Kinetic and kinematic adaptation to walking with a passive exoskeleton

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Motivation

The ability to walk is an important contributor to be able to participate in society. If this ability is partly or completely lost an exoskeleton might be a way of restoring this. Prototypes of exoskeletons have shown that EMG and in a lesser extend metabolic rate can be reduced by an exoskeleton [1, 2]. However, many of current exoskeletons rely on an external power supply or an exhaustible batteries. To make exoskeletons applicable for daily life, energy efficiency is a key issue to improve, since it will prolong their operation time. As a solution (quasi)-passive exoskeletons have been proposed on which we will focus.

State of the Art

State of the art in (quasi)-passive exoskeleton design are the exoskeletons that compensate gravity [3] or match joint moments [4, 5]. A well cited concept are the passive exotendons [6], where long springs spanning multiple joints temporary store and redistribute energy over the joints. We implemented this concept in an exoskeleton prototype [7]. For this and previously mentioned exoskeletons the assumption is made that joint moments and angle patters are invariant of the given support. For the moment patterns this is confirmed by [8]. Passive exoskeletons have not shown an absolute reduction in metabolic rate, and a mismatch between models and reality persists.

Own Approach

The limited results with our exoskeleton were a motivation to revise our basic assumptions about invariant joint angle and moment patterns. We built a lighter (6.9 kg) version of the exoskeleton, called the XPED2 (Fig. 1). This exoskeleton was used for a pilot study where we studied walking kinetics and kinematics of walking with and without exoskeletal support. Two subjects volunteered for the study (1 male, 1 female, healthy 22 and 20 years old). They were allowed to practice with the exoskeleton for two days. On a third day they walked with the exoskeleton with and without the artificial tendons. An instrumented treadmill recorded ground reaction forces, an optical tracking system recorded kinematics, and forces in the tendons were measured by load cells. The data was split into different steps and a median step was calculated.

Current Results

Fig. 2 shows the median step for the two subjects walking with and without the support. Most changes occur at the ankle where the highest amount of support is given. At the ankle we see an increase in plantarflexion moment and the subjects walks more on their toes. The hip flexion moment decreases. We concluded that walking with our passive exoskeleton leads to a considerable different gait, and earlier assumptions about invariant gait patterns do not apply to our, and possibly other, exoskeletons.

Best Possible Outcome

The substantial change in joint moment patterns are in contrast with earlier finding of [8] with an active exoskeleton where moment patters were invariant. Our ideal result would be that we could predict human adaptation to the support in advance. This knowledge can be used to design better exoskeletons that help people reduce their metabolic cost of walking.

References

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Fig. 1: XPED2 passive exoskeleton

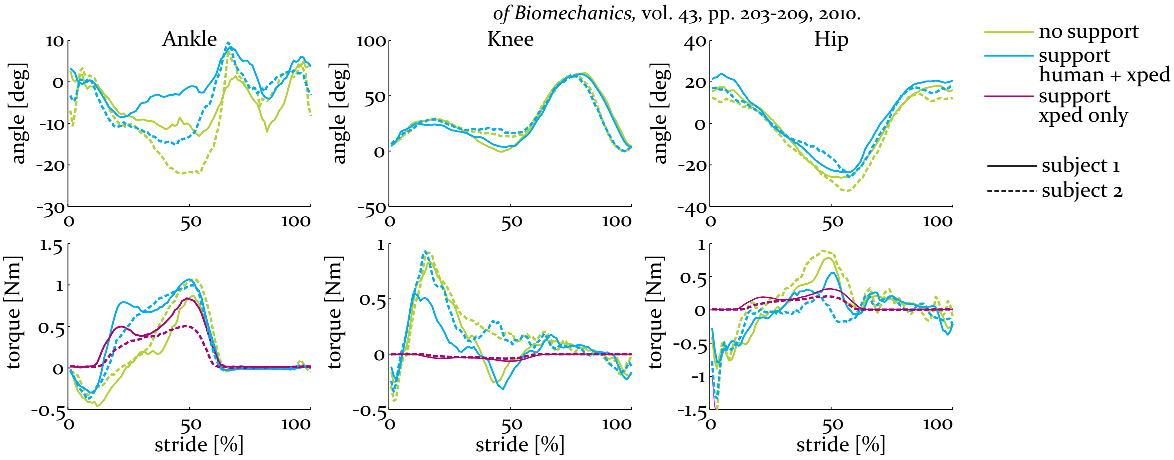

Fig. 2: Test results for walking with the XPED with and without the support of exotendons. Upper row shows joint angles. Bottom row shows joint torques. (Plantar-)flexion is positive.