AUXIVO

CarrySuit
Performance Sheet

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Introduction

This performance sheet addresses the principles by which the CarrySuit provides support and presents the results of the ergonomic evaluation of the performance of the CarrySuit exoskeleton when carrying heavy objects.

The CarrySuit is a passive exoskeleton that relieves the arm, shoulder, neck and back muscles during carrying work. The CarrySuit was developed together with and for workers in the construction, window and beverage industries. Two research groups have carried out ergonomic assessments of the exoskeleton support. The studies, from the University of San Francisco de Quinto and the University of Cincinnati, have shown that wearing the CarrySuit reduces muscle activity and cardiac cost. If the muscles tire more slowly, users feel less fatigue and can therefore perform the carrying tasks for longer.

Study at the University of San Francisco de Quinto USFQ
The aim of this study was to investigate the effects of CarrySuit support during carrying work. Thirty participants (16 women) with an average age of 21 years carried a 15 kg box for 10 minutes in rounds. During this work, the muscle activity, heart rate, and perception of the participants were recorded to compare the work with and without the support of the CarrySuit.

Study at the University of Cincinnati
The aim of this study was to investigate the effects of CarrySuit support on muscle activity and heart rate during various carrying tasks. Twenty participants (9 women), with an average age of 24 years, performed various carrying tasks with and without the CarrySuit. The activities included 2-minute carrying tasks of 9 and 18 kg boxes, as well as 9 and 18 kg bags. The muscle activity, heart rate and perception of the users while working with the exoskeleton were measured and compared.

Muscle Load
- The CarrySuit reduced muscle activity in the arm, shoulder and neck muscles by up to 60%.
- The reduced strain on the muscles made carrying heavy loads much more comfortable.
- When the muscles are working less hard they fatigue less fast.

Cardiac Cost
- When muscles are working less hard they use less oxygen, which can lower the users heart rate.
- When using the CarrySuit while carrying heavy loads, the heart rate was 38% lower.

Ergonomics and Comfort
- Carrying heavy loads can be uncomfortable. The CarrySuit reduces perceived discomfort in the neck, upper and lower arm.
- Carrying loads with the CarrySuit is preferred and recommended by 83% of participants.

Functioning Principles of the Support

The CarrySuit relieves the user's arms, shoulders, neck and back through two main biomechanical principles: by creating an alternative load path and by redistributing the load.

The Bypass Principle
This is a comparatively simple but effective approach. The CarrySuit mechanically bypass the load around one or more human joints. So, for the body parts covered by the exoskeleton, it transfers the load (or part of it) from your body to the exoskeleton, and the load is then routed through the exoskeleton and bypasses your musculoskeletal system. At the lower attachment point of the exoskeleton, for the CarrySuit the hip, the load is transferred back to the body, where it is transferred to the ground, similar to the load path without the exoskeleton.

For example, when you are holding a mass of 20 kg in your hand, this load is channeled through your wrist, elbow, and shoulder, down your spine, through the hip into your legs, knees, ankles, and eventually into the ground. Along the way, it puts strain on all these body parts. When using a carrying exoskeleton, like the Auxivo CarrySuit, a significant part of the load is directly transferred from the mass to your torso, bypassing the comparatively vulnerable joints in the arm, shoulder, and spine.

The Load Redistributing Principle
When an external load affects your body locally or asymmetrically, e.g., when you carry something heavy with one hand, it will typically cause most of the strain on only a small part of your body. This happens because the load will be routed along the most direct path through your body to the ground. This also means that you have a high risk of local overload in specific joints, while the rest of your body may be barely affected by the load.

This is something that exoskeletons can change by redistributing the load and spreading it more evenly over larger parts of the body and away from body parts at risk of a local overload. The Auxivo CarrySuit consists of a frame around the upper body. When a load is attached to it, the frame will automatically distribute the load more evenly across the user's body, connecting it to the hip and shoulder on both the left and right bodyside.

Applying this principle, of course, means that the CarrySuit may increase the load on other parts of the body, such as the hip, which, out of context, might sound counterproductive. However, it also means the load is more evenly distributed across your body, avoiding local peak loads that often increase the risk of injuries.

Effects on Muscle Load

In the studies the support provided by the CarrySuit reduced the load on the shoulder muscles by 60% and the neck muscles by 45% when carrying a heavy load.

Scientific Method
Muscle activity was measured using surface electromyography. Specifically, muscles of the forearm (brachioradialis), the upper arm (biceps), the shoulder (deltoid), the neck (trapezius), the lower back (erector spinae) and the abdomen (rectus abdominis) were measured.

The signal was recorded and processed according to European guidelines (SENIAM). Prior to the test series, participants performed maximal muscle contractions. Muscle activity was normalized to the maximal voluntary contraction.

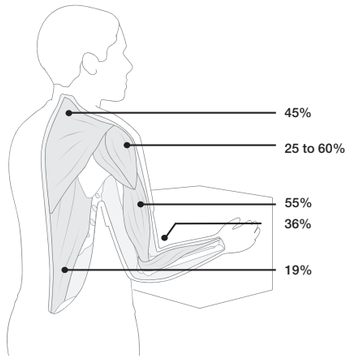
As an indicator of how much the muscles are used during each task, we give the root mean square of the normalized muscle activity.

The use of the CarrySuit significantly reduced muscle activity in the shoulder and neck muscles during the carrying tasks.

The maximum activity of the forearm muscles was reduced by 36% while carrying a 15 kg crate during the exercise. Furthermore, the upper arms were relieved by 55% and the shoulders by 25%. The lower back was reduced by 19%.

The average reduction in shoulder muscle activity was up to 60% when carrying an average 15 kg load on the treadmill. The neck muscles were reduced by 45%. No negative effects, such as an increase in muscle activity in the lower back or abdomen, were observed.

When the muscles have to be loaded less, the movements are more precise and the muscles tire more slowly.



Effects on Cardiac Cost

When muscles are working less hard they use less oxygen, which lowers our users heart rate. Using the CarrySuit while carrying loads led to a reduction in cardiac cost of up to 38%.

Scientific Method
Heart rate was recorded using a heart rate belt or wrist band sensor. The signal was processed using the accompanying softwares 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.

The heart rate when walking in laps and carrying a 15 kg box was 121 bpm on average. During the study, the heart rate was reduced by 38% to 105 bpm with the support of the CarrySuit.

The figure shows the average heart rate of 30 participants during the rest period and while walking in laps and carrying a 15 kg box.

The maximum heart rate when carrying a 9 or 18 kg box or bags on the treadmill was 110 beats per minute without exoskeleton support. During the study, the maximum heart rate was reduced to 103 bpm with the support of the CarrySuit.

Reduction in heart rate upto 38%

Ergonomics and Comfort

The CarrySuit reduced reported discomfort in the neck, upper and lower arm area. Carrying loads with the CarrySuit is preferred by 83% of users, and 87% recommend using the CarrySuit for carrying heavy loads.

Scientific Method
Discomfort was assessed using standardized questionnaires, one with the “Body Discomfort Scale” and one with the “Nordic Questionnaire”. The test subjects were asked to rate the feeling of discomfort of the type of task on a 10-point scale, once with and once without the exoskeleton.

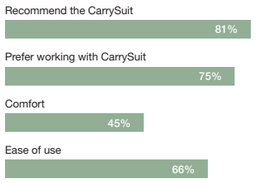
A questionnaire on user-friendliness was completed after the work had been carried out once with and once without the exoskeleton. It consisted of four questions: how easy it was to perform the task with the exoskeleton, how comfortable it was to perform the task with the exoskeleton, whether performing the task with or without the exoskeleton was preferred and whether the exoskeleton was recommended for carrying tasks.

Comfort
After 10 minutes of carrying a 15 kg box using the CarrySuit, discomfort in the elbows and arms, hands and wrist and general fatigue were significantly reduced. When carrying various loads on the treadmill, the discomfort in the neck, upper arm, forearm and upper back caused by the carrying work could even be completely eliminated with the use of the CarrySuit.

Reported support and ease of use
After the task, 60% (18/30) of the participants rated the ease of completing the task with the exoskeleton as Good to Excellent. The comfort of performing the task with the CarrySuit was rated Good to Excellent by 53% (16/30) of the participants.

Carrying loads with the CarrySuit is preferred by 83% (25/30) of users to carrying loads without an exoskeleton, and 87% (26/30) of the participants recommend the use of the CarrySuit for carrying.

Participants experienced mild to moderate support from the exoskeleton and reported feeling less fatigued when carrying boxes and bags on the treadmill.



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