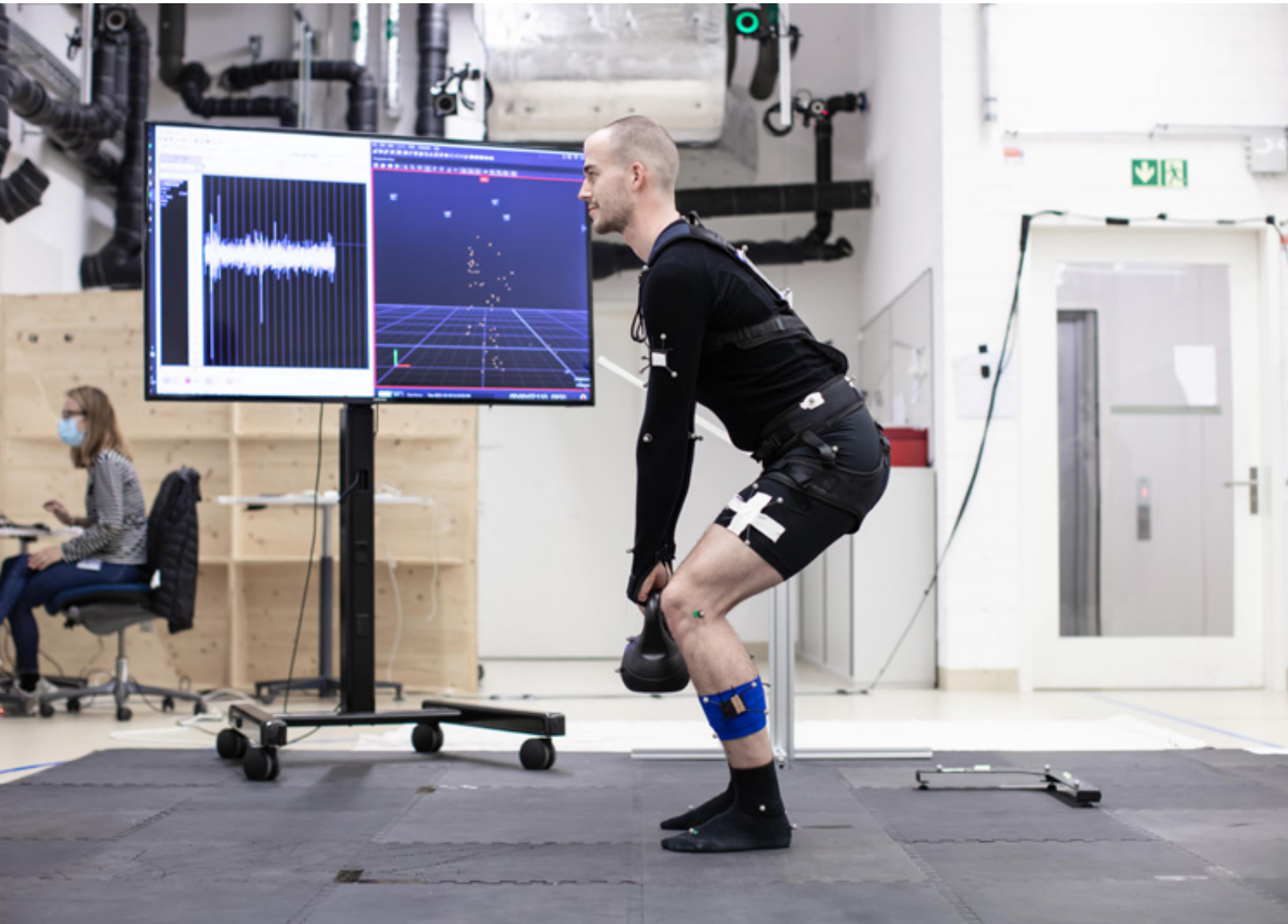
AUXIVO

LiftSuit
Performance Sheet

auxivo.com



Introduction

Ergonomic evaluation of the support provided by the LiftSuit back exoskeleton during work involving forward-leaning postures or repetitive lifting of objects in men and women of working age.

The LiftSuit is a passive lightweight exoskeleton that supports the back and hip muscles when leaning forward and bending down. It features integrated elastic elements that store energy to support the user and reduce the workload. Two scientific studies performed at the EUROBENCH exoskeleton testing facility in Hospital Los Madroños in Spain and the Swiss Federal Institute of Technology - ETH Zurich have shown that wearing the LiftSuit reduces muscle activity and delays the process of fatiguing. When muscles fatigue slower, the user will experience less tiredness and can perform the same task longer.

Study at the EUROBENCH exoskeleton test facility

The first study aimed to assess the effect of LiftSuit support on back muscle fatigue during work in forward-leaning positions. Fourteen participants (9 female) between 21 and 35 years old held a heavy box while in a forward-leaning posture. During this task, the participants' muscle activity and muscle fatigue were recorded to compare the muscular effort when working with and without the support provided by the LiftSuit.

Study at the Swiss Federal Institute of Technology

The second study aimed to assess the effect of LiftSuit support on muscle activity and movement patterns during forward leaning and repetitive lifting movements. Thirty participants (8 female) between 20 to 62 years visited the Rehabilitation Engineering Laboratory to perform occupational tasks with and without the LiftSuit. Tasks included forward leaning and repetitive lifting of weights between 6 and 20 kg. The peak muscle activity, the total muscle effort, movement kinematics, and user experience of working with the exoskeleton were recorded.

Muscle Load

- The LiftSuit reduced back muscle activity by 33% when holding a load in a forward-leaning posture.
- The peak muscle activity in the lower back was reduced by 21% while lifting 6 kg using the exoskeleton, compared to lifting the same load without exoskeleton support.
- When the muscles are working less hard, they fatigue less fast.

Muscle Fatigue

- The LiftSuit reduced back muscle fatigue by 10% and hip muscle fatigue by 44%.
- Changes in muscle fatigue are associated with how exhausted the users feel and how long they can perform the task.

Cardiac cost

- When muscles work less hard, they use less oxygen, which can lower the heart rate.
- When wearing the LiftSuit to lift loads, the cardiac cost was reduced by 7%.

Ergonomics and Comfort

- Participants performed repetitive lifting movements using a semi-squat lifting technique.
- Using the LiftSuit did not influence the hip and knee angle, suggesting that the participants performed ergonomic lifting movements when wearing the device.
- Most participants (>85%) reported that the LiftSuit did not or almost not hinder their movement.
- Half of the users reported the LiftSuit support level to be exactly right.

Effects on Muscle Load

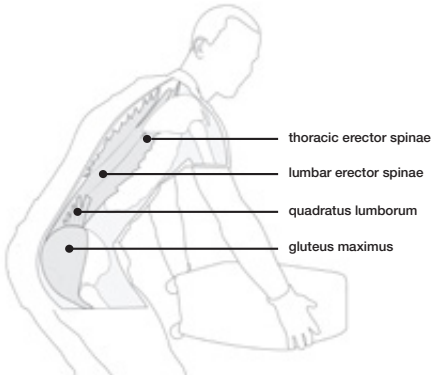
The study showed that using the LiftSuit reduces back muscle load by up to 33% while leaning forward and by up to 20% during repetitive lifting of heavy loads.

Scientific Method
Muscle activity was measured using surface electromyogrphy. Specifically, muscles in the lower back (lumbar erector spinae, quadratus lumborum), upper back (thoracic erector spinae), hip (gluteus maximus), and abdomen (rectus abdominis) were measured.

The signal was recorded and processed according to European guidelines (SENIAM). Before the lifting task, participants performed maximal voluntary contractions. The muscle activity data were normalized to the average of two maximal voluntary contraction attempts.

To indicate how hard the muscles are working during each task, we report the root mean square of the muscle activity and the peak normalized muscle activity.

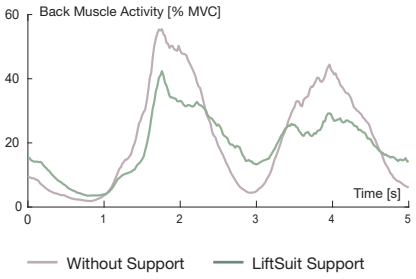
Benefits in forward leaning postures
When leaning forward while standing or kneeling on the ground, the back muscles worked significantly less hard while wearing the LiftSuit. When leaning forward in a standing position, common, e.g., in nursing and agriculture, lower back activity was reduced by 12%. When holding a heavy box while leaning forward, the muscle activity in the back was reduced by up to 33%. When leaning forward in a kneeling position, common, e.g., in construction tasks like tile laying, lower back muscle load was reduced by 19%.



Gravity to stretch the elastic elements
Stretching the elastic elements of the LiftSuit does not require the users to invest additional energy because the LiftSuit, by design, only counteracts gravity. The users can use their upper body weight to stretch the elastic elements of the LiftSuit by leaning forward and releasing their upper body weight to the LiftSuit. The study results confirm that this design works well, as no increased activity in the abdomen muscles was measured when working with the LiftSuit.

Benefits when lifting loads
During repetitive lifting of loads between 6 and 20 kg, the exoskeleton significantly reduced peak muscle activity of the lower back muscles. Peak muscle activity in the quadratus lumborum was reduced by up to 21%. Besides reducing peak muscle activity, the exoskeleton reduced the total muscular effort of the hip and back muscles by up to 16% during repetitive lifting.

The diagram below shows the average muscle activity of the lumbar erector spinae muscle during five lifting movements. The participant bends down, grabs and lifts the weight, and then places the weight back down. Both during lifting and lowering the weight, the peak back muscle activity without exoskeleton support is between 40 and 60% of maximal activity. When working with the exoskeleton the peak back muscle activity of this person was reduced by 30%



Effects on Muscle Fatigue

In the study, the support of the LiftSuit reduced fatigue by 44% in the hip muscles and 10% in the lower back muscles while holding a heavy box in a forward-leaning body position.

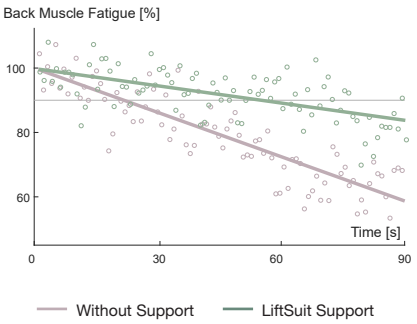
Scientific Method
Muscle activity was measured using surface electromyogrphy. Specifically, muscles in the lower back (lumbar erector spinae, quadratus lumborum), upper back (thoracic erector spinae), hip (gluteus maximus), and abdomen (rectus abdominis) were measured on the left and right side of the body.

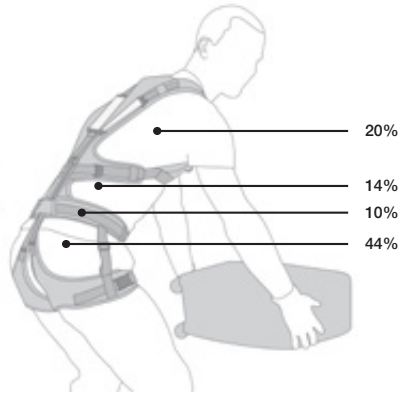
The signal was recorded and processed according to European guidelines (SENIAM).

As an indication of how quickly muscles are fatiguing during the task, we look at the rate at which the median frequency of the muscle activity sinks with time. The average fatigue in the left and right body side over all participants is reported.

When muscles fatigue, the ratio between activated fast-twitch and slow-twitch muscle fibers changes. This results in a shift in the frequency content of the muscle activity signal. The lower the median frequency compared to the start of the task, the more the muscles are fatigued.

The figure shows that the right erector spinae muscles of one example participant fatigue over time when doing the task without support. With LiftSuit support, hardly any fatigue occurs during the task.





Averaged across all participants, the rate at which the median frequency sinks was significantly lower when wearing the LiftSuit. In the study, the support of the LiftSuit reduced the rate of fatigue by 44% in the hip muscles and by 10% in the lower back while holding a heavy box in a forward-leaning body position.

The reduction of muscle fatigue is important because previous research has shown that cumulative back muscle fatigue plays a role in the occurrence of low-back injuries in occupations that require repetitive lifting of heavy loads and working in forward-leaning postures. Muscular fatigue is also related to the time a worker can perform a task and the feeling of overall fatigue at the end of a workday.

Effects on Cardiac Cost

When muscles work less hard, they use less oxygen, which lowers the heart rate. Wearing the LiftSuit during repetitive lifting tasks led to a reduction in cardiac cost of 7%.

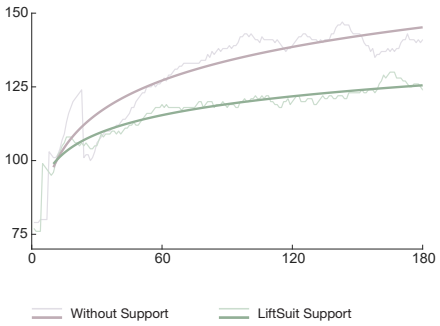
Scientific Method
Heart rate was recorded using a polar heart rate belt around the chest directly on the skin. The signal was processed using the accompanying software to obtain beats per minute (bpm).

Cardiac cost is calculated as the difference between the heart rate during work and the resting heart rate. It reflects the additional beats per minute the heart needs to do the job.

The average cardiac cost of 8 participants is reported.

When starting an activity, our muscles immediately begin to work and use oxygen. To supply the muscles with the extra needed oxygen and to remove waste products, the heart starts beating faster. After a few minutes of uninterrupted work, the heart rate stabilizes, and the cardiac cost of the task can be calculated.

In the figure, the heart rate of one participant is visualized while repetitively lifting a 6 kg weight from the floor for three minutes.



The average heart rate while repetitively lifting loads without the exoskeleton was 122 bpm. This was reduced to 117 bpm when working with the LiftSuit. The associated cardiac cost was reduced from 58 to 54 bpm, implying a 7% relief for the cardiovascular system.

Cardiac Cost up to 7%

Ergonomics and Comfort

The LiftSuit supports ergonomic lifting movements and reminds the user to work ergonomically. Most participants reported that their movements were unconstrained when using the LiftSuit.

Scientific Method
The participants' movements were captured in 3D using an optical motion capture system. For the experiment, 58 reflective markers were placed on the body segments and joints of the participant. The location of each marker was captured using 15 cameras placed around the room.

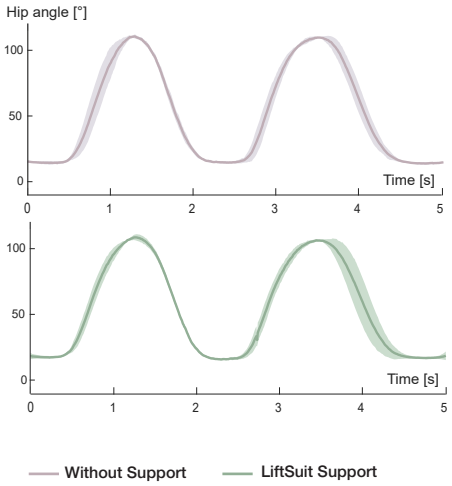
Using biometric data, an anatomical model of each individual was created.

To assess the ergonomics of the body posture, we calculated the hip and knee angles during repetitive lifting of loads. The maximum and minimum hip and knee angle were reported.

Device usability was assessed using a custom questionnaire.

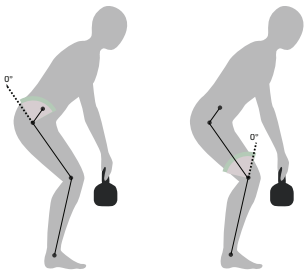
When performing physically heavy work, an ergonomic way of moving is essential. Users report that the LiftSuit reminds them to perform lifting movements correctly.

The study results showed that participants performed semi-squat lifting movements. The use of the exoskeleton did not negatively change the movement pattern.



The minimum and maximum hip and knee angles remained unchanged during lifting movements when using the LiftSuit. These results suggest that the participants did not alter their motion patterns and performed ergonomic lifting movements.

Most participants (>85%) also reported that the LiftSuit did not or almost not hinder their movement.



Contact

Headquarter

Auxivo AG
Sonnenbergstrasse 74
CH-8603 Schwerzenbach
Telephone +41 77 250 35 31
info@auxivo.com

Sales Area

Switzerland
Banu Aslan
Area Sales Representative
T +41 78 204 09 05
banu.aslan@auxivo.com

Germany
Marc Kunkel
Area Sales Representative
T +49 16 2238 0780
marc.kunkel@auxivo.com

France
Oscar Fernandez
Sales Manager
T +33 642 458 114
oscar.fernandez@auxivo.com

Margaux Garcia
Area Sales Representative
T +33 663 826 313
margaux.garcia@auxivo.com

Benelux
Joël Bonsafo Bawua
Area Sales Representative
T +32 483 581 451
joel.bonsafo@auxivo.com

Spain
Oscar Fernandez
Sales Manager
T +33 642 458 114
oscar.fernandez@auxivo.com

Designed & Engineered in Switzerland