Adopting Passive Exoskeletons: Worker Perspectives and Impact on Work Productivity and Quality

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SUMMARY

Exoskeletons help augment worker strength and may reduce the effects of physically demanding work; however, health benefits alone may not necessarily facilitate its adoption by organizations. Through a survey study with 40 construction workers who used an exoskeleton over multiple shifts, workers believed exoskeletons were usable and beneficial for prolonged overhead work. A subsequent systematic review suggests that quality and productivity impacts of exoskeleton use are dependent on task characteristics.

KEYWORDS

Economic impact, usability, inclusive design

Introduction

Passive exoskeletons are wearable devices that are designed to augment a worker's strength. In laboratory studies, passive exoskeletons may increase muscular endurance. Our recent multi-day field studies have shown the potential of passive exoskeletons to reduce bodily exertion and discomfort in construction work. Therefore, exoskeletons are perceived as a promising solution to reduce the risk of musculoskeletal disorders (MSD) that are highly prevalent and costly in Canada.

Despite emerging evidence that exoskeletons may reduce the effects of high physical demands, the health benefits alone may not necessarily facilitate their adoption by an organization. An exoskeleton's practical use and application for work tasks as well as worker perceptions on its comfort and usability are important factors for adoption. Additionally, improvements to quality, productivity, and reduced costs are powerful business agendas that would likely receive more resources and attention. This study examined the perceptions of construction workers who have used an exoskeleton for multiple work shifts to identify tasks that may benefit from exoskeletons and identify design improvements to facilitate their adoption. We also report on a systematic review of scientific literature to synthesize the current state of knowledge on the impact of exoskeletons on work productivity, quality, and their economic implications.

Method

We recruited 40 residential, ICI (Industrial, Commercial, Institutional), and modular construction workers to participate in a survey study. Participants were surveyed on their job sites after using a passive upper extremity exoskeleton (Hilti Exo-01) to perform their jobs for multiple work shifts. We elicited participants' perceptions on the usability of exoskeletons, the features of an exoskeleton most beneficial for overhead work, the types of construction tasks suitable for upper extremity exoskeletons, and design recommendations to improve exoskeleton adoption.

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, we identified, reviewed and extracted data from journal articles obtained from six large databases. We included research articles that focused on exoskeletons worn during occupational tasks and that had evaluated its effects on quality and productivity, or its economic impacts.

Preliminary Findings

Eighty percent of participating construction workers believed the passive upper extremity exoskeleton was easy to use. Participants preferred the exoskeleton for the reduction in muscular effort, their looks, and feeling safe, but preferred their usual method for manoeuvrability, thermal comfort, and feel/fit (Figure 1). Workers believed exoskeletons were helpful for prolonged, static overhead tasks in open spaces, such as installing upper tracks and light fixtures, framing and drywalling bulkheads, and taping and mudding ceilings. On the other hand, exoskeletons were viewed as cumbersome in tight spaces or below shoulder height. Participants recommended better design compatibility with tools and PPE, close-fitting design for confined spaces, breathable materials, debris prevention, and better fit to accommodate different body sizes and dimensions.

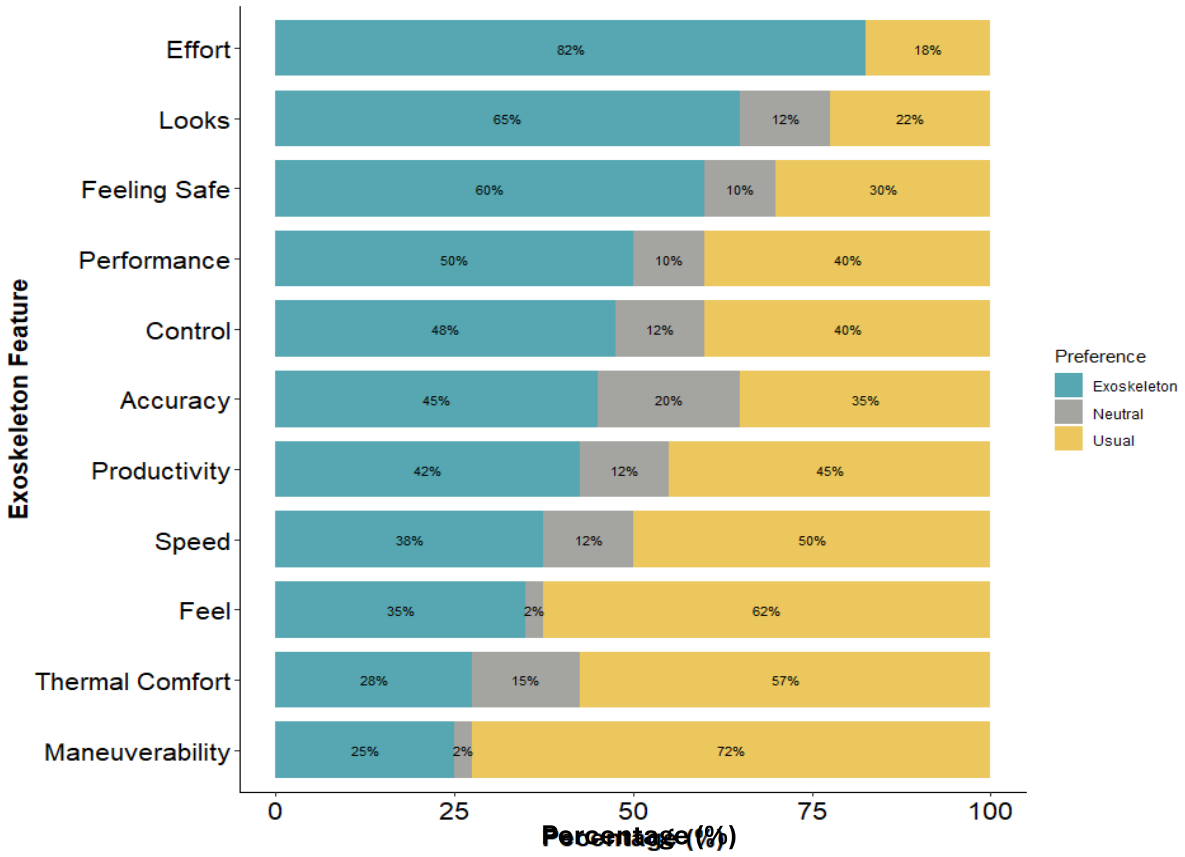

Figure 1: Preferences of using an exoskeleton for overhead work compared to usual methods.

Fifteen articles examined the effects of exoskeleton on work productivity and quality. Exoskeleton use positively affected productivity in certain tasks such as shovelling, welding, and electrostatic painting. However, there were mixed productivity findings during simulated manual material handling, drilling, and manual assembly tasks. Welders and electrostatic painters experienced quality improvements in their task, while the impact of exoskeleton on committing errors during repetitive drilling tasks was dependent on work height. No articles assessed the economic impact.

Key Takeaways

- Exoskeletons were perceived to be usable by almost 80% of our 40 sampled construction workers who used a passive upper extremity exoskeleton for multiple work shifts. However, there remains issues with manoeuvrability, thermal discomfort, and fit/feel.
- Upper extremity exoskeletons may be most beneficial for tasks requiring prolonged, static overhead work in open spaces.
- The current state of the literature suggests that quality and productivity impacts of exoskeleton use are dependent on task characteristics.
- There remains a need for cost-benefit analysis and studies on return on investment to justify the benefits of exoskeleton adoption for the organization and its workers.
- Future studies should continue to consider evaluating exoskeletons with actual workers and identify possible effects of sex and gender.