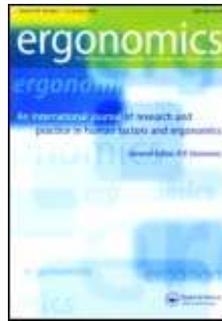


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Jürgen Sauer; Dina Burkolter; Annette Kluge; Sandrina Ritzmann; Kerstin Schüler. *The effects of heuristic rule training on operator performance in a simulated process control environment. S. 953–967.*

In complex work environments, the occurrence of novel system states represents a particular challenge for the design of training. This article is concerned with the use of heuristic rules to prepare operators for the management of unfamiliar fault states. An experiment was carried out to examine the effects of heuristic rule training on operator performance and system management behaviour. Thirty-nine trainee operators from the chemical industry took part in the study. They were trained for 4 h on a PC-based simulation of a process control task. Operators in the experimental group received training on heuristic rules while operators in the control group did not. One week later the operators participated in a 70-min testing session. While the results showed that heuristic rules training led to better diagnostic performance, it was also associated with increased operator fatigue and impaired secondary task performance. The implications of the findings for using heuristic rule training are discussed.

- **Keywords:** training; heuristic rule; process control; performance

Jan Johansson Hanse; Jørgen Winkel. *Work organisation constructs and ergonomic outcomes among European forest machine operators. S. 968–981.*

The aims of the study were to: 1) create work organisation constructs for forest machine operators; 2) examine relationships between these work organisation constructs and different ergonomic outcomes. The study was carried out among forest machine operators in six European countries and was based on a questionnaire survey (n = 358). Exploratory factor analysis (EFA) was used in the formation of the construct measures of work organisation. The EFA resulted in a five-factor structure. The factors were named 'job control', 'variation', 'job rotation', 'breaks' and 'rate of work'. Three multiple regression analyses were carried out separately for the dependent variables job satisfaction, musculoskeletal symptoms and headache/sleeping problems. All regression analyses resulted in significant overall models. The highest explained variance among the dependent variables was found for job satisfaction (R = 0.51, i.e. 'large' effect size). The unique contribution of the work organisation constructs varied in the models, but 'job rotation' contributed significantly in all regression models. The results may be used as a source for ergonomic improvements to work organisation. The present study was performed as part of the EU project 'ErgoWood', which resulted in a European handbook

for mechanised forest operations (Gellerstedt *et al.* 2005). The results delivered part of the evidence base for a toolbox in this handbook regarding changes in work organisation to improve health and performance.

- **Keywords:** logging; factor analysis; job satisfaction; musculoskeletal symptoms

R. Schleicher; N. Galley; S. Briest; L. Galley. *Blinks and saccades as indicators of fatigue in sleepiness warnings : looking tired?* S. 982–1010.

The present study examines changes in a variety of oculomotoric variables as a function of increasing sleepiness in 129 participants, who have been passed through a broad range of subjective alertness. Up to now, spontaneous eye blinks are the most promising biosignal for in-car sleepiness warnings. Reviewing the current literature on eye movements and fatigue, experimental data are provided including additional indicative oculomotoric parameters; inter-individual differences in the experiments were also assessed. Here, self-rated alertness decreased over six steps on average and proved itself a reliable measurement. Regarding oculomotoric parameters, blink duration, delay of lid reopening, blink interval and standardised lid closure speed were identified as the best indicators of subjective as well as objective sleepiness. Saccadic parameters and fixation durations also showed specific changes with increasing sleepiness. Substantial inter-individual differences in all of these variables were illustrated. Oculomotoric parameters were linked to three different components of sleepiness while driving: a) deactivation; b) decreasing attention, resulting in disinhibition of spontaneous blinks and reflexive saccades; c) increasing attempts of self-activation. Finally, implications for the development of drowsiness detection devices were discussed.

- **Keywords:** fatigue; subjective rating scales; blink, saccade; fixation; EOG

Sirkka Rissanen; Irma Jousela; Jeong-Rim Jeong; Hannu Rintamäki. *Heat stress and bulkiness of chemical protective clothing impair performance of medical personnel in basic lifesaving tasks.* S. 1011–1022.

The study examined the impact of chemical protective (CP) clothing on the performance of lifesaving tasks in thermoneutral and cold conditions. Eleven males performed pre-exercise followed by lifesaving tasks wearing either field combat uniform at 21°C (U) or CP clothing at 21°C (CPN) and -5°C (CPC). The tasks were ventilating a doll (VA) and connecting an intravenous line (IV). Mean skin temperature was significantly higher for CPN compared to U and CPC during pre-exercise, VA and IV. Changes in blood pressure were significantly greater with CP clothing than without during VA and IV. The number of breaths per min (in VA) and time needed for IV increased by 19% ($p < 0.05$) and 18%, respectively, for CPN compared to U. Due to the cold, the additional increment was 5% and 17%, respectively, for CPC. Wearing of CP clothing in thermoneutral or in cold conditions may not prevent but, especially in the cold, significantly impede the performance of basic medical tasks. The findings of this study showed that performing medical tasks while wearing nuclear, biological and chemical protective clothing is impaired due to significant changes in physiological strain. This suggests that realistic training in local conditions as well as in cold conditions is needed to realise the restrictions due to protective clothing.

- **Keywords:** NBC; paramedic; cannulation; ventilation assistance; cold strain; heat strain

V. L. Richmond; M. P. Rayson; D. M. Wilkinson; J. M. Carter; S. D. Blacker. *Physical demands of firefighter search and rescue in ambient environmental conditions.* S. 1023–1031.

This study investigated the physiological responses and limitations to a simulated search and rescue scenario in a high-rise building under ambient conditions. Sixteen firefighters performed the scenario under four conditions: standard duration breathing apparatus (SDBA) and 45 mm hose; extended duration breathing apparatus (EDBA) and 45 mm hose; SDBA and 70 mm hose; EDBA and 70 mm hose. Core temperature, skin temperature and heart rate were monitored. In four of 32 trials the casualty was rescued; the remainder of the trials were terminated for safety, high core temperature or shortage of air. Final core temperature and heart rate were higher in the EDBA (39.1°C; 72% heart rate reserve (HRR)) than SDBA conditions (38.6°C; 67%HRR). No differences were observed between hose sizes. The scenario proved too onerous to complete successfully in the majority of cases. Replacing SDBA with EDBA eliminates air supply as a limiting factor, but brings with it challenges of managing thermal strain.

- **Keywords:** firefighter; breathing apparatus; hose; high rise; core temperature

Diane E. Gregory; Sonia Narula; Samuel J. Howarth; Caryl Russell; Jack P. Callaghan. *The effect of fatigue on trunk muscle activation patterns and spine postures during simulated firefighting tasks.* S. 1032–1041.

The purpose of this study was to determine the effect of a fatiguing task (3 min intense stair climbing) on the adopted spinal postures and trunk muscular activation patterns during three highly physically demanding simulated firefighting tasks. Following the fatigue protocol, it was observed that individuals adopted significantly greater spinal flexion (16.3° maximum prior to fatigue as compared to 20.1° post fatigue) and displayed reduced abdominal muscle activation as compared to before the fatigue protocol (mean ranging from 16.6% maximum voluntary contraction (MVC) to 30.6% MVC prior to fatigue as compared to ranging from 14.6% MVC to 25.2% MVC post fatigue). The reduced abdominal activation may be due to a reduction in co-contraction during these tasks, which may compromise spinal stability. Reduced co-contraction combined with the increased spinal flexion may increase the risk of sustaining an injury to the low back.

- **Keywords:** ergonomics; firefighting; fatigue; EMG; spine posture; injury

J. Skotte; N. Fallentin. *Low back injury risk during repositioning of patients in bed: the influence of handling technique, patient weight and disability.* S. 1042–1052.

The objective of the study was to investigate the low back load during repositioning of patients in bed and to assess the influence of patient's weight and disability. Nine female health care workers (HCWs) carried out six patient-handling tasks with different patient weight (59 ± 1 , 83 ± 2 and 110 ± 4 kg) and handicap (hemiplegia, paraplegia and near-paralysis). The tasks were performed with optional use of simple, low-tech assistive devices (draw and sliding sheets). Peak low back compression exceeded the National Institute for Occupational Safety and Health action level of 3400 N in 25% of all trials (418). The influence of the HCW, i.e. the technique and assistive devices used, was higher than the effect of weight and disability in all tasks studied. ANOVA showed that on average for the six tasks 37%, 10% and 6% of the variance in low back loading was caused by variation in the factors HCW, patient's weight and disability, respectively. The result of this study is relevant for HCWs. It is shown that the repositioning technique and use of friction-reducing devices have higher influence on the low back load of the HCW than the patient's weight and disability.

- **Keywords:** repositioning of patients; handling technique; weight; disability; low back; compression

Marco J. M. Hoozemans; Idsart Kingma; Wiebe H. K. de Vries; Jaap H. van Dieën. *Effect of lifting height and load mass on low back loading. S. 1053–1063.*

The objective of this study was to quantify the effect of lifting height and mass lifted on the peak low back load in terms of net moments, compression forces and anterior-posterior shear forces. Ten participants had to lift a box using four handle heights. Low back loading was quantified using a dynamic 3-D linked segment model and a detailed electromyographic driven model of the trunk musculature. The effects of lifting height and lifting mass were quantified using a regression technique (GEE) for correlated data. Results indicate that an increase in lifting height and a decrease in lifting mass were related to a decrease in low back load. It is argued that trunk flexion is a major contributor to low back load. For ergonomic interventions it can be advised to prioritise optimisation of the vertical location of the load to be lifted rather than decreasing the mass of the load for handle heights between 32 cm and 155 cm, and for load masses between 7.5 and 15 kg. Lifting height and load mass are important determinants of low back load during manual materials handling. This paper provides the quantitative effect of lifting height and mass lifted, the results of which can be used by ergonomists at the workplace to evaluate interventions regarding lifting height and load mass.

- **Keywords:** lifting; lifting height; low back; spine; ergonomics

Bryan Buchholz; Jung-Soon Park; Judith E. Gold; Laura Punnett. *Subjective ratings of upper extremity exposures : inter-method agreement with direct measurement of exposures. S. 1064–1077.*

This study examined the agreement of subjective ratings of upper extremity exposures with corresponding direct measurements obtained simultaneously from workers. Psychophysical ratings of exposure, based on the Borg CR-10 scale, were obtained for the period of time in which direct measurements were acquired using electrogoniometers (wrist), electroinclinometers (shoulder) and electromyography (grip force). Subjects were selected from workers at two automobile manufacturing plants. Significant relationships between subjective ratings of wrist position and measured wrist posture or motion and between ratings of shoulder position and measured shoulder posture were not found. Ratings of manual effort were significantly correlated with directly measured grip force (% maximum voluntary contraction). Ratings of pace were significantly correlated with directly measured wrist motion and this relationship was strengthened with the addition of relative grip force as a covariate. Workers with hand/wrist symptoms provided ratings that were more strongly related to the directly measured exposures than those without symptoms. Self-report by workers is an alternative to more resource-intensive and invasive exposure assessment methods. However, the validity of workers' self-reported exposure assessments has been questioned. The objective of this study was to examine the agreement of selected questionnaire items with corresponding direct measurements from bioinstrumentation and to provide a better understanding of worker self-reports.

- **Keywords:** ergonomic exposure assessment; bioinstrumentation; electrogoniometry; electromyography; self-report; questionnaire

Pascal Madeleine; Michael Voigt; Svend Erik Mathiassen. *The size of cycle-to-cycle variability in biomechanical exposure among butchers performing a standardised cutting task. S. 1078–1095.*

The effects of employment duration and pain development on motor variability were investigated during repetitive work. Electromyographic (EMG) and kinematics data from two previous studies were re-analysed. Newly employed butchers were followed prospectively in relation to employment duration and pain development. Healthy

butchers with long-term experience were compared with novices. The variability of the cycle time, EMG ratio and arm and trunk movement was expressed as cycle-to-cycle standard deviations. During the first 6 months of employment, cycle time variability decreased, while posture and movement variability increased ($p < 0.05$). In presence of pain, the variability of the initial arm position decreased while it increased for the trunk ($p < 0.05$). Experienced butchers showed a larger variability than novices for work cycle and several kinematic variables, but a smaller EMG ratio variability ($p < 0.05$). These findings indicate that the variability of motor patterns in repetitive work changes with experience and pain. A change towards a more variable motor strategy may protect workers from work-related musculoskeletal disorders.

- **Keywords:** variation; work experience; motor control; pain; work-related musculoskeletal disorders

F. A. Fathallah; J. H. Chang; R. L. Berg; W. Pickett; B. Marlenga. *Forces required to operate controls on farm tractors : implications for young operators.* S. 1096-1108.

Farm tractors account for the majority of fatal injuries to adolescents working in agriculture and therefore remain a leading occupational priority. The question of whether these injuries occur because adolescents are assigned tractor jobs beyond their physical capabilities has not been answered. The purpose of this study was to estimate the activation forces required to operate controls on 40 tractors in common use in the US and compare them with existing estimates of physical strength for children of varying ages and with recommended ergonomic force limits for repeatedly engaging controls. Activation forces for steering, brakes and clutch were measured on each tractor. The main study finding was that the activation forces required to operate tractors typically exceeded the physical abilities of most children aged 13 to 17 years. This raises serious questions about the ability of children to safely operate tractors in common use on US farms. This study provides an ergonomic approach for evaluating the potential mismatch between young people's strength capabilities and forces required in operating farm tractors. This approach could be used in similar situations where adolescents may operate vehicles (e.g. all-terrain vehicles), machinery or other mechanical devices requiring activation of levers and controls. Study findings potentially inform the establishment of occupational policies surrounding tractor operation by young people.

- **Keywords:** agriculture; children; safety; strength

Jie Tang; Xudong Zhang; Zong-Ming Li. *Operational and maximal workspace of the thumb.* S. 1109-1118.

The purposes were to examine the workspace of the thumb during its operational (submaximal and random) movement and to compare the operational workspace with its maximal workspace. Fifteen female subjects with asymptomatic hands performed the thumb circumduction and operational motion. Linear and angular measurements of the thumb were obtained by a marker-based motion analysis system. During the circumduction, the linear ranges of motion of the thumb tip were 102.8 ± 9.9 mm and 130.7 ± 14.1 mm in abduction/adduction and flexion/extension directions, respectively, and the corresponding values for the operational motion were 67.3 ± 16.1 mm and 73.1 ± 18.0 mm, respectively. The angular ranges of motion of the carpometacarpal (CMC) and metacarpophalangeal joints during the operational motion were less than 65% of their maximal motion ranges. In addition, the CMC joint tended to move in directions oblique to its anatomical defined axes. The results of operational motion may provide guidelines for ergonomic design of thumb-operated tools and hand-held electronics devices.

- **Keywords:** hand; thumb; movement; operational; workspace