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Real-time Monitoring of Injury Risk During Manual Material Handling Using Wearable Sensors

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Introduction: Low back injuries (LBI) and low back pain (LBP) are prevalent occupational musculoskeletal disorders (MSD). Repeated lifting and carrying heavy loads contribute to an increased risk for LBP and LPI. Enhanced risk factors monitoring can provide information to assess dose-response relationships between load carriage and LBP. The objective of this study is to investigate the feasibility of a lightweight, minimally invasive and low-cost Lifting Coach system that workers wear during MMH. The system would detect lifting events, estimate carried load magnitude and distance and extract features to estimate injury risk factors using the revised NIOSH lifting equation (RNLE). Additionally, it would provide instantaneous alerts and coaching cues to modify behaviors and notify workers of risk. The Lifting Coach serves as an MMH activity monitor which records cumulative lifting exposure over time (i.e. day, shift, etc). This exposure information is reported to the workers and their employers to identify risk of MMH related MSDs.

Methods: We performed a preliminary study to estimate load carriage using pressure sensitive insoles. A healthy male subject performed four load carrying trials by carrying a box with four different loads (4.75, 11.25, 17.75 and 22.15 kg). The thin pressure sensitive insoles were inserted in subjects shoes. Pressure measurements were wirelessly transmitted through Bluetooth and recorded at 30 Hz. The four individual cells per insole were separately calibrated. A least square method was applied on a small set of walking data to determine the weighting coefficients of the individual cells to estimate the ground reaction forces. Subjects body weight was subtracted and the signal was low-pass filtered to suppress the majority of dynamic effects. The load estimation results were compared to the actual carried weights.

Results: We successfully extracted information of the carried load during MMH using pressure sensitive insoles measurements. Estimated loads from the four trials carrying four different weights were 5.5 ± 3.0 kg, 8.3 ± 2.7 kg, 20.5 ± 4.0 kg and 22.9 ± 7.0 kg. The errors between the extracted and actual loads were 0.7 kg (15.3%), -2.9 kg (25.9%), 2.7 kg (15.4%), and 0.7 kg (3.4%). The average trial duration was 27.1 ± 6.9 sec.

Conclusion: The Lifting Coach enables real-time continuous monitoring to estimate job exposure with acceptable resolution and accuracy. This represents a significant step forward in job exposure monitoring methods to help address the high incidence of MSDs during MMH. A Lifting Coach could serve as a training tool for new workers and reinforce training to improve lifting techniques. Also, a persons injury risk estimation can be improved by considering a worker's age, BMI, gender and other personal factors that have been identified through longitudinal, epidemiological studies. Benefits of more complete exposure information will improve injury model predictions. However, it is unknown how these improvements in exposure measurement will lead to our ability to prevent MSDs in the workplace. Access to more exposure data may also help improve work scheduling and assign more effective job rotation for workers exceeding recommended exposure limits. We anticipate that results from this pilot work set a foundation to perform future longitudinal studies enabling insight into enhanced understanding of exposure-injury dose-response relationship.

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