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Arun Garg, J. Steven Moore & Jay M. Kapellusch. *The Composite Strain Index (COSI) and Cumulative Strain Index (CUSI): methodologies for quantifying biomechanical stressors for complex tasks and job rotation using the Revised Strain Index. Pages: 1033-1041.*

The Composite Strain Index (COSI) quantifies biomechanical stressors for complex tasks consisting of exertions at different force levels and/or with different exertion times. The Cumulative Strain Index (CUSI) further integrates biomechanical stressors from different tasks to quantify exposure for the entire work shift. The paper provides methodologies to compute COSI and CUSI along with examples. Complex task simulation produced 169,214 distinct tasks. Use of average, time-weighted average (TWA) and peak force and COSI classified 66.9, 28.2, 100 and 38.9% of tasks as hazardous, respectively. For job rotation the simulation produced 10,920 distinct jobs. TWA COSI, peak task COSI and CUSI classified 36.5, 78.1 and 66.6% jobs as hazardous, respectively. The results suggest that the TWA approach systematically underestimates the biomechanical stressors and peak approach overestimates biomechanical stressors, both at the task and job level. It is believed that the COSI and CUSI partially address these underestimations and overestimations of biomechanical stressors. **Practitioner Summary:** COSI quantifies exposure when applied hand force and/or duration of that force changes during a task cycle. CUSI integrates physical exposures from job rotation. These should be valuable tools for designing and analysing tasks and job rotation to determine risk of musculoskeletal injuries.

- **Keywords:** Ergonomics tools and methods, methods and approaches, task analysis, job-rotation, human-machine systems, workstation design, human-machine systems, job design and analysis, system performance, risk assessment and management, health and safety

David I. Douphrate, Nathan B. Fethke, Matthew W. Nonnenmann, Anabel Rodriguez, Robert Hagevoort & David Gimeno Ruiz de Porras. *Full-shift and task-specific upper extremity muscle activity among US large-herd dairy parlour workers. Pages: 1042-1054.*

US large-herd dairy parlour workers experience a high prevalence of musculoskeletal symptoms in the upper extremity. The purpose of this study was to estimate and compare full-shift and task-specific muscle activity of the upper extremity among parlour workers. Surface electromyography data were recorded continuously throughout a full work shift for each participant ($n = 60$). For a subset of participants ($n = 33$), muscular effort was estimated for milking task cycles. Lower muscle activity levels and higher per cent muscular rest was observed among rotary parlour participants as compared to herringbone and parallel parlour participants for anterior deltoid, forearm flexor and forearm extensor muscles. These findings suggest rotary parlours may offer workstation designs or work organisational dynamics which may be more beneficial to the health and performance of the worker, as compared to parallel or herringbone parlours. **Practitioner Summary:** Study findings suggest milking parlour configurations present different biomechanical demands on workers which may influence worker health and performance. Our findings will enable more informed decisions regarding both engineering (e.g. parlour configuration or milking equipment) and administrative (e.g. work organisation) control strategies for large-herd milking parlours.

- **Keywords:** Agriculture ergonomics, intervention effectiveness, biomechanics, equipment design, task analysis

Ana E. Rodriguez-Soto, David B. Berry, Rebecca Jaworski, Andrew Jensen, Christine B. Chung, Brenda Niederberger, Aziza Qadir, Karen R. Kelly & Samuel R. Ward. *The effect of training on lumbar spine posture and intervertebral disc degeneration in active-duty Marines. Pages: 1055-1063.*

Military training aims to improve load carriage performance and reduce risk of injuries. Data describing the lumbar spine (LS) postural response to load carriage throughout training are limited. We hypothesised that training would reduce the LS postural response to load. The LS posture of 27 Marines was measured from upright MR images: with and without load (22.6 kg) at the beginning, middle, and end of School of Infantry (SOI) training. Disc degeneration was graded at L5–S1. No changes in posture and disc degeneration were found throughout training. During load carriage the LS became less lordotic and the sacrum more horizontal. Marines with disc degeneration had larger sacral postural perturbations in response to load. Our findings suggest that the postural response to load is defined more by the task needs than by the physical condition of the Marine. **Practitioner Summary:** The effect of military training on lumbar spine posture is unknown. The lumbar posture of 27 Marines was measured from upright MR images, with and without load throughout infantry training. No changes in posture or IVD degeneration were found across training. Marines with degeneration at the L5–S1 level had larger sacral postural perturbations in response to load.

- **Keywords:** Military, training, load carriage, posture, lumbar spine, sacral slope

Xiaoke Zeng, Aaron M. Kociolek, Muhammad Idrees Khan, Stephan Milosavljevic, Brenna Bath & Catherine Trask. *Whole body vibration exposure patterns in Canadian prairie farmers. Pages: 1064-1073.*

Whole body vibration is a significant physical risk factor associated with low back pain. This study assessed farmers' exposure to whole body vibration on the Canadian prairies according to ISO 2631-1. Eighty-seven vibration measurements were collected with a triaxial accelerometer embedded in a rubber seat pad at the operator-seat interface of agricultural machinery, including tractors, combines, pickup trucks, grain trucks, sprayers, swathers, all-terrain vehicles, and skid steers. Whole body vibration was highest in the vertical axis, with a mean (range) frequency-weighted root mean squared acceleration of 0.43 m/s^2 ($0.19\text{--}1.06 \text{ m/s}^2$). Mean crest factors exceeded 9 in all 3 axes,

indicating high mechanical shock content. The vertical axis vibration dose value was $7.55 \text{ m/s}^{1.75}$ ($2.18\text{--}37.59 \text{ m/s}^{1.75}$), with 41.4% of measurements within or above the health guidance caution zone. These high exposures in addition to an ageing agricultural workforce may increase health risks even further, particularly for the low back. **Practitioner Summary:** Agricultural workers are frequently exposed to whole body vibration while operating farm equipment, presenting a substantial risk to musculoskeletal health including the low back. Assessing vibration exposure is critical in promoting a safe occupational environment, and may inform interventions to reduce farmer's exposure to vibration.

- **Keywords:** Agriculture, machinery, mechanical shock, occupational exposure, back pain

Xiaoshu Lü, Esa-Pekka Takala, Esko Toppila, Ykä Marjanen, Leena Kaila-Kangas & Tao Lu. *An optimal sampling approach to modelling whole-body vibration exposure in all-terrain vehicle driving.* Pages: 1074-1084.

Exposure to whole-body vibration (WBV) presents an occupational health risk and several safety standards obligate to measure WBV. The high cost of direct measurements in large epidemiological studies raises the question of the optimal sampling for estimating WBV exposures given by a large variation in exposure levels in real worksites. This paper presents a new approach to addressing this problem. A daily exposure to WBV was recorded for 9–24 days among 48 all-terrain vehicle drivers. Four data-sets based on root mean squared recordings were obtained from the measurement. The data were modelled using semi-variogram with spectrum analysis and the optimal sampling scheme was derived. The optimum sampling period was 140 min apart. The result was verified and validated in terms of its accuracy and statistical power. Recordings of two to three hours are probably needed to get a sufficiently unbiased daily WBV exposure estimate in real worksites. The developed model is general enough that is applicable to other cumulative exposures or biosignals. **Practitioner Summary:** Exposure to whole-body vibration (WBV) presents an occupational health risk and safety standards obligate to measure WBV. However, direct measurements can be expensive. This paper presents a new approach to addressing this problem. The developed model is general enough that is applicable to other cumulative exposures or biosignals.

- **Keywords:** Whole-body vibration, exposure analysis, exposure modelling, occupational exposure, long-term measures, optimal sampling, variogram, all-terrain vehicle

Eunyeong Kim, Mohammad Fard & Kazuhito Kato. *Characterisation of the human-seat coupling in response to vibration.* Pages: 1085-1100.

Characterising the coupling between the occupant and vehicle seat is necessary to understand the transmission of vehicle seat vibration to the human body. In this study, the vibration characteristics of the human body coupled with a vehicle seat were identified in frequencies up to 100 Hz. Transmissibilities of three volunteers seated on two different vehicle seats were measured under multi-axial random vibration excitation. The results revealed that the human-seat system vibration was dominated by the human body and foam below 10 Hz. Major coupling between the human body and the vehicle seat-structure was observed in the frequency range of 10–60 Hz. There was local coupling of the system dominated by local resonances of seat frame and seat surface above 60 Hz. Moreover, the transmissibility measured on the seat surface between the human and seat foam is suggested to be a good method of capturing human-seat system resonances rather than that measured on the human body in high frequencies above 10 Hz. **Practitioner Summary:** The coupling characteristics of the combined human body and vehicle seat system has not yet been fully understood in frequencies of 0.5–100 Hz. This study shows the human-seat system has distinctive dynamic coupling

characteristics in three different frequency regions: below 10 Hz, 10–60 Hz, and above 60 Hz.

- **Keywords:** Human-seat system, human-seat coupling, vehicle seat, resonance frequency, mode shape

John Paul Plummer, David Schuster & Joseph R. Keebler. *The effects of gender, flow and video game experience on combat identification training.* Pages: 1101-1111.

The present study examined the effects of gender, video game experience (VGE), and flow state on multiple indices of combat identification (CID) performance. Individuals were trained on six combat vehicles in a simulation, presented through either a stereoscopic or non-stereoscopic display. Participants then reported flow state, VGE and were tested on their ability to discriminate friend vs. foe and identify both pictures and videos of the trained vehicles. The effect of stereoscopy was not significant. There was an effect of gender across three dependent measures. For the two picture-based measures, the effect of gender was mediated by VGE. Additionally, the effect of gender was moderated by flow state on the identification measures. Overall, the study suggests that gender differences may be overcome by VGE and by achieving flow state. Selection based on these individual differences may be useful for future military simulation.

Practitioner Summary: This work investigates the effect of gender, VGE and flow state on CID performance. For three measures of performance, there was a main effect of gender. Gender was mediated by previous VGE on two measures, and gender was moderated by flow state on two measures.

- **Keywords:** Combat identification, training technologies, video game experience, learning and memory

Kevin R. Harris, David W. Eccles, Carlos Freeman & Paul Ward. *'Gun! Gun! Gun!': An exploration of law enforcement officers' decision-making and coping under stress during actual events.* Pages: 1112-1122.

Research on decision-making under stress has mainly involved laboratory-based studies with few contextual descriptions of decision-making under stress in the natural ecology. We examined how police officers prepared for, coped with and made decisions under threat-of-death stress during real events. A delayed retrospective report method was used to elicit skilled police officers' thoughts and feelings during attempts to resolve such events. Reports were analysed to identify experiences of stress and coping, and thought processes underpinning decision-making during the event. Officers experienced a wide range of events, coped with stress predominantly via problem-focused strategies, and adapted their decision-making under stress based on the available context. Future officer training should involve a greater variety of training scenarios than is involved in current training, and expose trainees to the possible variants of each situation to foster better situational representation and, thus, a more reliable and adaptive mental model for use in decision-making. **Practitioner Summary:** This study concerns decision-making and coping strategies used by skilled police officers during real threat-of-death situations. Officers' decision-making strategies differed according to the complexity of the situation and they coped with the stress of these situations via attempts to resolve the situations (e.g. by planning responses) and, to a lesser extent, via attempts to deal with their emotions.

- **Keywords:** Anxiety, coping, naturalistic decision-making, threat, training

Simeon Gill & Christopher J. Parker. *Scan posture definition and hip girth measurement: the impact on clothing design and body scanning.* Pages: 1123-1136.

Ergonomic measurement is central to product design and development; especially for body worn products and clothing. However, there is a large variation in measurement definitions, complicated by new body scanning technology that captures measurements in a posture different to traditional manual methods. Investigations of hip measurement definitions in current clothing measurement practices supports analysis of the effect of scan posture and hip measurement definition on the circumferences of the hip. Here, the hip girth is a key clothing measurement that is not defined in current body scanning measurement standards. Sixty-four participants were scanned in the standard scan posture of a [TC]² body scanner, and also in a natural posture similar to that of traditional manual measurement collection. Results indicate that scan posture affects hip girth circumferences, and that some current clothing measurement practices may not define the largest lower body circumference. Recommendations are made concerning how the hip is defined in measurement practice and within body scanning for clothing product development. **Practitioner Summary:** The hip girth is an important measurement in garment design, yet its measurement protocol is not currently defined. We demonstrate that body posture during body scanning affects hip circumferences, and that current clothing measurement practices may not define the largest lower body circumference. This paper also provides future measurement practice recommendations.

- **Keywords:** Body scanning, measurement, scan posture, clothing, hip girth, clothing design

Scott C. White & David Hostler. *The effect of firefighter protective garments, self-contained breathing apparatus and exertion in the heat on postural sway.* Pages: 1137-1145.

Fire suppression wearing thermal protective clothing (TPC) and self-contained breathing apparatus (SCBA) challenges a firefighter's balance and may explain firefighter falls. Postural control based on force plate centre of pressure (COP) was compared for healthy subjects wearing TPC and SCBA before and after 20 min of heavy physical exertion in hot conditions. Baseline measures with and without TPC and SCBA (two different SCBA cylinder masses) were compared before and after exertion that included elements of fire suppression activities in an environmental chamber. COP excursion and variability increased with exertion for TPC and SCBA conditions compared to non-stressed conditions. The two different cylinder masses had no significant effect. Wearing TPC and SCBA when physically stressed in a hot environment increases postural sway and exacerbates postural control. Subjects compensated for the extra mass and adjusted to control postural sway with the addition of TPC and SCBA, but the stress protocol amplified these adjustments. **Practitioner Summary:** Firefighters wear thermal protective clothing (TPC) and self-contained breathing apparatus (SCBA) when heat-stressed and fatigued. Wearing TPC and SCBA was found to negatively impact balance when stressed, but not for non-stressed or two different sized SCBA tanks. Simulating fire-ground conditions wearing TPC and SCBA should be considered for improving balance.

- **Keywords:** Turnout gear, physical stress, thermal stress, balance, fatigue

Errol R. Hoffmann & Alan H. S. Chan. *The effect of display movement angle, indicator type and display location on control/display stereotype strength.* Pages: 1146-1157.

Much research on stereotype strength relating display and control movements for displays moving in the vertical or horizontal directions has been reported. Here we report effects of display movement angle, where the display moves at angles (relative to the vertical) of between 0° and 180°. The experiment used six different controls, four display locations relative to the operator and three types of indicator. Indicator types were included because of the strong effects of the 'scale-side principle' that are variable with display angle. A directional indicator had higher stereotype strength than a neutral indicator, and showed an apparent reversal in control/display stereotype direction beyond an angle of 90°. However, with a neutral indicator this control reversal was not present. **Practitioner Summary:** The effects of display moving at angles other than the four cardinal directions, types of control, location of display and types of indicator are investigated. Indicator types (directional and neutral) have an effect on stereotype strength and may cause an apparent control reversal with change of display movement angle.

- **Keywords:** Control/display, compatibility, Wickens FORT model, display movement angle, indicator type

Yue Chen, Qin Gao, Fei Song, Zhizhong Li & Yufan Wang. *Procedure and information displays in advanced nuclear control rooms: experimental evaluation of an integrated design.* Pages: 1158-1172.

In the main control rooms of nuclear power plants, operators frequently have to switch between procedure displays and system information displays. In this study, we proposed an operation-unit-based integrated design, which combines the two displays to facilitate the synthesis of information. We grouped actions that complete a single goal into operation units and showed these operation units on the displays of system states. In addition, we used different levels of visual salience to highlight the current unit and provided a list of execution history records. A laboratory experiment, with 42 students performing a simulated procedure to deal with unexpected high pressuriser level, was conducted to compare this design against an action-based integrated design and the existing separated-displays design. The results indicate that our operation-unit-based integrated design yields the best performance in terms of time and completion rate and helped more participants to detect unexpected system failures. **Practitioner Summary:** In current nuclear control rooms, operators frequently have to switch between procedure and system information displays. We developed an integrated design that incorporates procedure information into system displays. A laboratory study showed that the proposed design significantly improved participants' performance and increased the probability of detecting unexpected system failures.

- **Keywords:** Computerised procedures, information displays, integrated displays, advanced control rooms, situation awareness