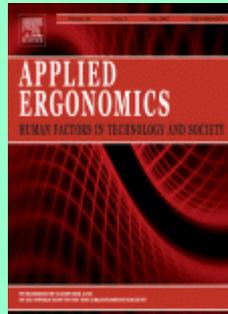


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Abdulaziz Alshaer, Holger Regenbrecht, David O'Hare. *Immersion factors affecting perception and behaviour in a virtual reality power wheelchair simulator. Pages 1-12.*

Virtual Reality based driving simulators are increasingly used to train and assess users' abilities to operate vehicles in a controlled and safe way. For the development of those simulators it is important to identify and evaluate design factors affecting perception, behaviour, and driving performance. In an exemplary power wheelchair simulator setting we identified the three immersion factors display type (head-mounted display v monitor), ability to freely change the field of view (FOV), and the visualisation of the user's avatar as potentially affecting perception and behaviour. In a study with 72 participants we found all three factors affected the participants' sense of presence in the virtual environment. In particular the display type significantly affected both perceptual and behavioural measures whereas FOV only affected behavioural measures. Our findings could guide future Virtual Reality simulator designers to evoke targeted user behaviours and perceptions.

- **Keywords:** Human factors; Sense of presence; Virtual environments; Navigation; Simulation; Affordance

Germán Gálvez-García, Javier Albayay, Lucio Rehbein, Francisco Tornay. *Mitigating Simulator Adaptation Syndrome by means of tactile stimulation. Pages 13-17.*

Some drivers experience Simulator Adaptation Syndrome (SAS), a condition in which nausea, disorientation, dizziness, headache, and difficulty focusing, are exhibited when driving in a simulator. To reduce this syndrome, we investigated the efficacy of tactile stimulation (TS) on mitigating Simulator Adaptation Syndrome (SAS) in a driving simulation. Fifteen drivers (eight women; mean age = 24.07 years) participated in this experiment. We compared the total scores of the Simulator Sickness Questionnaire (SSQ) across two stimulation conditions (TS condition and no stimulation condition as a baseline measure). The experimental outcomes revealed that TS seemed to decrease SAS due to attentional distraction from the symptoms and not because of an improvement in balance ability.

- **Keywords:** Simulator Adaption Syndrome; Tactile stimulation

Grant R. Tomkinson, Nathan Daniell, Ashley Fulton, Alistair Furnell. Time changes in the body dimensions of male Australian Army personnel between 1977 and 2012. Pages 18-24.

The aim of this study was to quantify time changes in the body dimensions of male Australian Army personnel. Following a systematic review, two studies were identified and matched for occupation and age ($n = 669$) with time changes in 12 absolute and 11 proportional body dimensions assessed between 1977 and 2010–12. Changes in means were expressed as absolute, percent and standardised changes, with changes in variability assessed visually and as the ratio of coefficients of variation (CVs). Time changes in absolute dimensions were typically positive (increases) and moderate in magnitude (median standardised change \pm 95%CI: 0.53 ± 0.23), and while changes in proportional dimensions were typically negligible (median standardised change \pm 95%CI: 0.16 ± 0.33), substantial changes (standardised changes ≥ 0.2 or ≤ -0.2) were observed in several dimensions. Variability in body dimensions has also typically increased (median ratio of CVs \pm 95%CI: 1.10 ± 0.07) and become more right-skewed. These findings have important implications for the design and acquisition of new military vehicles, body equipment and clothing.

- **Keywords:** Time changes; Military; Anthropometry

Niek Beckers, Sam Schreiner, Pierre Bertrand, Bruce Mehler, Bryan Reimer. *Comparing the demands of destination entry using Google Glass and the Samsung Galaxy S4 during simulated driving.* Pages 25-34.

The relative impact of using a Google Glass based voice interface to enter a destination address compared to voice and touch-entry methods using a handheld Samsung Galaxy S4 smartphone was assessed in a driving simulator. Voice entry (Google Glass and Samsung) had lower subjective workload ratings, lower standard deviation of lateral lane position, shorter task durations, faster remote Detection Response Task (DRT) reaction times, lower DRT miss rates, and resulted in less time glancing off-road than the primary visual-manual interaction with the Samsung Touch interface. Comparing voice entry methods, using Google Glass took less time, while glance metrics and reaction time to DRT events responded to were similar. In contrast, DRT miss rate was higher for Google Glass, suggesting that drivers may be under increased distraction levels but for a shorter period of time; whether one or the other equates to an overall safer driving experience is an open question.

- **Keywords:** Attention; Workload; Detection response task; Distraction

Iraj Mohammadfam, Fakhradin Ghasemi, Omid Kalatpour, Abbas Moghimbeigi. Constructing a Bayesian network model for improving safety behavior of employees at workplaces. Pages 35-47.

Introduction: Unsafe behavior increases the risk of accident at workplaces and needs to be managed properly. The aim of the present study was to provide a model for managing and improving safety behavior of employees using the Bayesian networks approach. **Methods:** The study was conducted in several power plant construction projects in Iran. The data were collected using a questionnaire composed of nine factors, including management commitment, supporting environment, safety management system, employees' participation, safety knowledge, safety attitude, motivation, resource allocation, and work pressure. In order for measuring the score of each factor assigned by a responder, a measurement model was constructed for each of them. The Bayesian network was constructed using experts' opinions and Dempster-Shafer theory. Using belief updating, the best intervention strategies for improving safety behavior also were selected. **Results:** The result of the present study demonstrated that the majority of employees do not tend to consider safety rules, regulation, procedures and norms in

their behavior at the workplace. Safety attitude, safety knowledge, and supporting environment were the best predictor of safety behavior. Moreover, it was determined that instantaneous improvement of supporting environment and employee participation is the best strategy to reach a high proportion of safety behavior at the workplace. **Conclusion:** The lack of a comprehensive model that can be used for explaining safety behavior was one of the most problematic issues of the study. Furthermore, it can be concluded that belief updating is a unique feature of Bayesian networks that is very useful in comparing various intervention strategies and selecting the best one from them.

- **Keywords:** Bayesian network; Human behavior; Accident prevention; Safety climate

Michael W. Boyce, Janan Al-Awar Smither, Daniel O. Fisher, P.A. Hancock. *Design of instructions for evacuating disabled adults. Pages 48-58.*

We investigated how the design of instructions can affect performance in preparing emergency stair travel devices for the evacuation of disable individuals. We had three hypotheses: 1) Design of instructions would account for a significant portion of explained performance variance, 2) Improvements in design of instructions would reduce time on task across device type and age group, and 3) There would be a performance decrement for older adults compared to younger adults based on the slowing of older adult information processing abilities. Results showed that design of instructions does indeed account for a large portion of explained variance in the operation of emergency stair travel devices, and that improvements in design of instructions can reduce time on task across device type and age group. However, encouragingly for real-world operations, results did not indicate any significant differences between older versus younger adults. We look to explore ways that individuals with disabilities can exploit these insights to enhance the performance of emergency stair travel devices for use.

- **Keywords:** Aging; Design of instructions; Assistive technology

Neal Wiggermann. *Effect of a powered drive on pushing and pulling forces when transporting bariatric hospital beds. Pages 59-65.*

Powered drives designed to assist with moving hospital beds are commercially available but no studies have evaluated whether they reduce the push and pull forces likely contributing to injury in caregivers. This study measured hand forces of 10 caregivers maneuvering a manual and powered bariatric bed through simulated hospital environments (hallway, elevator, and ramp). Peak push and pull forces exceeded previously established psychophysical limits for all activities with the manual bed. For the powered bed, peak forces were significantly ($p < 0.05$) lower for all tasks, and below psychophysical limits. Powered drive reduced peak forces between 38% (maneuvering into elevator) and 94% (descending ramp). Powered drive also reduced stopping distance by 55%. When maneuvering, the integral of hand force was 34% lower with powered drive, but average forces during straight-line pushing did not differ between beds. Powered drive may reduce the risk of injury or the number of caregivers needed for transport.

- **Keywords:** Pushing; Pulling; Hospital bed; Patient handling; Patient transport

Ruth E. Mayagoitia, John Harding, Sheila Kitchen. *Identification of stair climbing ability levels in community-dwelling older adults based on the geometric mean of stair ascent and descent speed: The GeMSS classifier. Pages 81-88.*

The aim was to develop a quantitative approach to identify three stair-climbing ability levels of older adults: no, somewhat and considerable difficulty. Timed-up-and-go test, six-minute-walk test, and Berg balance scale were used for statistical comparison to a new stair climbing ability classifier based on the geometric mean of stair speeds (GeMSS) in ascent and descent on a flight of eight stairs with a 28° pitch in the housing unit where the participants, 28 (16 women) urban older adults (62–94 years), lived. Ordinal logistic regression revealed the thresholds between the three ability levels for each functional test were more stringent than thresholds found in the literature to classify walking ability levels. Though a small study, the intermediate classifier shows promise of early identification of difficulties with stairs, in order to make timely preventative interventions. Further studies are necessary to obtain scaling factors for stairs with other pitches.

- **Keywords:** Balance; Strength; Endurance; Timed-up-and-down-stairs

Ève Laperrière, Karen Messing, Renée Bourbonnais. *Work activity in food service: The significance of customer relations, tipping practices and gender for preventing musculoskeletal disorders.* Pages 89-101.

Some evidence shows that food servers are exposed to an elevated risk of musculoskeletal disorders and injuries, and that their work activity varies by gender. Interviews of servers and observations of food service in Québec, Canada, were carried out in three restaurants and a questionnaire was administered to 64 workers from 44 other restaurants. The relationship with the customer has specific effects on work activity and transforms the physical, emotional and cognitive work. Strategies intended to speed service or otherwise related to the customer relationship can involve health risks. Women reported more direct food service ($p < 0.01$), a tendency to do more “housekeeping” tasks ($p < 0.07$) and fewer hours of work per week ($p < 0.01$). Women workers reported experiencing more sites of pain ($p < 0.003$). This exploratory study suggests that managing the server-customer relationship could be important in preventing musculoskeletal disorders in this population and that women are at particular risk.

- **Keywords:** Food service; Musculoskeletal disorders; Gender; Work activity analysis; Tipping

Tara McCurdie, Penelope Sanderson, Leanne M. Aitken, David Liu. *Two sides to every story: The Dual Perspectives Method for examining interruptions in healthcare.* Pages 102-109.

Interruptions are widely considered a problem in healthcare. Results from observation and experimental studies have guided extensive mitigation efforts, but the effectiveness of interventions remains mixed. We have built on current theories and methods for studying interruptions to develop a novel observational approach – the Dual Perspectives Method – for examining interruptions from the perspectives of the different work functions in an Intensive Care Unit (ICU). We detail the method and provide representative examples of the insights it offers, such as why interruptions happen, the role they play, and the consequences of preserving them or eliminating them. We anticipate that the Dual Perspectives Method will help us to arrive at a better basis on which to draw conclusions about interruptions, and will lead to the development of appropriate and sustainable interventions to ensure the effective and safe functioning of the work system under examination.

- **Keyword:** Interruptions; Healthcare; Sociotechnical systems

Jillian Dorrian, Crystal Grant, Siobhan Banks. *An industry case study of 'stand-up' and 'sleepover' night shifts in disability support: Residential support worker perspectives.* Pages 110-118.

Purpose: Residential support workers (RSW) engage in overnight “sleepover” shifts as well as more traditional “standup” night shifts. While research has investigated the consequences of night and on-call work for sleep in other industries, the sleep of RSW has not been evaluated. **Method:** In a single-provider case study, six employees completed the Pittsburgh Sleep Quality Index (PSQI), the Depression Anxiety Stress Scale (DASS), a 2-week sleep diary, and a 30 min interview, and four also completed the Shirom-Melamed Burnout Measure (SMBM). **Results:** Participants reported sleep of poor quality, low-mild DASS scores, and evidence of SMBM scores that were elevated relative to norms. Sleep was significantly lower ($p < 0.01$) following “standup” shifts (mean = 4.1, SD = 1.8 h) and during “sleepover” shifts (mean = 5.6, SD = 2.0 h) compared to non-shift nights (mean = 7.3, SD = 2.3 h). Interviews suggested that sleep fluctuates with level of patient care, colleague assistance, stress, and the quality of the sleeping environment (including bed comfort, light, noise and perceived safety). **Conclusions:** Findings suggest that this group have sleep that is insufficient and of poor quality and that they may be at risk of burnout. Consideration of ways to optimise sleeping conditions at work (e.g. through noise or stress reduction) would be beneficial. Research in this area has the potential to facilitate improvements in health and safety in this growing industry.

- **Keywords:** Residential support; Disability; Aged care; Sleep; Burnout

George M. Sammonds, Mike Fray, Neil J. Mansfield. *Effect of long term driving on driver discomfort and its relationship with seat fidgets and movements (SFMs)*. Pages 119-127.

Discomfort in vehicle seats is a multifactorial problem with large increases in discomfort occurring during extended duration driving. Due to the nature of driver discomfort, previous research has found it difficult to accurately quantify long term driver discomfort via the use of objective measures. This paper reports a laboratory study that investigates a novel objective measure of long term driver discomfort and its correlation with subjective discomfort ratings. Analysis of driver’s seat fidgets and movements was conducted over the duration of a 140 min drive on a driving simulator in addition to collecting subjective ratings of discomfort. It is shown that as subjects’ subjective discomfort increases, the frequency of subjects’ seat fidgets and movements increases congruently. A large correlation is observed between the subjective and objective measures of driver discomfort and provides the opportunity for long term discomfort evaluations to be made via remote monitoring; removing the need for subjective assessment.

- **Keywords:** Automotive ergonomics; Seat design; Driver comfort; Vibration

Daniël Lacko, Jochen Vleugels, Erik Fransen, Toon Huysmans, Guido De Bruyne, Marc M. Van Hulle, Jan Sijbers, Stijn Verwulgen. *Ergonomic design of an EEG headset using 3D anthropometry*. Pages 128-136.

Although EEG experiments over the past decades have shown numerous applications for brain-computer interfacing (BCI), there is a need for user-friendly BCI devices that can be used in real-world situations. 3D anthropometry and statistical shape modeling have been shown to improve the fit of devices such as helmets and respirators, and thus they might also be suitable to design BCI headgear that better fits the size and shape variation of the human head. In this paper, a new design method for BCI devices is proposed and evaluated. A one-size-fits-all BCI headset frame is designed on the basis of three digital mannequins derived from a shape model of the human head. To verify the design, the geometric fit, stability and repeatability of the prototype were compared to an EEG cap and a commercial BCI headset in a preliminary experiment. Most design specifications were met, and all the results were found to be similar to those of the

commercial headset. Therefore, the suggested design method is a feasible alternative to traditional anthropometric design for BCI headsets and similar headgear.

- **Keywords:** 3D anthropometry; Statistical shape model; Headgear; EEG; Brain-computer interfacing

Dana L. Keester, Carolyn M. Sommerich. *Investigation of musculoskeletal discomfort, work postures, and muscle activation among practicing tattoo artists. Pages 137-143:*

Tattoo artists are an understudied worker population with respect to investigation of work-related musculoskeletal (MSK) discomfort and associated risk factors. Results from one discomfort survey has been published; no analysis of worker biomechanics has been published. As such, a study was conducted to begin exposure assessment of tattoo artists to work factors that could result in MSK discomfort. Consistent with the prior survey, the current study showed an elevated prevalence of MSK discomfort. Twelve month discomfort prevalence exceeded 50% in the neck, shoulders, hands/wrists, and upper and lower back (range: 53–94%). Seventy-one percent of postures evaluated during 16 h of observation had total RULA scores of 5, 6, or 7 (investigation and changes are required soon or immediately). Static muscle activity levels in the left, right, or both upper trapezius muscles in each study participant exceeded the 2–5% MVE limit recommended in the literature. Intervention concepts are also discussed.

- **Keywords:** Musculoskeletal discomfort; Sustained awkward posture; Unsupported seated work

Glenn Legault, Alexandra Clement, Glen P. Kenny, Stephen Hardcastle, Nancy Keller. *Cognitive consequences of sleep deprivation, shiftwork, and heat exposure for underground miners. Pages 144-150.*

Sleep deprivation, abnormal sleep patterns arising from working rotating shifts, and exposure to high ambient temperatures contribute to physical and cognitive dysfunction. We examined the effects of these on 19 (41.5 ± 5.1 years) male underground miners. Data were collected for 28 to 30 consecutive days such that the participants experienced their full rotating shift schedule, including days off. Objective measures of sleep quality (actigraphy), attentional capacity (psychomotor vigilance task), core body temperature (visceral pill), executive function (BRIEF-A) and subjective measures of fatigue (Karolinska and Epworth Sleepiness scales) were obtained over the 28–30 day period. Non-parametric analyses (χ^2 , Wilcoxon Signed ranks) were used to determine differences between shift types and days off. Z-tests were used to compare sample data to population norms. These revealed that the participants experienced poor quality of sleep relative to age-matched norms irrespective of the shift being worked or if the participant was on a scheduled day off [30–39 year olds: $z = -14.62$, $p < 0.001$; 40–49 year olds: $z = -4.44$, $p < 0.001$]. Participants when working day shift experienced less sleep prior to beginning work compared to their days off or night shift; however, no differences in total sleep time between when participants worked day or night shifts were observed [χ^2 (2, $n = 18$) = 13.44, $p < 0.01$]. When measured subjectively, the only time participants reported excessive sleepiness was after a night shift. Objective measures of attentional capacity showed best performance at the beginning of night shifts in contrast to any other time that the task was completed; however, performance degraded dramatically over the course of the night shift [χ^2 (2, $n = 12$) = 6.50, $p < 0.05$]. We show that underground miners reported for work sleep deprived. The cognitive consequences of this poor sleep were most pronounced during night shift when their attentional capacity declined rapidly over the course of the night shift.

- **Keywords:** Fatigue; Sleep deprivation; Heat exposure; Cognition

Amit J. Nimunkar, Keum San Chun, Ngoc Phung, Kevin Wreksoatmodjo, Thomas Y. Yen, Robert G. Radwin. *Reducing thumb extensor risk in laboratory rat gavage. Pages 151-155.*

Gavage is a common technique for orally administering compounds to small laboratory animals using a syringe. It involves highly repetitive thumb extensor exertions for filling the syringe, a risk factor for DeQuervain's tenosynovitis. As an intervention, a series of bench tests were performed varying fluid viscosity, syringe size and needle size to determine the forces required for drawing fluid. Forces up to 28 N were observed for a viscosity of 0.29 Pa s. A guide is presented to minimize thumb forces for a particular combination of syringe (3 mL, 5 mL and 10 mL), fluid viscosity (0.001 Pa s, 0.065 Pa s, 0.21 and 0.29 Pa s), and needle length (52 mm, 78 mm and 100 mm) based on maximum acceptable exertion levels. In general, a small syringe and large needle size had a greater number of acceptable rat gavages per day due to the lower forces experienced as compared to all other syringe and needle combinations.

- **Keywords:** Thumb extensor forces; Repetitive motion injuries; Intervention

Federica Caffaro, Alberto Mirisola, Eugenio Cavallo. *Safety signs on agricultural machinery: Pictorials do not always successfully convey their messages to target users. Pages 156-166.*

This study investigated the extent to which a sample of Italian users comprehended safety pictorials used on agricultural machinery. A questionnaire with 12 safety pictorials was administered to 248 users of agricultural machinery. For each of the pictorials, the participants were asked to select the most appropriate description of four written choices. The investigated safety pictorials were, in general, not well comprehended. Two different classes of participants were identified, each with a different level of comprehension. The participants with better comprehension were characterized by the regular use of agricultural machinery and frequent previous exposure to pictorials. The need for training courses focusing on safety pictorials and their meanings, as well as the need for improvement to the pictorials themselves to make them more easily comprehended, is discussed.

- **Keywords:** Agriculture; Pictorial comprehension; Safety

Annie W.Y. Ng, Alan H.S. Chan, Vincy W.S. Ho. *Comprehension by older people of medication information with or without supplementary pharmaceutical pictograms. Pages 167-175.*

This study examined the benefits of pharmaceutical pictograms for improving comprehension of medication information for older people. Fifty Hong Kong Chinese older people completed a medical information comprehension task for five drugs. Participants in the control group were presented with text labels while those in the experimental group were given the text labels plus supplementary pharmaceutical pictograms, and then all reported their understanding of the medication information conveyed. Lower educated older people had poorer understanding of medication information. The addition of pharmaceutical pictograms significantly improved the comprehension of medication information for older people. The majority of older people tested with pictograms favored adding pictograms to text and thought the pictograms were useful for conveying medical information rather than using written text alone. The findings suggested that pharmaceutical and health care professionals should include pharmaceutical pictograms on labels to better convey instructions on medication to older people.

- **Keywords:** Medication information; Pharmaceutical symbols; Comprehension; Older people

Deanna S. Asakawa, Jack T. Dennerlein, Devin L. Jindrlich. *Index finger and thumb kinematics and performance measurements for common touchscreen gestures.* Pages 176-181.

This study aimed to quantify differences in 7 touchscreen gestures. Eighteen participants performed index finger tapping, sliding in 4 orthogonal directions, and index finger and thumb pinch and stretch gestures on a touchscreen tablet computer. We hypothesized that two finger gestures would require longer task completion time and greater finger joint excursions than sliding gestures using only the index finger. We measured task completion times and finger joint kinematics. Tapping showed the fastest average (\pm SD) task completion time, 567(190) ms, of all gestures ($p < 0.001$). Pinch had faster task completion time, 765(277) ms, than all single-finger sliding gestures ($p < 0.001$). Stretch was faster to complete at 843(317) ms ($p < 0.001$) than all sliding gestures except slide right. Stretch demonstrated greater mean index finger metacarpophalangeal flexion/extension joint excursions, $63(16)^\circ$, compared to sliding gestures, $34(10)^\circ$, and tapping, $27(13)^\circ$ ($p < 0.01$). Overall, two-finger gestures were faster to complete and showed greater joint excursions than single-finger sliding gestures.

- **Keywords:** Mobile technology; Pinch; Thumb

Grazyna Bartkowiak, Anna Dabrowska, Anna Marszalek. *Assessment of an active liquid cooling garment intended for use in a hot environment.* Pages 182-189.

This paper discusses the construction of a designed active liquid cooling garment (LCG) that has been developed in order to reduce thermal discomfort of persons working in hot environments. It consists of clothing with a tube system distributing a cooling liquid, a sensor measuring the microclimate under the clothing, and a portable cooling unit with a module controlling the temperature of the cooling liquid depending on the microclimate temperature under the clothing. The LCG was validated through tests on volunteers in a climatic chamber at 30 °C, a relative humidity of 40%, and an air movement rate of 0.4 m/s. The obtained test results confirmed the beneficial effects of the cooling system used on mean weighted skin temperature, the physical parameters of the microclimate under the clothing, and the participants' subjective assessments, as well as confirmed that the functioning of the control system regulating liquid temperature in the LCG was correct.

- **Keywords:** Liquid cooling garment; Thermal comfort; Protective clothing

Melissa M. White, Olivia N. Morejon, Shijing Liu, Mei Y. Lau, Chang S. Nam, David B. Kaber. *Muscle loading in exoskeletal orthotic use in an activity of daily living.* Pages 190-197.

Strokes are the leading cause of major adult disability with up to 85% of U.S. survivors experiencing hemiparesis. Physical characteristics of upper-extremity exoskeletal orthotics, used in stroke rehabilitation, were evaluated in terms of performance of activities of daily living (ADL), perceived exertion, and muscle load. Simulated orthotic weight distributions, with total extremity loads of 0.81 kg, 1.25 kg and 2.27 kg, were evaluated along with a 0 kg control condition. Response measures included average shoulder/elbow muscle surface electromyography (sEMG) signal amplitude, quality of task completion and total rest time during performance, and Borg CR-10 scale ratings. Device weight distribution, or imposed shoulder moment, was found to have a significant effect on biceps brachii and anterior deltoid activation levels, percent task completion, total rest time, and perceived exertion ratings. Results suggest that heavier upper-extremity orthotics could cause undesirable effects in terms of muscle loading,

performance and exertion; such adverse effects could potentially lead to lack of use during patient's rehabilitation.

- **Keywords:** Surface electromyography; Stroke rehabilitation; Orthotics

Sang Min Ko, Kwangil Lee, Daeho Kim, Yong Gu Ji. *Vibrotactile perception assessment for a haptic interface on an antigravity suit.* Pages 198-207.

Haptic technology is used in various fields to transmit information to the user with or without visual and auditory cues. This study aimed to provide preliminary data for use in developing a haptic interface for an antigravity (anti-G) suit. With the structural characteristics of the anti-G suit in mind, we determined five areas on the body (lower back, outer thighs, inner thighs, outer calves, and inner calves) on which to install ten bar-type eccentric rotating mass (ERM) motors as vibration actuators. To determine the design factors of the haptic anti-G suit, we conducted three experiments to find the absolute threshold, moderate intensity, and subjective assessments of vibrotactile stimuli. Twenty-six fighter pilots participated in the experiments, which were conducted in a fixed-based flight simulator. From the results of our study, we recommend 1) absolute thresholds of ~11.98–15.84 Hz and 102.01–104.06 dB, 2) moderate intensities of 74.36 Hz and 126.98 dB for the lower back and 58.65 Hz and 122.37 dB for either side of the thighs and calves, and 3) subjective assessments of vibrotactile stimuli (displeasure, easy to perceive, and level of comfort). The results of this study will be useful for the design of a haptic anti-G suit.

- **Keywords:** Haptics; Vibrotactile; Anti-G suit

Ewa Gustafsson, Sara Thomée, Anna Grimby-Ekman, Mats Hagberg. *Texting on mobile phones and musculoskeletal disorders in young adults: A five-year cohort study.* Pages 208-214.

The aim was to examine whether texting on a mobile phone is a risk factor for musculoskeletal disorders in the neck and upper extremities in a population of young adults. In a longitudinal population-based cohort study with Swedish young adults (aged 20–24 years) data were collected via a web-based questionnaire at baseline (n = 7092) and after one and five years. Cross-sectional associations were found between text messaging and reported ongoing symptoms in neck and upper extremities (odds ratios, ORs 1.3–2.0). Among symptom-free at baseline prospective associations were only found between text messaging and new cases of reported symptoms in the hand/fingers (OR 2.0) at one year follow up. Among those with symptoms at baseline prospective associations were found between text messaging and maintained pain in neck/upper back (OR 1.6). The results imply mostly short-term effects, and to a lesser extent, long-term effects on musculoskeletal disorders in neck and upper extremities.

- **Keywords:** SMS; Neck pain; Upper extremities

Mark Stephen Dennison, Michael D'Zmura. *Cybersickness without the wobble: Experimental results speak against postural instability theory.* Pages 215-223.

It has been suggested that postural instability is necessary for cybersickness to occur. Seated and standing subjects used a head-mounted display to view a virtual tunnel that rotated about their line of sight. We found that the offset direction of perceived vertical settings matched the direction of the tunnel's rotation, so replicating earlier findings. Increasing rotation speed caused cybersickness to increase, but had no significant impact on perceived vertical settings. Postural sway during rotation was similar to postural sway

during rest. While a minority of subjects exhibited postural sway in response to the onset of tunnel rotation, the majority did not. Furthermore, cybersickness increased with rotation speed similarly for the seated and standing conditions. Finally, subjects with greater levels of cybersickness exhibited less variation in postural sway. These results lead us to conclude that the link between postural instability and cybersickness is a weak one in the present experiment.

- **Keywords:** Vection; Virtual reality; Visually induced motion sickness; Cybersickness; Perceived vertical; Postural instability

Sam Howard, Alexandra Lang, Sarah Sharples, Dominick Shaw. See *I told you I was taking it!: Attitudes of adolescents with asthma towards a device monitoring their inhaler use: Implications for future design.* Pages 224-237.

Adherence to treatment in asthma is often poor, particularly in adolescents and children where the condition is most prevalent. Electronic monitoring devices have shown potential for improving inhaler use, yet little research has considered the attitudes of patients towards these devices. We gave seven adolescents with asthma an electronic monitoring device to use for one month and collected their views on important issues including monitoring and data sharing. Our results showed that participants felt positively about using the data to demonstrate responsibility for their condition to both their parents and medical professionals, but expressed concern for the attention the device's appearance could draw to them and their asthma. This paper considers the positive and negative perceptions of this novel device and provides new insight into the attitudes of adolescents towards inhaler monitoring, as well as future directions for design and development of monitoring devices for asthma and other chronic medical conditions.

- **Keywords:** Adolescence; Teenagers; Asthma; Adherence; Devices; Attitudes; Data; Design

Francesco Biondi, David L. Strayer, Riccardo Rossi, Massimiliano Gastaldi, Claudio Mulatti. *Advanced driver assistance systems: Using multimodal redundant warnings to enhance road safety.* Pages 238-244.

This study investigated whether multimodal redundant warnings presented by advanced assistance systems reduce brake response times. Warnings presented by assistance systems are designed to assist drivers by informing them that evasive driving maneuvers are needed in order to avoid a potential accident. If these warnings are poorly designed, they may distract drivers, slow their responses, and reduce road safety. In two experiments, participants drove a simulated vehicle equipped with a forward collision avoidance system. Auditory, vibrotactile, and multimodal warnings were presented when the time to collision was shorter than five seconds. The effects of these warnings were investigated with participants performing a concurrent cell phone conversation (Exp. 1) or driving in high-density traffic (Exp. 2). Braking times and subjective workload were measured. Multimodal redundant warnings elicited faster braking reaction times. These warnings were found to be effective even when talking on a cell phone (Exp. 1) or driving in dense traffic (Exp. 2). Multimodal warnings produced higher ratings of urgency, but ratings of frustration did not increase compared to other warnings. Findings obtained in these two experiments are important given that faster braking responses may reduce the potential for a collision.

- **Keywords:** Warnings; Automation; Multimodal

Jenny Gremark Simonsen, Anna Axmon, Catarina Nordander, Inger Arvidsson. *Neck and upper extremity pain in sonographers: Associations with occupational factors.* Pages 245-253.

Sonographers have a high risk of musculoskeletal disorders. This study explores the associations between working conditions and musculoskeletal pain based on the frequency and intensity of pain in the neck and upper extremities. A questionnaire was answered by 291 female sonographers. High prevalence of neck/shoulder pain was associated with eye complaints and headache related to work on the computer, dissatisfaction with the computer workstation, high mechanical exposure index (MEI) and high demands. The possibility to adjust the keyboard and chair, and adequately corrected eyesight were positive factors. High prevalence of elbow/hand pain was associated with performing echocardiography, computer-related eye complaints, high MEI and high job and sensory demands. In echocardiography, working with a straight wrist and holding the transducer with a two-handed grip or alternating hands was associated with a low prevalence of elbow/hand pain. Thus, further improvements in the working conditions are possible and are recommended.

- **Keywords:** Sonography; Ergonomics; Psychosocial factors

Ko-Chiu Wu, Lih-Yau Song. *A case for inclusive design: Analyzing the needs of those who frequent Taiwan's urban parks.* Pages 254-264.

Taiwan's declining birthrate has resulted in an aging population, and the needs addressed by public facilities are changing along with the shifting population structure. Visitors to urban parks filled out 869 questionnaires on the topic of inclusive design. Structural equation modeling revealed that park patrons could be categorized as those with special needs, and the general public. The biggest difference between these two groups manifests in their disparate needs concerning outdoor primary service facilities, followed by facilities related to accessibility, automation and the functions performed in open areas. Difficulty with autonomous access was identified as the leading cause of exclusion. Based on the autonomous access principle, three inclusive needs levels were identified: safety (high priority), accessibility (moderately-high), and regular maintenance (average). Inclusive design in public parks aims to equalize usage by all sectors of society.

- **Keywords:** Inclusive design; Park planning; Aging society

Arthur Stewart, Robert Ledingham, Hector Williams. *Variability in body size and shape of UK offshore workers: A cluster analysis approach.* Pages 265-272.

Male UK offshore workers have enlarged dimensions compared with UK norms and knowledge of specific sizes and shapes typifying their physiques will assist a range of functions related to health and ergonomics. A representative sample of the UK offshore workforce ($n = 588$) underwent 3D photonic scanning, from which 19 extracted dimensional measures were used in k-means cluster analysis to characterise physique groups. Of the 11 resulting clusters four somatotype groups were expressed: one cluster was muscular and lean, four had greater muscularity than adiposity, three had equal adiposity and muscularity and three had greater adiposity than muscularity. Some clusters appeared constitutionally similar to others, differing only in absolute size. These cluster centroids represent an evidence-base for future designs in apparel and other applications where body size and proportions affect functional performance. They also constitute phenotypic evidence providing insight into the 'offshore culture' which may underpin the enlarged dimensions of offshore workers.

- **Keywords:** Offshore workers; Body size; Body shape; 3D scanning; Cluster analysis

Morten Villumsen, Pascal Madeleine, Marie Birk Jørgensen, Andreas Holtermann, Afshin Samani. *The variability of the trunk forward bending in standing activities during work vs. leisure time.* Pages 273-280.

High level of occupational physical activity (PA), contrary to leisure time activities, is generally associated with detrimental health outcomes. We hypothesized that this contrast may be associated with a different pattern of exposure variability in PA, e.g., forward bending of the trunk. The study was conducted on 657 blue-collar workers. Two accelerometers were used to identify the body posture and forward bending of the trunk during work and leisure time. The pattern of forward bending was analyzed using exposure variation analysis (EVA). The recordings comprised of 2.6 ± 0.97 working days in average, with 19.9 ± 8.1 h work and 22.9 ± 8.9 h leisure. The standard deviation and entropy of the EVA profile indicated 11% and 6% (for about 80% of subjects) less variable pattern during work compared with the leisure time, respectively. These new findings contribute to the understanding the paradoxical outcomes of PA during work and leisure.

- **Keywords:** Exposure variation analysis; Diurnal measurements; Physical activity

Kayla M. Fewster, Kaitlin M. Gallagher, Jack P. Callaghan. *The effect of standing interventions on acute low-back postures and muscle activation patterns.* Pages 281-286.

Occupations requiring prolonged periods of constrained standing are associated with the development of low back pain (LBP). Many workplaces use improvised standing aids aimed to reduce LBP. Unfortunately, there is little scientific evidence to support the use of such standing interventions in effectively reducing LBP. To assess some commonly implemented standing interventions, thirty-one participants stood in four different standing positions (Level Ground (control), Sloped, Elevated, and Staggered) for 5 min each. The use of an elevated surface changed the lumbar spine posture of participants such that participants stood in a more flexed lumbar spine posture. This change in lumbar spine posture may be an indication that the elevated standing aid intervention can positively impact lumbar spine posture in standing pain developers and potentially reduce LBP.

- **Keywords:** Low back pain; Standing aid; Standing intervention; Prolonged standing

Peter Vink, Daan Lips. *Sensitivity of the human back and buttocks: The missing link in comfort seat design.* Pages 287-292.

Purpose: The purpose of this study is to examine the differences in pressure sensitivity for areas of the human body in contact with the seat pan and backrest of a vehicle seat. These could provide a theoretical base for adapting the softness of the foam or the flexibility components used in seat design. **Methods:** Sensitivity was recorded at 32 points touching the seat pan and backrest by pushing a cylinder with a diameter of 20 mm into the seat until the participant reported that they were no longer comfortable. The force at which discomfort was reported was recorded using an advanced force gauge. **Results and conclusions:** The area of the body having contact with the front of the seat pan was more sensitive than the rest of those parts touching the seat pan. The area of the seat touching the shoulders was significantly more sensitive than the area in between the shoulders and lower down the back. Translating these findings directly into seat design should be done with care. Tests are still needed to confirm the assumed

relationship between sensitivity and foam softness. Further information is also needed regarding the complete use of a seat, including analysis of vibrations while driving and comfort during ingress and egress.

- **Keywords:** Human sensitivity; Back; Buttock; Passenger discomfort; Seating

Teresa Cotrim, José Carvalhais, Catarina Neto, Júlia Teles, Paulo Noriega, Francisco Rebelo. *Determinants of sleepiness at work among railway control workers.* Pages 293-300.

In the last two decades the control of the Portuguese railway network has become much more centralized in three centres, there integrating the functions of route flow management, electrical control and signalling. This study aimed to investigate the influence of work and individual determinants in sleepiness among railway control workers, namely socio-demographic factors, work ability, psychosocial factors, shiftwork characteristics, fatigue perception, and sleep. Sleepiness by shift was associated with quality of sleep, job satisfaction, fatigue perception, quantitative demands, and age. The results indicate a high prevalence of sleepiness during the night shift and show the relevance of the quality of sleep as a predictor in the three models of sleepiness for morning, afternoon and night shifts. This study, done at the major Portuguese railway control centre, alerted managers to the importance of schedule planning as well as sleepiness prevention plans and makes these results a reference for future research.

- **Keywords:** Shiftwork; Sleepiness; Railway control

Onur Asan. *Providers' perceived facilitators and barriers to EHR screen sharing in outpatient settings.* Pages 301-307.

As health care becomes more patient-centered, some scholars and policy makers propose shifting use of electronic health records (EHRs) to a tool to educate and engage patients. Physician-patient screen sharing may provide a way to achieve this. However, the barriers and facilitators that physicians experience with screen sharing are unknown. In this study, we explored providers' facilitators and barriers to using EHR as a primary care communication tool. We conducted an interview study with 14 primary care providers to discover their views on screen sharing. We used the work system model as a conceptual framework to classify emergent factors. Content analysis yielded 28 facilitators and 56 barriers to patient-centered screen sharing in primary care. We linked these to work system elements. We outline suggestions for more patient-centered EHR systems, and for provider communication training. Finally, we consider the role screen sharing might play in the development of physician-patient situation awareness.

- **Keywords:** EHRs; Works system model; Physician-patient communication; Physician-EHR interaction; Barriers and facilitators

Hang Xu, Sree Jampala, Donald Blowski, Jie Zhao, Andrew Merryweather. *Evaluation of knee joint forces during kneeling work with different kneepads.* Pages 308-313.

The main purpose of this study is to determine knee joint forces resulting from kneeling work with and without kneepads to quantify how different kneepads redistribute force. Eleven healthy males simulated a tile setting task to different locations during six kneepad states (five different kneepad types and without kneepad). Peak and average forces on the anatomical landmarks of both knees were obtained by custom force sensors. The results revealed that kneepad design can significantly modify the forces on the knee joint through redistribution. The Professional Gel design was preferred among the five tested kneepads which was confirmed with both force measurements and

participants' responses. The extreme reaching locations induced significantly higher joint forces on left knee or right knee depending on task. The conclusion of this study is that a properly selected kneepad for specific tasks and a more neutral working posture can modify the force distribution on the knees and likely decrease the risk of knee disorders from kneeling work.

- **Keywords:** Kneeling; Biomechanics; Kneepad; Knee disorder

R. Califano, A. Naddeo, P. Vink. *The effect of human-mattress interface's temperature on perceived thermal comfort.* Pages 334-341.

In recent years, methods that allow for an objective evaluation of perceived comfort, in terms of postural, physiological, cognitive and environmental comfort, have received a great deal of attention from researchers. This paper focuses on one of the factors that influences physiological comfort perception: the temperature difference between users and the objects with which they interact. The first aim is to create a measuring system that does not affect the perceived comfort during the temperatures' acquisition. The main aim is to evaluate how the temperature at the human-mattress interface can affect the level of perceived comfort. A foam mattress has been used for testing in order to take into account the entire back part of the human body. The temperature at the interface was registered by fourteen 100 Ohm Platinum RTDs (Resistance Temperature Detectors) placed on the mattress under the trunk, the shoulders, the buttocks, the legs, the thighs, the arms and the forearms of the test subject. 29 subjects participated in a comfort test in a humidity controlled environment. The test protocol involved: dress-code, anthropometric-based positioning on mattress, environment temperature measuring and an acclimatization time before the test. At the end of each test, each of the test subject's thermal sensations and the level of comfort perception were evaluated using the ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) scale. The data analyses concerned, in the first instance, correlations between the temperature at the interface and comfort levels of the different parts of the body. Then the same analyses were performed independently of the body parts being considered. The results demonstrated that there was no strong correlation among the studied variables and that the total increase of temperature at interface is associated with a reduction in comfort.

- **Keywords:** Comfort evaluation; Objectifying comfort; Temperature; Thermal comfort; Mattress; Bedding systems

William J. Horrey, Mary F. Lesch, Angela Garabet, Lucinda Simmons, Rammohan Maikala. *Distraction and task engagement: How interesting and boring information impact driving performance and subjective and physiological responses.* Pages 342-348.

As more devices and services are integrated into vehicles, drivers face new opportunities to perform additional tasks while driving. While many studies have explored the detrimental effects of varying task demands on driving performance, there has been little attention devoted to tasks that vary in terms of personal interest or investment—a quality we liken to the concept of task engagement. The purpose of this study was to explore the impact of task engagement on driving performance, subjective appraisals of performance and workload, and various physiological measurements. In this study, 31 participants (M = 37 yrs) completed three driving conditions in a driving simulator: listening to boring auditory material; listening to interesting material; and driving with no auditory material. Drivers were simultaneously monitored using near-infrared spectroscopy, heart monitoring and eye tracking systems. Drivers exhibited less variability in lane keeping and headway maintenance for both auditory conditions; however, response times to critical braking events were longer in the interesting audio condition. Drivers also perceived the interesting material to be less demanding and less complex, although the material was objectively matched for difficulty. Drivers showed a

reduced concentration of cerebral oxygenated hemoglobin when listening to interesting material, compared to baseline and boring conditions, yet they exhibited superior recognition for this material. The practical implications, from a safety standpoint, are discussed.

- **Keywords:** Driver distraction; Task engagement/interest; Cerebral blood oxygenation; Heart rate; Pupillometry; Driving performance

Sébastien Tremblay, Jean-François Gagnon, Daniel Lafond, Helen M. Hodgetts, Maxime Doiron, Patrick P.J.M.H. Jeuniaux. *A cognitive prosthesis for complex decision-making. Pages 349-360.*

While simple heuristics can be ecologically rational and effective in naturalistic decision making contexts, complex situations require analytical decision making strategies, hypothesis-testing and learning. Sub-optimal decision strategies – using simplified as opposed to analytic decision rules – have been reported in domains such as healthcare, military operational planning, and government policy making. We investigate the potential of a computational toolkit called “IMAGE” to improve decision-making by developing structural knowledge and increasing understanding of complex situations. IMAGE is tested within the context of a complex military convoy management task through (a) interactive simulations, and (b) visualization and knowledge representation capabilities. We assess the usefulness of two versions of IMAGE (desktop and immersive) compared to a baseline. Results suggest that the prosthesis helped analysts in making better decisions, but failed to increase their structural knowledge about the situation once the cognitive prosthesis is removed.

- **Keywords:** Complex decision making; Visual analytics; Knowledge representation

Ari Kolbeinsson, Peter Thorvald, Jessica Lindblom. *Coordinating the interruption of assembly workers in manufacturing. Pages 361-371.*

This paper examines how interruptions from information and communications technology systems affect errors and the time to complete tasks for assembly workers. Interruptions have previously been examined in laboratory experiments and office environments, but not much work has been performed in other authentic environments. This paper contains the results of an experiment that was performed in a simulated manufacturing assembly environment, which tested the effects of interruptions on a manual assembly task. The experiment used existing interruption coordination methods as a basis, and the results showed a difference in the effect of interruptions and interruption coordination between cognitively complex laboratory tasks and manual assembly tasks in an authentic environment. Most notably, the negative effects of interruptions delivered without consideration were smaller in this experiment. Based on these findings, recommendations were developed for designing interruption systems for minimizing the costs (errors and time) imposed by interruptions during assembly tasks in manufacturing.

- **Keywords:** Interruptions; Manual assembly; Manufacturing

Vitor Carneiro, Ângela Gomes, Bárbara Rangel. *Proposal for a universal measurement system for school chairs and desks for children from 6 to 10 years old. Pages 372-385.*

In a primary education classroom of any country, children of the same age have very different statures, reaching variations of 200 mm (Gonçalves, 2012). However, the school furniture provided is not suitable or adaptable to these differences. Designing school furniture able to respond to these variations is, therefore, a challenge for

ergonomics and design in a global market. It is clearly not viable for industries to adapt productions for each country. When competitiveness and limitation of resources are essential for the viability of any product it becomes essential to find a universal system adapted to the requisites of any country. Taking as prescription measure the popliteal height obtained from the data of different countries, a universal measurement system for the school chair and desk set is proposed, combining the ellipse methodology used by Molenbroek et al. (2003) and the (mis)match equations mentioned by Castellucci et al. (2014b). From the results obtained, it can be concluded that only 5 sizes are needed to implement this new measurement system of evolutionary school furniture for the primary education classroom.

- **Keywords:** School furniture; Universal measurement system; Children

Steven A. Lavender, Shasank Nagavarapu, W. Gary Allread. *An electromyographic and kinematic comparison between an extendable conveyor system and an articulating belt conveyor used for truck loading and unloading tasks.* Pages 398-404.

Many retail distribution centers (DCs) manually load and unload boxes into or out of trailers and shipping containers. This study investigated whether an articulating belt conveyor with a height adjustable platform, positioned at the end of an extendable conveyor, significantly reduces shoulder and back muscle loading and the spine kinematics associated with these tasks. Electromyographic and kinematic data were collected from eight volunteer employees as trailers at a shoe DC were unloaded and from nine volunteer employees as trailers at an apparel DC were loaded. Participants in this repeated measures study handled boxes with a conventional powered extendable conveyor system and with the articulating belt conveyor positioned at the end of the extendable conveyor. Bilaterally the normalized activation levels of the erector spinae and anterior deltoid muscles were reduced when loading and unloading boxes with the articulating belt conveyor. Spine movement speeds were also reduced with the articulating conveyor.

- **Keywords:** Musculoskeletal disorders; Distribution centers; Conveyor systems

Deirdre Holly, Vivien Swanson, Philip Cachia, Beverley Beasant, Colville Laird. *Development of a behaviour rating system for rural/remote pre-hospital settings.* Pages 405-413.

Background: Remote and Rural pre-hospital care practitioners manage serious illness and injury on an unplanned basis, necessitating technical and non-technical skills (NTS). However, no behaviour rating systems currently address NTS within these settings. Informed by health psychology theory, a NTS-specific behaviour rating system was developed for use within pre-hospital care training for remote and rural practitioners. **Method:** The Immediate Medical Care Behaviour Rating System (IMCBRS), was informed by literature, expert advice and review and observation of an Immediate Medical Care (IMC) course. Once developed, the usability and appropriateness of the rating system was tested through observation of candidates' behaviour at IMC courses during simulated scenarios and rating their use of NTS using the IMCBRS. **Results and conclusion:** Observation of training confirmed rating system items were demonstrated in 28–62% of scenarios, depending on context. The IMCBRS may thus be a useful addition to training for rural and practitioners.

- **Keywords:** Non-technical skills; Rural and remote; Pre-hospital emergency care

Christer Ahlstrom, Katja Kircher. *Changes in glance behaviour when using a visual eco-driving system: A field study.* Pages 414-423.

While in-vehicle eco-driving support systems have the potential to reduce greenhouse gas emissions and save fuel, they may also distract drivers, especially if the system makes use of a visual interface. The objective of this study is to investigate the visual behaviour of drivers interacting with such a system, implemented on a five-inch screen mounted above the middle console. Ten drivers participated in a real-world, on-road driving study where they drove a route nine times (2 pre-baseline drives, 5 treatment drives, 2 post-baseline drives). The route was 96 km long and consisted of rural roads, urban roads and a dual-lane motorway. The results show that drivers look at the system for 5–8% of the time, depending on road type, with a glance duration of about 0.6 s, and with 0.05% long glances (>2s) per kilometre. These figures are comparable to what was found for glances to the speedometer in this study. Glance behaviour away from the windscreen is slightly increased in treatment as compared to pre- and post-baseline, mirror glances decreased in treatment and post-baseline compared to pre-baseline, and speedometer glances increased compared to pre-baseline. The eco-driving support system provided continuous information interspersed with additional advice pop-ups (announced by a beep) and feedback pop-ups (no auditory cue). About 20% of sound initiated advice pop-ups were disregarded, and the remaining cases were usually looked at within the first two seconds. About 40% of the feedback pop-ups were disregarded. The amount of glances to the system immediately before the onset of a pop-up was clearly higher for feedback than for advice. All in all, the eco-driving support system under investigation is not likely to have a strong negative impact on glance behaviour. However, there is room for improvements. We recommend that eco-driving information is integrated with the speedometer, that optional activation of sound alerts for intermittent information is made available, and that the pop-up duration should be extended to facilitate self-regulation of information intake.

- **Keywords:** Eco-driving; Spare capacity; Glance behaviour

Sruthy Orozhiyathumana Agnisarman, Kapil Chalil Madathil, Kevin Smith, Aparna Ashok, Brandon Welch, James T. McElligott. *Lessons learned from the usability assessment of home-based telemedicine systems.* Pages 424-434.

At-home telemedicine visits are quickly becoming an acceptable alternative for in-person patient visits. However, little work has been done to understand the usability of these home-based telemedicine solutions. It is critical for user acceptance and real-world applicability to evaluate available telemedicine solutions within the context-specific needs of the users of this technology. To address this need, this study evaluated the usability of four home-based telemedicine software platforms: Doxy.me, Vidyo, VSee, and Polycom. Using a within-subjects experimental design, twenty participants were asked to complete a telemedicine session involving several tasks using the four platforms. Upon completion of these tasks for each platform, participants completed the IBM computer system usability questionnaire (CSUQ) and the NASA Task Load Index test. Upon completing the tasks on all four platforms, the participants completed a final post-test subjective questionnaire ranking the platforms based on their preference. Of the twenty participants, 19 completed the study. Statistically significant differences among the telemedicine software platforms were found for task completion time, total workload, mental demand, effort, frustration, preference ranking and computer system usability scores. Usability problems with installation and account creation led to high mental demand and task completion time, suggesting the participants preferred a system without such requirements. Majority of the usability issues were identified at the telemedicine initiation phase. The findings from this study can be used by software developers to develop user-friendly telemedicine systems.

- **Keywords:** Telemedicine; Telehealth; Home-based video telemedicine systems; Usability; User experience

Simone Secchi, Antonio Lauria, Gianfranco Cellai. *Acoustic wayfinding: A method to measure the acoustic contrast of different paving materials for blind people.* Pages 435-445.

Acoustic wayfinding involves using a variety of auditory cues to create a mental map of the surrounding environment. For blind people, these auditory cues become the primary substitute for visual information in order to understand the features of the spatial context and orient themselves. This can include creating sound waves, such as tapping a cane. This paper reports the results of a research about the "acoustic contrast" parameter between paving materials functioning as a cue and the surrounding or adjacent surface functioning as a background. A number of different materials was selected in order to create a test path and a procedure was defined for the verification of the ability of blind people to distinguish different acoustic contrasts. A method is proposed for measuring acoustic contrast generated by the impact of a cane tip on the ground to provide blind people with environmental information on spatial orientation and wayfinding in urban places.

- **Keywords:** Accessibility; Blind pedestrians; Acoustic wayfinding

Anja Kraneburg, Steffen Franke, Ralf Methling, Barbara Griefahn. *Effect of color temperature on melatonin production for illumination of working environments.* Pages 446-453.

We studied the influence of correlated color temperature (CCT) of 7 polychromatic white light illuminations (1600 K–14,000 K, 200 lx) in two experiments. Visual performance was tested in 17 students (8 men) during daytime. Visual acuity, contrast sensitivity and sleepiness did not vary with illuminations but polychromatic white light of <2000 K impaired color discrimination. Melatonin synthesis was tested with weekly intervals in 8 trials from 10pm to 2am (7 polychromatic illuminations and a dim light reference (<0.1 lx)) in 16 students (9 men, semi-recumbent position). Melatonin suppression was almost negligible for CCT <2000 K but increased with increasing CCT. **Conclusions:** CCTs <2000 K are not suitable for work places. Polychromatic white light with higher CCTs and significant melatonin suppression is expected to shift the circadian rhythm and to accelerate the adaptation to night work. This effect should be enhanced with elevation of luminance.

- **Keywords:** Chronodisruption; Polychromatic light; Melatonin; Night work; Shift work; Phase shift; Melatonin suppression

Scott R. Walter, Magdalena Z. Raban, William T.M. Dunsmuir, Heather E. Douglas, Johanna I. Westbrook. *Emergency doctors' strategies to manage competing workload demands in an interruptive environment: An observational workflow time study.* Pages 454-460.

An observational workflow time study was conducted involving doctors in the emergency department (ED) of a large Australian hospital. During 121.7 h across 58 sessions, we observed interruptive events, conceptualised as prompts, and doctors' strategies to handle those prompts (task-switching, multitasking, acknowledgement, deferral and deflection) to assess the role of multiple work system factors influencing doctors' work in the ED. Prompt rates varied vastly between work scenarios, being highest during non-verbal solo tasks. The propensity to use certain strategies also differed with task type, prompt type and location within the department, although task-switching was by far the most frequent. Communicative prompts were important in patient treatment and workload management. Clinicians appear to adjust their communication strategies in response to contextual factors in order to deliver patient care. Risk due to the

interruptive nature of ED communication is potentially outweighed by the positive effects of timely information transfer and advice provision.

- **Keywords:** Task-switching; Interruption; Multitasking; Clinical work systems; Emergency medicine

Sukru Karali, Neil J. Mansfield, Diane E. Gyi. *An approach to vehicle design: In-depth audit to understand the needs of older drivers.* Pages 461-470.

The population of older people continues to increase around the world, and this trend is expected to continue; the population of older drivers is increasing accordingly. January 2012 figures from the DVLA in the UK stated that there were more than 15 million drivers aged over 60; more than 1 million drivers were aged over 80. There is a need for specific research tools to understand and capture how all users interact with features in the vehicle cabin e.g. controls and tasks, including the specific needs of the increasingly older driving population. This paper describes an in-depth audit that was conducted to understand how design of the vehicle cabin impacts on comfort, posture, usability, health and wellbeing in older drivers. The sample involved 47 drivers (38% female, 62% male). The age distribution was: 50–64 (n = 12), 65–79 (n = 20), and those 80 and over (n = 15). The methodology included tools to capture user experience in the vehicle cabin and functional performance tests relevant to specific driving tasks. It is shown that drivers' physical capabilities reduce with age and that there are associated difficulties in setting up an optimal driving position such that some controls cannot be operated as intended, and many adapt their driving cabins. The cabin set-up process consistently began with setting up the seat and finished with operation of the seat belt.

- **Keywords:** Vehicle design; Driving; Automotive ergonomics; Older drivers; Ageing; Human factors; Posture; Seat design; Control design

Juergen Sauer, Alain Chavallaz. *The use of adaptable automation: Effects of extended skill lay-off and changes in system reliability.* Pages 471-481.

This experiment aimed to examine how skill lay-off and system reliability would affect operator behaviour in a simulated work environment under wide-range and large-choice adaptable automation comprising six different levels. Twenty-four participants were tested twice during a 2-hr testing session, with the second session taking place 8 months after the first. In the middle of the second testing session, system reliability changed. The results showed that after the retention interval trust increased and self-confidence decreased. Complacency was unaffected by the lay-off period. Diagnostic speed slowed down after the retention interval but diagnostic accuracy was maintained. No difference between experimental conditions was found for automation management behaviour (i.e. level of automation chosen and frequency of switching between levels). There were few effects of system reliability. Overall, the findings showed that subjective measures were more sensitive to the impact of skill lay-off than objective behavioural measures.

- **Keywords:** Automation; Reliability; Skill lay-off; Trust; Complacency

David I. Douphrate, David Gimeno Ruiz de Porras, Matthew W. Nonnenmann, Robert Hagevoort, Stephen J. Reynolds, Anabel Rodriguez, Nathan B. Fethke. *Effects of milking unit design on upper extremity muscle activity during attachment among U.S. large-herd parlor workers.* Pages 482-490.

Background: Large-herd dairy parlor workers experience a high prevalence of musculoskeletal symptoms in the upper extremity. The purpose of this study was to evaluate the effect of milking unit design on upper extremity muscle activity during milking unit attachment. **Methods:** Upper extremity muscle activity was recorded among U.S. large-herd parlor workers (n=11) using surface electromyography. Participants performed several milking unit attachment cycles with each of six milking unit designs. Muscle activity levels were then compared between unit designs. **Results:** Mean muscle activity levels (in %MVE) across milking units ranged from 6.8 to 8.2 for the upper trapezius, 8.2 to 10.3 for the anterior deltoid, 13.8 to 17.2 for the forearm flexors, and 9.9 to 12.4 for the forearm extensors. Pairwise comparisons between milking units did not reveal statistically significant differences in muscle activity levels across milking unit designs. However, a general pattern of higher muscle activity was observed with specific milking units. Milking unit weight, milk tube spread, and teat cup shape may explain differences in muscle activity levels. **Conclusions:** Milking unit design may influence muscle activity levels among parlor workers. Small reductions in muscle activity associated with milking unit design have the potential to delay the onset of fatigue or development of musculoskeletal health outcomes among parlor workers.

- **Keywords:** Dairy; Electromyography; Milking unit; Equipment

Charlotte Diana Nørregaard Rasmussen, Naja Klærke Lindberg, Marie Højbjerg Ravn, Marie Birk Jørgensen, Karen Søgaard, Andreas Holtermann. *Processes, barriers and facilitators to implementation of a participatory ergonomics program among eldercare workers. Pages 491-499.*

This study aimed to investigate the processes of a participatory ergonomics program among 594 eldercare workers with emphasis on identified risk factors for low back pain and solutions, and reveal barriers and facilitators for implementation. Sixty-nine per cent of the identified risk factors were physical ergonomic, 24% were organisational and 7% were psychosocial risk factors. Most solutions were organisational (55%), followed by physical (43%) and psychosocial solutions (2%). Internal factors (e.g. team or management) constituted 47% of the barriers and 75% of the facilitators. External factors (e.g. time, financial resources, collaboration with resident or relatives) constituted 53% of the barriers and 25% of the facilitators. This study revealed the processes and implementation of a participatory ergonomics program among eldercare workers. The findings can be transferred to workers, workplaces, health and safety professionals, and researchers to improve future participatory ergonomics programs.

- **Keywords:** Workplace intervention; Low back pain; Stepped wedge design; Healthcare workers; Nurses' aides; Randomized controlled trial; Physical training; Cognitive behavioural training

Bassam Hasanain, Andrew D. Boyd, Judy Edworthy, Matthew L. Bolton. *A formal approach to discovering simultaneous additive masking between auditory medical alarms. Pages 500-514.*

The failure of humans to respond to auditory medical alarms has resulted in numerous patient injuries and deaths and is thus a major safety concern. A relatively understudied source of response failures has to do with simultaneous masking, a condition where concurrent sounds interact in ways that make one or more of them imperceptible due to physical limitations of human perception. This paper presents a method, which builds on a previous implementation, that uses a novel combination of psychophysical modeling and formal verification with model checking to detect masking in a modeled configuration of medical alarms. Specifically, the new method discussed here improves the original method by adding the ability to detect additive masking while concurrently improving

method usability and scalability. This paper describes how these additions to our method were realized. It then demonstrates the scalability and detection improvements via three different case studies. Results and future research are discussed.

- **Keywords:** Medical alarms; Masking; Psychoacoustics; Formal methods; Model checking

Simon Fass, Rami Yousef, Divakaran Liginlal, Priyanka Vyas. *Understanding causes of fall and struck-by incidents: What differentiates construction safety in the Arabian Gulf region?* Pages 515-526.

Rapid growth in the Arabian Gulf region has fueled an explosive pace of construction and a rise in risks of occupational injury. Scarcity of pertinent data, however, makes it hard to determine whether accident characteristics, causal factors and remedial interventions identified elsewhere apply to the Gulf in comparable ways. This difficulty stems from unusual construction sector characteristics, notably a heterogeneous mix of expatriate laborers and firms working without a common language, work culture or labor practices. Does this change the mix of accident types or the ranking of main causes and priority remedies? To answer this question, a sample of 519 incident records was analyzed to determine whether accident types and frequencies are comparable to elsewhere. Site safety experts were then interviewed to determine whether rankings of factors and interventions should be similar. Findings are that types are indeed comparable, but the rankings of factors and interventions may not be. Main factors have to do with worker skills and training, experience, use of safety gear and risk perception. The overarching safety issue, however, is that firms and governments do not have strong incentive to address these factors.

- **Keywords:** Construction safety; Fall and struck-by accidents; Middle East

Guillaume Doisy, Adi Ronen, Yael Edan. *Comparison of three different techniques for camera and motion control of a teleoperated robot.* Pages 527-534.

This research aims to evaluate new methods for robot motion control and camera orientation control through the operator's head orientation in robot teleoperation tasks. Specifically, the use of head-tracking in a non-invasive way, without immersive virtual reality devices was combined and compared with classical control modes for robot movements and camera control. Three control conditions were tested: 1) a condition with classical joystick control of both the movements of the robot and the robot camera, 2) a condition where the robot movements were controlled by a joystick and the robot camera was controlled by the user head orientation, and 3) a condition where the movements of the robot were controlled by hand gestures and the robot camera was controlled by the user head orientation. Performance, workload metrics and their evolution as the participants gained experience with the system were evaluated in a series of experiments: for each participant, the metrics were recorded during four successive similar trials. Results shows that the concept of robot camera control by user head orientation has the potential of improving the intuitiveness of robot teleoperation interfaces, specifically for novice users. However, more development is needed to reach a margin of progression comparable to a classical joystick interface.

- **Keywords:** Teleoperation; Human factors; Interface design

R. Scott Dainty, Diane E. Gregory. *Investigation of low back and shoulder demand during cardiopulmonary resuscitation.* Pages 535-542.

Limited research has examined the effect of different compression-ventilation ratios on the ergonomic demand of performing cardiopulmonary resuscitation (CPR) over time. This study aimed to compare the biomechanical demand of performing continuous chest compression CPR (CCC-CPR) and standard CPR (30:2 compression to breath ratio). Fifteen CPR certified individuals performed both standard CPR and CCC-CPR, randomly assigned, for three 2-min periods. Trunk and upper limb muscle activation, lumbar spine posture and compression force applied to a testing mannequin chest were measured throughout each CPR trial. No differences in muscle activation of spine posture were observed, however chest compression force decreased over the two minutes ($p < 0.0001$). Further, this drop in force was larger and initiated immediately during the CCC-CPR trials. This immediate drop in force during the CCC-CPR trials may be an anticipatory adjustment in order to be able to sustain continuous compressions for the full 2 min duration.

- **Keywords:** CPR; Electromyography; Spine; Biomechanics; Experience

Christian Purucker, Frederik Naujoks, Andy Prill, Alexandra Neukum. *Evaluating distraction of in-vehicle information systems while driving by predicting total eyes-off-road times with keystroke level modeling.* Pages 543-554.

Increasingly complex in-vehicle information systems (IVIS) have become available in the automotive vehicle interior. To ensure usability and safety of use while driving, the distraction potential of system-associated tasks is most often analyzed during the development process, either by employing empirical or analytical methods, with both families of methods offering certain advantages and disadvantages. The present paper introduces a method that combines the predictive precision of empirical methods with the economic advantages of analytical methods. Keystroke level modeling (KLM) was extended to a task-dependent modeling procedure for total eyes-off-road times (TEORT) resulting from system use while driving and demonstrated by conducting two subsequent simulator studies. The first study involved the operation of an IVIS by $N = 18$ participants. The results suggest a good model fit ($R^2_{Adj.} = 0.67$) for predicting the TEORT, relying on regressors from KLM and participant age. Using the parameter estimates from study 1, the predictive validity of the model was successfully tested during a second study with $N = 14$ participants using a version of the IVIS prototype with a revised design and task structure ($r_{Pred.-Obs.} = 0.58$). Possible applications and shortcomings of the approach are discussed.

- **Keywords:** Automotive keystroke level modeling; Total eyes-off-road times; Secondary tasks; In-vehicle infotainment systems

Wen Yi, Albert P.C. Chan, Francis K.W. Wong, Del P. Wong. *Effectiveness of a newly designed construction uniform for heat strain attenuation in a hot and humid environment.* Pages 555-565.

This study aims to evaluate the effectiveness of a newly designed construction uniform in combating heat stress. Ten male volunteers performed treadmill running in a climatic chamber maintained at 34.5 °C temperature, 75% relative humidity, 0.3 m/s air velocity, and solar radiation of 450 W/m² that simulates typical summer working environment of construction sites in Hong Kong. The participants were tested while wearing two kinds of construction uniforms: a commonly worn uniform A, or a newly designed uniform B. It was found during exercise that T_c (38.34 ± 0.14 vs 38.45 ± 0.11 °C, $p = 0.03$), T_{sk} (36.01 ± 0.36 vs 36.27 ± 0.34 °C, $p = 0.03$), HR (162.7 ± 10.1 vs 172.5 ± 9.2 bpm, $p < 0.01$), PSI (7.0 ± 0.4 vs 7.5 ± 0.5 , $p = 0.04$), thermal sensation (1.7 ± 0.9 vs 2.6 ± 0.7 , $p = 0.02$), and wetness sensation (1.9 ± 0.9 vs 2.6 ± 0.8 , $p < 0.01$) was lower when wearing uniform B than that of uniform A. It was found during recovery that

T_{c} (37.89 ± 0.13 vs 38.06 ± 0.13 °C, $p < 0.01$), T_{sk} (35.68 ± 0.37 vs 36.02 ± 0.41 °C, $p < 0.01$), HR (104.2 ± 10.1 vs 112.6 ± 10.7 bpm, $p < 0.01$), PSI (3.3 ± 0.7 vs 4.1 ± 1.0 , $p < 0.01$), thermal sensation (0.1 ± 0.9 vs 1.0 ± 0.8 , $p = 0.02$), and wetness sensation (1.1 ± 1.0 vs 2.3 ± 0.8 , $p = 0.02$) was lower when wearing uniform B than that of uniform A. The findings of this study suggested the newly designed construction uniform could reduce thermoregulatory and cardiovascular strain, and improve thermal comfort while exercising in a hot and humid environment.

- **Keywords:** Construction uniform; Heat strain; Moisture management textile

Richard J. Simpson, Scott M. Graham, Christopher Connaboy, Richard Clement, Luca Pollonini, Geraint D. Florida-James. *Blood lactate thresholds and walking/running economy are determinants of backpack-running performance in trained soldiers. Pages 566-572.*

We developed a standardized laboratory treadmill protocol for assessing physiological responses to a simulated backpack load-carriage task in trained soldiers, and assessed the efficacy of blood lactate thresholds (LTs) and economy in predicting future backpack running success over an 8-mile course in field conditions. LTs and corresponding physiological responses were determined in 17 elite British soldiers who completed an incremental treadmill walk/run protocol to exhaustion carrying 20 kg backpack load. Treadmill velocity at the breakpoint ($r = -0.85$) and $\Delta 1$ mmol l⁻¹ ($r = -0.80$) LTs, and relative $\dot{V}O_2$ at 4 mmol l⁻¹ ($r = 0.76$) and treadmill walk/run velocities of 6.4 ($r = 0.76$), 7.4 ($r = 0.80$), 11.4 ($r = 0.66$) and 12.4 ($r = 0.65$) km h⁻¹ were significantly associated with field test completion time. We report for the first time that LTs and backpack walk/run economy are major determinants of backpack load-carriage performance in trained soldiers.

- **Keywords:** Load-carriage; Ventilatory threshold; Special forces; Treadmill protocol; Occupational physiology; Field test

Ademola James Adeyemi, Jafri Mohd Rohani, Mat Rebi Abdul Rani. *Backpack-back pain complexity and the need for multifactorial safe weight recommendation. Pages 573-582.*

The study analysed backpack-related back pain in school children by investigating the possibility of multiple interactions among causative factors, which may be responsible for the non-conclusive findings on the issue. Using data from 444 prepubescent schoolchildren, a mixed method design combining survey, observation and direct measurement strategies was implemented. Using a multivariate structural equation modelling approach, the study investigated interactions among anthropometry, posture, backpack volume, rating and back pain constructs, with each construct made of 2–4 indicators. Additionally, regression analysis was used to determine the feasibility of considering the two additional factors of age and body mass index along with the globally accepted recommendation of a load of 10–15% of body weight. Our model demonstrated an acceptable model fit and revealed direct and indirect effects of the factors. Obese children were recommended to carry a one-third lighter load than other children. The application of systematic/multiple strategies provided an explanation for some of the issues associated with school children's backpack-related back pain.

- **Keywords:** School children; Backpack; Back pain

Deena S. Rosalky, David Hostler, Heather E. Webb. *Work duration does not affect cortisol output in experienced firefighters performing live burn drills. Pages 583-591.*

Work duration may affect firefighters' stress responses. Forty-two firefighters (38 males) performed either 2 (SWD) or 3 (LWD) bouts of simulated fire suppression activity. Salivary cortisol, self-reported fear and anxiety, and perceptual thermal responses were measured. Cortisol was evaluated using area-under-the-curve calculations (Pruessner et al., 2003). Affective responses between the two conditions were compared using T-tests. Pearson product moment correlations were used to analyze the relationships between affect and change in thermal load perception. Cortisol decreased across the protocol in both groups, and no difference was found in cortisol or affect between the groups. Cortisol decreased ($F_{4,36} = 3.43$, $p < 0.05$) in the SWD group from a mean concentration of 40.93 ± 11.41 nmol/L to 25.07 ± 9.88 nmol/L at the end of the protocol. In the LWD group, the mean cortisol concentration decreased from 42.89 ± 11.83 to 25.07 ± 8.82 at the end of the protocol ($F_{5,50} = 14.77$, $p < 0.01$). Anxiety increased in the LWD ($F_{4,72} = 5.11$, $p = 0.001$) but not the SWD group. Fear increased in the SWD ($F_{3,48} = 14.15$, $p < 0.001$) and LWD group ($F_{4,60} = 4.47$, $p < 0.01$). The present findings suggests a moderate fear load with firefighting, which appears not to be associated with duration of work bout. Examination of more varied work bout lengths may reveal an association between anxiety and work duration. However, the work bout durations investigated in the current study comprise the range of what is practical from an occupational standpoint and the physiological capabilities of the firefighters.

- **Keywords:** Firefighting; Work interval; Fear; Anxiety

Amy Hocraffer, Chang S. Nam. *A meta-analysis of human-system interfaces in unmanned aerial vehicle (UAV) swarm management. Pages 66-80.*

A meta-analysis was conducted to systematically evaluate the current state of research on human-system interfaces for users controlling semi-autonomous swarms composed of groups of drones or unmanned aerial vehicles (UAVs). UAV swarms pose several human factors challenges, such as high cognitive demands, non-intuitive behavior, and serious consequences for errors. This article presents findings from a meta-analysis of 27 UAV swarm management papers focused on the human-system interface and human factors concerns, providing an overview of the advantages, challenges, and limitations of current UAV management interfaces, as well as information on how these interfaces are currently evaluated. In general allowing user and mission-specific customization to user interfaces and raising the swarm's level of autonomy to reduce operator cognitive workload are beneficial and improve situation awareness (SA). It is clear more research is needed in this rapidly evolving field.

- **Keywords:** Unmanned aerial vehicle (UAV); Swarm; Multi-robot systems; Human factors; Human-system interface; Human-robot interaction; Human-swarm interaction

Johanna Persson. *A review of the design and development processes of simulation for training in healthcare: A technology-centered versus a human-centered perspective. Pages 314-326.*

This article reviews literature about simulation systems for training in healthcare regarding the prevalence of human-centered approaches in the design and development of these systems, motivated by a tradition in this field of working technology-centered. The results show that the focus on human needs and context of use is limited. It is argued that a reduction of the focus on technical advancements in favor of the needs of the users and the healthcare community, underpinned by human factors and ergonomics theory, is favorable. Due to the low number of identified articles describing or discussing human-centered approaches it is furthermore concluded that the publication culture promotes technical descriptions and summative evaluations rather than descriptions and

reflections regarding the design and development processes. Shifting the focus from a technology-centered approach to a human-centered one can aid in the process of creating simulation systems for training in healthcare that are: 1) relevant to the learning objectives, 2) adapted to the needs of users, context and task, and 3) not selected based on technical or fidelity criteria.

- **Keywords:** Interactive learning environments; Simulations; Virtual reality; Human-centered design

Sheila J. Bosch, Arsalan Gharaveis. *Flying solo: A review of the literature on wayfinding for older adults experiencing visual or cognitive decline.* Pages 327-333.

Accessible tourism is a growing market within the travel industry, but little research has focused on travel barriers for older adults who may be experiencing visual and cognitive decline as part of the normal aging process, illness, or other disabling conditions. Travel barriers, such as difficulty finding one's way throughout an airport, may adversely affect older adults' travel experience, thereby reducing their desire to travel. This review of the literature investigates wayfinding strategies to ensure that older passengers who have planned to travel independently can do so with dignity. These include facility planning and design strategies (e.g., layout, signage) and technological solutions. Although technological approaches, such as smart phone apps, appear to offer the most promising new solutions for enhancing airport navigation, more traditional approaches, such as designing facilities with an intuitive building layout, are still heavily relied upon in the aviation industry. While there are many design guidelines for enhancing wayfinding for older adults, many are not based on scientific investigation.

- **Keywords:** Wayfinding; Airport design; Older adults

Rosimeire Simprini Padula, Maria Luiza Caires Comper, Emily H. Sparer, Jack T. Dennerlein. *Job rotation designed to prevent musculoskeletal disorders and control risk in manufacturing industries: A systematic review.* Pages 386-397.

To better understand job rotation in the manufacturing industry, we completed a systematic review asking the following questions: 1) How do job-rotation programs impact work-related musculoskeletal disorders (MSDs) and related risk control for these MSDs, as well as psychosocial factors? and 2) How best should the job rotation programs be designed? We searched MEDLINE, EMBASE, Business Source Premier, ISI Web of Knowledge, CINAHL, PsyINFO, Scopus, and SciELO databases for articles published in peer-reviewed journals. Eligible studies were examined by two independent reviewers for relevance (population of manufacturing workers, outcomes of musculoskeletal disorders, physical factors, psychosocial factors, and strategies used in job-rotation implantation) and methodological quality rating. From 10,809 potential articles, 71 were read for full text analysis. Of the 14 studies included for data extraction, two were non-randomized control trial studies, one was a case-control study, and 11 were cross-sectional comparisons. Only one, with a case-control design, was scored with good methodological quality. Currently, weak evidence exists supporting job rotation as a strategy for the prevention and control of musculoskeletal disorders. Job rotation did not appear to reduce the exposure of physical risk factors; yet, there are positive correlations between job rotation and higher job satisfaction. Worker training has been described as a crucial component of a successful job-rotation program. The studies reported a range of parameters used to implement and measure job-rotation programs. More rigorous studies are needed to better understand the full impact of job rotation on production and health.

- **Keywords:** Task rotation; Ergonomics; Industrial workers