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J. Klein Hesselink; J. de Leede; A. Goudswaard. *Effects of the new fast forward rotating five-shift roster at a Dutch steel company. Pages 727 – 738.*

This article reports a field study of a shift roster change in a large steel producer. The changes in the roster are threefold: (1) from backward rotating to forward rotating; (2) from rather slow (three) to fast rotating (two consecutive shifts); (3) the number of days off after the night shifts was changed from two to three. Company data cover 1 year before and 1 year after the implementation of the new roster and involve all employees in the five-shift system (4600 workers) and all daytime workers (1450 workers) in technical and maintenance jobs as a control group. The study reports a decrease in absence figures (particularly on midterm sickness absence) of in total 0.6%. Furthermore, improvements in health indicators are presented, such as fatigue, musculoskeletal complaints, relationship work and health and workload in the year after implementation of the new roster. These positive effects are stronger for older workers (50 + years old). The results were significantly more positive for the shift workers compared with the control group. **Statement of Relevance:** This article reports an evaluation study of the largest continuous roster change in the Netherlands for decades: 4600 employees at Corus changed from a slowly backward rotating schedule to a fast forward rotating schedule. The effects are mainly positive (0.6% less absence in the first year; less fatigue). A positive association with age was also found: older workers benefit more.

- **Keywords:** absenteeism; effect evaluation; fatigue; health; shift roster design

Robert S. Bridger; Kate Brasher; Angela Dew; Kathy Sparshott; Shaun Kilminster. *Job strain related to cognitive failure in naval personnel. Pages 739 – 747.*

The Naval Service Stress Study (2007-2012) is investigating job strain, its characteristics, causes and distribution in the Service. Data from phases I, II and III of the study (January 2007, June 2007 and January 2008) were analysed to determine the relationship between General Health questionnaire scores and a score on the Cognitive Failures Questionnaire (CFQ) completed at phase III. Of 791 personnel who completed questionnaires at all phases, 43.6% had no job strain at any phase, whereas 9.9% had strain on all three occasions ('chronic strain'). 27% had strain at one of the three phases

and 19% had strain at two of the three phases. The particular phase at which job strain was experienced was not related to CFQ score at phase III, whereas the total strain experienced over the period was related. High strain over the year was the strongest predictor of high CFQ score. A 'strain dose' variable, which combined both the amount of strain exposure and the timing of the exposure, explained little additional variance in CFQ score. The findings might be interpreted to indicate that a high CFQ score is a vulnerability factor for adverse reactions to work stress. The hypothesis that recent job strain elevates CFQ score was not supported. **Statement of Relevance:**Current models of occupational stress focus on psychosocial factors and much of the advice about stress management in organisations is centred on the identification and control of psychosocial risk factors. The present paper provides evidence that cognitive factors are also important and suggests that support for those with poor executive function should be part of stress management in complex environments.

- **Keywords:** cognitive failure; Navy; occupational stress; psychological strain

R. Burgess-Limerick; V. Krupenia; G. Wallis; A. Pratim-Bannerjee; L. Steiner. *Directional control-response relationships for mining equipment. Pages 748 – 757.*

A variety of directional control-response relationships are currently found in mining equipment. Two experiments were conducted in a virtual environment to determine optimal direction control-response relationships in a wide variety of circumstances. Direction errors were measured as a function of control orientation (horizontal or vertical), location (left, front, right) and directional control-response relationships. The results confirm that the principles of consistent direction and visual field compatibility are applicable to the majority of situations. An exception is that fewer direction errors were observed when an upward movement of a horizontal lever or movement of a vertical lever away from the participants caused extension (lengthening) of the controlled device, regardless of whether the direction of movement of the control is consistent with the direction in which the extension occurs. Further, both the control of slew by horizontally oriented controls and the control of device movements in a frontal plane by the perpendicular movements of vertical levers were associated with relatively high rates of directional errors, regardless of the directional control-response relationship, and these situations should be avoided. **Statement of Relevance:**The results are particularly applicable to the design of mining equipment such as drilling and bolting machines, and have been incorporated into MDG35.1 *Guideline for bolting & drilling plant in mines* (Industry & Investment NSW, 2010). The results are also relevant to the design of any equipment where vertical or horizontal levers are used to control the movement of equipment appendages, e.g. cranes mounted to mobile equipment and the like.

- **Keywords:** control-response relationship; directional compatibility; equipment design; simulation; mining

J. H. Chang; F. A. Fathallah; W. Pickett; B. J. Miller; B. Marlenga. *Limitations in fields of vision for simulated young farm tractor operators. Pages 758 – 766.*

Farm tractors account for the majority of deaths and injuries among youths working on North American farms. A vehicle operator's field of vision is an important operational aspect for safe driving. However, very little is known about visual limitations of young tractor operators compared to adult operators. The main purpose of this study was to quantify limitations in fields of vision of children with different anthropometry. The study was based on assessment of 42 farm tractors in popular use in the USA. The results showed that youth operators typically had diminished fields of vision compared to the average adult operator. The degree of visual limitation is greatest for objects at close distances and when objects are straight in front of the operator/tractor. This has serious

implications in terms of risks for runovers, rollovers and collisions. Study findings may help illuminate the development of policies and guidelines in tractor-related jobs for children. **Statement of Relevance:** This study provides an ergonomic approach for evaluation of children's visual limitations in tractor operations. This approach could be used in other related cases, where children are allowed to operate vehicles.

- **Keywords:** agriculture; children; field of vision; safety; tractor

R. H. Y. So; B. Ngan; A. Horner; J. Braasch; J. Blauert; K. L. Leung. *Toward orthogonal non-individualised head-related transfer functions for forward and backward directional sound : cluster analysis and an experimental study. Pages 767 – 781.*

Individualised head-related transfer functions (HRTFs) have been shown to accurately simulate forward and backward directional sounds. This study explores directional simulation for non-individualised HRTFs by determining orthogonal HRTFs for listeners to choose between. Using spectral features previously shown to aid forward-backward differentiation, 196 non-individualised HRTFs were clustered into six orthogonal groups and the centre HRTF of each group was selected as representative. An experiment with 15 listeners was conducted to evaluate the benefits of choosing between six centre-front and six centre-back directional sounds rather than the single front/back sounds produced by MIT-KEMAR HRTFs. Sound localisation error was significantly reduced by 22% and 65% of listeners reduced their front-back confusion rates. The significant reduction was maintained when the number of HRTFs was reduced from six to five. This represents a preliminary success in bridging the gap between individual and non-individual HRTFs for applications such as spatial surround sound systems. **Statement of Relevance:** Due to different pinna shapes, directional sound stimuli generated by non-individualised HRTFs suffer from serious front-back confusion. The reported work demonstrates a way to reduce front-back confusion for centre-back sounds generated from non-individualised HRTFs.

- **Keywords:** HRTFs; binaural cues; cluster analyses; spectral cues; sound localisation

Deepti Majumdar; Madhu Sudan Pal; Dhurjati Majumdar. *Effects of military load carriage on kinematics of gait. Pages 782 – 791.*

Manual load carriage is a universal activity and an inevitable part of the daily schedule of a soldier. Indian Infantry soldiers carry loads on the waist, back, shoulders and in the hands for a marching order. There is no reported study on the effects of load on gait in this population. It is important to evaluate their kinematic responses to existing load carriage operations and to provide guidelines towards the future design of heavy military backpacks (BPs) for optimising soldiers' performance. Kinematic changes of gait parameters in healthy male infantry soldiers whilst carrying no load (NL) and military loads of 4.2-17.5 kg (6.5-27.2% body weight) were investigated. All comparisons were conducted at a self-selected speed. Soldier characteristics were: mean (SD) age 23.3 (2.6) years; height 172.0 (3.8) cm; weight 64.3 (7.4) kg. Walk trials were collected using a 3-D Motion Analysis System. Results were subjected to one-way ANOVA followed by Dunnett *post hoc* test. There were increases in step length, stride length, cadence and midstance with the addition of a load compared to NL. These findings were resultant of an adaptive phenomenon within the individual to counterbalance load effect along with changes in speed. Ankle and hip ranges of motion (ROM) were significant. The ankle was more dorsiflexed, the knee and hip were more flexed during foot strike and helped in absorption of the load. The trunk showed more forward leaning with the addition of a load to adjust the centre of mass of the body and BP system back to the NL condition. Significant increases in ankle and hip ROM and trunk forward inclination ($\geq 10^\circ$) with lighter loads, such as a BP (10.7 kg), BP with rifle (14.9 kg) and BP with a light machine

gun (17.5 kg), may cause joint injuries. It is concluded that the existing BP needs design improvisation specifically for use in low intensity conflict environments. **Statement of Relevance:**The present study evaluates spatial, temporal and angular changes at trunk and limb joints during military load carriage of relatively lighter magnitude. Studies on similar aspects on the specific population are limited. These data can be used for optimising load carriage and designing ensembles, especially a heavy BP, for military operations.

- **Keywords:** angular displacement; kinematics; load carriage; ROM

Jaap H. van Dieën; Gert S. Faber; Romy C. C. Loos; P. Paul F.M. Kuijer; Idsart Kingma; Henk F. van der Molen; Monique H. W. Frings-Dresen. *Validity of estimates of spinal compression forces obtained from worksite measurements. Pages 792 – 800.*

Estimates of peak spinal compression in manual materials handling were compared between a state-of-the-art laboratory technique and a method applicable at the worksite. Nine experienced masons performed seven simulated tasks in a mock-up in the laboratory and nine matched masons were studied during actual performance of the same tasks at the worksite. From kinematic and kinetic data obtained in the laboratory, compression forces on the L5S1 joint were calculated. In addition, compression forces were estimated from the horizontal and vertical position of the blocks handled relative to the subject measured at the worksite. Comparison of group-averaged values showed that the worksite method underestimated peak compression by about 20%. Rank ordering of tasks for back load was, however, consistent between methods, supporting validity of the worksite method to compare different tasks or to determine the effects of ergonomic interventions with regard to mechanical back load. **Statement of Relevance:**This study validated a method that can be used by ergonomists to determine the effects of (characteristics of) manual materials handling tasks on back load at the worksite.

- **Keywords:** biomechanics; lifting; manual materials handling; spine; workload

Yoshiyuki Higuchi; Hiroyuki Izumi; Mashaharu Kumashiro. *Development of a simple measurement scale to evaluate the severity of non-specific low back pain for industrial ergonomics. Pages 801 – 811.*

This study developed an assessment scale that hierarchically classifies degrees of low back pain severity. This assessment scale consists of two subscales: 1) pain intensity; 2) pain interference. First, the assessment scale devised by the authors was used to administer a self-administered questionnaire to 773 male workers in the car manufacturing industry. Subsequently, the validity of the measurement items was examined and some of them were revised. Next, the corrected low back pain scale was used in a self-administered questionnaire, the subjects of which were 5053 ordinary workers. The hierarchical validity between the measurement items was checked based on the results of Mokken Scale analysis. Finally, a low back pain assessment scale consisting of seven items was perfected. Quantitative assessment is made possible by scoring the items and low back pain severity can be classified into four hierarchical levels: none; mild; moderate; severe. **Statement of Relevance:**The use of this scale devised by the authors allows a more detailed assessment of the degree of risk factor effect and also should prove useful both in selecting remedial measures for occupational low back pain and evaluating their efficacy.

- **Keywords:** categorical component analysis; Mokken scale analysis; occupational low back pain; questionnaire; severity evaluation

Mehmet Uygur; Paulo B. de Freitas; Slobodan Jaric. *Frictional properties of different hand skin areas and grasping techniques. Pages 812 – 817.*

High friction is crucially important in manipulation activities for reducing the hand grip forces and improving control of manipulative tasks. The aim of this study was to assess the coefficient of friction (COF) of various areas of hand skin. Static COF of nine different grasping techniques applied against two object coatings was assessed by means of the 'slip point' method in 16 participants. COF measures proved to be both highly reliable and considerably variable across participants (coefficients of variation ranging from 25 to 75%, depending on the applied grasp). COF was also higher in 'specialised' than in 'non-specialised' skin areas for grasping, as well as in palms, than in the tips of the fingers. The observed findings are of importance for optimisation of object manipulations and also emphasise the importance of measuring individual COF in ergonomic, biomechanics and motor control studies. **Statement of Relevance:**The results reveal prominent differences in skin friction not only across various areas of the hand, but also across participants. While the former finding is relevant for optimisation of manipulation activities, the latter emphasises the importance of assessment of individual COF in studies of hand function.

- **Keywords:** coefficient of friction; force; grip; manipulation

Dong-Eun Kim; Karen LaBat. *Design process for developing a liquid cooling garment hood. Pages 818 – 828.*

A liquid cooling garment (LCG) protects astronauts by providing cooling effects and preventing them from overheating. The objectives of this project were to improve fit and comfort of the original LCG hood of the MACS-Delphi garment and develop a new prototype. The project was conducted by researchers with different backgrounds: apparel design and physiology and psychology. A design process framework developed by LaBat and Sokolowski (1999) was used in order to help facilitate the process and aid in communication during the multi-disciplinary collaboration. Four crucial problems were identified: 1) the tubing layout that circulates water did not conform to the shape of the head and tubing distribution was not maximised; 2) a difficult stitching method was being used to attach tubing; 3) fabric sources were inconsistent; 4) the hood did not fit properly. Each problem was addressed, improvements implemented and a revised hood was developed. The hood was tested in an environmental chamber and demonstrated effective cooling. Revisions implemented for the LCG hood may be applied to revisions of the whole-body LCG. **Statement of Relevance:**The objectives of this project were to improve fit and comfort of the original LCG hood and develop a new prototype. The new prototype will increase safety of the astronauts by providing better heat extraction quality and improved fit and increased wearer comfort.

- **Keywords:** fit and size; functional clothing; liquid cooling garment; product design; thermal comfort