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OmniSuit
Performance Sheet

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EN

Introduction

Ergonomic evaluation of the support provided by the OmniSuit exoskeleton. The OmniSuit provides back and shoulder support while manipulating loads between ground and overhead level, and while leaning forward.

The OmniSuit is a passive lightweight exoskeleton that supports the arm, shoulder, neck, and back muscles while working. As a multitask exoskeleton combining back and shoulder support, the OmniSuit seamlessly provides lifting and overhead assistance and can support users over the entire vertical range of motion. This versatility makes it suitable for logistics, construction, or manufacturing applications, where many tasks and movements are frequently required.

It features integrated elastic elements that store energy to support the user and reduce the workload. Scientific evaluation of the back and shoulder support modules was performed in multiple studies. The data shows that the OmniSuit reduces muscle activity and delays the process of fatiguing.

All values presented in this performance sheet are average values calculated across all participants of the respective study. The individual support a user can expect can vary significantly. It depends on many factors, such as body size, weight, specific task execution, and even the amount of training they have using the OmniSuit.

For example, the shoulder muscle support when using a power tool to work overhead is reported here with a 33% average load reduction. This means the mean load reduction over all 32 participants was 33%. When we look at the individual support level, we will see some participants received less than the average support, and some received more. In the power tool example with an average reduction of 33%, 25% of participants had below 25% load reduction, while 25% percent received even more than 40% support, and the participant with the maximum support benefited from over 85% muscle load reduction in the shoulder.

As a result, the average values will provide a good general performance indication, but only a personal test will allow the assessment of the individual support level.

Muscle Load
- The OmniSuit reduced suscel load in the shoulder by 33% when using a power tool and by 36% when manipulating small objects.
- The OmniSuit 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 when using the exoskeleton.
- When the muscles are working less hard they fatigue less fast.

Muscle Fatigue
- The shoulder support module reduced fatigue by 45% in the shoulder muscles, 60% in the upper arm and 75% in the neck while holding a power tool above the head.
- The back support module reduced back muscle fatigue by 10% and hip muscle fatigue by 44%.
- Changes in muscle fatigue are associated with changes in how exhausted the user feels and how long they can perform the task.

Cardiac Cost
- When muscles are working less hard they use less oxygen, which can lower the heart rate.
- When wearing the shoulder support module while using a power tool cardiac cost was reduced by 15%.
- When using the back support module to lift loads, the cardiac cost was reduced by 7%.

Ergonomics
- Overhead work can be uncomfortable. The shoulder support module reduced reported discomfort in the shoulder, neck and upper arm.
- The users reported little to minor constraint of their movement by the exoskeleton.

Effect of the Shoulder Support Module on Muscle Load

The shoulder support module reduced average shoulder muscle load by 33% when using a power tool and by 36% during an assembly task. Average shoulder muscle activity was reduced by 65% during static tasks.

Scientific Method
Thirty-two participants (15 female) of working age (20 to 65 years) performed occupational tasks with and without shoulder support. Tasks included using a powered drill above shoulder level, manipulating small objects above shoulder level, and holding various arm positions with and without power tool.

During these tasks the participants' heart rate, muscle activity, muscle fatigue, perceived fatigue and user experience were measured to compare working with and without exoskeleton support.

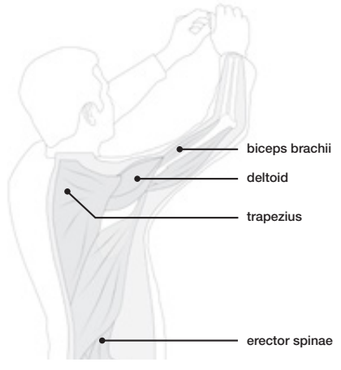
Muscle activity was measured using surface electromyography. Specifically, muscles in the arm (biceps brachii), shoulder (anterior deltoid), neck (upper trapezius) and lower back (erector spinae at lumbar level) were measured.

The signal was recorded and processed according to European guidelines (SENIAM). Prior to the tasks participants performed maximal voluntary contractions. The muscle activity was normalized to the highest of two maximal voluntary contraction attempts.

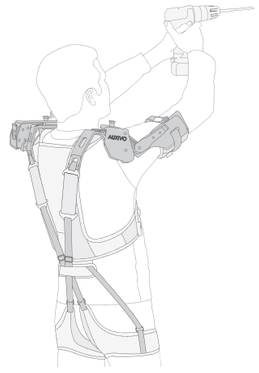
As an indication of how hard the muscles are working during each task we report the root mean square of the normalized muscle activity.

Benefits when working overhead
Using the shoulder support module significantly reduced the muscle activity in the arm, shoulder and neck muscles across tasks. The average reduction in shoulder muscle activity was as high as 65% when holding the arms at a 90° angle in front of the body. No negative effects, such as additional activation of the lower back muscles, were observed. Back muscle activity was even significantly reduced when holding a 1.8 kg power drill.

When the muscles need to work less hard, the movements become more precise, and muscles fatigue slower.



Benefits when using a power tool
While fastening screws with a powered drill, the shoulder support module significantly reduced average muscle load in the shoulder by 33%, in the neck by 22% and in the arm by 17%.



Benefits when manipulating objects
While manipulating small objects above shoulder level without a tool, the support provided by the exoskeleton significantly reduced upper body muscle load. Specifically, average muscle load in the shoulder was reduced by 36%, the neck by 34% and the arm by 37%.

Effects of the Back Support Module on Muscle Load

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

Scientific Method
Thirty participants (8 female) of working age performed occupational tasks with and without back support. Tasks included lifting loads below hip level and maintaining forward leaning positions.

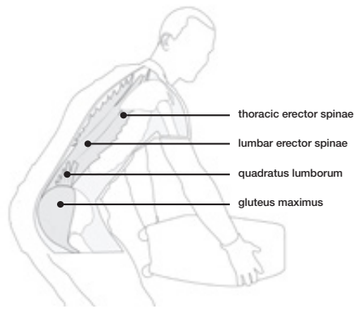
During these tasks the participants' heart rate, muscle activity, muscle fatigue, perceived fatigue and user experience were measured to compare working with and without exoskeleton support.

Muscle activity was measured using surface electromyography. 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.

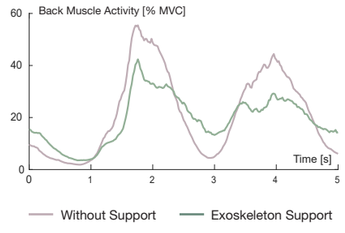
Benefits in forward-leaning postures
When leaning forward while standing or kneeling on the ground, the back muscles worked significantly less hard while wearing the exoskeleton. When leaning forward in a standing position, common, e.g., in nursing and agriculture, lower back activity was reduced by 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 OmniSuit does not require the users to invest additional energy, because the OmniSuit, by design, only counteracts gravity. The users can use their upper body weight to stretch the elastic elements of the back support module by leaning forward and releasing their upper body weight to the OmniSuit. The study results confirm that the back support module design works well, as no increased activity in the abdomen muscles was measured when working with the exoskeleton.

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 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 Fatigue

The shoulder support module reduced average fatigue in the arm, neck and shoulders up to 75% during overhead work. While the back support module reduced back and hip muscle fatigue by 44% on average during forward leaning.

Scientific Method
Muscle activity was measured using surface electromyography. In the study assessing the shoulder support module the muscles in the arm (biceps), shoulder (deltoid), neck (upper trapezius) and back (erector spinae) were measured. In the study assessing the back support module the muscles in the back (erector spinae) and the hip (gluteus maximus) were measured.

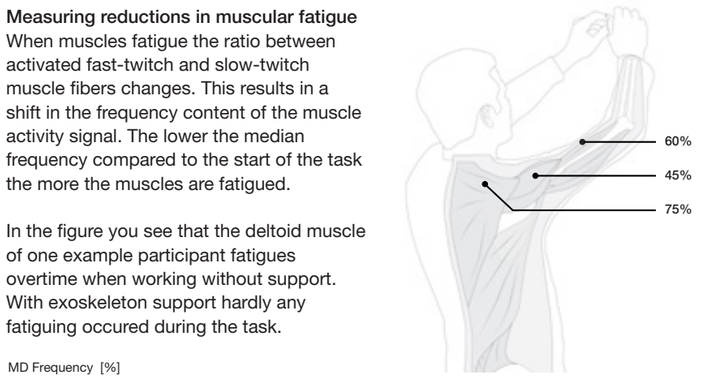
The signal was recorded and processed according to European guidelines (SENIAM).

As an indication of how quickly muscles are fatiguing during the task, we looked at the rate at which the median frequency of the muscle activity reduces over time.

During the shoulder support module task the participants rated their perceived exertion on a 10-point scale from no exertion to maximal effort.

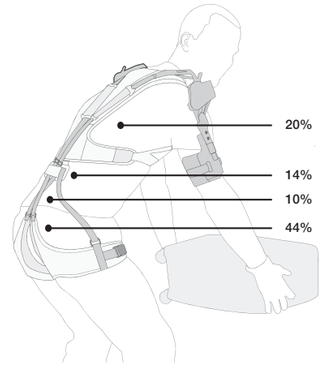
Measuring reductions in muscular fatigue
When muscles fatigue the ratio between activated fast-twitch and slow-twitch muscle fibers changes. This results in a shift in the frequency content of the muscle activity signal. The lower the median frequency compared to the start of the task the more the muscles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

In the figure you see that the deltoid muscle of one example participant fatigues overtime when working without support. With exoskeleton support hardly any fatiguing occured during the task.



Over all participants the rate in which the median frequency sinks was significantly lower when wearing the shoulder support module. In the study the exoskeleton support reduced fatigue by 45% in the shoulder muscles, 60% in the upper arm and 75% in the neck while holding a power tool above the head.

The back support module reduced the rate of fatigue by 44% in the hip muscles and by 14% in the lower back while holding a heavy box in a forward-leaning body position.



Effects on perceived fatigue
Overhead work is exerting. The reduced rate at which the muscles fatigued in the study are reflected in the experience of the participants. Using the exoskeleton reduced their reported levels of exertion by 20%. These instant changes in feeling fatigued likely amplify during a full-days work. This means workers will go home feeling less tired after a days work with the OmniSuit.

Effects on Cardiac Cost

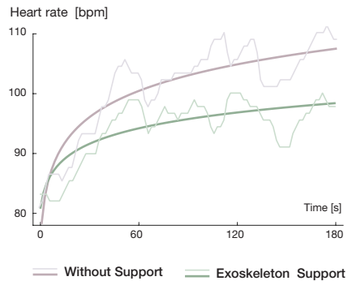
When muscles are working less hard they use less oxygen, which can lower the heart rate. Using the shoulder support module to handle a power tool led to an average reduction in the cardiac cost of 15%.

Scientific Method
Heart rate was recorded using an optical heart rate sensor worn at the non-dominant wrist or using a chest belt. The signal was processed using the accompanying software to obtain beats per minute (bpm).

Cardiac cost is calculated as heart rate during the task minus resting heart rate. It reflects the additional beats per minute the heart needs to make to complete the task at hand.

When starting a task our muscles immediately activate 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 one can see the heart rate of one participant while using a powertool above shoulder level with and without exoskeleton support.



Cardiac cost of fastening screws with a powered drill above the head was 21 bpm. During the study using the shoulder support module reduced the cardiac cost by 15% to 18 bpm.

The cardiac cost of manipulating small objects above shoulder height was 23 bpm without exoskeleton support. During the study exoskeleton support reduced the cardiac cost by 12% to 20 bpm.

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



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