EFFECTS OF USING AN ASSISTIVE DEVICE FOR OVERHEAD WORK

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INTRODUCTION

Work-related musculoskeletal disorders (WMSDs) in the upper extremity (UE) are an important issue in the modern U.S. workplace. Shoulder WMSDs in particular accounted for ~13% of all cases in 2011, with greater severity than other body regions [1]. Overhead work – working with the arms at or above the shoulder – is an important risk factor for shoulder injuries [2], since overhead work, by its nature, places concurrent demands (e.g., non-neutral postures and increased muscular activity) on the UE musculature and connective tissues.

Unless overhead work can be eliminated, the effects of overhead work can potentially be reduced by implementing engineering controls. As one example, the use of an inverted drill press in construction reduced extreme UE working postures and shoulder loading [3]. More generally, though, there is a lack of readily-available control measures for overhead work. Here, we explored a new approach – developed from a combination of a commercially-available mechanical arm (zeroG2; Equipois Inc., Los Angeles, CA) and an exoskeletal vest (Fawcett ExoVest™; The Tiffen Company, Hauppauge, NY) – as a potential assistive device for overhead work and that could be used in manufacturing environments (Figure 1).

METHODS

Twelve male participants, with no self-reported musculoskeletal disorders, completed the experiment after giving informed consent (procedures were approved by the Virginia Tech Institutional Review Board). Participant mean (SD) age, stature, and body mass were 27 (2.6) yrs, 178 (4.6) cm, and 76 (4.6) kg, respectively. A repeated-measures design was used, in which each participant performed a 10-min simulated overhead work task in six trials involving all combinations of two Intervention and three Payload conditions. Trials involved a 50% duty cycle and 30 sec cycle time. The task involved maintaining a hex socket engaged with a fixed bolt oriented downward, such that the hands were slightly above individual head height (Figure 1). The two Intervention conditions were with vs. without use of the assistive device (arm + vest). The three Payload conditions involved light (1.1 kg), medium (3.4 kg), and heavy (8.1 kg) masses, selected to represent a range of powered or pneumatic hand tools likely used in auto and aircraft manufacturing environments.

Rates of perceived discomfort (RPDs) and electromyography (EMG) were obtained from the upper arm, shoulder, and low back. RPDs were collected every four cycles (i.e., every 2 min) using a 10-point scale [4]. EMG was monitored bilaterally from: triceps brachii (TB), anterior and middle deltoid (AD and TB), and iliocostalis lumborum pars lumborum (ILL). Pairs of bipolar Ag/AgCl electrodes (AccuSensor, Lynn Medical, MI) were placed on the skin surface with a 2.5 cm inter-electrode distance. Raw EMG signals were sampled at 960 Hz using a telemetered system (TeleMyo 900, Noraxon, AZ) and bandpass filtered (20 - 400 Hz). In each work period, EMG root mean square (RMS) values were obtained with a time constant of 250 ms, and were averaged over the sampling duration. Mean RMS values were then normalized (nRMS) to corresponding reference RMS values; these were obtained initially, while participants maintained the same working postures without any payload.

For each trial, final values of RPD and the mean values of nRMS in the last cycle (after 20 cycles, or 10 min) were statistically analyzed. Separate repeated-measures analyses of variance (RANOVAs) were performed to assess the effects of Intervention and Payload. Post hoc comparisons were performed using Tukey’s HSD where relevant.
All statistical analyses were conducted using JMP Pro 10 (SAS Institute Inc., Cary, NC), and statistical significance was determined when \( p < 0.05 \).

**RESULTS AND DISCUSSION**

RPDs for the upper arm and shoulder significantly decreased with the use of the assistive device (all \( p \) values \( \leq 0.019 \)). This decrease was most pronounced when handling the medium and heavy payloads, with respective reductions of 47% and 54% (Figure 2). In contrast, low back RPD values increased with the use of assistive device across all conditions (\( p = 0.007 \)). This divergence in effects was likely caused by the fact that the vertical rigid frame of the exoskeletal vest enabled a redistribution of external loads from the shoulder to the torso and pelvis (see Figure 1).

Use of the assistive device had a significant effect on bilateral AD nRMS (\( p < 0.0002 \)), with respective decreases of 41% and 54% on the right and left sides. Although MD was not significantly affected by Intervention, the left TB was significantly affected across all levels of Intervention and Payload (\( p \) values \( \leq 0.0034 \)). TB nRMS values substantially decreased with the use of the assistive device when handling the medium (45%) and heavy (37%) payloads. On the other hand, increasing payload resulted in greater ILL nRMS bilaterally. Use of the assistive device also caused a substantial increase in right ILL nRMS (> 40%, \( p < 0.0001 \)). This latter effect could be due to the connection of the zeroG\(^2\) arm to the exoskeletal vest being on the left side. As such, it is likely that the right ILL activity increased to equilibrate the resulting asymmetric external torso moment. In addition to observed increased demands on the low back with the assistive device, the rigidity of the vest likely constrained trunk movement, and which may have further increased back muscle activity and contributed to increased levels of perceived discomfort reported for the low back.

Overall, the assistive device seems to effectively reduce demands on the UE, particularly when handling heavier payloads (> 3.1 kg), though also imposing increased demands on the low back. The latter effect, however, was of smaller relative magnitude than the former, and suggests potential utility of this approach as a practical intervention. However, the duration of simulated work was relatively short (10 min) here, and generalization to more realistic (prolonged) working conditions is unclear. Future study is thus warranted to understand the longer-term effects of the assistive device and its acceptance to workers in the field.

**REFERENCES**