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Suzanne Hiemstra-van Mastrigt, Liesbeth Groenesteijn, Peter Vink & Lottie F. M. Kuijt-Evers. *Predicting passenger seat comfort and discomfort on the basis of human, context and seat characteristics: a literature review.* Pages: 889-911.

This literature review focused on passenger seat comfort and discomfort in a human-product-context interaction. The relationships between anthropometric variables (human level), activities (context level), seat characteristics (product level) and the perception of comfort and discomfort were studied through mediating variables, such as body posture, movement and interface pressure. It is concluded that there are correlations between anthropometric variables and interface pressure variables, and that this relationship is affected by body posture. The results of studies on the correlation between pressure variables and passenger comfort and discomfort are not in line with each other. Only associations were found between the other variables (e.g. activities and seat characteristics). A conceptual model illustrates the results of the review, but relationships could not be quantified due to a lack of statistical evidence and large differences in research set-ups between the reviewed papers. **Practitioner Summary:** This literature review set out to quantify the relationships between human, context and seat characteristics, and comfort and discomfort experience of passenger seats, in order to build a predictive model that can support seat designers and purchasers to make informed decisions. However, statistical evidence is lacking from existing literature.

- **Keywords:** Sitting comfort, body posture, anthropometry, pressure distribution, seat design

Arun Garg, J. Steven Moore & Jay M. Kapellusch. *The Revised Strain Index: an improved upper extremity exposure assessment model.* Pages: 912-922.

The Revised Strain Index (RSI) is a distal upper extremity (DUE) physical exposure assessment model based on: intensity of exertion, frequency of exertion, duration per exertion, hand/wrist posture and duration of task per day. The RSI improves upon the 1995 Strain Index (SI) by using continuous rather than categorical multipliers, and replacing duty cycle with duration per exertion. In a simulation of 13,944 tasks, the RSI

and 1995 SI showed good agreement in risk predictions for 1995 SI scores ≤ 3 (safe) and >13.5 (hazardous). For tasks with 1995 SI scores of >3 and ≤ 13.5 , the two models showed marked disagreement, with the RSI providing much greater discriminations between 'safe' and 'hazardous' tasks for various combinations of force, repetition and duty cycle. We believe the RSI is a substantially improved model that will be useful for DUE task analysis, intervention and design. **Practitioner Summary:** RSI is a substantial improvement over the 1995 SI. It should be a valuable tool for designing and analysing tasks to determine risk of musculoskeletal injuries. RSI is applicable to a wide variety of tasks including very low force and very high repetition tasks such as keyboard use.

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

Marcus Yung & Richard P. Wells. *Sensitivity, reliability and the effects of diurnal variation on a test battery of field usable upper limb fatigue measures.* Pages: 923-939.

Fatigue has been linked to deficits in production quality and productivity and, if of long duration, work-related musculoskeletal disorders. It may thus be a useful risk indicator and design and evaluation tool. However, there is limited information on the test-retest reliability, the sensitivity and the effects of diurnal fluctuation on field usable fatigue measures. This study reports on an evaluation of 11 measurement tools and their 14 parameters. Eight measures were found to have test-retest ICC values greater than 0.8. Four measures were particularly responsive during an intermittent fatiguing condition. However, two responsive measures demonstrated rhythmic behaviour, with significant time effects from 08:00 to mid-afternoon and early evening. Action tremor, muscle mechanomyography and perceived fatigue were found to be most reliable and most responsive; but additional analytical considerations might be required when interpreting daylong responses of MMG and action tremor. **Practitioner Summary:** This paper presents findings from test-retest and daylong reliability and responsiveness evaluations of 11 fatigue measures. This paper suggests that action tremor, muscle mechanomyography and perceived fatigue were most reliable and most responsive. However, mechanomyography and action tremor may be susceptible to diurnal changes.

- **Keywords:** Fatigue, measurement, diurnal fluctuations, reliability, field testing

Marcus Yung & Richard P. Wells. *Responsive upper limb and cognitive fatigue measures during light precision work: an 8-hour simulated micro-pipetting study.* Pages: 940-956.

Many contemporary occupations are characterised by long periods of low loads. These lower force levels, which are relevant to the development of work-related musculoskeletal disorders, are usually not the focus of fatigue studies. In studies that did measure fatigue in light manual or precision work, within and between measurement responses were inconsistent. The aim of this study was to identify fatigue measures that were responsive at lower force levels ($<10\%$ MVC) over the course of an 8-h period. A complementary set of fatigue measures, reflecting both neuromuscular and cognitive mechanisms, was measured during a light precision micro-pipetting task performed by 11 participants. Nine measures were found to be significantly responsive over the 8-h period, including: ratings of perceived fatigue, postural tremor, blink frequency and critical flicker fusion frequency threshold. Common field measures, specifically electromyography RMS amplitude and maximum voluntary contractions, did not lead to extraordinary time effects. **Practitioner summary:** The findings provide insight towards the responsiveness of a complementary set of field usable fatigue measures at low work

intensities Although commonly used measures did not reveal significant increases in fatigue, nine alternative measures were significantly responsive over the 8-h period.

- **Keywords:** Physical fatigue, mental fatigue work measurement, low-load work, daylong

Javier Cepriá-Bernal, Antonio Pérez-González, Marta C. Mora & Joaquín L. Sancho-Bru. *Grip force and force sharing in two different manipulation tasks with bottles.* Pages: 957-966.

Grip force and force sharing during two activities of daily living were analysed experimentally in 10 right-handed subjects. Four different bottles, filled to two different levels, were manipulated for two tasks: transporting and pouring. Each test subject's hand was instrumented with eight thin wearable force sensors. The grip force and force sharing were significantly different for each bottle model. Increasing the filling level resulted in an increase in grip force, but the ratio of grip force to load force was higher for lighter loads. The task influenced the force sharing but not the mean grip force. The contributions of the thumb and ring finger were higher in the pouring task, whereas the contributions of the palm and the index finger were higher in the transport task. Mean force sharing among fingers was 30% for index, 29% for middle, 22% for ring and 19% for little finger. **Practitioner Summary:** We analysed grip force and force sharing in two manipulation tasks with bottles: transporting and pouring. The objective was to understand the effects of the bottle features, filling level and task on the contribution of different areas of the hand to the grip force. Force sharing was different for each task and the bottles features affected to both grip force and force sharing.

- **Keywords:** Grasping, grip force, force sharing

Milad Vazirian, Iman Shojaei, Anuj Agarwal & Babak Bazrgari. *Lumbar contribution to the trunk forward bending and backward return; age-related differences.* Pages: 967-976.

Age-related differences in lumbar contribution to the trunk motion in the sagittal plane were investigated. Sixty individuals between 20–70 years old in five gender-balanced age groups performed forward bending and backward return with slow and fast paces. Individuals older than 50 years old, irrespective of the gender or pace, had smaller lumbar contribution than those younger than this age. The lumbar contribution to trunk motion was also smaller in female participants than male participants, and under fast pace than under the slow pace. Age-related differences in lumbar contributions suggest the synergy between the active and passive lower back tissues is different between those above and under 50 years old, differences that are likely to affect the lower back mechanics. Therefore, detailed modelling should be conducted in future to find the age-related differences in the lower back mechanics for tasks involving large trunk motion. **Practitioner Summary:** Lumbar contribution to the sagittal trunk motion was observed to be smaller in individuals above 50 years old than those below this age. This could be an indication of a likely change in the synergy between the active and passive lower back tissues, which may disturb the lower back mechanics.

- **Keywords:** Lumbopelvic coordination, ageing, spinal loading, low back pain, range of motion

Jared Gragg, Ellison Klose & James Yang. *Modelling the stochastic nature of the available coefficient of friction at footwear-floor interfaces.* Pages: 977-984.

The available coefficient of friction (ACOF) is a measure of the friction available between two surfaces, which for human gait would be the footwear–floor interface. It is often compared to the required coefficient of friction (RCOF) to determine the likelihood of a slip in gait. Both the ACOF and RCOF are stochastic by nature meaning that neither should be represented by a deterministic value, such as the sample mean. Previous research has determined that the RCOF can be modelled well by either the normal or lognormal distributions, but previous research aimed at determining an appropriate distribution for the ACOF was inconclusive. This study focuses on modelling the stochastic nature of the ACOF by fitting eight continuous probability distributions to ACOF data for six scenarios. In addition, the data were used to study the effect that a simple housekeeping action such as sweeping could have on the ACOF. **Practitioner Summary:** Previous research aimed at determining an appropriate distribution for the ACOF was inconclusive. The study addresses this issue as well as looking at the effect that an act such as sweeping has on the ACOF.

- **Keywords:** Available coefficient of friction, slips and falls, required coefficient of friction, stochastic nature, footwear–floor interface

Thilina W. Weerasinghe, Ravindra S. Goonetilleke & Uwe Reischl. *Pressure thresholds and stiffness on the plantar surface of the human foot.* Pages: 985-996.

A methodology to assess Pressure Discomfort Thresholds (PDT), Pressure Pain Thresholds (PPT) and tissue stiffness on the plantar surface of the foot was developed. Ten male and 10 female participants volunteered for the study. Foot landmarks were used to create a standardised grid-type template of 95 points. For each test point, PPT and PDT values were obtained, and stiffness was calculated for each of the 20 participants. Cluster analyses were performed to determine the regions of similarity for the three dependent variables, PPT, PDT and stiffness. Moran's-I-index was used to determine the spatial auto correlations. The use of k-means clustering showed five distinct clusters while the three dependent variables showed strong correlations to each other. Morisita's similarity index was used to check the similarity of the grid among all participants. Both male and female participants showed a Morisita's index greater than 0.7 confirming the reliability of the foot template. **Practitioner Summary:** Pressure Discomfort thresholds (PPT), Pressure pain thresholds (PPT) and tissue stiffness were evaluated at 95 points on the plantar surface of the foot. The PPT and related PDT map are useful to design the footbeds of shoes. Based on the data collected, five distinct clusters of locations were identified.

- **Keywords:** Algometry, discomfort, insoles, pressure pain threshold, tissue stiffness

Izabela Ciesielska-Wróbel, Emiel DenHartog & Roger Barker. *Measuring the effects of structural turnout suits on firefighter range of motion and comfort.* Pages: 997-1007.

Range of motion (ROM) can be restricted by wearing stiff and bulky clothing. This is particularly true of firefighter suits that are constructed using fabric layers to provide thermal protection from fire. This study developed an evaluation technique to quantify the loss of mobility associated with wearing firefighters' protective suits that were deliberately selected to represent similar ergonomic design features. The ROM of 10 firefighters was measured using electro-goniometers attached to their bodies while they wore uniforms and a reference outfit, and performed specific movements. The most restrictive uniform is the Bulky suit that contained additional layers of materials in sleeves and on the knees. The Traditional Suit was more ROM restrictive than Ergonomic. The subjective evaluation of suits supported the objective assessments provided by the electro-goniometers. A 3-D body scanning technique was employed to establish a

correlation between the bulkiness of firefighter outfits and subject ROM. **Practitioner Summary:** This study presents a methodology for measurements of range of motion (ROM) in firefighters wearing personal protective equipment (PPE). Even small differences in designs of PPE may impact firefighters' ROM, which can be detected by electro-goniometers providing measurements if they are attached along the joint to measure limb angular movement.

- **Keywords:** Range of motion, goniometer, personal protective equipment, firefighters, clothing design and testing

Peter James Barron, Katherine Burgess, Kay Cooper & Arthur D. Stewart. *The physiological effect of a 'climb assist' device on vertical ladder climbing.* Pages: 1008-1013.

'Climb assist' claims to reduce strain when climbing ladders; however, no research has yet substantiated this. The purpose of this study was to assess the physiological and psychophysical effects of climb assist on 30 m ladder climbing at a minimum acceptable speed. Eight participants (six male and two female) climbed a 30 m ladder at 24 rungs per minute with and without climb assist, and were monitored for heart rate (HR), $\dot{V}O_2$ and rate of perceived exertion (RPE). All three variables decreased significantly ($p < 0.05$) with climb assist with $\dot{V}O_2$ decreasing by 22.5%, HR by 14.8% and RPE decreasing by a mean of 2.3 units on the 10-point Borg scale. When descending the ladder $\dot{V}O_2$ decreased by a mean of 42% compared to that ascending. At the minimal acceptable climbing speed climb assist decreases the physiological strain on climbers, as demonstrated by reduced $\dot{V}O_2$, HR and perceived exertion. **Practitioner Summary:** 'Climb assist' systems claim to reduce strain when climbing, however; no research has yet been published to substantiate this. A crossover study compared $\dot{V}O_2$, HR and RPE at a minimal acceptable climbing speed with and without climb assist. Climb assist significantly reduced all variables confirming it reduces strain when climbing.

- **Keywords:** Ladder climbing, climb assist, vertical ladders, climbing physiology

Sarah J. Isherwood & Denis McKeown. *Semantic congruency of auditory warnings.* Pages: 1014-1023.

The aim of this study was to explore operator experience and performance for semantically congruent and incongruent auditory icons and abstract alarm sounds. It was expected that performance advantages for congruent sounds would be present initially but would reduce over time for both alarm types. Twenty-four participants (12M/12F) were placed into auditory icon or abstract alarm groupings. For each group both congruent and incongruent alarms were used to represent different driving task scenarios. Once sounded, participants were required to respond to each alarm by selecting a corresponding driving scenario. User performance for all sound types improved over time, however even with experience a decrement in speed of response remained for the incongruent iconic sounds and in accuracy of performance for the abstract warning sounds when compared to the congruent auditory icons. Semantic congruency was found to be of more importance for auditory icons than for abstract sounds. **Practitioner Summary:** Alarms are used in many operating systems as emergency, alerting, or continuous monitoring signals for instance. This study found that the type and representativeness of an auditory warning will influence operator performance over time. Semantically congruent iconic sounds produced performance advantages over both incongruent iconic sounds and abstract warnings.

- **Keywords:** Auditory warnings, auditory icons, human-computer interaction, user experience, auditory displays

Samantha Jamson & Marco Mrozek. Is three the magic number? *The role of ergonomic principles in cross country comprehension of road traffic signs*. Pages: 1024-1031.

Road sign comprehension plays an important part in road safety management, particularly for those drivers who are travelling in an unfamiliar country. Previous research has established that comprehension can be improved if signs are designed to adhere to ergonomic principles. However, it may be difficult for sign designers to incorporate all the principles into a single sign and may thus have to make a judgement as to the most effective ones. This study surveyed drivers in three countries to ascertain their understanding of a range of road signs, each of which conformed in varying degrees and combinations to the ergonomic principles. We found that using three of the principles was the most effective and that the most important one was that relating to standardisation; the colours and shapes used were key to comprehension. Other concepts which related to physical and spatial characteristics were less important, whilst conceptual compatibility did not aid comprehension at all. **Practitioner Summary:** This study explores how road sign comprehension can be improved using ergonomic principles, with particular reference to cross-border drivers. It was found that comprehension can be improved significantly if standardisation is adhered to and if at least three principles are used.

- **Keywords:** Road signs, comprehension, cross-border, safety