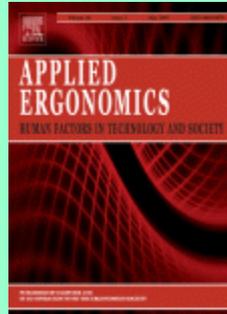


## **Applied Ergonomics - rok 2011, ročník 42**

### **Číslo 1 (December 2010)**



#### **Jaejin Hwang, Yong-Ku Kong, Myung-Chul Jung. *Posture evaluations of tethering and loose-housing systems in dairy farms.* Pages 1-8.**

The purpose of this study was to evaluate the most common simultaneous and individual segment postures in terms of body and finger posture classifications. Observations were made at three dairy farms. One employed a tethering system and the other two used loose-housing systems. The evaluations of the tethering system were performed through six processes that were subdivided into 11 operations, whereas only one process of 'milking' was investigated in loose-housing systems. Generally, farmers who worked in both systems bent and/or twisted their upper-body segments and continuously used a power grasp to wrap an object with all five fingers. Posture analyses of the tethering system revealed that 'moving corn' seemed less stressful, whereas 'cleaning udders,' 'attaching the machine,' 'washing the machine,' and 'sweeping the floor' were more stressful than other operations. Postural workloads on the trunk and head were greater in the tethering system than in the loose-housing systems due to differences in implements, the working height, and the working distance.

- **Keywords:** Simultaneous posture; Individual posture; Body posture; Finger posture; Milking system

#### **Laura A. Frey Law, Jennifer E. Lee, Tara R. McMullen, Ting Xia. *Relationships between maximum holding time and ratings of pain and exertion differ for static and dynamic tasks.* Pages 9-15.**

Ratings of perceived discomfort (0 to 10 scale) have been used to estimate relative maximum holding times (%MHT), particularly for static tasks. A linear 1:10% ratio has been described, where a rating of 5 corresponds to 50%MHT. It is unknown whether this linear ratio is valid for dynamic tasks. Additionally, whether pain or exertion are the primary predictors of discomfort is not clear. Thus, the goal of this study was to investigate both pain and exertion ratings during static (50% maximum;  $N = 42$ ) and dynamic (75% maximum;  $N = 34$ ) elbow flexion tasks until failure. Gender, self-reported physical activity, and peak torque were also assessed. Pain and exertion ratings reasonably matched the 1:10% ratio during the static task but not during the dynamic task. Exertion related more strongly to MHT than pain in both tasks. Neither gender nor activity level appeared to influence perceptual ratings, but peak torque explained approximately 20% of the variance in MHT.

- **Keywords:** Muscle fatigue; Discomfort; Isometric; Isokinetic

**Hamed Fazlollahtabar. *A subjective framework for seat comfort based on a heuristic multi criteria decision making technique and anthropometry.* Pages 16-28.**

Consumer expectations for automobile seat comfort continue to rise. With this said, it is evident that the current automobile seat comfort development process, which is only sporadically successful, needs to change. In this context, there has been growing recognition of the need for establishing theoretical and methodological automobile seat comfort. On the other hand, seat producer need to know the costumer's required comfort to produce based on their interests. The current research methodologies apply qualitative approaches due to anthropometric specifications. The most significant weakness of these approaches is the inexact extracted inferences. Despite the qualitative nature of the consumer's preferences there are some methods to transform the qualitative parameters into numerical value which could help seat producer to improve or enhance their products. Nonetheless this approach would help the automobile manufacturer to provide their seats from the best producer regarding to the consumers idea. In this paper, a heuristic multi criteria decision making technique is applied to make consumers preferences in the numeric value. This Technique is combination of Analytical Hierarchy Procedure (AHP), Entropy method, and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS). A case study is conducted to illustrate the applicability and the effectiveness of the proposed heuristic approach.

- **Keywords:** Automobile seat comfort; Conceptual framework; Multi criteria decision making

**Li Lan, Zhiwei Lian, Li Pan. *The effects of air temperature on office workers' well-being, workload and productivity-evaluated with subjective ratings.* Pages 29-36.**

Productivity bears a close relationship to the indoor environmental quality (IEQ), but how to evaluate office worker's productivity remains to be a challenge for ergonomists. In this study, the effect of indoor air temperature (17 °C, 21 °C, and 28 °C) on productivity was investigated with 21 volunteered participants in the laboratory experiment. Participants performed computerized neurobehavioral tests during exposure in the lab; their physiological parameters including heart rate variation (HRV) and electroencephalograph (EEG) were also measured. Several subjective rating scales were used to tap participant's emotion, well-being, motivation and the workload imposed by tasks. It was found that the warm discomfort negatively affected participants' well-being and increased the ratio of low frequency (LF) to high frequency (HF) of HRV. In the moderately uncomfortable environment, the workload imposed by tasks increased and participants had to exert more effort to maintain their performance and they also had lower motivation to do work. The results indicate that thermal discomfort caused by high or low air temperature had negative influence on office workers' productivity and the subjective rating scales were useful supplements of neurobehavioral performance measures when evaluating the effects of IEQ on productivity.

- **Keywords:** Air temperature; Productivity; Workload; Motivation; Well-being

**Margaret McCallig, Gurmail Paddan, Eric Van Lente, Ken Moore, Marie Coggins. *Evaluating worker vibration exposures using self-reported and direct observation estimates of exposure duration.* Pages 37-45.**

The objective of this study was to compare objective and subjective methods of collecting exposure time data for hand arm vibration (HAV) and whole-body vibration (WBV), and to evaluate the impact of inaccurate exposure times' on the calculation of the average vibration exposure over an 8 h working day A(8). The study was carried out in the

engineering services and maintenance departments of a construction and property management company. Worker exposure time data was collected using three methods, questionnaire surveys, daily worker interviews and 8 h direct workplace observations. Vibration magnitudes ( $m/s^2$ ) were measured for a range of hand tools and vehicles, and daily vibration exposure estimates A(8) were calculated using exposure times observed, reported in interview and self reported in the questionnaire. Results from the study showed that self-reported exposure time estimates from the questionnaire survey were a factor of 9.0 (median value) times greater for HAV and a factor of 6.0 (median value) times greater for WBV when compared with direct observation estimates. Exposure times reported in interview were higher, than those observed, but more reliable than those self reported in the questionnaire; a factor of 2.1 (median value) times greater for HAV and a factor of 1.4 (median value) times greater for WBV. A(8) values calculated using questionnaire exposure times were up to 66% and 75% greater for sources of HAV and WBV respectively when compared to A(8) values calculated using observed exposure times. For the purposes of carrying out a reliable risk assessment, results from this study indicate that direct measurements of worker exposure time are not recommended over questionnaires especially where work is highly variable for example in construction and property management. Worker interviews or direct workplace observation methods were found to be reliable alternative methods for collecting exposure time.

- **Keywords:** Hand arm vibration; Whole body vibration; Exposure assessment

**Marius Brazaitis, Sigitas Kamandulis, Albertas Skurvydas, Laura Daniusevičiūtė. *The effect of two kinds of T-shirts on physiological and psychological thermal responses during exercise and recovery.* Pages 46-51.**

The aim of this study was to investigate the physiological and psychological responses during and after high-intensity exercise in a warm and humid environment in subjects wearing shirts of different fabrics. Eight healthy men exercised on two separate occasions, in random order, wearing two types of long-sleeve T-shirt: one made of polyester (PES) and the other of cotton fabric (CT). They performed three 20 min exercise bouts, with 5 min rest between each, and then rested in a chair for 60 min to recover. The ambient temperature was 25 °C and relative humidity was 60%. The exercise comprised of treadmill running at 8 km/h at 1° grade. Rectal temperature, skin temperatures at eight sites, heart rate, T-shirt mass and ratings of thermal, clothing wettedness, and shivering/sweating sensation were measured before the experiment, during the 5 min rest period after each exercise bout, and during recovery. Nude body mass was measured before the experiment and during recovery. The physiological stress index showed that the exercise produced a state of very high heat stress. Compared with exercise wearing the CT shirt, exercise wearing the PES fabric produced a greater sweating efficiency and less clothing regain (i.e., less sweat retention), but thermophysiological and subjective sensations during the intermittent high-intensity exercise were similar for both fabrics. However, skin temperature returned to the pre-exercise level faster, and the thermal and rating of shivering/sweating sensation were lower after exercise in the warm and humid environment in subjects wearing PES than when wearing the more traditional CT fabric.

- **Keywords:** Heat stress; Thermal comfort; Rectal and skin temperature; Physiological stress index

**Rebecca Tremaine, Jill Dorrian, Leon Lack, Nicole Lovato, Sally Ferguson, Xuan Zhou, Greg Roach. *The relationship between subjective and objective sleepiness and performance during a simulated night-shift with a nap countermeasure.* Pages 52-61.**

The aim of the present study was to investigate the relationship between perceived and actual sleepiness and performance during a simulated night-shift that included a 30-min night-nap as an on-duty sleepiness countermeasure. Twenty-four healthy young adults (nine males, fifteen females) participated in a repeated measures design comprising two experimental conditions: no night-nap and 30-min night-nap. Both groups were given a 2-h prophylactic afternoon sleep opportunity (1500–1700 h). Measures of subjective sleepiness (Stanford Sleepiness Scale, Karolinska Sleepiness Scale and Visual Analogue Scale), objective sleepiness (sleep latency tests), objective performance (Symbol-Digit Substitution Task) and reaction time (Psychomotor Vigilance Task) were taken before the night-nap (0230 h) and at several intervals post-nap. Time-series correlation analyses indicated that subjective sleepiness was less correlated with objective sleepiness and objective performance when participants were given a 30-min night-nap. However subjective sleepiness and reaction time performance was strongly correlated in both conditions, and there was no significant difference between the nap and no-nap conditions. Consistent with previous research, results of the present study indicate that subjective and objective indicators of sleepiness and performance may not always correspond, and this relationship may be reduced by the inclusion of a night-nap.

- **Keywords:** Subjective sleepiness; Objective sleepiness; Night-nap

**Andreas Lumbe Aas, Torbjørn Skramstad. A case study of ISO 11064 in control centre design in the Norwegian petroleum industry. Pages 62-70.**

In 2006–2008 we performed a case study for the purpose of assessing the industrial application of the seven part Control Centre (CC) design standard ISO 11064 to identify positive and negative experiences among stakeholders in the Norwegian petroleum sector. We mainly focused on ISO 11064 Part 1, because this was the most commonly used among the identified stakeholders. ISO 11064 is generally appreciated and applied in the industry, but we did observe a significant variance in use between the different parts of the standard. We also identified potential areas for improvements, like scope and application adaptation. Thus we suggest a more goal-based approach based on one normative part only.

- **Keywords:** Human factors; Control centre; Control room design standard; Ergonomics standard; Prescriptive; Offshore; Oil and gas

**Sally A. Ferguson, Angela A. Baker, Nicole Lamond, David J. Kennaway, Drew Dawson. Sleep in a live-in mining operation : the influence of start times and restricted non-work activities. Pages 71-75.**

The amount of sleep obtained between shifts is influenced by numerous factors including the length of work and rest periods, the timing of the rest period relative to the endogenous circadian cycle and personal choices about the use of non-work time. The current study utilised a real-world live-in mining environment to examine the amount of sleep obtained when access to normal domestic, family and social activities was restricted. Participants were 29 mining operators (26 male, average age  $37.4 \pm 6.8$  years) who recorded sleep, work and fatigue information and wore an activity monitor for a cycle of seven day shifts and seven night shifts (both 12 h) followed by either seven or fourteen days off. During the two weeks of work participants lived on-site. Total sleep time was significantly less ( $p < 0.01$ ) while on-site on both day ( $6.1 \pm 1.0$  h) and night shifts ( $5.7 \pm 1.5$  h) than days off ( $7.4 \pm 1.4$  h). Further, night shift sleep was significantly shorter than day-shift sleep ( $p < 0.01$ ). Assessment of subjective fatigue ratings showed that the sleep associated with both days off and night shifts had a greater recovery value than sleep associated with day shifts ( $p < 0.01$ ). While on-site, participants obtained only 6 h of sleep indicating that the absence of competing domestic, family and social activities did not convert to more sleep. Factors including shift start times and circadian influences appear to have been more important.

- **Keywords:** Sleep; Shiftwork; Mining; Fatigue

**N. Theberge, W.P. Neumann. *Doing 'organizational work' : expanding the conception of professional practice in ergonomics. Pages 76-84.***

Literature on ergonomic practice contains many discussions of how ergonomists *should* work but far less attention has been paid to how they *do* work and the factors that influence their practice. In an effort to improve our understanding of ergonomic practice as it occurs and how it is conditioned by broader contexts, we conducted an interview study with 21 ergonomists in Canada. We were particularly interested to understand the different kinds of activities study participants engaged in during the course of their work, the challenges they faced and the strategies they employed for facing these challenges. Findings indicate that in the course of their professional practice ergonomists engage in a variety of types of activities. This includes consulting on risk factors as well as a proactive role of fostering the application of ergonomics in organizations. The process of advocating for ergonomics brought study participants into a variety of interactions and collaborations with workplace parties in a type of activity we have called "organizational work". In the course of doing organizational work, ergonomists utilize different strategies, including "political manoeuvring", tailoring data collection and report presentations to clients' concerns and 'goal hooking' in order to make the case for implementing ergonomics in workplaces. The article concludes with a list of "tips" for practicing ergonomists that are suggested by the analysis.

- **Keywords:** Ergonomics; Professional practice; Organizational work

**Leena Korpinen, Rauno Pääkkönen. *Self-reported use of ICT (Information and communication technology) uptake in 2002 and discomfort amongst Finns aged 45–66. Pages 85-90.***

In recent years the use of new technical equipment and the Internet by middle-aged people has increased. This paper presents middle-aged people's (45 years old or older) usage of new technical equipment and analyses how their (2704 persons) symptoms are associated with the equipment. Over 70% of Finland's middle-aged population use mobile phones daily and less than 30% use desktop computers at leisure. For example, over 80% of middle-aged people had sometimes or often experienced pain, numbness or aches in the neck and about 70% had aches in the hip and lower back. The use of new technical equipment among the group of people who are outside working life was smaller than the people's usage in general. In the future, when new technical equipment is developed, it is important to take into account, that people (outside working life) do not use, e.g., the Internet as much as people in general. The working environment will be much more ergonomic also at home and the Internet services will be easy to use for almost everyone, even those who have little experience or knowledge of computers and the Internet.

- **Keywords:** Middle-aged people; Questionnaire study; Computer; Symptoms

**Bert H. Jacobson, Ali Boolani, Guy Dunklee, Angela Shepardson, Hom Acharya. *Effect of prescribed sleep surfaces on back pain and sleep quality in patients diagnosed with low back and shoulder pain. Pages 91-97.***

The purpose of this study was to assess sleep quality and comfort of participants diagnosed with low back pain and stiffness following sleep on individually prescribed mattresses based on dominant sleeping positions. Subjects consisted of 27 patients (females,  $n = 14$ ; males,  $n = 13$ ; age 44.8 yrs  $\pm$  SD 14.6, weight 174 lb.  $\pm$ SD 39.6, height 68.3 in.  $\pm$  SD 3.7) referred by chiropractic physicians for the study. For the

baseline (pretest) data subjects recorded back and shoulder discomfort, sleep quality and comfort by visual analog scales (VAS) for 21 days while sleeping in their own beds. Subsequently, participants' beds were replaced by medium-firm mattresses specifically layered with foam and latex based on the participants' reported prominent sleeping position and they again rated their sleep comfort and quality daily for the following 12 weeks. Analysis yielded significant differences between pre- and post means for all variables and for back pain, we found significant ( $p < 0.01$ ) differences between the first posttest mean and weeks 4 and weeks 8–12, thus indicating progressive improvement in both back pain and stiffness while sleeping on the new mattresses. Additionally, the number of days per week of experiencing poor sleep and physical discomfort decreased significantly. It was concluded that sleep surfaces are related to sleep discomfort and that is indeed possible to reduce pain and discomfort and to increase sleep quality in those with chronic back pain by replacing mattresses based on sleeping position.

- **Keywords:** Mattress; Back; Pain; Stiffness; Sleep quality; Position

**Christian Korunka, Elisabeth Dudak, Martina Molnar, Peter Hoonakker. *Predictors of a successful implementation of an ergonomic training program. Pages 98-105.***

Job, organizational and individual predictors of a successful implementation of an ergonomic training program were evaluated in a single-case study. The conceptual model of learning transfer of Baldwin and Ford (1988) was adapted for an ergonomic context. 116 employees in a large production company underwent a comprehensive ergonomic training. Transfer of training into practice was measured by the number of ergonomic improvements which were realized in the company in the years after the training. Job, organizational and individual variables explained 35% of the variance of learning transfer in to the organization. Psycho-social resistance attitudes and management support were found to be the most important predictors of implementation failure and success.

- **Keywords:** Ergonomic training program; Learning transfer

**William L. Porter, Alan G. Mayton, Susan M. Moore. *Pressure distribution on the anatomic landmarks of the knee and the effect of kneepads. Pages 106-113.***

This study examines stress transmitted to anatomic landmarks of the knee (patella, combined patella tendon and tibial tubercle) while in static kneeling postures without kneepads and while wearing two kneepads commonly worn in the mining industry. Ten subjects (7 male, 3 female) simulated postures utilized in low-seam mines: kneeling in full flexion; kneeling at 90° of knee flexion; and kneeling on one knee while in one of three kneepad states (no kneepads, non-articulated kneepads, and articulated kneepads). For each posture, peak and mean pressure on the anatomic landmarks of the knee were obtained. The majority of the pressure was found to be transmitted to the knee via the combined patellar tendon and tibial tubercle rather than through the patella. While the kneepads tested decreased the maximum pressure experienced at the combined patellar tendon and tibial tubercle, peak pressures of greater than 25 psi were still experienced over structures commonly injured in mining (e.g. bursa sac – bursitis/Miner's Knee). The major conclusion of this study is that novel kneepad designs that redistribute the stresses at the knee across a greater surface area and to other regions of the leg away from key structures of the knee are needed.

- **Keywords:** Mining; Workplace activity; Knee

**Jian-Ping Liu, Chong Zhang, Chong-Xun Zheng. *Estimation of the cortical functional connectivity by directed transfer function during mental fatigue*. Pages 114-121.**

In this paper, the directed transfer function (DTF) method is used to characterize changes in the functional coupling of EEG rhythms in different brain cortical areas due to the mental fatigue caused by long-term cognitive tasks. There is a parietal-to-frontal functional coupling of the total (0.5–30 Hz) EEG frequency band in the right and middle brain cortical areas during the pre-task period, and an inversion of that direction, even a significant prevalence of the frontal-to-parietal direction, after the completion of the task. When mental fatigue levels increase, the parietal-to-frontal functional coupling of the alpha (8–12 Hz) frequency band is weakened, and the beta (13–30 Hz) frequency band changes from a balanced directionality of the functional cortical coupling to frontal-to-parietal functional coupling, whereas the frontal-to-center functional coupling of the total frequency band is enhanced in the right hemisphere, and the frontal-to-center functional coupling of the beta frequency band is heightened in the left hemisphere. Meanwhile, in the central cortical area, the middle-to-left functional coupling of the total, beta and alpha frequency bands increases significantly and the middle-to-right functional coupling of the total and beta frequency bands increases significantly after the task as compared to the pre-task period. These findings suggest that the functional coupling of the frontal, central and parietal brain cortical areas is strongly correlated with a change in mental fatigue levels in the wake–fatigue transition. The experimental results indicate that the DTF method can effectively explore the change of the direction and strength of the information flow underlying cortical-to-cortical functional coupling when mental fatigue is increased by long-term cognitive work. The DTF method may open a promising way to study mental fatigue.

- **Keywords:** Mental fatigue; Electroencephalogram (EEG); Directed transfer function (DTF)

**Wei-Cheng Chao, Eric Min-yang Wang. *An approach to estimate body dimensions through constant body ratio benchmarks*. Pages 122-130.**

Building a new anthropometric database is a difficult and costly job that requires considerable manpower and time. However, most designers and engineers do not know how to convert old anthropometric data into applicable new data with minimal errors and costs (Wang et al., 1999). To simplify the process of converting old anthropometric data into useful new data, this study analyzed the available data in paired body dimensions in an attempt to determine constant body ratio (CBR) benchmarks that are independent of gender and age. In total, 483 CBR benchmarks were identified and verified from 35,245 ratios analyzed. Additionally, 197 estimation formulae, taking as inputs 19 easily measured body dimensions, were built using 483 CBR benchmarks. Based on the results for 30 recruited participants, this study determined that the described approach is more accurate and cost-effective than alternative techniques.

- **Keywords:** Anthropometry; Constant body ratio benchmarks; Estimation formula

**Xiaopeng Ning, Gary A. Mirka. *The effect of sinusoidal rolling ground motion on lifting biomechanics*. Pages 131-137.**

The objective of this study was to quantify the effects of ground surface motion on the biomechanical responses of a person performing a lifting task. A boat motion simulator (BMS) was built to provide a sinusoidal ground motion (simultaneous vertical linear translation and a roll angular displacement) that simulates the deck motion on a small fishing boat. Sixteen participants performed lifting, lowering and static holding tasks under conditions of two levels of mass (5 and 10 kg) and five ground moving conditions. Each ground moving condition was specified by its ground angular displacement and

instantaneous vertical acceleration: A):  $+6^\circ$ ,  $-0.54 \text{ m/s}^2$ ; B):  $+3^\circ$ ,  $-0.27 \text{ m/s}^2$ ; C):  $0^\circ$ ,  $0 \text{ m/s}^2$ ; D):  $-3^\circ$ ,  $0.27 \text{ m/s}^2$ ; and E):  $-6^\circ$ ,  $0.54 \text{ m/s}^2$ . As they performed these tasks, trunk kinematics were captured using the lumbar motion monitor and trunk muscle activities were evaluated through surface electromyography. The results showed that peak sagittal plane angular acceleration was significantly higher in Condition A than in Conditions C, D and E ( $698^\circ/\text{s}^2$  vs.  $612\text{--}617^\circ/\text{s}^2$ ) while peak sagittal plane angular deceleration during lowering was significantly higher in moving conditions (conditions A and E) than in the stationary condition C ( $538\text{--}542^\circ/\text{s}^2$  vs.  $487^\circ/\text{s}^2$ ). The EMG results indicate that the boat motions tend to amplify the effects of the slant of the lifting surface and the external oblique musculature plays an important role in stabilizing the torso during these dynamic lifting tasks.

- **Keywords:** Lifting biomechanics; Ground motion; Fishing industry

**C. Melody Carswell, Cindy H. Lio, Russell Grant, Martina I. Klein, Duncan Clarke, W. Brent Seales, Stephen Strup. *Hands-free administration of subjective workload scales : Acceptability in a surgical training environment. Pages 138-145.***

**Introduction:** Subjective workload measures are usually administered in a visual-manual format, either electronically or by paper and pencil. However, vocal responses to spoken queries may sometimes be preferable, for example when experimental manipulations require continuous manual responding or when participants have certain sensory/motor impairments. In the present study, we evaluated the acceptability of the hands-free administration of two subjective workload questionnaires – the NASA Task Load Index (NASA-TLX) and the Multiple Resources Questionnaire (MRQ) – in a surgical training environment where manual responding is often constrained. **Method:** Sixty-four undergraduates performed fifteen 90-s trials of laparoscopic training tasks (five replications of 3 tasks – cannulation, ring transfer, and rope manipulation). Half of the participants provided workload ratings using a traditional paper-and-pencil version of the NASA-TLX and MRQ; the remainder used a vocal (hands-free) version of the questionnaires. A follow-up experiment extended the evaluation of the hands-free version to actual medical students in a Minimally Invasive Surgery (MIS) training facility. **Results:** The NASA-TLX was scored in 2 ways – (1) the traditional procedure using participant-specific weights to combine its 6 subscales, and (2) a simplified procedure – the NASA Raw Task Load Index (NASA-RTLX) – using the unweighted mean of the subscale scores. Comparison of the scores obtained from the hands-free and written administration conditions yielded coefficients of equivalence of  $r = 0.85$  (NASA-TLX) and  $r = 0.81$  (NASA-RTLX). Equivalence estimates for the individual subscales ranged from  $r = 0.78$  (“mental demand”) to  $r = 0.31$  (“effort”). Both administration formats and scoring methods were equally sensitive to task and repetition effects. For the MRQ, the coefficient of equivalence for the hands-free and written versions was  $r = 0.96$  when tested on undergraduates. However, the sensitivity of the hands-free MRQ to task demands ( $\eta_{\text{partial}}^2 = 0.138$ ) was substantially less than that for the written version ( $\eta_{\text{partial}}^2 = 0.252$ ). This potential shortcoming of the hands-free MRQ did not seem to generalize to medical students who showed robust task effects when using the hands-free MRQ ( $\eta_{\text{partial}}^2 = 0.396$ ). A detailed analysis of the MRQ subscales also revealed differences that may be attributable to a “spillover” effect in which participants’ judgments about the demands of completing the questionnaires contaminated their judgments about the primary surgical training tasks. **Conclusion:** Vocal versions of the NASA-TLX are acceptable alternatives to standard written formats when researchers wish to obtain global workload estimates. However, care should be used when interpreting the individual subscales if the object is to make comparisons between studies or conditions that use different administration modalities. For the MRQ, the vocal version was less sensitive to experimental manipulations than its written counterpart; however, when medical students rather than undergraduates used the vocal version, the instrument’s sensitivity increased well beyond that obtained with any other combination of

administration modality and instrument in this study. Thus, the vocal version of the MRQ may be an acceptable workload assessment technique for selected populations, and it may even be a suitable substitute for the NASA-TLX.

- **Keywords:** Minimally invasive surgery; Surgical training; Mental workload; Reliability; Usability metrics; Human factors evaluation; Administration procedures

**Miwa Nakanishi, Kei-ichiro Taguchi, Yusaku Okada. *Suggestions on the applicability of visual instructions with see-through head mounted displays depending on the task.* Pages 146-155.**

Task instructions have traditionally been communicated orally in many fields. However, recently more and more wearable displays, such as the see-through head mounted displays (HMDs) have been developed, and some studies have provided ideas on applying visual instruction using these new interfaces to particular situations. However, in some cases, where instructions are communicated amongst the workers, the data is not sufficient for field workers to choose the best way of communicating instructions depending on the situation. Thus, this study aims to clarify the cases in which it is effective to apply visual instructions with HMDs, and to provide information that suggests the applicability of such visual instructions instead of or in addition to the traditional auditory instructions in different situations. These suggestions will be a useful reference for workers in safety-critical fields, helping them make better decisions about whether, when, and where to introduce the new method of instructions. It will also address some of the unsolved problems in the field, such as errors, low efficiency, and discomfort in communication.

- **Keywords:** Instruction communication; Multi-modalities; HMD; SRK model; Human error

**Kihyo Jung, Ochaekwon, Heecheon You. *Evaluation of the multivariate accommodation performance of the grid method.* Pages 156-161.**

The present study examined the multivariate accommodation performance (MAP) of the grid method, a distributed representative human models (RHM) generation method, in the context of men's pants sizing system design. Using the 1988 US Army male anthropometric data and  $\pm 2.5$  cm of fitting tolerance, the grid method selected two key dimensions (waist girth and crotch height) out of 12 anthropometric dimensions and identified 25 RHMs to accommodate 95% of the population. The average MAP of the RHMs decreased dramatically as the number of anthropometric dimensions considered increased (99% for single dimension and 14% for 12 dimensions). A standardized regression model was established which explains the effects of two factors (sum of anthropometric dimension ranges; adjusted  $R^2$  between key dimensions and other anthropometric dimensions) on the MAP of RHMs. This regression model can be used to prioritize anthropometric dimensions for efficient MAP improvement of men's pants design.

- **Keywords:** Multivariate accommodation performance; Grid method; Representative human model generation; Anthropometry

**C. Balderrama, G. Ibarra, J. De La Riva, S. López. *Evaluation of three methodologies to estimate the  $VO_{2max}$  in people of different ages.* Pages 162-168.**

Aging and gender are factors that affect the variation of physical work capacity. The present paper highlights the importance of the metabolism used by ergonomics to

establish the appropriate limits of loads at work. This study compares the aerobic capacity of people from 20 to 71 years old split in 5 different groups. The laboratory experiment tested 33 volunteers (19 women and 14 men). A submaximal step test was used to measure the  $VO_2$  using a portable breath by breath metabolic system and a telemetric heart rate monitor. Three methods to estimate the  $VO_{2max}$  were compared: 1) a direct measurement of  $VO_2$ , 2) estimation by heart rate, and 3) a step test method using predetermined charts. Significant difference was encountered among the estimation methods as well as among the age ranges ( $F_{2,92} = 6.43, p < 0.05$  y  $F_{4,92} = 7.18, p < 0.05$  respectively). The method of direct measurement and the method of predetermined charts were different for the estimation of the  $VO_{2max}$  with a confidence level of 95%. The method of predetermined charts is better adapted for males and people younger than 30 years. The estimation through non invasive heart rate apparatus was a good appraiser of the maximal oxygen consumption considering both genders and all the age groups.

- **Keywords:** Maximal oxygen consumption; Submaximal test; Metabolic rate

**Elodie Chateauroux, Xuguang Wang. *Car egress analysis of younger and older drivers for motion simulation. Pages 169-177.***

This paper presents a detailed description of car egress motion by younger and older participants. The objective of these analyses is to gather knowledge about egress motion in order to simulate them using a Digital Human Model. Seven young (from 20 to 35 years old) and eighteen older volunteers (from 63 to 82 years old) participated in the experiment. Their ingress and egress motions were captured for 4 different types of car. Motions were reconstructed through inverse kinematics using the RPx Software and the RAMSIS® model. Motions were analysed through the interactions between the participant and the environment. Key-frames were defined in order to split the motions up. Two main car egress strategies were observed: 'Left Leg first' (LLF) and 'Two Legs Out' (TLO). Only older participants used the TLO strategy. For each strategy, a detailed motion description is presented together with the identification of sub-strategies and constraints. The motion descriptions and the constraints also help to better understand the difficulties of older people when getting out of a car. All motion constraints described in this study should be considered to simulate realistic egress motion.

- **Keywords:** Car accessibility; Digital human model; Motion simulation; Older drivers

**Molly Follette Story, Jack M. Winters, Melissa R. Lemke, Alan Barr, Elizabeth Omiatek, Ira Janowitz, David Brafman, David Rempel. *Development of a method for evaluating accessibility of medical equipment for patients with disabilities. Pages 178-183.***

**Objective:** The purpose of this study was to develop a method for evaluating accessibility of medical equipment for patients with disabilities. **Methods:** The researchers reviewed videotapes of patient-participants with various physical and sensory disabilities using different types of medical equipment. For each of 11 videotapes, four observers independently identified and documented access and safety barriers, such as physical, sensory, cognitive, and environmental barriers. Inter-observer variability for identifying barrier presence was assessed with kappa statistics for pairs of observers. **Results:** A list of 10 access and safety barriers was developed through an iterative consensus process, which identified design features of medical equipment that presented difficulties for participants with disabilities. The list is useful for identifying and categorizing accessibility problems found in equipment. While reliability of barrier identification was substantial or moderate for some barriers, reconciliation of barrier events identified by multiple video observers is recommended for optimal results.

**Myung-Chul Jung, DongHyun Park, Soo-Jin Lee, Kyung-Suk Lee, Dae-Min Kim, Yong-Ku Kong. *The effects of knee angles on subjective discomfort ratings, heart rates, and muscle fatigue of lower extremities in static-sustaining tasks.* Pages 184-192.**

The purpose of this study was to investigate the effects of knee-flexion angles on subjective discomfort ratings, heart rates, and muscle fatigue using median frequency (MDF) in a static-sustaining task. Thirty healthy participants maintained 13 postures including standing, squatting, sitting, and kneeling postures and then MDFs from the erector spinae, biceps femoris, vastus medialis, gastrocnemius, and tibialis anterior muscles, subjective discomfort, and heart rates were collected every 3 min during a sustained 15 min task. Results showed that the discomfort, heart rate and muscle fatigue were significantly influenced by the body postures. In general, standing and sitting postures showed less discomfort as well as lower heart rates, whereas squatting postures (KF120, KF90, KF60) had higher discomfort and heart rates. Three MDF change trends were reported associated with postures in this study. First, there were less changes of MDFs for standing and sitting postures; second, all patterns of MDFs for KF 150 and KF120 decreased, and lastly some MDFs had increasing trends and others showed decreasing trends for KF30, KF30T, and kneeling postures.

- **Keywords:** Knee angles; Median frequency; Subjective discomfort rating; Heart rate