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Gyouhyung Kyung & Maury A. Nussbaum. *Age-related difference in perceptual responses and interface pressure requirements for driver seat design.* Pages 1795-1805.

Due to typical physiological changes with age, older individuals are likely to have different perceptual responses to and different needs for driver–seat interface design. To assess this, a study was conducted in which a total of 22 younger and older participants completed six short-term driving sessions. Three subjective ratings (comfort, discomfort and overall) were obtained, along with 36 driver–seat interface pressure measures, and were used to assess differences and similarities between the two age groups. For both age groups, localised comfort ratings were more effective at distinguishing between driver seats and workspaces. Older individuals appeared to be less sensitive to discomfort than younger individuals. Across age groups, two distinct processes were used in determining whole-body comfort and discomfort perceptions based on localised comfort/discomfort perceptions. Whole-body discomfort levels were largely affected by lower back discomfort in the younger group versus upper back discomfort in the older group. Four specific pressure measures at several body regions differed between the age groups, suggesting distinct contact pressure requirements and loading patterns among these groups.

Practitioner Summary: Driver seats appear to be differentiable only in terms of perceived comfort, but not in terms of perceived discomfort. Different pressure requirements for each age group and for each seat side should be considered comprehensively when designing driver seats and workspaces.

- **Keywords:** age, comfort, discomfort, driving experience, seat interface pressure

K.N. Dewangan, S. Rakheja, Pierre Marcotte, A. Shahmir & S.K. Patra. *Comparisons of apparent mass responses of human subjects seated on rigid and elastic seats under vertical vibration.* Pages 1806-1822.

The apparent mass (AM) responses of human body seated on elastic seat, without and with a vertical back support, are measured using a seat pressure sensing mat under three levels of vertical vibration (0.25, 0.50 and 0.75 m/s² rms acceleration) in 0.50–20 Hz frequency range. The responses were also measured with a rigid seat using the pressure mat and a force plate in order to examine the validity of the pressure mat. The

pressure mat resulted in considerably lower AM magnitudes compared to the force plate. A correction function was proposed and applied, which resulted in comparable AM from both measurement systems for the rigid seat. The correction function was subsequently applied to derive AM of subjects seated on elastic seat. The responses revealed lower peak magnitude and corresponding frequency compared to those measured with rigid seat, irrespective of back support and excitation considered.

Practitioner Summary: Seated body biodynamic responses to vibration have been widely reported for rigid seats due to measurement complexities with realistic elastic seats. A pressure sensing mat is used to measure AM response of the body with elastic seats. Considerable differences between the responses with rigid and elastic seats are observed.

- **Keywords:** biodynamic response of body coupled with elastic seats, thin-film pressure sensing systems, body–seat interface force

Thomas W. McDowell, Ren G. Dong, Daniel E. Welcome, Xueyan S. Xu & Christopher Warren. *Vibration-reducing gloves: transmissibility at the palm of the hand in three orthogonal directions.* Pages 1823-1840.

Vibration-reducing (VR) gloves are commonly used as a means to help control exposures to hand-transmitted vibrations generated by powered hand tools. The objective of this study was to characterise the vibration transmissibility spectra and frequency-weighted vibration transmissibility of VR gloves at the palm of the hand in three orthogonal directions. Seven adult males participated in the evaluation of seven glove models using a three-dimensional hand–arm vibration test system. Three levels of hand coupling force were applied in the experiment. This study found that, in general, VR gloves are most effective at reducing vibrations transmitted to the palm along the forearm direction. Gloves that are found to be superior at reducing vibrations in the forearm direction may not be more effective in the other directions when compared with other VR gloves. This casts doubts on the validity of the standardised glove screening test.

Practitioner Summary: This study used human subjects to measure three-dimensional vibration transmissibility of vibration-reducing gloves at the palm and identified their vibration attenuation characteristics. This study found the gloves to be most effective at reducing vibrations along the forearm direction. These gloves did not effectively attenuate vibration along the handle axial direction.

- **Keywords:** hand–arm vibration, acceleration exposures, personal protective equipment, musculoskeletal disorders, upper limb disorders

C.B. Irwin, J.D. Towles & R.G. Radwin. *Development and application of a multi-axis dynamometer for measuring grip force.* Pages 1841-1849.

Objective: This paper describes the development and application of a novel multi-axis hand dynamometer for quantifying 2D grip force magnitude and direction in the flexion-extension plane of the fingers. *Methods:* A three-beam reconfigurable form dynamometer, containing two active beams for measuring orthogonal forces and moments regardless of point of force application, was designed, fabricated and tested. Maximum grip exertions were evaluated for 16 subjects gripping cylindrical handles varying in diameter. *Results:* Mean grip force magnitudes were 231 N (SD = 67.7 N), 236 N (72.9 N), 208 N (72.5 N) and 158 N (45.7 N) for 3.81 cm, 5.08 cm, 6.35 cm and 7.62 cm diameter handles, respectively. Grip force direction rotated clockwise and the centre of pressure moved upward along the handle as handle diameter increased. *Conclusions:* Given that the multi-axis dynamometer simultaneously measures planar grip force magnitude and direction, and centre of pressure along the handle, this novel sensor design provides more grip force characteristics than current sensor designs

that would improve evaluation of grip characteristics and model-driven calculations of musculoskeletal forces from dynamometer data.

Practitioner Summary: The dynamometer was designed to isolate and describe force vectors produced by the finger segments. It may be particularly more suitable than current grip force dynamometers for improving model-based estimations of musculoskeletal forces and stresses that could ultimately improve ergonomic design of devices that interface with the hand.

- **Keywords:** 2D grip force, multi-axis grip dynamometer, handle design

Matt J. Camilleri, Ajith Malige, Jeffrey Fujimoto & David M. Rempel. *Touch displays: the effects of palm rejection technology on productivity, comfort, biomechanics and positioning.* Pages 1850-1862.

Direct touch displays can improve the human-computer experience and productivity; however, the higher hand locations may increase shoulder fatigue. *Palm rejection* (PR) technology may reduce shoulder loads by allowing the palms to rest on the display and increase productivity by registering the touched content and fingertips through the palms rather than shoulders. The effects of PR were evaluated by having participants perform touch tasks while posture and reaction force on the display were measured. Enabling PR, during which the subjects could place the palms on the display (but were not required to), resulted in increased wrist extension, force applied to the display and productivity, and less discomfort, but had no effect on the self-selected positioning of the display. Participants did not deliberately place their palms on the display; therefore, there was no reduction in shoulder load and the increased productivity was not due to improved hand registration. The increased productivity may have been due to reduced interruptions from palm contacts or reduced motor control demands.

Practitioner Summary: Since placing the palms on a touch display would decrease shoulder loads and provide for improved registration with the touched content, a laboratory study assessing the effects of palm rejection technology was performed. With palm rejection enabled, task speed increased and self-reported discomfort decreased even though palms were rarely placed on the display.

- **Keywords:** tablet, touchscreen, gesture interaction, shoulder, wrist

Loïc Caroux, Ludovic Le Bigot & Nicolas Vibert. *Impact of the motion and visual complexity of the background on players' performance in video game-like displays.* Pages 1863-1876.

The visual interfaces of virtual environments such as video games often show scenes where objects are superimposed on a moving background. Three experiments were designed to better understand the impact of the complexity and/or overall motion of two types of visual backgrounds often used in video games on the detection and use of superimposed, stationary items. The impact of background complexity and motion was assessed during two typical video game tasks: a relatively complex visual search task and a classic, less demanding shooting task. Background motion impaired participants' performance only when they performed the shooting game task, and only when the simplest of the two backgrounds was used. In contrast, and independently of background motion, performance on both tasks was impaired when the complexity of the background increased. Eye movement recordings demonstrated that most of the findings reflected the impact of low-level features of the two backgrounds on gaze control.

Practitioner Summary: Variations in the low-level features of visual backgrounds may be used to control challenge in video games. Using a visually complex background will

always increase game difficulty. For the simplest game tasks, background motion will also impair users' performance if background complexity is low.

- **Keywords:** shooting task, visual search, low-level visual features, eye movements, virtual environments

Nicky Nibbeling, Raoul R.D. Oudejans, Rouwen Cañal-Bruland, Peter van der Wurff & Hein A.M. Daanen. *Pursue or shoot? Effects of exercise-induced fatigue on the transition from running to rifle shooting in a pursuit task. Pages 1877-1888.*

To investigate to what degree exercise-induced fatigue influences behavioural choices, participants' transition from running to rifle shooting in a pursue-and-shoot task was assessed. Participants ran on a treadmill and chased a target in a virtual environment and were free to choose when to stop the treadmill and shoot at the target. Fatigue increased progressively throughout the 20-minute test. Results indicated that shooting accuracy was not affected by fatigue. However, the distance to the target at which participants decided to shoot showed a U-shaped relationship with fatigue, $R^2 = 0.884$, $p = 0.013$. At low fatigue levels (ratings of perceived exertion [RPE] < 6.5), the distance to the target at which participants shot decreased, whereas at higher fatigue levels (RPE > 6.5) shooting distance increased again. At high levels of fatigue, participants stopped running sooner, aimed at the target longer and shot less often. Findings indicate that physiological parameters influence not only perception but also actual transitions between different actions.

Practitioner Summary: This study was conducted to investigate to what degree exercise-induced fatigue influences behavioural choices. This is an original research article. Our major finding is that physiological parameters influence not only perceptual estimates of action possibilities but also actual behaviours and transitions between different actions.

- **Keywords:** action possibilities, behavioural choices, exercise-induced fatigue, far aiming, virtual environment

Liang Ma, Wei Zhang, Bo Hu, Damien Chablat, Fouad Bennis & François Guillaume. *Determination of subject-specific muscle fatigue rates under static fatiguing operations. Pages 1889-1900.*

Cumulative local muscle fatigue may lead to potential musculoskeletal disorder (MSD) risks, and subject-specific muscle fatigability needs to be considered to reduce potential MSD risks. This study was conducted to determine local muscle fatigue rate at shoulder joint level based on an exponential function derived from a muscle fatigue model. Forty male subjects participated in a fatiguing operation under a static posture with a range of relative force levels (14–33%). Maximum muscle strengths over time were measured after different fatiguing sessions. The time course of strength decline was fitted to the exponential function. Subject-specific fatigue rates of shoulder joint moment strength were determined. Good correspondence ($R^2 > 0.8$) was found in the regression of the majority (35 out of 40 subjects). Substantial inter-individual variability in fatigue rate was found and discussed.

Practitioner Summary: Different workers have different muscle fatigue attributes. Determination of joint-level subject-specific muscle fatigue rates can facilitate physical task assignment, work–rest scheduling, MSD prevention and worker training and selection.

- **Keywords:** static muscular strength, joint strength decline, muscle fatigue rate, subject-specific fatigue rate

S. Andy Sparks, Phillip Chandler, Thomas G. Bailey, David C. Marchant & Duncan Orme. *The energy demands of portable gas analysis system carriage during walking and running. Pages 1901-1907.*

The aim of this study was to evaluate the carriage of a portable gas analyser during prolonged treadmill exercise at a variety of speeds. Ten male participants completed six trials at different speeds (4, 8 and 12 km h⁻¹) for 40 min whilst wearing the analyser (P) or where the analyser was externally supported (L). Throughout each trial, respiratory gases, heart rate (HR), perceptions of effort and energy expenditure (EE) were measured. Significantly higher EE occurred during P12 ($p = 0.01$) than during L12 (855.3 ± 104.3 ; CI = 780.7–930.0 and 801.5 ± 82.2 kcal; CI = 742.7–860.3 kcal, respectively), but not at the other speeds; despite this, perceptions of effort and HR responses were unaffected. This additional EE is likely caused by alterations to posture which increase oxygen demand. The use of such systems is unlikely to affect low-intensity tasks, but researchers should use caution when interpreting data, particularly when exercise duration exceeds 30 min and laboratory-based analysers should be used where possible.

Practitioner Summary: There is extensive use of portable gas analysers in many settings. This study suggests that there is no additional effect on energy expenditure until running speeds of 8 km h⁻¹ are exceeded. Future work should consider the effects of gas analyser carriage in a wider variety of populations, environments and terrain.

- **Keywords:** load carriage, locomotion, prolonged exercise, oxygen cost, energy expenditure

Shi Wei Mo, Dong-Qing Xu, Jing Xian Li & Meng Liu. *Effect of backpack load on the head, cervical spine and shoulder postures in children during gait termination. Pages 1908-1916.*

Twelve boys with an average age of 9.9 years were instructed to carry backpacks that weighed 0%, 10% and 15% of their body weights (BWs) to complete planned and unplanned gait termination experiments. The craniohorizontal, craniovertebral and sagittal shoulder posture angles at the sagittal plane as well as the anterior head alignment and coronal shoulder posture angles at the coronal plane were analysed. Results revealed significantly smaller craniohorizontal and sagittal shoulder posture angles during planned gait termination and a significantly smaller sagittal shoulder posture angle during unplanned gait termination under loaded conditions compared with those at 0% BW backpacks. Furthermore, the coronal shoulder posture angles at 10% and 15% BW during planned and unplanned gait terminations were significantly larger than those at 0% BW. Therefore, subjects were more likely to have a forward head posture, rounded shoulder posture and increased lateral tilting of the shoulders during gait termination as backpack loads were increased. However, gait termination, whether planned or unplanned, did not elicit a remarkable effect on posture.

Practitioner Summary: This descriptive study was performed to quantify the effects of carrying different backpack loads on the postures of children during planned and unplanned gait terminations. An increase in backpack loads resulted in a more forward head posture, more rounded shoulder posture and increased lateral tilting of the shoulders during unplanned gait termination.

- **Keywords:** backpack, load, children, gait termination, posture

Deepti Majumdar, Madhu Sudan Pal, Anilendu Pramanik & Dhurjati Majumdar. *Kinetic changes in gait during low magnitude military load carriage. Pages 1917-1927.*

Indian infantry soldiers carry smaller magnitudes of loads for operational requirements. The ground reaction forces (GRFs) and impulse responses of 10 healthy male Indian infantry soldiers were collected while they walked carrying operational loads between 4.2 and 17.5 kg (6.5–27.2% of mean body weight (BW)) and a control condition of no external load (NL). The GRF and impulse components were normalised for BW, and data for each load condition were compared with NL in each side applying one-way analysis of variance followed by Dunnett's *post hoc* test. Right foot data were compared with corresponding left foot GRF data for all load conditions and NL. There were significant increases in vertical and anteroposterior GRFs with increase in load. Left and right feet GRF data in corresponding load conditions were significantly different in anteroposterior plane. No significant change was observed in the temporal components of support phase of gait. Changes in impulse parameter were observed in the anteroposterior and vertical planes while carrying load greater than 23 and 16.6% of BW for the right foot and left foot, respectively. Result indicates that smaller magnitudes of loads produced kinetic changes proportional to system weight, similar to heavier loads with the possibility of increased injury risk. Observed smaller asymmetric changes in gait may be considered as postural adjustment due to load. Unique physical characteristics of Indian soldiers and the probable design shortcomings of the existing backpack might have caused significant changes in GRF and peak impulse during smaller load carriage.

Practitioner Summary: This study evaluates stress on foot by recording GRF and impulse changes due to small increments of comparatively lighter military loads. Such data should be considered in evaluating the injury risk of feet during the process of optimisation of safer military load carriage and overall improvement in combat performances.

- **Keywords:** system weight, ground reaction forces, asymmetry of gait, centre of mass

Martina Kotzé & Leon Steyn. *The role of psychological factors in workplace safety. Pages 1928-1939.*

Workplace safety researchers and practitioners generally agree that it is necessary to understand the psychological factors that influence people's workplace safety behaviour. Yet, the search for reliable individual differences regarding psychological factors associated with workplace safety has led to sparse results and inconclusive findings. The aim of this study was to investigate whether there are differences between the psychological factors, cognitive ability, personality and work-wellness of employees involved in workplace incidents and accidents and/or driver vehicle accidents and those who are not. The study population ($N = 279$) consisted of employees employed at an electricity supply organisation in South Africa. Mann-Whitney *U*-test and one-way ANOVA were conducted to determine the differences in the respective psychological factors between the groups. These results showed that cognitive ability did not seem to play a role in workplace incident/accident involvement, including driver vehicle accidents, while the wellness factors burnout and sense of coherence, as well as certain personality traits, namely conscientiousness, pragmatic and gregariousness play a statistically significant role in individuals' involvement in workplace incidents/accidents/driver vehicle accidents. Safety practitioners, managers and human resource specialists should take cognisance of the role of specifically work-wellness in workplace safety behaviour, as management can influence these negative states that are often caused by continuously stressful situations, and subsequently enhance work place safety.

Practitioner Summary: Differences in psychological factors between employees involved in workplace incidents/accidents and driver vehicle accidents were investigated. Certain work-wellness factors (burnout and sense of coherence) and personality traits (conscientiousness, pragmatic and gregariousness) were shown to play a role in workplace incidents/accidents and driver vehicle accidents.

- **Keywords:** workplace safety, workplace incidents/accidents, psychological factors, human error