RESULTS OF A STUDY WITH THE GOAL TO OPTIMISE HARNESSES BY MEANS OF UP-TO-DATE BIOMECHANICAL ENGINEERING

Thomas Bertels, Diploma Biomedical Engineer
R&D - Upper Limb Prosthetics
Otto Bock HealthCare GmbH, Duderstadt, Germany

ABSTRACT

Body harnesses control body-powered and hybrid prostheses of the upper extremities. They transfer muscular forces from the amputee through motion of the shoulder girdle or stump directly to the artificial limb. The development of body harnesses requires not only to look at technical possibilities, but even more important, to take the biomechanical abilities of the patient into consideration. Different tests were performed to identify typical motion patterns of the patients and to measure the forces produced thereby.

Founded on the results of this biomechanical study and the comparison between different harnesses, a new above elbow body harness has been developed. It was ergonomically optimised to provide a more efficient force transmission. Modern materials and easily replaceable axillar pads complete the advantages and support today’s hygienic aspects. There are new accessories available allowing easy and fast adaptation of the harness to patient and prostheses without any need for sewing.

INTRODUCTION

Body powered and hybrid prostheses use the patient’s own body power to control functions of the artificial limb. Therefore, the harness is an important component in this kind of prosthesis. The harness takes motion and forces from the residual limb, shoulder girdle and trunk and transfers them directly to the prosthesis. Natural muscle motion helps the patient perform his activities smoothly. Furthermore, the pressure of the harness on the body gives the patient sensory feedback. In cases of above elbow amputations, the harness provides supplementary fixation of the prosthetic socket to the residual limb. The higher the amputation level, the more difficult it becomes to control and fix the prosthesis. Nevertheless, it is possible to also fit patients with shoulder-level amputations. Besides the gripping process, the harness can be used to control elbow flexion and locking. In cases of below elbow fittings, the harness activates only the terminal device. There is a variety of harness systems for different amputation levels.

For above elbow prostheses two very different harness systems have been proven in practice. In Central Europe, the triple-pull harness after Kuhn and Hepp is preferred. Using this harness, all three required functions (i.e. activating the terminal device, below elbow flexion and locking or releasing the elbow joint) can be performed individually. On the American market double-control harnesses are usually fitted. This system is different from triple-pull harnesses because prehensile control and elbow flexion are activated with one cable and controlled with one motion. Therefore, when the elbow is flexed, the path of this harness required for opening the terminal device is longer. Because prehensile function as well as flexion
of the elbow depend on whether the elbow is locked or released, an additional motion always has to be performed between these actions. These harness systems are also differentiated by the fact that they are controlled by different motions.

**METHODS AND SURVEY**

This survey was done to find out with which harness system the patient can be fitted most effectively. An important part of the survey deals with measuring the mobility of the shoulder joint using the shoulder joint simulator IKARUS, from the company Biofeedback Motor Control GmbH in Leipzig, Germany. This device represents a three-dimensional measuring and motion simulation system for testing and training the biofeedback of shoulder and joint. Through use of the shoulder simulator the mobility of the shoulder joints and force activation at any measuring point of the anatomic plane can be shown. The tests were performed with and without above elbow socket according to the neutral-zero method.

![Figure 1: Shoulder joint simulator IKARUS](image1.png) ![Figure 2: Motion analysis](image2.png)

To be able to assess the motion patterns with fitted body harness more detailed, measurements of the upper body were carried out in a motion analysis laboratory. For this purpose reflectors were attached to prominent points of the body and the prosthesis of a test patient wearing a prosthetic socket with different body harnesses. Using the optical-electronic measuring system PRIMAS, all typical motion patterns were recorded. At the same time, the body harness was equipped with a compression-tension sensor. In addition, the produced forces enabled the evaluation of motion efficiency.

Furthermore, it is important for optimal function of the harness to make most effective use of movements. The prosthetist has to assess how to fit the harness most appropriate for the patient. For this reason, measurements were taken describing the maximum possible paths for different motion patterns of several harnesses.
RESULTS
The results clearly show that there is sufficient force to operate the different cable-activated prostheses. Concerning the required paths, however, there are significant problems which become obvious when comparing different harnesses. Harnesses with ring have the problem that the ring slips upwards after a few movements. The tests with such a harness were performed at first with the ring placed at optimal position and then with the ring placed in the neck region. Looking at the paths there are clear differences. Therefore, it is of high importance to adjust the cable-activated components of a prosthesis most effectively for the patient.

NEW HARNESS
Founded on the results of the study a new triple-pull harness was developed. It allows to perform each single function of the prosthesis individually.

The cables for suspension and elastic straps are flexible and run from the harness ring to the prosthetic socket. Inner perlon cables transfer the forces from the patient to the prosthesis. These perlon cables are connected with the harness ring. Common body harnesses with ring show the problem that the ring slips upwards on the back of the patient after few motions. The optimised ring is furnished with integrated cable guides preventing the perlon cables from moving on the ring. They block each other and thus avoid slipping of the whole harness system. The straps always remain in optimal position. The path and the forces of the patient are transferred to the prosthesis with high efficiency. The patient is able to control his body powered prosthesis by unobtrusive motions. In addition, optimised harness fit offers increased wearing comfort. Replaceable and washable axillar pads as well as washable harness straps support hygienic needs. A new strap connector allows to produce the harness without need for sewing.
CONCLUSION
Because of the individual needs of the patients, there is a variety of body harness systems which can be cut-to-size. But normally, ready-made harness systems are used. The triple-pull harness and the American double-control harness represent basic models for fitting above elbow amputees. It is highly important that the harness is carefully fitted to the patient and meets his requirements. Sensory feedback of performed activities and effective control of functions depend on an optimal fit of the body harness.

The new harness system was developed for the patient to make operation with the artificial limb easier.

REFERENCES