EFFECTS OF AN ACTIVE BACK-SUPPORTING EXOSKELETON ON KINEMATICS DURING LIFTING AND CARRYING LOADS

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Introduction

Exposure to ergonomic risk factors is one of the major occupational safety and health problems today. Repeated exposure to awkward postures and / or repetitive manual tasks can lead to work-related musculoskeletal disorders. Complaints in the neck and shoulder region and especially in the lower back are common among workers in manufacturing and logistics [1]. For several years, there has been growing interest in the use of active exoskeletons as a supportive ergonomic measure to control and reduce exposure to risk factors of work-related musculoskeletal disorders. There is evidence of the effects of back-supporting exoskeletons on kinematics and muscle activity during lifting and carrying external loads [2, 3]. However, there are few studies that explore the effect of active back-supporting exoskeletons on walking, as the most important secondary activity. The aim of this study was to analyze the effect of an active exoskeleton on kinematics for both lifting and carrying loads.

Methods

Ten healthy male volunteers (age: 41 years ± 12, height: 180 cm ± 6, weight: 81 kg ± 11) performed six gait cycles each with and without the use of an active exoskeleton (Cray X 5th generation, German Bionic Systems, Augsburg, Germany) for three different load scenarios (no additional weight, 5 kg, 15 kg). In addition, lifting tasks from the floor to pelvic height were performed (external load 5 kg, 15 kg).

Kinematic parameters were determined using an eight camera marker-based Vicon system and an extended plug-in gait marker model (40 reflective markers). In addition to knee, hip joint and spinal angles, spatio-temporal parameters were determined for analysis of gait pattern and lifting times for more detailed study of lifting.

The paired t-test was used for statistical analysis.

Results

Overall, carrying tasks with exoskeleton showed significantly reduced gait velocity (Table 1).

The joint angles studied tended to show a slightly lower range of motion during exoskeleton use in both the stance phase and swing phase ($p > 0.05$). Significantly lower range of motion were found for spinal rotation and lateral flexion ($p < 0.01$). The spine showed a slightly increased extension when using the exoskeleton.

Gait velocity	No Exo	With Exo	p-Value
None	1.33 ± 0.13	1.12 ± 0.14	< 0.01
5 kg	1.38 ± 0.13	1.18 ± 0.14	< 0.01
15 kg	1.43 ± 0.13	1.24 ± 0.14	< 0.01

Table 1: Gait velocity [m/s] with and without exoskeleton (Exo) in different weight conditions.

For lifting tasks, significant differences were observed in hip and spine flexion at the start of the movement (grasping the weight) (Table 2). No significant differences were found for lifting times.

Joint angle	No Exo	With Exo	p-Value
Hip: 5 kg	85 ± 9	106 ± 11	< 0.01
Hip: 15 kg	89 ± 9	110 ± 10	< 0.01
Spine: 5 kg	26 ± 10	-3 ± 11	< 0.01
Spine 15 kg	25 ± 10	-3 ± 10	< 0.01

Table 2: Joint angles [°] with and without exoskeleton (Exo) when grasping the weight under different weight conditions.

Discussion

Use of the exoskeleton caused minor changes in lower limb kinematics during walking. Reduced gait speed may be attributed to the exoskeleton's own weight. During the lifting task, two different movement strategies could be observed. Grasping the weight on the ground occurred without exoskeleton primarily by flexion of the spine and with exoskeleton by means of flexion in the hip joint.. In a next step, the influence of the exoskeleton on muscle activity during walking and lifting will be investigated which could be further applied for comparisons of muscle control.

References

1. de Kok et al, EU-OSHA, 2019.
2. de Looze et al, Ergonomics, 59:671-681, 2016.
3. von Glinski et al, J Clin Neurosci, 63:249-255, 2019.

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