

EFFECTS OF USING A PROTOTYPE WHOLE-BODY POWERED EXOSKELETON FOR PERFORMING INDUSTRIAL TASKS

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Despite advances in industry automation and mechanization, many workers are still exposed frequently and/or routinely to ergonomic risk factors (e.g., forceful exertions, repetitive motions) for work-related musculoskeletal disorders (WMSDs). Having an effective and sustainable solution to prevent or minimize ergonomic risks is thus important, to assist workers in performing their work tasks efficiently and safely. Industrial exoskeleton technologies have recently received substantial and growing attention as an alternative intervention to control WMSDs (de Looze, Bosch, Krause, Stadler, & O Sullivan, 2016).

Active (or powered) exoskeletons are mainly in early developmental phases. Existing reports on active exoskeletons have focused typically on structural design and control algorithm development, while targeting a specific body part such as the lower back and/or lower extremity (e.g., Hyun, Park, Ha, Park, & Jung, 2017; Ito, Ayusawa, Yoshida, & Kobayashi, 2016; Toxiri et al., 2015), or the upper extremity (e.g., Bai, Christensen, & Islam, 2017; Ebrahimi, 2017). However, the development of a powered exoskeleton for the whole body still remains a major challenge in the field.

The current study assessed how using an early prototype version of a state-of-the-art, whole-body, powered exoskeleton (GuardianTM XO, www.sarcos.com) affects upper limb control and associated muscle activity levels during the performance of two simulated industrial tasks. Of note, no task-specific training was provided to the participants or task-specific optimization was applied to the XO controller here, since the current study was a preliminary investigation in support of larger efforts to advance industrial powered exoskeleton design use in a workplace.

A convenience sample of five healthy male participants completed the study. They were trained to use the XO in 3-5 sessions over a 2- to 3-week period. Both with and without the XO, participants completed a one-arm load handling task (consecutive transferring of a 11.3 kg load between the three shelves of a storage rack, using the dominant arm) and a repetitive pointing task (light, repetitive tapping two targets in alteration at a rate of 45 beats per min. for ~1 min., using their dominant arm). For the latter task, the targets were placed either 45 cm (inner targets condition) or 90 cm apart (outer targets condition).

Segmental whole-body kinematics were monitored using a wearable inertial motion capture system (MVN Awinda, Xsens Technologies B.V., the Netherlands). Muscle activity was monitored using a telemetered surface electromyography (EMG) system (UltiumTM Noraxon, AZ, USA), and raw EMG signals were sampled at 2 kHz. Prior to data collection, participants completed trials of maximum voluntary isometric contractions for normalizing EMG (nEMG). Outcome

measures were the peak and median levels of anterior deltoid, descending trapezius, and erector spinae muscle activities for the one-arm load handling task. The outcome measure of the repetitive pointing task was the jerk index (JI) for the hand trajectory, computed to assess the smoothness of arm movement (Hogan and Sternad, 2010).

During the one-arm load handling task, using the XO resulted in reduced or comparable levels of peak and median nEMG. Depending on the specific muscle group, peak and median nEMGs decreased by means of 0.4 - 59.4% and 12.3 - 63.8%, respectively. During the repetitive pointing task, using the XO resulted in decreased movement smoothness (increased JI values, ranging from 87.2-230.2% of the no-XO condition, depending on the participant and target condition).

Use of industrial, powered exoskeletons has the potential to empower workers with improved work capacity (e.g., greater strength, endurance, etc.) in diverse work environments. Given that such exoskeleton development is still in the prototype/research stage, the purpose of our study was to explore the impacts of using a powered exoskeleton (XO) for different manual tasks, to guide both further development and application for specific industrial use cases. Based on our results, it appears that using the XO reduced physical demands, especially in the more physically demanding load-handling task. However, both task completion time in the load handling task, and movement smoothness of the hand (i.e., end effector) in the pointing task, were increased with using the prototype XO, suggesting there may be increased movement control efforts required from the users. In addition, required control efforts may depend on specific task condition, suboptimal XO fit on the participants (given there was only 1 prototype sizing at the time of the study), and reflect differences in skill between participants when using the exoskeleton.

In summary, we demonstrated in this preliminary investigation that using an industrial, whole-body powered exoskeleton can reduce physical demands, while requiring slightly higher control efforts. The current results support future studies to develop and assess the impacts of powered exoskeletons to accommodate varying task requirements and individual differences.

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