

METABOLIC ANALYSIS OF A WEARABLE UPPER LIMB EXOSKELETON FOR OVERHEAD WORK

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Introduction

Work related musculoskeletal injuries are a major cause of reduced productivity in the industrial sector. Long-term overhead work may lead to severe injury of the shoulders and has been recognized as a major cause of workdays lost [1]. As many modern production lines still require workers to perform long-term overhead tasks, wearable support devices were recently developed with the aim to mitigate the stress on the shoulders, preserve workers healthiness and ultimately increase productivity. The modern designs proposed are currently object of extensive research aimed to assess the impact on the worker, changes in posture, ergonomics and overall effectiveness [2]. The aim of this work was to test the effects on user's metabolic expenditure of an upper limb exoskeleton recently designed by the authors for supporting overhead tasks.

Methods

The new exoskeleton (Fig. 1) was based on a previous design conceived for rehabilitation purposes and hand-to-mouth tasks [3]. The kinematics of the shoulder joint and the gravity support mechanism were specifically adapted to: (i) generate a suitable torque to support the arm in conditions of shoulder elevation larger than 90 deg. and (ii), extend the support to both arms. The gravity-support mechanism was designed to allow adjusting the level of compensation required for the task.

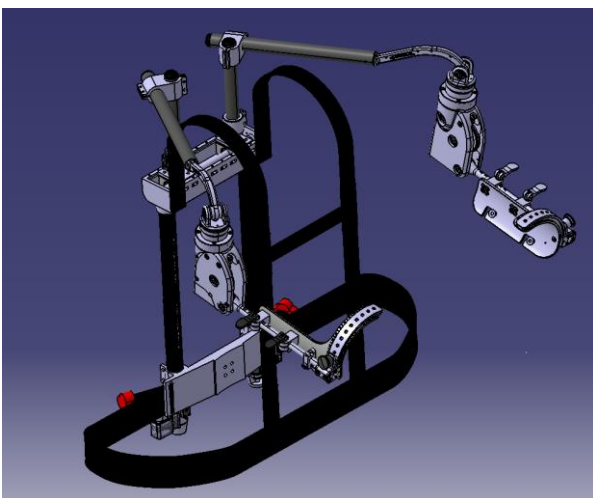


Figure 1: CAD design of exoskeleton

A healthy subject (male, 35 years, 196 cm, 96 kg) performed an overhead task consisting of slowly moving a weight of 1.5 kg with both hands, at shoulder

elevation angle of about 120 deg., while standing still. This task simulated the use of a heavy power tool in overhead position. The task had a total duration of about 10 minutes, the subject had the opportunity to have a quick rest every minute. The task was repeated twice: with and without the exoskeleton. The user's metabolic rate during the task was assessed via indirect calorimetry, using a COSMED K5 (www.cosmed.com). The readings were taken every 10 s in mix-chamber mode. Data from the first minute was discarded. The quantities measured were: respiratory frequency (Rf), respiratory exchange ratio (RER), metabolic equivalent (MET) and heart rate (HR).

Results

The comparison of the parameters is reported in table 1:

Parameter	Free	With exo.
Rf (1/min)	20,2 (2.5)	14,5 (2.3)
RER (-)	1,003 (0,068)	0,950 (0,042)
METS (-)	2,1 (0,2)	2,0 (0,2)
HR (bpm)	85,3 (3,6)	80,2 (2,2)

Table 1: Comparison of the metabolic parameters. Average and standard deviation over time.

All the differences were statistically significant (t-test, p-value < 0.05). All the parameters showed a reduced metabolic cost during the task with the exoskeleton.

Discussion and conclusion

Passive exoskeletons are designed to reduce the load on the targeted joints by redistributing it to other parts of the body. This leads to a different motor recruitment strategy needed to achieve the task. The metabolic cost of the task may be reduced. These preliminary results showed that the metabolic cost was reduced during an overhead task involving holding a heavy tool with both hands. Further work will require testing more subjects, extending the recording time and including different tasks. Moreover, the motor strategy should be further investigated by means of EMG and/or biomechanical modelling.

References

1. Grieve et al, Occupational Ergonomics 8(1), 2008
2. De Bock et al, Applied Ergonomics 98, 2022
3. Puchinger et al, IEEE BioRob, 7, 2018

