WearRAcon Europe 2023
European Exoskeleton Conference
October 25-26, 2023

ANALYSIS OF THE LUMBAR LOAD REDUCTION OF DIFFERENT BACK-SUPPORT EXOSKELETONS

Johns J[1], Schultes I[1], Heinrich K[1], Glitsch U[1]

[1] Institute for Occupational Safety and Health, German Social Accident Insurance, Alte Heerstr. 111, 53757 Sankt Augustin, Germany

ABSTRACT

The aim of this study was to determine the supporting effect of one active (A1) and two passive (P1 and P2) back support exoskeletons. The muscular activity and lumbar compression forces of 12 subjects were analyzed during dynamic lifting and static holding of 10kg. For the muscular activity reductions of 13% to 32% were found during lifting and 16% to 54% during holding. The lumbar compression forces were reduced by 11% to 22% during lifting and 12% to 41% during holding. During the analysis it became apparent that the passive exoskeletons performed quite consistently across the different tasks and loading parameters, while the active system could only provide its maximum support during static holding.

Keywords: Back-support exoskeleton, lumbar compression forces, muscle activity

1. INTRODUCTION

Exoskeletons are a novel approach to address work-related musculoskeletal disorders, such as low back pain, which still affect a significant proportion of workers. Specifically, back-supporting exoskeletons aim to reduce lumbar loading, the main biomechanical risk factor, by providing external support to the lumbar spine. Recent advancements in exoskeleton technology have led to increased commercial availability, with active and passive systems showing promising reductions in back extensor muscle activity and spinal loading [1-4]. However, there is still ongoing discussion regarding the evaluation and implementation of exoskeleton support into established biomechanical modelling approaches. This study aims to investigate the effects of active and passive exoskeletons on lumbar loading during dynamic lifting and static holding tasks, using a biomechanical approach.

2. MATERIALS AND METHODS

Kinematic data and back muscle activity were collected from 12 subjects during simulated lifting and holding of 10 kg. An inverse dynamic top-down modelling approach was used to calculate lumbar loading. During modelling, the exoskeleton support was considered as a contact force acting normal to the thorax surface. For the passive systems, the support was determined experimentally as the flexion angle-dependent torque, and for the active system internal torque sensor data were used. Lumbar compression forces (normalized to bodyweight [BW]), and muscle activation (normalized to maximum voluntary contractions [%MVC]) were considered in the evaluation. Statistical analysis was performed with a 2-way mixed ANOVA with the random effect subject and fixed effect exoskeleton condition.

3. RESULTS AND DISCUSSION

During the lifting task, exoskeletons A1 and P1 showed reductions of 15% ($p<0.01$) and 11% ($p<0.01$) for peak lumbar compression forces, respectively, compared to the condition without exoskeleton, while for P2 a decrease of 22% ($p<0.01$) was observed. Peak muscle activity during lifting was significantly reduced by all systems (A1: 32%; P1: 13%; P2: 17%, $p<0.01$; Figure 1). In the holding task, comparable reductions in peak lumbar compression forces of 12% ($p<0.01$) for P1 and 20% ($p<0.01$) for P2, were identified for both passive systems, whereas a greater reduction of 41% ($p<0.01$) was found for A1. Muscle activation data showed a comparable pattern with similar reductions in mean EMG amplitude for P1 (23%, $p<0.01$) and P2 (16%, $p<0.01$), as well as a greater reduction of 54% for A1 (Figure 2).

The passive exoskeletons performed consistent across both tasks and the differences in load reductions between the systems can be attributed to the different support provided. The active exoskeleton showed its full potential only during the static holding tasks. This was mainly attributed to a certain latency of the active control unit.

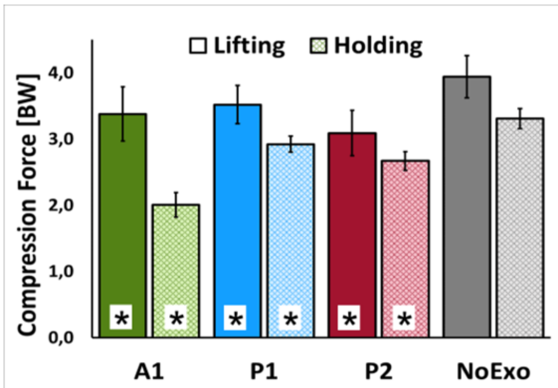

Figure 1: Lumbar compression forces during dynamic lifting and static holding of 10 kg for NoExo, A1, P1 and P2. * -sig. difference from NoExo at $p<0.05$

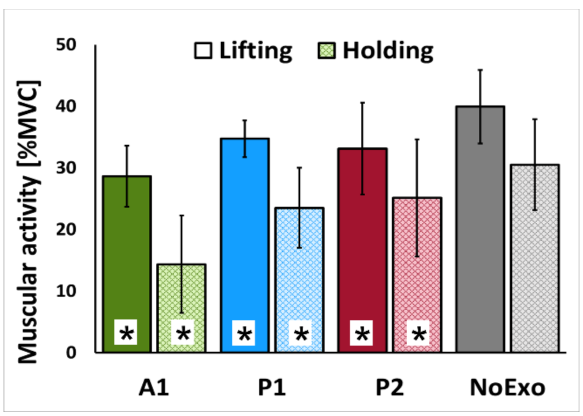

Figure 2: Muscular activity during dynamic lifting and static holding of 10 kg for NoExo, A1, P1 and P2. * -sig. difference from NoExo at $p<0.05$

4. CONCLUSION

The aim of this study was to better understand the user-exoskeleton interaction and assess the relief provided by exoskeletons during material handling tasks. The results confirm that currently available industrial exoskeletons can partially support users in both static and dynamic load handling. It became apparent that the exoskeleton-specific support is a crucial parameter for modeling musculoskeletal loading. Matching appropriate tasks to specific exoskeletons is essential to ensure the best outcome and evaluating user acceptance will be important for successful implementation in industrial workplaces.

REFERENCES

[1] Madinei, S., Nussbaum, M.A., 2023. Estimating lumbar spine loading when using back-support exoskeletons in lifting tasks. J Biomech 147, 111439.

[2] Koopman, A.S., Kingma, I., de Looze, M.P., van Dieen, J.H., 2020. Effects of a passive back exoskeleton on the mechanical loading of the low-back during symmetric lifting. J Biomech 102, 109486.

[3] Reimeir, B., Calisti, M., Mittermeier, R., Ralfs, L., Weidner, R., 2023. Effects of back-support exoskeletons with different functional mechanisms on trunk muscle activity and kinematics. Wearable Technologies 4.

[4] Glitsch, U., Bäuerle, I., Hertrich, L., Heinrich, K., Liedtke, M., 2020. Biomechanische Beurteilung der Wirksamkeit von rumpfunterstützenden Exoskeletten für den industriellen Einsatz. Zeitschrift für Arbeitswissenschaft 74, 294-305.