

This study examined the concurrent performance of military gunnery, robotics control and communication tasks in a simulated environment. More specifically, the study investigated how aided target recognition (AiTR) capabilities (delivered either through tactile or tactile + visual cueing) for the gunnery task might benefit overall performance. Results showed that AiTR benefited not only the gunnery task, but also the concurrent robotics and communication tasks. The participants' spatial ability was found to be a good indicator of their gunnery and robotics task performance. However, when AiTR was available to assist their gunnery task, those participants of lower spatial ability were able to perform their robotics tasks as well as those of higher spatial ability. Finally, participants' workload assessment was significantly higher when they teleoperated (i.e. remotely operated) a robot and when their gunnery task was unassisted. These results will further understanding of multitasking performance in military tasking environments. These results will also facilitate the implementation of robots in military settings and will provide useful data to military system designs.

- **Keywords:** human-robot interaction; military; multitasking; workload; individual differences

T. Manser; Steven K. Howard; David M. Gaba. *Adaptive coordination in cardiac anaesthesia: a study of situational changes in coordination patterns using a new observation system.* S. 1153–1178.

Patient care in hospital settings requires coordinated team performance. Studies in other industries show that successful teams adapt their coordination processes to the situational task requirements. This prospective field study aimed to test a new observation system and investigate patterns of adaptive coordination within operating room teams. A trained observer recorded coordination activities during 24 cardiac surgery procedures. The study tested whether different patterns occur during different phases of and between different types of surgical procedures (two-way multivariate ANOVA with repeated measure). A statistically significant increase was found in clinical and coordination activities in phases of the operation with high task interdependence. The highest level of 'coordination via the work environment' (i.e. an implicit coordination mechanism) was recorded during the actual procedure on the beating heart. These findings prove the sensitivity of the observation system developed and evaluated in this study and provide insight into patterns of adaptive coordination in cardiac anaesthesia. This study furthers our understanding of adaptive coordination as a cornerstone of effective team performance in complex work environments. Using a new observation system, it describes patterns employed by health care professionals in response to changing task demands in an acute patient care setting.

- **Keywords:** adaptive coordination; behavioural task analysis; cardiac anaesthesia; observation method; teamwork

Ulrika Aasa; Karl-Axel Ängquist; Margareta Barnekow-Bergkvist. *The effects of a 1-year physical exercise programme on development of fatigue during a simulated ambulance work task.* S. 1179 – 1194

The aim of the study was to evaluate the effects of individually prescribed physical exercise programmes on development of fatigue during the carrying of a loaded stretcher up and down the stairs. Nineteen ambulance personnel performed the training for 1 year. Testing occurred before and after 1 year of the training. Both the training group (n = 19) and the control group (n = 15) were assessed for physical capacity and lactate concentration in blood and ratings of perceived exertion during carrying a stretcher on the stairs. When comparisons were made between those who had been training three times/week for 1 year and the control group, lactate concentration was significantly decreased. In conclusion, markers of fatigue during stretcher carrying can be reduced by the use of individually prescribed physical exercise programmes.

- **Keywords:** training; prevention; physical demands; occupational; ambulance personnel

Ash M. Genaidy; Magda M. Rinder; Amal D. A-Rehim. *The work compatibility improvement framework : an assessment of the worker-work environment interaction in the manufacturing sector.* S. 1195–1218.

The manufacturing sector in the US is challenged by high health care costs and shortage of qualified workers, which are largely attributed to the degree of fit between the worker and work environment. In this regard, a healthy worker-work environment interface is a necessary and sufficient condition for the containment of health care costs and the retaining/attraction of highly qualified knowledge workers and should be based on the principles of optimum physical, cognitive and emotional health for the workers. In prior research, the Work Compatibility Improvement Framework (WCIF) was introduced as a vehicle to address these issues and was defined as the identification, improvement and maintenance of the well-being characteristics of the workforce and its interaction with the work environment through the application of engineering, medicine, management and human sciences methodologies, technologies and best practices. This paper advances WCIF by examining its applications in manufacturing with regard to the evaluation of working conditions impacting musculoskeletal/stress outcome measures. A study was conducted in a machining department of a bag packaging manufacturer in the Midwest of the United States. The work tasks were planned and executed with regard to the following aims: (1) to compute work compatibility as a function of work demands and energisers; (2) to establish whether the prevalence of musculoskeletal/stress disorders increases with a decrease in the quality of worker-work environment interface in terms of work compatibility level and other work factors such as shift and job category. A major finding is that a 'poor' work environment (a function of all work domains) results in musculoskeletal/stress disorders that are 105% and 67% higher than those for a 'good' work environment. The evening shift exhibited the poorest compatibility followed by the night shift relative to the day shift. Application of the work compatibility approach demonstrated the detection of non-added value work. It is essential to evaluate the various domains of worker-work environment interface to uncover the root causes that tend to sub-optimize the physical/cognitive/emotional health of the workforce. The WCIF was used to uncover the non-value added effort in the work process. These findings will have major implications for developing and implementing customised design interventions with the aim to maximise the benefit and reduce the cost of employees in a manufacturing enterprise. The study findings suggest that the WCIF should be pursued as a potential strategic tool for optimising human performance in an enterprise to create healthy workplaces.

- **Keywords:** human performance; methods and approaches; manufacturing; musculoskeletal and stress disorders

Claire A. Williams; Roger A. Haslam; David J. Weiss. *The Cochran-Weiss-Shanteau performance index as an indicator of upper limb risk assessment expertise.* S. 1219–1237.

Ergonomists and many other professionals apply ergonomics principles to musculoskeletal health problems. This study examines whether there are differences when it comes to judgement expertise concerning upper limb disorders (ULDs) between ergonomists and those with less ergonomics training. The Cochran-Weiss-Shanteau (CWS) performance index combines judgement consistency with discrimination into one CWS index. Fifty-eight professionals working in the musculoskeletal health area, from four different professions, judged the likelihood of staff complaining of ULDs in a number of written work scenarios containing ULD risk factors. A student group (n = 148) taking

an introductory ergonomics module was used as a reference. The ergonomists scored higher on the CWS index than all of the other groups, performing significantly better than all but the occupational health advisors. Performance improved with increased training level but not with experience. This study suggests that ergonomists are quantifiably different from other ergonomics advisors in their judgement performance in this context. Given the global cost of musculoskeletal disorders, assessing the expertise of those giving ergonomics advice for the management of musculoskeletal health is of great significance. This study presents a method for assessing judgement performance in ULD risk assessment, an important part of musculoskeletal health management.

- **Keywords:** musculoskeletal disorders; competence; professional practice; risk assessment

Michael Greig; Richard Wells. *A systematic exploration of distal arm muscle activity and perceived exertion while applying external forces and moments.* S. 1238–1257.

The purpose of this study was to systematically explore and describe the response of selected hand and forearm muscles during a wide range of static force and moment exertions. Twenty individuals with manual work experience performed exertions in power grip, pulp pinch and lateral pinch grips. Electromyography (EMG) from eight sites of the hand and forearm, grip force as well as ratings of perceived exertion (RPE) were monitored as each participant exerted approximately 350 short (5 s) static grip forces and external forces and moments. As expected, strong relationships were found between grip force alone without other actions and muscle activation. When the hand was used to grip and transmit forces and moments to the environment, the relationships between grip force and muscle activation were much weaker. Using grip force as a surrogate for forearm and hand tissue loading may therefore be misleading.

- **Keywords:** hand strength; grip; EMG; perceived exertion

K. P. Granata; P. Gottipati. *Fatigue influences the dynamic stability of the torso.* S. 1258–1271.

Fatigue in the extensor muscles of the torso affects neuromuscular recruitment and control of the spine. The goal of this study was to test whether fatigue influences stability of dynamic torso movements. A controlled laboratory experiment measured the change in the maximum finite-time Lyapunov exponent, λ_{\max} , before and after fatigue of the extensor muscles. Non-linear analyses were used to compute stability from the embedding dimension and Lyapunov exponent recorded during repetitive dynamic trunk flexion tasks. Torso extensor muscles were fatigued to 60% of their unfatigued isometric maximum voluntary exertion force then stability was re-measured. Independent variables included fatigue, task asymmetry and lower-limb constraint. λ_{\max} values increased with fatigue suggesting poorer dynamic stability when fatigued. Embedding dimension declined with fatigue indicating reduced dynamic complexity when fatigued. Fatigue-related changes in spinal stability may contribute to the risk of low-back injury during fatiguing occupational lifting tasks. The findings reported here indicate that one mechanism by which fatigue contributes to low back disorders may be spinal instability. This information may contribute to the development of ergonomic countermeasures to help prevent low back disorders.

- **Keywords:** low back; fatigue; stability; dynamics

Shuping Xiong; Ravindra S. Goonetilleke; Channa P. Witana; Emily Yim Lee Au. *Modelling foot height and foot shape-related dimensions.* S. 1272–1289.

The application of foot anthropometry to design good-fitting footwear has been difficult due to the lack of generalised models. This study seeks to model foot dimensions so that the characteristic shapes of feet, especially in the midfoot region, can be understood. Fifty Hong Kong Chinese adults (26 males and 24 females) participated in this study. Their foot lengths, foot widths, ball girths and foot heights were measured and then evaluated using mathematical models. The results showed that there were no significant allometry ($p > 0.05$) effects of foot length on ball girth and foot width. Foot height showed no direct relationship with foot length. However, a normalisation with respect to foot length and foot height resulted in a significant relationship for both males and females with R^2 greater than 0.97. Due to the lack of a direct relationship between foot height and foot length, the current practice of grading shoes with a constant increase in height or proportionate scaling in response to foot length is less than ideal. The results when validated with other populations can be a significant way forward in the design of footwear that has an improved fit in the height dimension.

- **Keywords:** anthropometry; allometry; footwear fit; midfoot; midfoot height; modelling; anatomy; foot