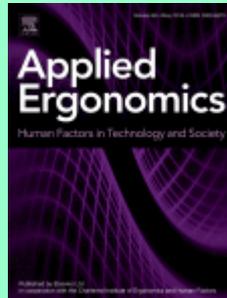


## **Applied Ergonomics - rok 2020, Volume 88**

**October 2020**



### ***Jeong Ho Kim, Hemateja Ari, Charan Madasu, Jaejin Hwang. Evaluation of the biomechanical stress in the neck and shoulders during augmented reality interactions.***

This study aimed to characterize the biomechanical stresses in the neck and shoulder, self-reported discomfort, and usability by different target distance or size during augmented reality (AR) interactions. In a repeated-measures laboratory-based study, 20 participants (10 males) performed three standardized AR tasks (3-dimensional (3-D) cube, omni-directional pointing, and web-browsing tasks) with three target distances (0.3, 0.6, and 0.9 m from each participant denoted by near, middle, far targets) for the 3-D cube and omni-directional pointing tasks or three target sizes: small (30% smaller than default), medium (default: 1.0 × 1.1 m), and large (30% larger than default) for the web-browsing task. Joint angle, joint moment, muscle activity, self-reported discomfort and comfort in the neck and shoulders; and subjective usability ratings were measured. The results showed that shoulder angle (flexion and abduction), shoulder moment (flexion), middle deltoid muscle activity significantly increased as the target distance increased during the 3-D cube task ( $p$ 's < 0.001). Self-reported neck and shoulder discomfort significantly increased after completing each task ( $p$ 's < 0.001). The participants preferred the near to middle distance (0.3–0.6 m) or the medium to large window size due to task easiness ( $p$ 's < 0.005). The highest task performance (speed) was occurred at the near distance or the large window size during the 3-D cube and web-browsing tasks ( $p$ 's < 0.001). The results indicate that AR interactions with the far target distance (close to maximum reach envelop) may increase the risk for musculoskeletal discomfort in the shoulder regions. Given the increased usability and task performance, the near to middle distance (less than 0.6 m) or the medium to large window size (greater than 1.0 × 1.1 m) would be recommended for AR interactions.

- **Keywords:** Electromyography; Joint moment; Joint angle; Computer-related musculoskeletal disorders; Usability; Augmented reality

### ***Natália Ransolin, Tarcisio Abreu Saurin, Carlos Torres Formoso. Integrated modelling of built environment and functional requirements: Implications for resilience.***

The built environment is a core part of most healthcare systems, involving a number of requirements such as those related to space and patients' well-being. However, these are usually addressed separately from other functional requirements, resulting in designs that do not support resilient performance. This study proposes a framework for the integrated modelling of built environment and other functional requirements, relying on

two approaches: Functional Resonance Analysis Method (FRAM), and Building Information Modelling (BIM). Requirements are defined as equivalent to the precondition aspect of FRAM functions. BIM allows the creation of a database of requirements and functions, linked to an object-oriented model of the built environment. The proposed framework was devised and tested in an intensive care unit. Findings shed light on the necessary resilience to cope with the gap between built environment-as-imagined in design and built environment-as-done due to performance adjustments. This type of resilience may have a long-lasting nature, as many built environment attributes cannot be easily changed.

- **Keywords:** Built environment; Resilience engineering; Intensive care unit; Requirements management

**Yen-Hui Lin, Shih-Yi Lu. *Effects of ground and load on upper trapezius, biceps brachii muscle and hand forces in one- and two-wheeled wheelbarrow pushing.***

This study examines the effects of ground surface, load, one- and two-wheeled wheelbarrow on muscular activities, hand force, and subject-perceived exertions while pushing a wheelbarrow in a straight line on a horizontal surface. The experimental results show that wheelbarrow load significantly affected muscular activities, hand force, and subject-perceived exertion. Additionally, different ground surfaces and wheelbarrow types also affected the muscular activities of the dominant hand; grass generated the highest muscle load and asphalt pavement generated the smallest muscle load. The user has to apply 57% and 23% more force in the vertical and horizontal direction while pushing one-vs. two-wheeled wheelbarrow. Muscular activity increased significantly in the dominant hand with the one-wheeled wheelbarrow compared with the two-wheeled wheelbarrow, suggesting that, in terms of muscle loads, the two-wheeled wheelbarrow is better than the one-wheeled wheelbarrow.

- **Keywords:** Pushing task; Wheelbarrow; Muscular activity; EMG

**Joseph K. Nuamah, Younho Seong, Steven Jiang, Eui Park, Daniel Mountjoy. *Evaluating effectiveness of information visualizations using cognitive fit theory: A neuroergonomics approach.***

Information visualizations may be evaluated from the perspective of how they match tasks that must be performed with them, a cognitive fit perspective. However, there is a gap between the high-level references made to cognitive fit and the low-level ability to identify and measure it during human interaction with visualizations. We bridge this gap by using an electroencephalography metric derived from frontal midline theta power and parietal alpha power, known as the task load index, to determine if cognitive effort measured at the level of cortical activity is less when cognitive fit is present compared to when cognitive fit is not. We found that when there is cognitive fit between the type of problem to be solved and the information displayed by a system, the task load index is lower compared to when cognitive fit is not present. We support this finding with subjective (NASA task load index) and performance (response time and accuracy) measures. Our approach, using electroencephalography, provides supplemental information to self-report and performance measures. Findings from this study are important because they (1) provide more validity to the cognitive fit theory using a neurophysiological measure, and (2) use the electroencephalography task load index metric as a means to assess cognitive workload and effort in general.

- **Keywords:** Cognitive fit theory; Visualization; Electroencephalography

**Fumie Sugimoto, Motohiro Kimura, Yuji Takeda, Motoyuki Akamatsu, Satoshi Kitazaki, Kazuo Yajima, Yonosuke Miki. *Effects of one-pedal automobile operation on the driver's emotional state and cognitive workload.***

A one-pedal system for operating an electric vehicle allows drivers to flexibly accelerate and decelerate (and even stop) by using just an accelerator pedal. Based on previous findings, one-pedal operation is considered to have the potential to increase positive emotions and decrease cognitive workload. To test this possibility, the present study compared the emotional state and cognitive workload between one-pedal and conventional two-pedal operation. Participants drove a vehicle on public roads, and driving enjoyment (i.e., pleasure and immersion) and the cognitive workload (i.e., ease and effortlessness) were assessed by means of questionnaires. In addition, physiological variations associated with driving pleasure and difficulty were assessed by electroencephalography (EEG). Both the questionnaire and EEG results revealed an increase in driving enjoyment in one-pedal operation. On the other hand, only the EEG results suggested a decrease in the cognitive workload in one-pedal operation; the questionnaire results did not show a significant difference between the pedal conditions. These findings support the notion that one-pedal operation has a positive influence on the driver's mental state, though its influence on the cognitive workload will require further investigation. We discuss future directions toward a better understanding of the effects of one-pedal operation on the driver's mental state.

- **Keywords:** One-pedal operation; Electric vehicle; Emotion; Workload; Attentional resources; Electroencephalogram

**Timothy L. White, P.A. Hancock. *Specifying advantages of multi-modal cueing: Quantifying improvements with augmented tactile information.***

This work examines how tactile cues, encoded with azimuth and distance information, compare with visual and speech cues on performance and mental workload in a target detection task. Two experiments are reported using a simulated environment in which targets were presented at varying azimuth and distance locations. In the first experiment, participants engaged targets both while stationary and while in motion using tactile, visual, or speech cues. A no cueing control was included. In the second multi-modal experiment, participants completed the same task using cue pairings. Performance metrics consisted of hits, misses due to non-detection, misses due to inaccurate engagement, false alarms, response time, navigation errors as well as subjective ratings of mental workload scores were also collected. Results demonstrate the superiority of tactile cues as a means to communicate target location information either as a single modality or when paired with the two other cue types.

- **Keywords:** Tactile; Multimodal; Dismounted

**Ali Mohammad Abbasi, Majid Motamedzade, Mohsen Aliabadi, Rostam Golmohammadi, Leili Tapak. *Combined effects of noise and air temperature on human neurophysiological responses in a simulated indoor environment.***

The aim of the present study was to evaluate the combined effects of noise and air temperature on the human body neurophysiological responses. This study was conducted on 35 male students, who were exposed to four different air temperatures (18 °C, 22 °C, 26 °C, and 30 °C) and two noise levels (55 dBA and 75 dBA) in eight sessions in a simulated indoor environment. The mean values of accuracy and time of response to stimuli in N-back test as well as neurophysiological responses were measured. In the studied experiment configurations, with increasing air temperature and noise, the

working memory and neurophysiological responses were disturbed. The results indicated the significant effect of noise on working memory, as compared with that of air temperature. The effects of air temperature on heart rate, respiratory rate as well as theta and alpha bands were more significant than the impact of noise. The combined effects of noise and air temperature were more significant than the influence of each of them alone. In the presence of high noise levels, the increase in air temperature did not worsen the response accuracy. However, in the presence of high noise level, the rise in air temperature aggravated the mean value of neurophysiological responses. Overall, noise has a greater effect on working memory, while the air temperature can disturb neurophysiological responses in a more profound way.

- **Keywords:** Indoor environment; Neurophysiological responses; Combined effects; Noise; Air temperature

**Tina Morgenstern, Elisabeth M. Wögerbauer, Frederik Naujoks, Josef F. Krems, Andreas Keinath. *Measuring driver distraction – Evaluation of the box task method as a tool for assessing in-vehicle system demand.***

Several tools have been developed over the past twenty years to assess the degree of driver distraction caused by secondary task engagement. A relatively new and promising method in this area is the box task combined with a detection response task (BT + DRT). However, no evaluation regarding the BT's sensitivity currently exists. Thus, the aim of the present study was to evaluate the BT + DRT by comparing its sensitivity to the sensitivity of already established methods. Twenty-nine participants engaged in several artificial and realistic secondary tasks while either performing the BT + DRT, the Lane Change Test (LCT), or driving through a simple course in a simulator. The results showed that the BT parameters (especially the standard deviation of box position and size) were sensitive to differences in demand across the visual-manual secondary tasks. This was comparable to what was found with the LCT. Surprisingly, the BT performance measures were more sensitive than those of the driving simulation task. The BT + DRT also captured cognitive distraction effects with the integration of the DRT. Hence, the BT + DRT could be a cost-effective method to assess in-vehicle system demand. However, further investigations are necessary to better understand the potential of the BT method.

- **Keywords:** Driver distraction; In-vehicle information systems; Evaluation methods

**Rossella Onofrio, Paolo Trucco. *A methodology for Dynamic Human Reliability Analysis in Robotic Surgery.***

Surgery has changed significantly in recent years due to the introduction of advanced technologies, resulting in increased system complexity at the technical, human and organisational levels, which may lead to higher variability of patient outcome due to new error pathways. Current approaches towards a safer surgery are largely based on ex-post analysis of events and process monitoring (e.g. root cause analysis, safety checklists, safety audits). However, adopting a proactive approach enables the prior identification of critical factors and the design of safer sociotechnical systems, thanks to a multi-level (or mesoergonomics) perspective. In this paper, a methodology for performing mesoergonomics analysis of surgical procedures is proposed. It is a methodology for Dynamic Human Reliability Analysis in Robotic Surgery based on a modified version of human error assessment and reduction technique (HEART) integrated with a method for incorporating uncertainties related to the influence of personal and organisational factors on the execution of a surgical procedure. The pilot application involves a robot-assisted radical prostatectomy procedure, and the results reveal that team-related factors have the greatest impact on patient outcome variability.

- **Keywords:** Human reliability analysis (HRA); HEART; Dynamic event tree (DET); Healthcare; Robotic surgery

**Saman Madinei, Mohammad Mehdi Alemi, Sunwook Kim, Divya Srinivasan, Maury A. Nussbaum. *Biomechanical assessment of two back-support exoskeletons in symmetric and asymmetric repetitive lifting with moderate postural demands.***

Two passive back-support exoskeleton (BSE) designs were assessed in terms of muscular activity, energy expenditure, joint kinematics, and subjective responses. Eighteen participants (gender-balanced) completed repetitive lifting tasks in nine different conditions, involving symmetric and asymmetric postures and using two BSEs (along with no BSE as a control condition). Wearing both BSEs significantly reduced peak levels of trunk extensor muscle activity (by ~9–20%) and reduced energy expenditure (by ~8–14%). Such reductions, though, were more pronounced in the symmetric conditions and differed between the two BSEs tested. Participants reported lower perceived exertion using either BSE yet raised concerns regarding localized discomfort. Minimal changes in lifting behaviors were evident when using either BSE, and use of both BSEs led to generally positive usability ratings. While these results are promising regarding the occupational use of BSEs, future work is recommended to consider inter-individual differences to accommodate diverse user needs and preferences.

- **Keywords:** Lifting; Low-back pain; Energy expenditure; Electromyography; Usability

**Laurie Lovett Novak, Howard B.A. Baum, Margaret H. Gray, Kim M. Unertl, Kathryn G. Tippey, Christopher L. Simpson, Jacob R. Uskavitch, Shilo H. Anders. *Everyday objects and spaces: How they afford resilience in diabetes routines.***

Thirty million Americans currently have diabetes, and a substantial portion do not reach the goals of clinical treatment. This is in part due to the complex barriers to effective self-care faced by people with diabetes. This study uses a patient work perspective, focusing on the everyday, lived experience of managing diabetes. Our primary research goal was to explore how the work of self-care is embedded in the other routines of everyday living. We found that everyday objects and spaces were instrumental in the incorporation of diabetes work into daily routines. Objects anchored diabetes tasks by linking illness-specific artifacts to space and time (e.g. a morning routine), and by enabling the performance on diabetes tasks while on the move in either planned or unplanned ways.

- **Keywords:** Patient work; Affordance; Resilience

**Bronson Du, Michelle Boileau, Kayla Wierst, Stephanie Beatrix Karch, Marcus Yung, Steven Fischer, Amin Yazdani. *Exploring the need for and application of human factors and ergonomics in ambulance design: Overcoming the barriers with technical standards.***

Ergonomic risk factors, such as excessive physical effort, awkward postures or repetitive movements, were the leading causes of injuries amongst EMS workers in the United States, of which 90% were attributed to lifting, carrying, or transferring a patient and/or equipment. Although the essential tasks of patient handling, transport, and care cannot be eliminated, the design of ambulances and associated equipment is modifiable. Our aims were to identify the extent of Human Factors and Ergonomic (HFE) considerations in existing ambulance design standards/regulations, and describe how HFE and the standards/regulations were applied in the EMS system. Through an extensive

environmental scan of jurisdictionally relevant standards/regulations and key informant interviews, our findings demonstrated that existing standards/regulations had limited considerations for HFE. As a result, HFE principles continue to be considered reactively through retrofit rather than proactively in upstream design. We recommend that performance-based HFE requirements be integrated directly into ambulance design standards.

- **Keywords:** Emergency medical services; Procurement; Management systems

**Wataru Toyoda, Eiji Tani, Susumu Oouchi, Masaki Ogata. *Effects of environmental explanation using three-dimensional tactile maps for orientation and mobility training.***

We developed a new kit to assemble three-dimensional (3D) tactile maps for orientation and mobility (O&M) training provided to persons with visual impairments. This study evaluated the effects of verbal explanations combined with 3D tactile map kits in improving understanding, recall, and walking along an unfamiliar route in comparison with the effects of only verbal explanation. The 3D tactile maps provided participants having severe visual impairments and little experience with tactile maps with a better understanding and recall of the environmental information concerning the route and landmarks. Participants who used the 3D tactile maps could find specific landmarks set as tasks more accurately and arrive at the destination alone getting lost less frequently. Tactile maps composed of 3D points, lines, and areal parts are useful as a support aid for O&M training because they have high tactile readability and can provide the environmental information that individuals with visual impairment require.

- **Keywords:** Visual impairment; Orientation and mobility; Tactile map

**Nicole E. Werner, Rachel Rutkowski, Amy Graske, Mary K. Finta, Craig R. Sellers, Sandhya Seshadri, Manish N. Shah. *Exploring SEIPS 2.0 as a model for analyzing care transitions across work systems.***

Care transitions across healthcare settings, specifically between the emergency department (ED) and the home, are pervasive among older adults, and represent persistent healthcare quality and safety challenges. Care transitions cross multiple distinct work systems, representing a conceptual and methodological challenge for the field of Human Factors/Ergonomics - how to analyze a process that occurs across multiple work systems. As an initial step in determining how to study care transitions across work systems, we applied the Systems Engineering Initiative for Patient Safety (SEIPS) 2.0 model, specifically the concept of configuration, to explore older adults' ED-to-home transitions. Our results suggest that configuration is useful for identifying and modeling work system barriers that interact across systems, but does not explicitly allow for the identification and analysis of the system boundaries that are crossed. To fully capture the complexity associated with care transitions, future iterations of SEIPS should introduce a mechanism to capture specific boundary types, so that system analysis can capture when and which boundaries are crossed.

- **Keywords:** Care transitions; Work systems; Sociotechnical systems; Older adults; Emergency department

**Jesús Vera, Beatriz Redondo, María Álvarez-Rodríguez, Rubén Molina, Raimundo Jiménez. *The intraocular pressure responses to oral academic examination: The influence of perceived levels of public speaking anxiety.***

We examined the intraocular pressure responsiveness to oral examination stress, as well as the mediating role of the perceived levels of public speaking anxiety on intraocular pressure changes. Thirty-two university students (intervention group) publicly defended their degree final project, and intraocular pressure and perceived levels of stress were measured before and after the oral presentation, and after 10 min of recovery. The control group (n = 32) was not exposed to any stressful situation, and the dependent measures were taken at the same time points. All participants completed the public speaking anxiety scale. The intervention group exhibited higher intraocular pressure values before the oral presentation (corrected p-values < 0.001), with these changes being positively associated with the perceived levels of public speaking anxiety (p < 0.001, r = 0.71). Our results reveal a mediating role of public speaking anxiety on the intraocular pressure responsiveness to oral examination stress, and highlight the utility of intraocular pressure as an indicator of stress in applied situations.

- **Keywords:** Ocular biomarkers; Ocular perfusion pressure; Physiological response; Neuroergonomics; Cardiovascular response; Blood pressure; Glaucoma management

**Shabila Anjani, Wenhua Li, Iemkje A. Ruiter, Peter Vink. *The effect of aircraft seat pitch on comfort.***

This study explores the relationship between seat pitch and comfort, and the influencing factors, like space experience and anthropometric measurements. Two hundred ninety-four participants experienced economy class seats in a Boeing 737 with 28-inch, 30-inch, 32-inch and 34-inch seat pitches. Anthropometric measurements of the participants were measured. Participants completed a questionnaire on comfort (10-scale), discomfort (CP-50) and space experience and the results were analysed using SPSS 25. This study showed a significant relationship between seat pitch and comfort as well as discomfort. Additionally, it was found that the mean rank of discomfort of each pitch size for the middle seat was higher than the window and aisle seat, though seat pitch did affect the (dis)comfort more compared with seat location. It was also found that anthropometric sizes significantly affect the (dis)comfort on smaller pitch sizes, and all space experience questions had a correlation to the pitch sizes.

- **Keywords:** Seat pitch; Comfort; Discomfort; Space experience; Anthropometric measurements

**Eric B. Weston, William S. Marras. *Comparison of push/pull force estimates using a single-axis gauge versus a three-dimensional hand transducer.***

This study investigated the effects of using a single-axis force gauge for push/pull force measurement on kinetic/kinematic measures associated with the exertion and assessed agreement between forces recorded from two technologies (single-axis gauge, three-dimensional hand transducer) and various test conditions via intraclass correlations. Independent measures included exertion type (push, pull, turn), test condition (natural/cart alone, using force gauge at fast/slow/self-selected paces), and cart weight (light, heavy). Dependent measures included mean angles of force application, peak forces recorded from both technologies, and cart velocity. Excellent agreement was observed between technologies (ICC = 0.998). Likewise, peak forces using the single-axis gauge at the fast pace agreed best with the natural test condition (ICC = 0.631). Forces should be measured using a faster initial acceleration and sustained velocity than is prescribed by the current standard if they are to accurately approximate forces relative to existing push/pull guidelines. Future work should also develop recommendations for measuring turning forces.

- **Keywords:** Digital force gauge; Force limit; Risk assessment

**Jussi Onninen, Tarja Hakola, Sampsa Puttonen, Asko Tolvanen, Jussi Virkkala, Mikael Sallinen. *Sleep and sleepiness in shift-working tram drivers.***

Driver sleepiness contributes to traffic accidents. However, sleepiness in urban public transport remains an understudied subject. To fill this gap, we examined the sleepiness, sleep, and on-duty sleepiness countermeasures (SCMs) in 23 tram drivers working morning, day, and evening shifts for three weeks. Sleepiness was measured using Karolinska Sleepiness Scale (KSS). Nocturnal total sleep time (TST) was measured with wrist actigraphy. SCMs and naps were self-reported with a smartphone application. Caffeine and napping were considered effective SCMs. Severe sleepiness (KSS  $\geq$  7) was observed in 22% of shifts with no differences between shift types. Rest breaks were associated with slight reductions in sleepiness. TST between days off averaged 7 h but was 1 h 33 min and 38 min shorter prior to morning and day shifts, respectively. The use of effective SCMs showed little variance between shift types. These results highlight the need for fatigue management in non-night-working tram drivers.

- **Keywords:** Sleep loss; Urban transportation; Driver fatigue

**Matthias Weigl, Ken Catchpole, Markus Wehler, Anna Schneider. *Workflow disruptions and provider situation awareness in acute care: An observational study with emergency department physicians and nurses.***

**Background:** The fast-paced and rapidly changing environment of an Emergency Department (ED) requires providers to have a high level of situation awareness (SA). However, acute clinical care also encompasses a multitude of interruption-laden work processes that might degrade SA. It is therefore important to understand how frequent interruptions affect ED provider cognition in general and SA in particular. **Objective:** We aimed to examine how sources and contents of provider workflow interruptions influence situation awareness of ED physicians and nurses. **Methods:** This prospective, multi-method study combined standardized observations, self-reports of ED providers, and ED administrative data of staffing and patient load. Expert observers identified ED providers' workflow interruptions during 90min observation sessions. Afterwards, each provider reported perceived disruptiveness and situation awareness. Controlling for patient load, patient acuity and staffing, we conducted regression analyses to explore prospective associations between interruptions and provider outcomes. **Results:** During 74 observation sessions of overall 110h and 40min, we observed 1205 workflow interruptions (mean rate: 10.9 interruptions/hour). Provider situation awareness was fairly high (M = 7.10; scale 0–10) with no difference between ED physicians and nurses. After controlling for ED workload data, we observed that high rates of interruptions were associated with lower levels of situation awareness ( $\beta = -0.27$ ). Further analyses revealed that particularly interruptions by telephone/beeper, technical malfunctions as well as interruptive communication related to completed cases were correlated to low SA. **Discussion:** This study in a naturalistic ED setting shows that ED physicians and nurses continuously cope with disruptions and interruptions. Our findings reveal that highly interruptive workflow environments impede providers' situation awareness. Moreover, it sheds light on specific sources and contents of interruptions that influence providers' SA in acute care. **Conclusion:** Frequent workflow interruptions can degrade ED providers' situation awareness. A deeper understanding of how avoidable and unavoidable interruptions affect provider cognitions with particular focus on social and technology-related disruptions is required. Further emphasis should be placed on the effective application of work re-design in this context to foster safe and efficient patient care.

- **Keywords:** Emergency care; Nursing; Clinical care; Task interruptions; Cognitive performance; Situation awareness

**Hailee R. Kulich, Sarah R. Bass, Jefferson S. Griscavage, Amogha Vijayvargiya, Jonathan S. Slowik, Alicia M. Koontz. *An ergonomic comparison of three different patient transport chairs in a simulated hospital environment.***

The purpose of this study was to compare caregiver muscle activation and joint angles between two ergonomic transport chairs designed to mitigate discomfort and safety risks associated with patient transport, the Stryker® Prime TC and the Staxi® Medical Chair, and a depot wheelchair. Twenty-three caregivers completed level walking and ramped tasks with each device and an 84 kg manikin. Surface electromyography for the upper extremities and back muscles and motion data were collected. The Staxi showed a statistical trend for higher wrist extensor and flexor carpi ulnaris activity compared to the Stryker chair ( $p \leq 0.078$ ) and greater wrist flexion than the Stryker and depot chairs ( $p \leq 0.004$ ). The depot chair showed greater peak trunk flexion than the Stryker chair ( $p = 0.004$ ). Overall results suggest that ergonomic chair design may improve joint positioning of the trunk and elbows when operating patient transport chairs over level and ramped surfaces.

- **Keywords:** Injury prevention; Hospital personnel; Patient handling

**Leslie Gunter, Jerry Davis, Yousif Abulhassan, Richard Sesek, Mark Schall, Sean Gallagher. *Increasing evacuation flow through school bus emergency roof hatches.***

Emergency escape roof hatches are used to evacuate school buses in rolled-over orientations. In the United States, the minimum opening size of a roof hatch is defined by Federal Motor Vehicle Safety Standard (FMVSS) no. 217. With the prevalence of rising obesity rates among children, the minimum roof hatch opening size may not be large enough to accommodate larger passengers. Post-accident conditions such as injuries, disorientation, and exit obstructions may also prevent unobstructed passage for egress within acceptable time limits. The purpose of this study was to redesign and fabricate a roof hatch with a larger opening and evaluate its egress characteristics for a range of typical school bus passengers. The larger roof hatch opening allows greater evacuation flow rates, and is almost functionally equivalent to the evacuation flow rate of the front door on an upright school bus.

- **Keywords:** Accident; Roll-over; Evacuation; School bus; Surface transportation; Students; Emergency exits

**Grace P.Y. Szeto, Sharon M.H. Tsang, Jie Dai, Pascal Madeleine. *A field study on spinal postures and postural variations during smartphone use among university students.***

This field study compared the real-time spinal movements and postural variations during smartphone-use versus non-use in university students. Ten males and eight females (mean age of  $21.5 \pm 2.6$  years) participated, with similar daily phone use time between the two sexes. Five inertial motion sensors were attached to the cervical, thoracic and lumbar spinal regions, and kinematics was recorded for 3 h while participants went about their usual academic activities within the university campus. Significantly greater degrees of cervical and upper thoracic flexion were adopted during phone use versus non-use time ( $p < 0.01$ ). There were also significantly greater frequency of postural variations (zero crossing per min) in all spinal regions in the sagittal plane (all  $p < 0.05$ ), and in some of the movements in transverse and frontal planes comparing phone use vs non-use. The postural variables also showed some significant correlations with self-reported pre-existing neck and upper back pain scores.

- **Keywords:** Kinematics; Neck pain; Spine; Smartphone

**Kurt E. Beschorner, Johanna L. Siegel, Sarah L. Hemler, Vani H. Sundaram, Arnab Chanda, Arian Iraqi, Joel M. Haight, Mark S. Redfern.** *An observational ergonomic tool for assessing the worn condition of slip-resistant shoes.*

Worn shoes are known to contribute to slip-and-fall risk, a common cause of workplace injuries. However, guidelines for replacing shoes are not well developed. Recent experiments and lubrication theory suggest that the size of the worn region is an important contributor to the shoe tread's ability to drain fluid and therefore the under-shoe friction. This study evaluated a simple test for comparing the size of the worn region relative to a common object (AAA and AA battery) as a means of determining shoe replacement. This study consisted of three components involving slip-resistant shoes: Experiment #1: a longitudinal, mechanical, accelerated wear experiment; Experiment #2: a longitudinal experiment where the same shoes were tested after each month of worker use; and Experiment #3: a cross-sectional experiment that exposed participants to a slippery condition, while donning their own worn shoes. The COF (Experiments #1 and #2); under-shoe fluid pressure (all experiments); and slip severity (Experiment #3) were compared across outcomes (fail/pass) of the battery tests. Larger fluid pressures, lower coefficient of friction, and more severe slips were observed for shoes that failed the battery tests compared with those passing the tests. This method offers promise for assessing loss in friction and an increase in slip risk for slip-resistant shoes.

- **Keywords:** Slip; Trip; And fall accidents; Footwear; Observational tools; Personal protective equipment; Equipment inspection

**A.G. González, J. Barrios-Muriel, F. Romero-Sánchez, D.R. Salgado, F.J. Alonso.** *Ergonomic assessment of a new hand tool design for laparoscopic surgery based on surgeons' muscular activity.*

Laparoscopic surgery techniques are customarily used in non-invasive procedures. That said traditional surgical instruments and devices used by surgeons suffer from certain ergonomic deficiencies that may lead to physical complaints in upper limbs and back and general discomfort that may, in turn, affect the surgeon's skills during surgery. A novel design of the laparoscopic gripper handle is presented and compared with one of the most used instruments in this field in an attempt to overcome this problem. The assessment of the ergonomic feature of the novel design was performed by using time-frequency analysis of the surface electromyography (sEMG) signal during dynamic activities. Singular Spectrum Analysis (SSA) was used to decompose the sEMG signal and extract the median frequency of each muscle to assess muscle fatigue. The results reveal that using the proposed ergonomic grip reduces the mean values of the muscle activity during each of the proposed tasks. The novel design also improves the ease of use in laparoscopic surgery as it minimises high-pressure contact areas, reduces large amplitude movements and promotes a neutral position of the hand, wrist and forearm. Furthermore, the SSA method for time-frequency analysis provides a powerful tool to analyse a prescribed activity in ergonomic terms. The proposed methodology to assess muscle activity during surgery activities may be useful in the selection of surgical instruments when programming extended procedures, as it provides an additional selection criterion based on the surgeon's biomechanics and the proposed activity.

- **Keywords:** Ergonomic assessment; Minimally invasive surgery; Surface electromyography signals; time-frequency analysis; Singular spectrum analysis

**Susanna Aromaa, Antti Väättänen, Iina Aaltonen, Vladimir Goriachev, Kaj Helin, Jaakko Karjalainen. *Awareness of the real-world environment when using augmented reality head-mounted display.***

Augmented reality (AR) systems are becoming common tools in industrial workplaces. However, factory workers are still concerned about whether head-mounted display (HMD)-based AR systems distract their awareness of the environment and therefore pose safety risks. The purpose of this study was to assess users' experience of real-world awareness when using an AR system. 19 study participants played a wooden block logic game in a laboratory with three different setups: real, AR and virtual reality (VR). Based on this study, it can be concluded that HMD-based AR systems do not decrease users' awareness of their surroundings if the virtual content is minimal and the task is done while seated. However, it was seen that more research in this area with more interactive virtual content is required. This study is an important step in understanding how AR may affect future work in industrial and safety-critical environments.

- **Keywords:** Augmented reality; Awareness; Workload

**Mohammad Hosein Ghasemi, Mehrdad Anbarian, Hamed Esmaeili. *Immediate effects of using insoles with various wedges on activation and co-contraction indices of selected trunk muscles during load lifting.***

Trunk muscles play an important role during load lifting and contract to control trunk stability. The aim of present study was to investigate immediate effects of using various insole wedges on activation and co-contraction indices of selected trunk muscles during load lifting. Thirty able-bodied males completed load lifting task using nine various insole wedges. The results showed these significant differences: for normalized mean amplitude of RA muscle between posterior and anterior-medial wedges and for QL muscle between posterior and lateral wedges, for normalized peak amplitude of RA muscle between posterior and anterior-medial wedges, for median frequency of LES muscle between anterior-medial and anterior-lateral wedges, and for co-contraction of RA/LES and RA/MU between posterior and anterior-medial wedges ( $P = 0.001$ ). These findings should be considered during designation of shoe or insole for work environments. Future studies need to assess other biomechanical aspects of using various insole wedges during work-related tasks.

- **Keywords:** Load lifting; Wedge; Trunk muscles

**Roberta Etzi, Alberto Gallace, Gemma Massetti, Marco D'Agostino, Viola Cinquetti, Francesco Ferrise, Monica Bordegoni. *Conveying trunk orientation information through a wearable tactile interface.***

We present the design and test of a wearable device capable to detect the user's trunk orientation with respect to the gravitational field and to provide tactile stimulation to correct tilted positions. Vibrations are delivered to the shoulders, the frontal and dorsal parts of the trunk, by using the human body as an indicator of the four cardinal directions. The device was experimentally tested in normal gravity conditions by thirty-nine volunteers. The efficacy of tactile cues was investigated in comparison to visual and visuo-tactile cues. The results revealed that, despite the fact that the time needed to complete the task was shorter when people were guided by visual signals, the tactile cues were equally informative and, in some cases, the trunk spatial orientation was even more accurate. Overall, tactile cues were evaluated by users as more intuitive, effective and accurate.

- **Keywords:** Haptics; Trunk orientation; Wearable device

**Ju-Yang Chi, Mark Halaki, Bronwen J. Ackermann. *Ergonomics in violin and piano playing: A systematic review.***

This systematic review aimed to evaluate whether muscle activity and playing-related musculoskeletal disorders are associated with musicians' anthropometrics and their instrument size or set-up during violin and piano performance. Studies were retrieved systematically from six databases on 1 April 2019 combined with hand searching results. The Appraisal tool for Cross-Sectional Studies (AXIS tool) was used to evaluate the methodological quality of the included papers. A total of twenty articles were identified. Most included studies focussed on either the adjustment of the shoulder rest in violinists, or the hand size in pianists. However, methodological quality was inconsistent. The electromyography data reported by the included studies were not appropriately processed and interpreted. Studies generally reported the use of a shoulder rest changes muscle activity and smaller hand size is correlated to increased playing-related musculoskeletal disorders incidence. However, no conclusions can be drawn due to heterogeneity and low quality of methodology in the available literature.

- **Keywords:** Instrument set-up; Anthropometric; Playing-related musculoskeletal disorders

**Azim Karimi, Iman Dianat, Abdullah Barkhordari, Iman Yusefzade, Marzieh Rohani-Rasaf. *A multicomponent ergonomic intervention involving individual and organisational changes for improving musculoskeletal outcomes and exposure risks among dairy workers.***

A field intervention study was implemented to evaluate the effects of individual (physical exercise programme and worker ergonomics training) and organisational changes (optimising work-rest schedule and revised task procedure) on musculoskeletal outcomes and their exposure risks among milking workers in a dairy plant. A questionnaire survey (including the Cornell Musculoskeletal Discomfort Questionnaire [CMDQ]) and direct observations of working postures by using the Quick Exposure Check (QEC) method were used at baseline and 12-month follow-up. Shoulder, lower back and neck discomfort were found to be the most common problems. The results showed significant improvements in the frequency (neck, shoulder, lower back, forearm and knee symptoms), severity (shoulder, lower back and knee symptoms) and interference with work (particularly due to lower back symptoms) as well as in the exposure risks to musculoskeletal problems (using the QEC method) after the intervention. The findings support the effectiveness of implemented multiple component intervention for improving musculoskeletal health and exposure risks in the studied occupational group.

- **Keywords:** Dairy farm; Milkers; Multiple component intervention; Quick exposure check

**Daanish M. Mulla, Alison C. McDonald, Peter J. Keir. *Joint moment trade-offs across the upper extremity and trunk during repetitive work.***

Individuals can coordinate small kinematic changes at several degrees of freedom simultaneously in the presence of fatigue, leaving it unclear how overall biomechanical demands at each joint are altered. The purpose of this study was to evaluate trade-offs in joint moments between the trunk, shoulder, and elbow during repetitive upper extremity work. Participants performed four simulated workplace tasks cyclically until meeting fatigue termination criteria. Emergent fatigue-induced adaptations to repetitive work resulted in task-dependent trade-offs in joint moments. In general, reduced shoulder moments were compensated for by increased elbow and trunk joint moment contributions. Although mean joint moment changes were modest (range: 1–3 Nm) across participants, a wide distribution of responses was observed, with standard

deviations exceeding 10 Nm. Re-distributing biomechanical demands across joints may alleviate constant tissue loads and facilitate continued task performance with fatigue but may be at the expense of increasing demands at adjacent joints.

- **Keywords:** Fatigue; Shoulder; Variability

**I. Bolis, S.N. Morioka, C.M. Brunoro, P.C. Zambroni-de-Souza, L.I. Sznelwar. *The centrality of workers to sustainability based on values: Exploring ergonomics to introduce new rationalities into decision-making processes.***

This article presents the results of an academic research project connecting the discipline of ergonomics (and work-related issues) with the theme of sustainability. Despite the stated aim of creating value for stakeholders, including employees, companies face difficulties in introducing effective sustainability policies. The research question addressed in this article is the following: How can companies improve their decision-making processes to increase workers' wellbeing using policies integrating issues related to corporate sustainability and ergonomics? Currently, corporate sustainability is focused mainly on the triple bottom line (TBL) concept. In this context, the integration of ergonomics is fragmented and arguably separate from strategic human-resource functions (which have largely been the primary promoter of the internal-social component of corporate sustainability). This research argues that corporate sustainability requires a new step, improving the decision-making process, with the inclusion of more types of rationalities and the recognition of the centrality of workers in the process of creating sustainable action. When corporate sustainability policies focus on worker centrality, they open space for the integration of ergonomics as a pillar of an organization's corporate sustainability strategy. Based on a complex view of work systems, ergonomics can introduce values aligned with sustainability and promote cooperation in organizations. Different stakeholders working at companies can make use of different concepts proposed by ergonomics and other work sciences to support changes in their decision-making processes. In view of broader sustainability objectives, integrating different work-related considerations can help improve performance, including productivity, quality and health.

- **Keywords:** Ergonomics; Sustainable development; Corporate sustainability; Decision-making process; Rationalities; Sustainability based on values

**Rachel L. Bartels, Diane DiTomasso, Gretchen A. Macht. *A mother-centered evaluation of breast pumps.***

Existing literature outlines mothers' negative experiences with breast pumps, yet a gap exists of which breast pump characteristics are important to mothers. Identifying which breast pump characteristics are important to breast pumping mothers, and any variation between mothers who do or do not work outside of the home, will help identify user needs. A survey collected information on mothers' experiences with breast pumps and impressions of their characteristics. Latent Class Analysis (LCA) was used to determine whether there were possible groupings of impressions of these characteristics. The LCA identified a two-class model with mothers' age as a significant covariate. Portability, ease of use, low-weight, fast milk extraction, comfortability, low-noise, and discreet were all found to be important to one group of mothers, while only portability, ease of use, fast milk extraction, and comfortability were found to be important to another group of mothers. Mothers' work status was not a significant covariate but did predict class membership when considered as a grouping variable in conjunction with age. Breast pumping mothers' needs were found to differ based on their work status and age together, and collecting and considering these different needs is vital to creating redesigns that improve mothers' breast pumping experience.

- **Keywords:** Breast pump experience; User-centered design; Latent class analysis