Effect of a Back-Assist Exosuit on Logistics Worker Perceptions, Acceptance, and Muscle Activity

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Abstract—A workplace study was conducted to evaluate user perceptions, acceptance, and muscle activity amongst logistics workers wearing an unmotorized, dual-mode, back-assist exosuit prototype. Eleven workers performed a lifting/lowering task with vs. without the exosuit, while back muscle activity was recorded. They then used the exosuit while performing their actual work tasks in a distribution center before completing a questionnaire about their user experience. Worker perceptions of the exosuit were overwhelmingly positive: 100% felt the exosuit could be useful and fit into their daily job without interfering, >90% felt assisted and that the exosuit made lifting easier, and >80% felt it was comfortable and that they were free to move naturally while wearing the exosuit. Finally, the majority of workers showed reduced back muscle activity while wearing the exosuit during lifting/lowering, consistent with results from prior lab studies. Worker feedback on this prototype was then used to inform design of the HeroWear Apex exosuit.

I. Introduction

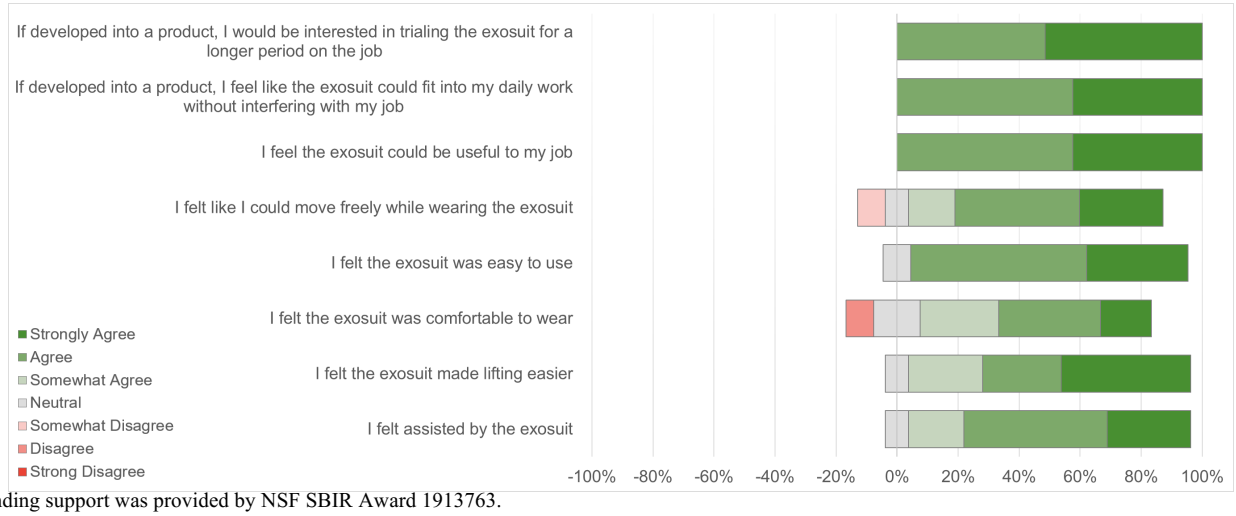
WORK-RELATED musculoskeletal disorders from overexertion due to lifting and handling objects is the leading cause of disabling injuries in the US (Liberty Mutual Workplace Safety Index, 2020), accounting for 23.5% of claims, and costing $14 billion. Back-assist exoskeletons are designed to reduce strain, fatigue, and injury risk for workers who bend, reach, and lift. A large body of evidence indicates that back-assist exoskeletons (both rigid devices and soft exosuits) can reduce back extensor muscle activity, muscle fatigue, spine compression, and/or metabolic cost for bending and lifting across various occupations, tasks, and postures (e.g., Alemi et al., 2020, Lamers et al., 2018 and 2020).

The potential for back-assist exoskeletons to impact safety, performance, health, and quality of life across a spectrum of occupations is promising; however, key adoption barriers have been related to practical factors such as comfort, fit, integration with typical workflow, and not interfering. Here we evaluated an unmotorized back-assist exosuit prototype on logistics workers in distribution centers. The exosuit is comprised of textiles and elastomers to achieve a lightweight, low-profile, flexible, and unobstructive design. It uses elastic bands along the back to provide assistive torque about the spine, and was previously found to reduce back strain and fatigue in lab studies (Lamers et al., 2018 and 2020). It also includes a proprietary dual-mode feature (patent-pending on/off switch) that enables users to quickly engage/disengage assistance. The goals of this field test were to evaluate worker perceptions of exosuit assistance, comfort, ease of use, and integration into daily work, and to confirm reductions in back muscle activity with the exosuit as observed in lab studies.

II. Methods

Eleven distribution center workers from an international logistics firm and national retailer participated in the study. All participants in this field study were male because the prototype available at the time of testing had a male-specific fit. Though it is noted that both prior lab studies involved males and females, and the subsequent version of this exosuit (HeroWear Apex) includes both male- and female-specific fits. This study was approved by the Vanderbilt University Institutional Review Board and the workers gave informed written consent prior to participation.

Fig. 1. Results from worker questionnaire after using exosuit on the job.



Funding support was provided by NSF SBIR Award 1913763.

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Training: Workers were introduced to the exosuit over a 45-minute period. This introduction included an overview of the exosuit and the testing protocol. Then each worker was fit with the exosuit and allowed a limited amount of time to acclimate by performing a series of general bending and lifting tasks to get a feel for how the device functioned.

Simulated lifting and lowering tasks: Workers were instrumented with electromyographical (EMG) sensors (Delsys Trigno Mini) on six back muscles: left and right Multifidus, Longissimus Thoracis, and Iliocostalis Lumborum. Workers then completed lifting cycles with and without wearing the exosuit. A full cycle of the task involved beginning in an upright standing posture, lifting a 22-lb box from a pallet (5.5 inches in height), turning 90 degrees, and setting the box down on a table (36 inches in height), then lifting, turning 90 degrees, and lowering the box down to the starting location, and returning to upright standing. Each cycle was repeated 15 times. Workers were allowed to lift/lower using any technique they would normally use at work (i.e., technique was not controlled). EMG data were analyzed to extract total and peak values, and averaged to obtain an EMG summary metric for comparison purposes.

Real work environment evaluation: After completion of the simulated tasks, individuals returned to work (Fig. 2) and wore the exosuit during their actual distribution center job for an average of 20-30 minutes. Workers did picking or auditing work (i.e., de-palletizing and re-palletizing product). User feedback and experiences were recorded through audio/video recordings and a 7-point Likert-scale questionnaire (Fig. 1).

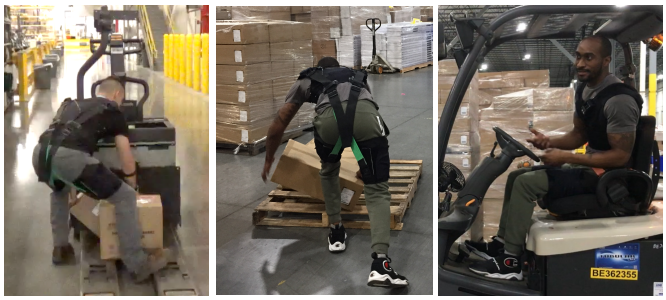

Fig. 2. Distribution center workers using an exosuit prototype on the job for a variety of logistics tasks: picking, palletizing, forklift driving.

III. Results

The questionnaire results (Fig. 1) indicate that the vast majority of the workers reported feeling assisted, comfortable, and free to move naturally while wearing the exosuit. They also felt the exosuit was easy to use, useful for their job, that it could fit into their daily work without interfering, and that they would be interested in using the exosuit to do their job for an extended period of time. The majority of workers showed reduced back muscle activity while wearing the exosuit during both lifting and lowering tasks (e.g., Fig. 3), consistent with results observed in prior lab studies (e.g., Lamers et al., 2018). Average reductions in peak and total back muscle activity were ~10% across the full lifting/lowering task, and about two-thirds of workers exhibited reductions >15% during lifting or lowering.

Worker testimonials corroborated the questionnaire results and reductions in back muscle activity. Example excerpts: (1) "I get tired quicker without the exosuit." (2) "The suit slingshots you back up. Once you start it pushes you the rest of the way." (3) "It didn't hinder the movements at all, I could still do everything I needed to do; boxes that I pick up all the time felt lighter and easier to pick up." (4) "Can already tell a big difference, feel that it's really helping. My back hurts 75% of the time, but I can already feel a difference."

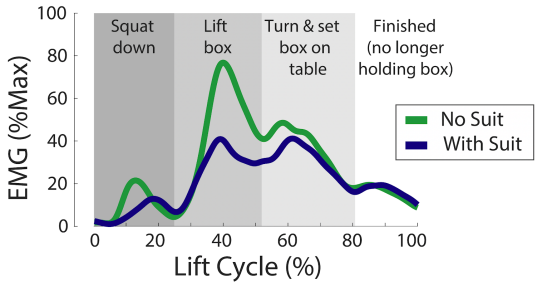

Fig. 3. Results from representative worker showing reduced back muscle activity (EMG) when wearing the exosuit prototype.

IV. Discussion & Conclusion

User feedback, perceptions, and acceptance of the exosuit prototype were all positive. The workers reported feeling assisted, comfortable, and unrestricted while wearing the exosuit. The workers also felt the exosuit could be useful and fit into their daily work without interfering. Because user acceptance plays such a critical role in sustained use and successful long-term outcomes from using any new technology, these results suggest that the exosuit has excellent potential for adoption by logistics workers. EMG testing in this logistics field study also confirmed and supported results observed in previous lab studies, indicating that the exosuit reduces peak back muscle activity (which may be associated with injury risk) and total back muscle activity (which may be associated with fatigue) during lifting, lowering and bending. Collectively these results demonstrate that this type of low-profile, unmotorized, dual-mode exosuit can reduce back strain and make lifting objects easier, without restricting posture or movement. Muscle activity findings and user feedback from this logistics field test on the prototype were used to inform and finalize design of the HeroWear Apex exosuit, which was commercially released in March 2020.

Acknowledgment

The authors thank: Shimra Fine for help with prototype development, Emily Matijevich for help with data collection.

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