the manually moved machine applicable and three out of ten found the self-propelled machine applicable. When compared with the traditional manner of floor laying, both electrical machines reduced the exposure towards kneeling and trunk flexion. **Practitioner Summary:** Electrical machines may help to reduce high physical work demands on floor layers. A manually moved machine is better applicable for the installation of screed floors in residences with smaller floor areas. A self-propelled machine is better applicable on large floor areas with a minimum width of 4 m.

- **Keywords:** Ergonomic measures, floor layers, work demands, low back, knees

Andrew P. Hunt, Paul J. Tofari, Daniel C. Billing & Aaron J. Silk. Tactical combat movements: inter-individual variation in performance due to the effects of load carriage. Pages 1232-1241.

An examination into the effects of carried military equipment on the performance of two tactical combat movement simulations was conducted. Nineteen Airfield Defence Guards performed a break contact (five 30-m sprints) and a fire and movement simulation (16 6-m bounds) in five load conditions (10–30 kg). Heavier loads significantly increased movement duration on the break contact (0.8%/kg load) and fire and movement (1.1%/kg). Performance deterioration was observed from the beginning to the end of the series of movements (bounds or sprints) with deterioration becoming significantly greater in heavier load conditions. Inter-individual variation between slower and faster participants showed a range in load effects; 0.6, 0.8%/kg for fast and 1.0, 1.4%/kg for slow (break contact, fire and movement, respectively). Velocity profiles revealed that the initial acceleration and peak velocity were the primary determinants of performance. As the duration of these tactical combat movements reflects periods of heightened vulnerability, these findings highlight important implications for commanders. **Practitioner Summary:** Increasing amounts of carried military equipment impairs the performance of tactical combat movements. Examination of inter-individual variation in velocity profiles identified that the initial acceleration and the peak velocity achieved during sprints and bounds are key determinants of overall performance.

- **Keywords:** Repeat sprint, performance deterioration, velocity, military

Kane J. Middleton, Greg L. Carstairs & Daniel J. Ham. Lift performance and lumbar loading in standing and seated lifts. Pages 1242-1250.

This study investigated the effect of posture on lifting performance. Twenty-three male soldiers lifted a loaded box onto a platform in standing and seated postures to determine their maximum lift capacity and maximum acceptable lift. Lift performance, trunk kinematics, lumbar loads, anthropometric and strength data were recorded. There was a significant main effect for lift effort but not for posture or the interaction. Effect sizes showed that lumbar compression forces did not differ between postures at lift initiation (Standing 5566.2 ± 627.8 N; Seated 5584.0 ± 16.0) but were higher in the standing

posture (4045.7 ± 408.3 N) when compared with the seated posture (3655.8 ± 225.7 N) at lift completion. Anterior shear forces were higher in the standing posture at both lift initiation (Standing 519.4 ± 104.4 N; Seated 224.2 ± 9.4 N) and completion (Standing 183.3 ± 62.5 N; Seated 71.0 ± 24.2 N) and may have been a result of increased trunk flexion and a larger horizontal distance of the mass from the L5-S1 joint. **Practitioner Summary:** Differences between lift performance and lumbar forces in standing and seated lifts are unclear. Using a with-in subjects repeated measures design, we found no difference in lifted mass or lumbar compression force at lift initiation between standing and seated lifts.

- **Keywords:** Biomechanics, physical work capacity, military ergonomics, manual handling, injury risks

Boyi Hu, Xiaopeng Ning, Fei Dai & Ibrahim Almuheidib. *The changes of lumbar muscle flexion-relaxation phenomenon due to antero-posteriorly slanted ground surfaces.* Pages 1251-1258.

Uneven ground surface is a common occupational injury risk factor in industries such as agriculture, fishing, transportation and construction. Studies have shown that antero-posteriorly slanted ground surfaces could reduce spinal stability and increase the risk of falling. In this study, the influence of antero-posteriorly slanted ground surfaces on lumbar flexion-relaxation responses was investigated. Fourteen healthy participants performed sagittally symmetric and asymmetric trunk bending motions on one flat and two antero-posteriorly slanted surfaces (-15° (uphill facing) and 15° (downhill facing)), while lumbar muscle electromyography and trunk kinematics were recorded. Results showed that standing on a downhill facing slanted surface delays the onset of lumbar muscle flexion-relaxation phenomenon (FRP), while standing on an uphill facing ground causes lumbar muscle FRP to occur earlier. In addition, compared to symmetric bending, when performing asymmetric bending, FRP occurred earlier on the contralateral side of lumbar muscles and significantly smaller maximum lumbar flexion and trunk inclination angles were observed. **Practitioner Summary:** Uneven ground surface is a common risk factor among a number of industries. In this study, we investigated the influence of antero-posteriorly slanted ground surface on trunk biomechanics during trunk bending. Results showed the slanted surface alters the lumbar tissue load-sharing mechanism in both sagittally symmetric and asymmetric bending.

- **Keywords:** Uneven ground surface, trunk bending, flexion-relaxation phenomenon, lower back pain

Ina Völker, Christine Kirchner & Otmar Leo Bock. *On the relationship between subjective and objective measures of fatigue.* Pages 1259-1263.

Objective: Objective and subjective methods have been used in the past to assess workplace fatigue, but little is known about correlations between them. We examine correlations between subjective and objective measures, including measures collected in a workplace scenario. **Methods:** 15 young and 17 older participants were assessed before and after work with four types of fatigue measure: objective physical (posturography), objective mental (psychomotor vigilance task), subjective physical and mental (self-assessment), objective and subjective realistic (oculomotor behaviour, observer-rated facial expression, typing performance). **Results:** Pre- and post-test scores were analysed with an ANOVA, significant differences were submitted to a factor analysis. It yielded three factors: one representing posturography, the second self-rated mental and physical fatigue and the third observer-rated facial expression. **Conclusions:** Results advocate the existence of three independent fatigue components: Objective physical fatigue, introspective and extrospective fatigue. **Practitioner Summary:** This study analyses correlations between different subjective and objective fatigue markers to

better understand the complex nature of workplace fatigue. Measurements were conducted directly at the workplace. Results reveal that fatigue comprises three independent fatigue components: Objective physical fatigue, introspective and extrospective fatigue.

- **Keywords:** Fatigue markers, multidimensional construct, workplace, fatigue detection