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AT THE FOREFRONT OF HF/E

Robinette, Kathleen M., Veitch, Daisy. *Sustainable Sizing*. Pages 657-664.

Objective: To provide a review of sustainable sizing practices that reduce waste, increase sales, and simultaneously produce safer, better fitting, accommodating products. **Background:** Sustainable sizing involves a set of methods good for both the environment (sustainable environment) and business (sustainable business). Sustainable sizing methods reduce (1) materials used, (2) the number of sizes or adjustments, and (3) the amount of product unsold or marked down for sale. This reduces waste and cost. The methods can also increase sales by fitting more people in the target market and produce happier, loyal customers with better fitting products. This is a mini-review of methods that result in more sustainable sizing practices. It also reviews and contrasts current statistical and modeling practices that lead to poor fit and sizing. Fit-mapping and the use of cases are two excellent methods suited for creating sustainable sizing, when real people (vs. virtual people) are used. These methods are described and reviewed. Evidence presented supports the view that virtual fitting with simulated people and products is not yet effective. **Conclusions:** Fit-mapping and cases with real people and actual products result in good design and products that are fit for person, fit for purpose, with good accommodation and comfortable, optimized sizing. While virtual models have been shown to be ineffective for predicting or representing fit, there is an opportunity to improve them by adding fit-mapping data to the models. This will require saving fit data, product data, anthropometry, and demographics in a standardized manner. For this success to extend to the wider design community, the development of a standardized method of data collection for fit-mapping with a globally shared fit-map database is needed. It will enable the world community to build knowledge of fit and accommodation and generate effective virtual fitting for the future. **Application:** A standardized method of data collection that tests products fit methodically and quantitatively will increase our predictive power to determine fit and accommodation, thereby facilitating improved, effective design. These methods apply to all products people wear, use, or occupy.

- **Keywords:** anthropometry, design strategies, fit-mapping, system design, workstation, test and evaluation

SPECIAL SECTION: IMPACT OF THOMAS WATERS ON THE FIELD OF ERGONOMICS, GUEST EDITORS: KERMIT G. DAVIS AND STEPHEN D. HUDOCK

Davis, Kermit G., Hudock, Stephen D. *Preface to the Special Section on the Impact of Thomas Waters on the Field of Ergonomics. Pages 665-666.*

Lu, Ming-Lun, Putz-Anderson, Vern, Garg, Arun, Davis, Kermit G. *Evaluation of the Impact of the Revised National Institute for Occupational Safety and Health Lifting Equation. Pages 667-682.*

Objective: The objective of this article is to evaluate the impact of the Revised National Institute for Occupational Safety and Health Lifting Equation (RNLE). BackgroundThe RNLE has been used extensively as a risk assessment method for prevention of low back pain (LBP). However, the impact of the RNLE has not been documented. **Methods:** A systematic review of the literature on the RNLE was conducted. The review consisted of three parts: characterization of the RNLE publications, assessment of the impact of the RNLE, and evaluation of the influences of the RNLE on ergonomic standards. The literature for assessing the impact was categorized into four research areas: methodology, laboratory, field, and risk assessment studies using the Lifting Index (LI) or Composite LI (CLI), both of which are the products of the RNLE. **Results:** The impact of the RNLE has been both widespread and influential. We found 24 studies that examined the criteria used to define lifting capacity used by the RNLE, 28 studies that compared risk assessment methods for identifying LBP, 23 studies that found the RNLE useful in identifying the risk of LBP with different work populations, and 13 studies on the relationship between LI/CLI and LBP outcomes. We also found evidence on the adoption of the RNLE as an ergonomic standard for use by various local, state, and international entities. **Conclusion:** The review found 13 studies that link LI/CLI to adverse LBP outcomes. These studies showed a positive relationship between LI/CLI metrics and the severity of LBP outcomes.

- **Keywords:** Revised NIOSH, Lifting Equation, lifting index, manual lifting, low back pain, impact

Garg, Arun, Kapellusch, Jay M. *The Cumulative Lifting Index (CULI) for the Revised NIOSH Lifting Equation: Quantifying Risk for Workers With Job Rotation. Pages 683-694.*

Objective: The objectives were to: (a) develop a continuous frequency multiplier (FM) for the Revised NIOSH Lifting Equation (RNLE) as a function of lifting frequency and duration of a lifting task, and (b) describe the Cumulative Lifting Index (CULI), a methodology for estimating physical exposure to workers with job rotation. **Background:** The existing FM for the RNLE (FME) does not differentiate between task duration >2 hr and <8 hr, which makes quantifying physical exposure to workers with job rotation difficult and presents challenges to job designers. **Method:** Using the existing FMs for 1, 2, and 8 hr of task durations, we developed a continuous FM (FMP) that extends to 12 hr per day. We simulated 157,500 jobs consisting of two tasks each and, using different combinations of Frequency Independent Lifting Index, lifting frequency and duration of lifting. Biomechanical stresses were estimated using the CULI, time-weighted average (TWA), and peak exposure. **Results:** The median difference between FME and FMP was $\pm 1\%$ (range: 0%–15%). Compared to CULI, TWA underestimated risk of low-back pain (LBP) for 18% to 30% of jobs, and peak exposure for an assumed 8-hr work shift overestimated risk of LBP for 20% to 25% of jobs. Peak task exposure showed 90% agreement with CULI but ignored one of two tasks. **Conclusion:** The CULI partially addressed the underestimation of physical exposure using the TWA approach and

overestimation of exposure using the peak-exposure approach. **Application:** The proposed FM and CULI may provide more accurate physical exposure estimates, and therefore estimated risk of LBP, for workers with job rotation.

- **Keywords:** frequency multiplier, overtime, peak exposure, time-weighted average, lifting duration

Waters, Thomas, Occhipinti, Enrico, Colombini, Daniela, Alvarez-Casado, Enrique, Fox, Robert. *Variable Lifting Index (VLI): A New Method for Evaluating Variable Lifting Tasks.* Pages 695-711.

Objective: We seek to develop a new approach for analyzing the physical demands of highly variable lifting tasks through an adaptation of the Revised NIOSH (National Institute for Occupational Safety and Health) Lifting Equation (RNLE) into a Variable Lifting Index (VLI). **Background:** There are many jobs that contain individual lifts that vary from lift to lift due to the task requirements. The NIOSH Lifting Equation is not suitable in its present form to analyze variable lifting tasks. **Method:** In extending the prior work on the VLI, two procedures are presented to allow users to analyze variable lifting tasks. One approach involves the sampling of lifting tasks performed by a worker over a shift and the calculation of the Frequency Independent Lift Index (FILI) for each sampled lift and the aggregation of the FILI values into six categories. The Composite Lift Index (CLI) equation is used with lifting index (LI) category frequency data to calculate the VLI. The second approach employs a detailed systematic collection of lifting task data from production and/or organizational sources. The data are organized into simplified task parameter categories and further aggregated into six FILI categories, which also use the CLI equation to calculate the VLI. **Results:** The two procedures will allow practitioners to systematically employ the VLI method to a variety of work situations where highly variable lifting tasks are performed. **Conclusions:** The scientific basis for the VLI procedure is similar to that for the CLI originally presented by NIOSH; however, the VLI method remains to be validated. **Application:** The VLI method allows an analyst to assess highly variable manual lifting jobs in which the task characteristics vary from lift to lift during a shift.

- **Keywords:** biomechanics, physical ergonomics, job analysis, manual materials handling, risk assessment

Battevi, Natale, Pandolfi, Monica, Cortinovis, Ivan. *Variable Lifting Index for Manual-Lifting Risk Assessment: A Preliminary Validation Study.* Pages 712-725.

Objective: The aim of this study was to evaluate the efficacy of the new Variable Lifting Index (VLI) method, theoretically based on the Revised National Institute for Occupational Safety and Health [NIOSH] Lifting Equation (RNLE), in predicting the risk of acute low-back pain (LBP) in the past 12 months. **Background:** A new risk variable termed the VLI for assessing variable manual lifting has been developed, but there has been no epidemiological study that evaluates the relationship between the VLI and LBP. **Method:** A sample of 3,402 study participants from 16 companies in different industrial sectors was analyzed. Of the participants, 2,374 were in the risk exposure group involving manual materials handling (MMH), and 1,028 were in the control group without MMH. The VLI was calculated for each participant in the exposure group using a systematic approach. LBP information was collected by occupational physicians at the study sites. The risk of acute LBP was estimated by calculating the odds ratio (OR) between levels of the risk exposure and the control group using a logistic regression analysis. Both crude and adjusted ORs for body mass index, gender, and age were analyzed. **Results:** Both crude and adjusted ORs showed a dose-response relationship. As the levels of VLI increased, the risk of LBP increased. This risk relationship existed when VLI was greater than 1. **Conclusion:** The VLI method can be used to assess the

risk of acute LBP, although further studies are needed to confirm the outcome and to define better VLI categories.

- **Keywords:** manual materials handling, job risk assessment, spine low-back pain, biomechanics, risk assessment

Poole Wilson, Tiffany, Davis, Kermit G. *Health Care Ergonomics: Contributions of Thomas Waters. Pages 726-747.*

Objective: The aim of this study was to assess the contributions of Thomas Waters's work in the field of health care ergonomics and beyond. **Background:** Waters's research of safe patient handling with a focus on reducing musculoskeletal disorders (MSDs) in health care workers contributed to current studies and prevention strategies. He worked with several groups to share his research and assist in developing safe patient handling guidelines and curriculum for nursing students and health care workers. **Methods:** The citations of articles that were published by Waters in health care ergonomics were evaluated for quality and themes of conclusions. Quality was assessed using the Mixed Methods Appraisal Tool and centrality to original research rating. Themes were documented by the type of population the citing articles were investigating. **Results:** In total, 266 articles that referenced the top seven cited articles were evaluated. More than 95% of them were rated either medium or high quality. The important themes of these citing articles were as follows: (a) Safe patient handling is effective in reducing MSDs in health care workers. (b) Shift work has negative impact on nurses. (c) There is no safe way to manually lift a patient. (d) Nurse curriculums should contain safe patient handling. **Conclusion:** The research of Waters has contributed significantly to the health care ergonomics and beyond. His work, in combination with other pioneers in the field, has generated multiple initiatives, such as a standard safe patient-handling curriculum and safe patient-handling programs.

- **Keywords:** safe patient handling, shift work, lift assist devices, musculoskeletal disorders

Wiggermann, Neal. *Biomechanical Evaluation of a Bed Feature to Assist in Turning and Laterally Repositioning Patients. Pages 748-757.*

Objective: This study investigated the effects of hospital bed features on the biomechanical stresses experienced by nurses when turning and laterally repositioning patients. Turn Assist, a common feature in ICU beds that helps to rotate patients, and side rail orientation were evaluated. **Background:** Manual patient handling is a risk factor for musculoskeletal injury, and turning patients is one of the most common patient handling activities. No known studies have evaluated bed attributes such as the Turn Assist feature and side rail orientation that may affect the stresses experienced by the nurse. **Method:** Nine female nurses laterally repositioned and turned a 63-kg and 123-kg subject on an ICU bed while motion capture, ground reaction forces, and hand force data were recorded. Loading of the spine and shoulder was modeled using 3D Static Strength Prediction Program (3DSSPP). **Results:** Spine compression and shear forces did not exceed recommended limits when turning or laterally repositioning. However, the mean pull forces required to manually laterally reposition even the 63-kg subject was 340 Newtons, more than 50% greater than limits established in psychophysical testing. Turn Assist considerably reduced spine loading and pull forces for both turning and laterally repositioning. Lowering side rails reduced spinal compression by 11% when turning patients. **Conclusion:** Laterally repositioning patients as part of turning may pose an injury risk to caregivers. Turn Assist reduces physical loading on nurses when turning and repositioning patients. **Application:** Caregivers should consider using Turn Assist and other aids such as mechanical lifts or sliding sheets especially when turning patients requires lateral repositioning.

Keywords: patient handling, repositioning, turning, bed

Fathallah, Fadi A., Tang, Steven C. H., Waters, Thomas. *Development and Evaluation of Ergonomic Interventions for Bucket Handling on Farms.* Pages 758-776.

Objective: The aim of this study was to introduce and evaluate two interventions, Ergo Bucket Carrier (EBC) and Easy Lift (EL), for youths (and adults) to handle water/feed buckets on farms. **Background:** The physical activities of both adult and youth farm workers contribute to the development of low-back disorders (LBDs). Many of the activities youths perform on farms are associated with increased LBD risk, particularly, the handling of water and feed buckets. **Method:** Seventeen adult and youth participants (10 males and seven females) participated in this study. To assess the risk of LBDs, the participants were instrumented with a three-dimensional spinal electrogonio-meter while lifting, carrying, and dumping water buckets using the traditional method and the two interventions. **Results:** For both the adult and youth groups, the results showed that the two interventions significantly decrease the magnitudes of LBD risk in many of the tasks evaluated. Overall, the use of the EBC resulted in a 41% reduction in the level of LBD risk for the carrying task and a reduction of 69% for the dumping task. Using the EL, on the other hand, is especially effective for lifting tasks (55% reduction in LBD risk). Results of the subjective response were consistent with the objective evaluations. **Conclusion:** This study demonstrated the potential for ergonomic interventions in reducing LBD risk during the common farming task of bucket handling. **Application:** Potential application of this study includes the introduction of the EBC and EL in family farms to reduce the LBD risk among youth and adult farmers.

- **Keywords:** family farm, intervention, youth, low back disorders, bucket

Ross, Jennifer A., Shipp, Eva M., Trueblood, Amber B., Bhattacharya, Amit. *Ergonomics and Beyond: Understanding How Chemical and Heat Exposures and Physical Exertions at Work Affect Functional Ability, Injury, and Long-Term Health.* Pages 777-795.

ObjectiveTo honor Tom Waters's work on emerging occupational health issues, we review the literature on physical along with chemical exposures and their impact on functional outcomes. **Background**Many occupations present the opportunity for exposure to multiple hazardous exposures, including both physical and chemical factors. However, little is known about how these different factors affect functional ability and injury. The goal of this review is to examine the relationships between these exposures, impairment of the neuromuscular and musculoskeletal systems, functional outcomes, and health problems with a focus on acute injury. **Method**Literature was identified using online databases, including PubMed, Ovid Medline, and Google Scholar. References from included articles were searched for additional relevant articles. **Results**This review documented the limited existing literature that discussed cognitive impairment and functional disorders via neurotoxicity for physical exposures (heat and repetitive loading) and chemical exposures (pesticides, volatile organic compounds [VOCs], and heavy metals). **Conclusion**This review supports that workers are exposed to physical and chemical exposures that are associated with negative health effects, including functional impairment and injury. **Innovation** in exposure assessment with respect to quantifying the joint exposure to these different exposures is especially needed for developing risk assessment models and, ultimately, preventive measures. **Application**Along with physical exposures, chemical exposures need to be considered, alone and in combination, in assessing functional ability and occupationally related injuries.

- **Keywords:** occupational, VOCs, metals, pesticides, postural sway