An active knee orthosis for supporting the elderly in daily life.

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Abstract
An active orthosis was designed to support users with reduced muscle strength with an additional knee joint torque to improve the independency in everyday activities. In two persons the hypothesis was tested that less muscle activity is necessary when standing up with the active support of a motorized orthosis. The orthosis is a custom-made knee-ankle-foot orthosis and is equipped with a series elastic actuator. A reduced EMG activity in the m. rectus femoris was found when supported by the active orthosis in the sit-to-stand task. The unchanged kinetics and kinematics show that the subject's sit-to-stand (STS) strategy is not influenced by the external torque; therefore amplifying torque generation seems to be a promising way of support.

1 Introduction
With the aging of the population [1] it is important that the elderly stay independent as long as possible. A prerequisite for walking or moving around is the ability for independent stand up. In the elderly, the strength of the knee flexors and extensors is reduced by approximately 30-40% [2]. This strength reduction in elderly persons may, possibly in combination with a higher body mass index, have an influence on the ability to stand up.

In this study, an active knee orthosis has been developed for assisting the elderly in challenging daily activities like stair-climbing or STS movements. Presently, active orthosis systems are mostly designed as a complete exoskeleton for military or industrial use or for use in rehabilitation [3]. In military use, the aim is to enable the user to walk over longer distances or carry heavy objects [4]. In rehabilitation, the exoskeletons are used to enable persons with a spinal cord injury to walk again. Here, the orthosis is controlled by a program which moves the user’s legs along pre-planned trajectories [5].

The aim of the present active orthosis is to support users with reduced muscle strength with an additional knee joint torque; not to provide the necessary torque for the total movement. This assistive device should help to retain the users’ fitness and improve the quality of life by improving the independency in everyday activities. To prove the hypothesis that the amount of support is reflected in less muscle activation the following experiment was conducted.

2 Methods
For two subjects bilateral knee-ankle-foot orthosis were custom-made in the clinic’s Prosthetics and Orthotics workshop.

A series elastic actuator [6] was mounted laterally on the thigh-brace of the knee-ankle-foot orthosis (Figure 1). The actuator consists of a motor, a planetary gear box, a torsion spring and a bevel gear (with a transmission ratio of 1:1.5) [7]. Two encoders measure at the motor and behind the spring (motor torque/angle and joint torque/angle). The angular difference between the two encoder signals is used to determine the supported torque and as input value for the controller. The setup has a peak power output of 45 W and a peak torque output of about 25 Nm. The dimensions are 270 mm x 60 mm x 45 mm and the total weight is 1.4 kg.

The series elastic actuator is torque controlled by a state-space controller with disturbance observer and disturbance compensation. An intuitive choice of the controller parameters is possible due to the linear and model based control structure. This setup allows a precise torque control, which is independent from the user’s movements; and can be controlled solely by the higher ranking orthosis controller. In contrast to classic geared direct drive actuators, the series-elastic actuator can also provide a zero torque output due to the elastic element in the drive chain and the torque controller [8].

The prototype was tested on two persons fitted with the device on the both legs. 3D-kinematics and kinetics were collected synchronously at 120 Hz by an optical motion capturing system (Vicon Mcam, Vicon, Oxford, UK). EMG of the m. rectus femoris (Biovision Inc., Wehrheim, Germany), the torque, current and the motor were recorded at 1080 Hz. Symmetric STS movements at self-selected velocity were performed 10 times with feet placed on two separate force platforms. The subject stood up from a bench placed on a third force platform to detect the seat-off-event. STS-movements were performed with a support of 25% of subject's maximum required knee torque and without supporting torque (0% support).
3 Results

It was found that with motor support the maximum activation of the m. rectus femoris around the seat off event was ca. 25% lower than STS without motor support (Figure 2). During STS without support through the actuator, the EMG of the m. rectus femoris was found to be similar to the situation when the STS was performed with just a passive orthosis without any instrumentation. Kinematics and kinetics were similar for the supported condition and the condition with no supporting torque. Furthermore, a good correlation was found between EMG and motor data. Both the activation of m. rectus femoris and the torque generation by the actuator started prior to seat off.

4 Discussion and conclusion

Amplifying torque generation seems to be a promising way of support. A reduced EMG activity was found when the user was supported by the active orthosis during the STS task. The unchanged kinetics and kinematics show that the subject's STS strategy is not influenced by the external torque. Of course, the experimental evaluation has to be expanded to more subjects and subjects of higher age, with lower fitness level and different body mass indices since it is known that these factors can influence the STS strategy [9].

The present hinge joint design leads to incongruence between the anatomical and orthotic knee axis and will be replaced by an adaptive joint mechanism in the second prototype. Comfort and natural and intuitive support of the orthosis are crucial for user acceptance. The new prototype will be equipped with force measuring insoles, a mechanical muscle activity sensor, and an intention estimation algorithm. Finally, the next generation of SEAs will provide higher performance and will have less size and weight to make the active orthosis an assistive device which can be worn all day without restraining the user in their activities.
5 References


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