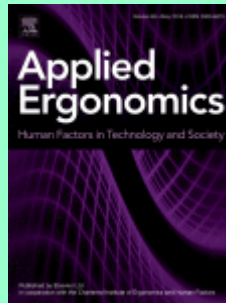


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Sol Lim, Clive D'Souza. Statistical prediction of load carriage mode and magnitude from inertial sensor derived gait kinematics. Pages 1-11.

Load carriage induces systematic alterations in gait patterns and pelvic-thoracic coordination. Leveraging this information, the objective of this study was to develop and assess a statistical prediction algorithm that uses body-worn inertial sensor data for classifying load carrying modes and load levels. Nine men participated in an experiment carrying a hand load in four modes: one-handed right and left carry, and two-handed side and anterior carry, each at 50% and 75% of the participant's maximum acceptable weight of carry, and a no-load reference condition. Twelve gait parameters calculated from inertial sensor data for each gait cycle, including gait phase durations, torso and pelvis postural sway, and thoracic-pelvic coordination were used as predictors in a two-stage hierarchical random forest classification model with Bayesian inference. The model correctly classified 96.9% of the carrying modes and 93.1% of the load levels. Coronal thoracic-pelvic coordination and pelvis postural sway were the most relevant predictors although their relative importance differed between carrying mode and load level prediction models. This study presents an algorithmic framework for combining inertial sensing with statistical prediction with potential use for quantifying physical exposures from load carriage.

- **Keywords:** Load carriage; Inertial sensors; Load classification; Gait kinematics

Ahmad Bazazan, Iman Dianat, Nafiseh Feizollahi, Zohreh Mombeini, Alireza Mohammad Shirazi, Héctor Ignacio Castellucci. *Effect of a posture correction-based intervention on musculoskeletal symptoms and fatigue among control room operators.* Pages 12-19.

This study was conducted to examine the effect of a posture correction-based intervention (with a biofeedback device) on the occurrence of musculoskeletal symptoms (MSS) and fatigue among control room operators in a petrochemical plant in Iran. A total of 188 office workers (91 in the case group and 97 in the control group) participated at baseline as well as at 6- and 12-month follow-up. A questionnaire survey (including the Nordic Musculoskeletal Questionnaire and Multidimensional Fatigue Inventory) and direct observations of working postures by using the Rapid Upper Limb Assessment (RULA) method were used. The occurrence of MSS in the shoulders, upper back, neck, and low back areas, as well as the mental and physical dimensions of fatigue were found to be the most common problems. The results showed considerable improvements in working postures (in the neck, trunk, and RULA grand scores) and the occurrence of MSS (particularly in the neck, shoulders, and upper back and low back areas) and fatigue (in

particular the mental and physical aspects) after the intervention. The overall mean RULA grand score for the case group was significantly decreased after the intervention (mean scores of 5.1, 4.4, and 4.6 at pre-intervention, post-intervention 1, and post-intervention 2, respectively). A total of 81 operators (89.0%) reported some kind of MSS at baseline, which were reduced to 75 operators (82.4%) and 77 operators (84.6%) at post-interventions 1 and 2, respectively. Significant differences were also found between the pre- and post-intervention scores for the physical fatigue (mean of 12.19, 10.16, and 9.99 at pre-intervention, post-intervention 1, and post-intervention 2, respectively) and mental fatigue (mean of 14.03, 12.05, and 12.16 at pre-intervention, post-intervention 1, and post-intervention 2, respectively) dimensions. The findings confirm the effectiveness of this low-cost, simple, and easy-to-use ergonomic intervention.

- **Keywords:** Ergonomic intervention; Office workers; Biofeedback; Petrochemical plant

Vicki Komisar, Konika Nirmalanathan, Emily C. King, Brian E. Maki, Alison C. Novak. *Use of handrails for balance and stability: Characterizing loading profiles in younger adults. Pages 20-31.*

Well-designed handrails significantly enhance balance recovery, by allowing users to apply high forces to the rail and stabilize their center of mass. However, data on user-applied handrail forces during balance recovery are limited. We characterized the peak forces that 50 young adults applied to a handrail during forward and backward falling motions; quantified effects of handrail height (34, 38, 42 inches) and position prior to balance loss (standing beside the rail with or without hand contact, or facing the handrail with two-handed contact); and examined the relationship between handrail forces and individual mass. The testing environment consisted of a robotic platform that translated rapidly to destabilize participants, and a height-adjustable handrail that was mounted to the platform. Our findings support our hypotheses that starting position and handrail height significantly affect peak handrail forces in most axes. The highest handrail forces were applied when participants faced the handrail and grasped with two hands. In these cases, increased handrail height was associated with increased anterior forces and decreased downward, upward and resultant forces. As hypothesized, peak handrail forces correlated strongly with individual weight in most axes. Implications of these findings for handrail design are discussed.

- **Keywords:** Balance recovery; Kinetics; Handrail design

Stefan Oliv, Ewa Gustafsson, Adnan Noor Baloch, Mats Hagberg, Helena Sandén. *The Quick Exposure Check (QEC) – Inter-rater reliability in total score and individual items. Pages 32-37.*

The development of musculoskeletal disorders has been linked to various risk factors in the work environment including lifting heavy loads, machine and materials handling, work postures, repetitive work, work with handheld vibrating tools, and work stress. The Quick Exposure Check (QEC) was designed to assess exposure to work-related musculoskeletal risk factors affecting the back, shoulder/arm, wrist/hand, and neck. We investigated the inter-rater reliability of the summary scores and individual items of the QEC by comparing two simultaneous assessments of 51 work tasks, performed by 14 different workers. The work tasks were mainly "light" to "moderately heavy". For total scores, the level of disagreement for shoulder/arm had a Relative Position of 0.13 (95% CI: 0.02; 0.23) and no statistically significant random disagreement. Percentage agreement was 63–100% for individual items and 71–88% for total score. Weighted Kappa of agreement for the individual items rated by the assessors were –0.94–0.77; highest for back motion, and lowest for wrist/hand position. The Swedish translation of the Quick Exposure Check has moderate to very good inter-rater reliability with fair to

slight levels of systematic disagreement. There was no statistically significant random disagreement.

- **Keywords:** Risk assesment; Ergonomics; Work related disorders

Dhananjay Singh Bisht, Mohammed Rajik Khan. *A novel anatomical woodworking chisel handle. Pages 38-47.*

A novel anatomically shaped ("anatomical") woodworking chisel handle was developed for wood scraping operation. 18 students participated in an evaluation study to compare the new handle against seven readymade handles of ¾-inch bench chisels in the context of a standard wood scraping task. A comfort questionnaire for hand tools (CQH) and a hand-based pain map were used for evaluating and comparing the handles. 'Functionality' and 'sweating' were found to be the most and least important comfort concerns, respectively. Maximum pain was reported at distal digit 1, and least pain at proximal digit 4. The anatomical handle was rated best for most of the comfort descriptors, least painful for most hand regions and took the least time for a standardized task.

- **Keywords:** Anatomical; Chisel; Wood scraping; Handle; Comfort; Pain

Aaron J. Derouin, Steven L. Fischer. *Validation of a three-dimensional visual target acquisition system for evaluating the performance effects of head supported mass. Pages 48-56.*

Night vision goggles (NVGs) enable aircrew to complete missions in the cover of night, but dramatically increase and alter the distribution of mass borne by the head. Our novel approach to visual target acquisition, based on Fitts' Law, was used to assess differences across three different performance metrics between low (L) and high (H) head supported mass (HSM) conditions. Fifteen healthy male participants completed time-optimal and reciprocal visual target acquisitions between target pairs arranged in four different movement trajectories. A significant interaction effect was found and subsequent post hoc analysis revealed that participants required more time to acquire the 20 mm target in the H-HSM condition. In the H-HSM condition participants had a higher error index during target acquisition and required more time to move off the target. Our approach demonstrates great promise in distinguishing performance decrements associated with the use of helmeted systems that include NVGs.

- **Keywords:** Fitts' Law; Head supported mass; Visual target acquisition performance

Alice Buso, Ninad Shitoot. *Sensitivity of the foot in the flat and toe off positions. Pages 57-63.*

The purpose of this study is to examine the differences in pressure sensitivity for areas of the foot in a toe-off position and with the feet on the ground. This data could provide a base for adapting the softness of different areas while designing footwear. 21 healthy subjects are asked to participate in a test where a researcher applies pressure with an advanced force gauge in 20 locations on the foot until the subject starts experiencing discomfort. Rigid shells of three sizes have been designed and 3D printed based on 3D foot scans. The test is performed in two positions: standing with load on the plantar surface and toe-off loading only the forefoot. The outcome is a pressure discomfort threshold map of the foot. Interestingly, in 16 locations the sensitivity was similar in both conditions (toe-off and complete foot on the ground). Especially, stretched areas showed increased sensitivity.

- **Keywords:** Foot; Sensitivity; Pressure discomfort; Pressure points; Footwear design

Alba Roda-Sales, Margarita Vergara, Joaquín L. Sancho-Bru, Verónica Gracia-Ibáñez, Néstor J. Jarque-Bou. *Effect of assistive devices on hand and arm posture during activities of daily living. Pages 64-72.*

Assistive devices (ADs) are products designed to overcome the grip strength and mobility difficulties produced by ageing and different pathologies. Nevertheless, little is known about the postural effect of such devices. This work aims to quantify this effect on the entire upper limb. Ten healthy right-handed subjects performed 13 activities of daily living (ADL) with normal products and 22 ADs and both arm (shoulder, elbow and wrist) and hand (grasp types and contacts) postures were analysed. ADs were found to affect upper limb postures in ADL, reducing the use of precision grasps in the right hand by 31.9% and increasing palm contact by 26% and 29.1% in right and left hands, respectively. Nevertheless, they were also found to increase shoulder flexion, elbow pronation and wrist deviation, which may be a drawback in some pathologies. Results may help in the selection of a suitable AD for enhancing ADL performance depending on the patient's limitations due to a particular pathology.

- **Keywords:** Assistive device; Activities of daily living; Upper limb posture; Grasp classification

Sindre Aske Høyland, Kari Anne Holte, Leif Jarle Gressgård, Kåre Hansen, Astrid Solberg. *Exploring multiple working arrangements in Norwegian engineering, procurement, and construction industry from a middle manager and supervisor perspective: A sociotechnical system perspective. Pages 73-81.*

With a scarcity of research on multiple working arrangements, the aim of the paper is to contribute empirical data from a Norwegian engineering, procurement, and construction enterprise that shed light on the challenges and benefits of a 14–21 working arrangement in itself and in relation to other working arrangements. We combine a sociotechnical system perspective with systematic content analysis using QSR NVivo, which reveals organizational complexity comprised of indirect, direct, positive, negative, and mutual interplays between various aspects of the enterprise, including processes and outcomes. We find that the 14–21 working arrangement, in combination with other factors of the work system, sets the premises for work processes and outcome factors that are both beneficial and challenging to individuals and the organization. We also find that work process factors, such as work and information flow as well as follow-up and facilitation, depend on the presence of, and dynamic coordination and communication among, individuals across the organization. This in turn requires a support network, work groups, and supervisors to be on the same working arrangement.

- **Keywords:** SEIPS; STS; Organizational complexity; EPC industry; Multiple working arrangements

Venerina Johnston, Elise M. Gane, Wendy Brown, Bill Vicenzino, Genevieve N. Healy, Nicholas Gilson, Michelle D. Smith. *Feasibility and impact of sit-stand workstations with and without exercise in office workers at risk of low back pain: A pilot comparative effectiveness trial. Pages 82-89.*

The aim of this study was to compare the feasibility and impact of sit-stand workstations plus advice, with or without exercise, on back pain and sitting time in office workers at risk of low back pain (LBP). Eligible participants (n=29/169; 17% overall) were

randomized to receive a sit-stand workstation and advice with (n=16) or without (n=13) progressive resistance exercise training for 4-weeks. Feasibility (recruitment, acceptability, adherence) and impact (LBP severity during a standardized standing task, workplace-sitting time) were assessed. Intervention acceptability (87.5% very satisfied) was good and adherence (60% completed all 12 exercise sessions) was satisfactory. Maximum LBP severity (mean difference of -1.3 (-2.0, -0.6) and workplace sitting time (82.7-99.3 min/8-hr workday reduction) were similarly reduced in both groups. The introduction of a sit-stand workstation with advice was feasible and achieved similar outcomes for LBP and workplace sitting time when administered with or without exercise.

- **Keywords:** Sit-stand workstation; Exercise; Low back pain

Marina Heiden, Camilla Zetterberg, Svend Erik Mathiassen. *Trunk and upper arm postures in paper mill work. Pages 90-96.*

The aim of this study was to assess postures and movements of the trunk and upper arm during paper mill work, and to determine the extent to which they differ depending on method of assessment. For each of 28 paper mill workers, postures and movements were assessed during three full shifts using inclinometer registration and observation from video. Summary metrics for each shift, e.g., 10th, 50th, and 90th posture percentile, were averaged across shifts and across workers. In addition, the standard deviation between workers, and the standard deviation between shifts within worker were computed. The results showed that trunk and arm postures during paper mill work were similar to other occupations involving manual materials handling, but the velocities of arm movements were lower. While postures determined by inclinometry and observation were similar on a group level, substantial differences were found between results obtained by the two methods for individual workers, particularly for extreme postures. Thus, measurements by either method on individuals or small groups should be interpreted with caution.

- **Keywords:** Exposure; Inclinometry; Observation

Amber R. Vocelle, Tony Trier, Laura Bix, Tamara Reid Bush. *A method for quantifying key components of the opening process for opening pouch-style packages containing medical devices. Pages 97-104.*

Healthcare-associated infections are a serious worldwide health concern. Although contaminated medical devices are an avenue for infection, little research has evaluated the techniques used to open sterile packages. The goal of this study was to develop a method to quantify aspects of the package opening process in accordance with opening guidelines and then to demonstrate this methodology through a small sample of clinicians opening two sizes of pouch-style packages. Using motion capture techniques, a method was designed to quantify 11 parameters associated with the opening process. The method was then tested with nine healthcare professionals. Results indicated that all participants crossed the sterile field when opening packages. When opening large packages, participants spent significantly more time over the simulated sterile field and there was a trend towards more manipulations as compared to opening smaller packages. This methodology can be used to quantify the opening process, compare opening practices, and for assessment during the learning process.

- **Keywords:** Healthcare-associated infection; Medical packaging; Motion capture methods

Sangeun Jin, Minsung Kim, Jihyeon Park, Minsung Jang, Kyuseok Chang, Daemin Kim. *A comparison of biomechanical workload between smartphone and smartwatch while sitting and standing. Pages 105-112.*

Increasing concerns about musculoskeletal disorders in the upper back arising from excessive daily use of the smartwatch have been widely validated by the rising prevalence of discomfort. This study explored the smartwatch as a potential ergonomic intervention over the smartphone. Fourteen healthy participants completed five tasks (application setting, calling, message typing, message checking and vocal message entry) with smartphone and smartwatch in both sitting and standing postures. The neck-shoulder kinematics and muscle activation levels were monitored to assess the effects of the tasks, devices, and postures. The results indicated greater head flexion, head rotation and shoulder abduction and greater muscle activities for smartwatch use compared to smartphone use, but the performance measure (i.e., elapsed time) was superior for smartwatch use in all tasks except message typing. Collectively, only short and simple tasks such as message checking and application setting should be conducted with the smartwatch.

- **Keywords:** Smartwatch; Smartphone; Head flexion

Marco De Angelis, Arjan Stuiver, Federico Fraboni, Gabriele Prati, Víctor Marín Puchades, Filippo Fassina, Dick de Waard, Luca Pietrantonì. *Green wave for cyclists: Users' perception and preferences.* Pages 113-121.

Several innovative measures in traffic control applied in Europe have successfully improved the comfort and safety of cycling, among which is the green waves for cyclists. Consecutive traffic lights are synchronised to create a green wave, increasing comfort and decreasing waiting times and related deliberate red-light running. This study focused on exploring the user acceptance of green wave systems and the user evaluation of six distinct interface designs (i.e. numeric-based countdown, dot-based vertical countdown, dot-based clockwise countdown, LED line, LED road surface, on-bike speed indicator). Results indicate a preference for three systems: numeric-based countdown, LED line and LED road surface. Results also show a significant influence of nationality on the evaluation of the interfaces. Based on our findings, we argue that the numeric-based countdown represents the most promising option for future adaptive green wave implementations. The outcomes of the present study represent a useful evidence and guidance for researchers, designers and decision makers in the field of green waves, mobility and traffic safety.

- **Keywords:** Green wave; User acceptance; User interface design

Matthew P. Mavor, Ryan B. Graham. *The effects of protective footwear on spine control and lifting mechanics.* Pages 122-129

Manual materials handling is often performed in hazardous environments where protective footwear must be worn; however, workers can wear different types of footwear depending on the hazards present. Therefore, the goal of this study was to investigate how three-dimensional lifting mechanics and trunk local dynamic stability are affected by different types of protective footwear (i.e. steel-toed shoes (unlaced boot), steel-toed boots (work boot), and steel-toed boots with a metatarsal guard (MET)). Twelve males and twelve females performed a repetitive lifting task at 10% of their maximum lifting effort, under three randomized footwear conditions. Footwear type influenced ankle range of motion (ROM). The work boot condition reduced ankle sagittal ROM ($p = 0.007$) and the MET condition reduced ankle ROM in the sagittal ($p = 0.004$), frontal ($p = 0.001$) and transverse ($p = 0.003$) planes. Despite these differences at the ankle, no other changes in participant lifting mechanics were observed.

- **Keywords:** Kinematics; Footwear; Local dynamic stability

Juhee Park, Woojin Park. *Functional requirements of automotive head-up displays: A systematic review of literature from 1994 to present.* Pages 130-146.

Despite the long history of automotive head-up displays (HUDs), what information they should display in different situations to best serve the driver remains unanswered. The lack of understanding hinders designing useful automotive HUD systems. In an effort to address this, the current study investigated the developer, researcher and user perspectives on the functional requirements of automotive HUDs through literature review. The review results indicated that: 1) the existing commercial HUDs perform largely the same functions as the conventional in-vehicle displays, 2) past research studies proposed various HUD functions for improving driver situation awareness and driving safety, 3) autonomous driving and other new technologies are giving rise to new HUD information, and 4) little research is currently available on HUD users' perceived information needs. Based on the review results, this study provides insights into the functional requirements of automotive HUDs and also suggests some future research directions for automotive HUD design.

- **Keywords:** Automotive head-up displays; Functional requirements; Head-up display design

Linda-Marie Lundqvist, Lars Eriksson. *Age, cognitive load, and multimodal effects on driver response to directional warning.* Pages 147-154.

Inattention can be considered a primary cause of vehicular accidents or crashes, and in-car warning signals are applied to alert the driver to take action even in automated vehicles. Because of age related decline of the older driver's abilities, in-car warning signals may need adjustment to the older driver. We therefore investigated the effects of uni-, bi- and trimodal directional warnings (i.e., light, sound, vibration) on young and older drivers' responses in a driving simulator. A young group of 15 drivers (20–25 years of age) and an older group of 16 drivers (65–79 years of age) participated. In the simulations, warning signal was presented at the left, the center, or the right in front of the participant. With a warning at the left, the center, and the right the correct response was to steer to the right, brake, and steer to the left, respectively. The main results showed the older drivers' responses were slower for each type of warning compared with the young drivers' responses. Overall, the responses were slower with an added cognitively loading task. The only multimodal type of warning inducing overall faster response than its constituent warning types was the vibration-sound, and only for the older drivers. Additionally, with the groups' responses collapsed, such a true multimodal effect on response time also showed for the center vibration-sound warning (i.e., braking response). The only multimodal warning showing clear reduction in response errors compared with its constituent warning types was the vibration-sound for the older drivers during extra cognitive load. The main conclusion is that older drivers can benefit from bimodal warning, as compared with unimodal, in terms of faster and more accurate response. The potential superiority of trimodal warning is nevertheless argued.

- **Keywords:** Multimodal; Multisensory; Bimodal; Trimodal; In-car warning

Amalia Vanacore, Antonio Lanzotti, Chiara Percuoco, Agostino Capasso, Bonaventura Vitolo. *Design and analysis of comparative experiments to assess the (dis-)comfort of aircraft seating.* Pages 155-163.

This paper focuses on the comparative assessment of comfort and discomfort (hereafter, (dis-)comfort) for aircraft seating. Subjective and objective data of seating (dis-)comfort were collected during an experiment involving 20 volunteers who tested 3 aircraft

double-seats in upright and reclined position. In order to minimize experimental uncertainty due to well-known noise factors (i.e. patterns of discomfort during the work week and during the work day, order of evaluation, inter-individual differences), experimental trials were performed according to a crossover design. Statistical data analysis aimed mainly at investigating (dis-)comfort differences across seat conditions; gender-based differences in perceived discomfort on different body parts; effect of sitting duration on perceived discomfort on different body parts. The experimental results show that differences across seat conditions impacted differently on perceived discomfort depending on gender, body parts and sitting duration. No significant differences in perceived discomfort across gender were evident for the lightweight seat in both upright and reclined positions. On the contrary, for both baseline configurations, perceived discomfort at head and neck areas was higher for males than for females. For all seat conditions, participants experienced a significant worsening of perceived comfort over time at shoulders, back, sacrum and thighs and, in addition, at upper body area (i.e. neck, arm and forearm) and knees only for seats in reclined position.

- **Keywords:** Aircraft seat; Seating discomfort; Seating comfort; Discomfort index