EFFECTS OF PASSIVE UPPER-EXTREMITY EXOSKELETON USE ON MOTOR PERFORMANCE

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Summary

This study investigated the effect of passive exoskeleton use on shoulder torque control in an intermittent shoulder-loading task. Sixteen participants completed 15 30-sec cycles of intermittent, isometric shoulder contraction at 90º both in the sagittal and scapular planes, with a 50% duty cycle at 30% of maximum torque; this was completed with and without external support from two exoskeletons. Torque steadiness was quantified using the coefficient of variation (CV) across work cycles. Repeated measures ANOVA was used to assess the effects of device support and time on torque CV, with user strength added as a covariate. Exoskeleton use significantly decreased torque CV in both the sagittal and scapular planes. While previous studies have shown exoskeleton-use to reduce musculoskeletal loads, our results show that exoskeleton-use may also improve motor performance by having a steadying effect on shoulder torque generation.

Introduction

Exoskeletons are wearable assistive devices that augment and assist physical activity by providing structural supports and assistive torques to the body. The potential use of industrial exoskeletons to mitigate the risk of musculoskeletal disorders in manual handling jobs is an emerging research topic [1]. While earlier work demonstrated the use of upper-extremity exoskeletons use can reduce shoulder demands [2], it remains unclear how such devices can affects the shoulder torque control performance. The aim of this study was thus to investigate the effects of passive exoskeleton use on shoulder joint torque control in an intermittent shoulder-loading task.

Methods

Sixteen healthy gender-balanced participants aged 27 (SD 5) years, 174 (4) cm tall, and with body mass 78.6 (13) kg, completed isometric, intermittent shoulder-loading tasks with their dominant arm. The task required isometric shoulder flexions at 90º and at 30% of maximum torque, with a 15–15 sec work-rest cycle over a 7.5 min period (15 cycles). Torque level was set at 30% of the maximum torque exerted, while adjusted for the weight of the participant's resting arm. This task was repeated in two planes – sagittal and scapular – and with four device conditions: 1) no device (ND), 2) Levitate AirFrame with support on (LE), 3) EksoBionics EksoWorks with support on (EB_{ON}) and 4) with support off (EB_{OFF}). Due to differences in the form/profile, design principle, weight, and cost of the LE and EB, both were included in this study. Participants selected their preferred support level for each device after a 1-min training in the task. External shoulder torque was measured using a dynamometer (Humac-NORM, CSMi, MA, USA), sampled at 100 Hz. Task performance (i.e., torque steadiness) was quantified as the CV in each work cycle, and 5 mean values were obtained from every three consecutive cycles to create torque control profiles across time. Repeated measures ANOVAs were performed separately for each plane (sagittal and scapular), to determine the effects of device condition and time on torque CV, with user strength added as a covariate. Significant effects ($p < 0.05$) were followed by Tukey's HSD post-hoc comparisons.

Results and Discussion

In the sagittal plane, only device had a significant effect on CVs. Torque CVs were lower for both device-supported conditions (LE and EB_{ON}) compared to the two conditions without support (p<0.0001, Figure 1). In the scapular plane, similar results were found, with the torque CVs being lower for both device conditions with support (p<0.0001, Figure 1). However, the EB_{ON} condition also led to significantly lower CVs compared to the LE condition. Furthermore, there was a significant effect of time, in that torque CVs were higher at the fifth time point (i.e., the last 3 cycles) compared to the first (i.e., first 3 cycles), which may represent fatigue effects. However, there were no significant interactions between device condition and time. Thus, although CVs were lower across all time points in the exoskeleton conditions, using an exoskeleton did not decrease the extent to which torque steadiness decreased over time.

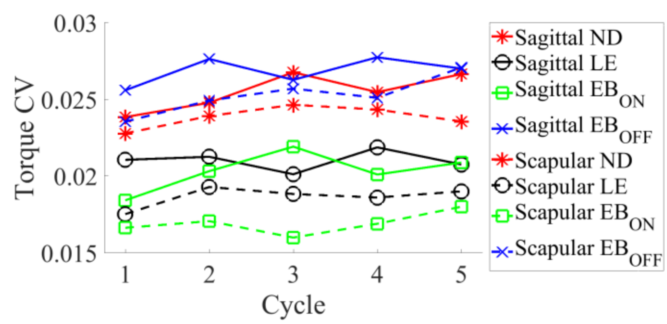

Figure 1: Torque CV in all conditions

Conclusions

The use of exoskeletons enhanced steadiness (decreased torque CV), and both devices produced comparable performance in the sagittal plane. However, for work outside the sagittal plane (i.e., scapular plane), use of the EksoBionics exoskeleton was associated with slightly better torque steadiness than the Levitate. Further research with longer task durations is required to demonstrate whether these changes also translate to differences in fatigue when performing prolonged shoulder-loading tasks.

References

[1] de Looze, MP et al. (2016). *Ergonomics*: **59** (5): 671–681.
[2] Kim, S et al. (2018). *Appl. Ergon.*: **70** (December 2017): 315–322.

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