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Technical note

# A new carbon fibre spring orthosis for children with plantarflexor weakness

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**Abstract**

We tested a new orthosis with a carbon fiber spring constructed to enable energy storing during increasing dorsiflexion in mid-stance, and to use the energy at the end of stance phase to aid push-off. The orthosis was tested on children with plantarflexor weakness due to motor disorders. All subjects were tested with 3D gait analysis with both the new orthosis and with their regularly used orthosis. In this technical note, the results of three individuals are reported. The preliminary findings show increased dorsiflexion, altered knee kinematics and improved kinetic and temporo-spatial parameters. Although the carbon spring orthosis influenced the subjects' gait in different ways, we conclude that the tested subjects with plantarflexion weakness benefit from the carbon fiber spring orthoses during walking. The parents' and children's subjective impressions as acquired from a questionnaire were also positive.


*Keywords:* AFO; Motor disorder; Calf muscle paresis; Ankle power; Joint work

## 1. Introduction

In children with motor disorders, plantarflexor muscle function may be decreased. Orthoses are commonly used to compensate for ankle joint instability associated with plantarflexor weakness. Another challenge in the field of orthotics is to compensate for the plantarflexors' propulsive dysfunction. This is important, as the mechanical energy from the plantarflexors adds to the kinetic energy of the leg, thigh and upper part of the body [1]. In our clinical practice we have attempted effective material solutions, enabling patients with plantarflexor weakness to control the second ankle rocker (tibial advancement over the foot) as well as to aid push-off during the third rocker by supplying adequate forefoot flexibility. In cerebral palsy patients with bilateral or unilateral involvement, the use of the posterior-leaf spring AFO was introduced to mechanically augment push-off in stance. However, this failed to store and return mechanical energy [2]. In above-knee amputees, energy-storing prosthetic ankles were found to produce about 20% of the ankle work measured in normal ambulators [3].

In the past decade a German orthotics company has been developing an orthosis based on design principles from carbon fiber prosthetic feet. This orthosis was built to accommodate a carbon fiber spring and designed for individuals with plantarflexor weakness due to motor disorders. It aimed to store energy in spring tension during increasing dorsiflexion in mid-stance and to use this energy at the end of stance phase for push-off [4]. Clinical impression from video observation suggested that subjects walking with the carbon fiber spring orthosis achieved a more fluent gait, decreased lateral trunk sway, and increased walking velocity compared to conventional orthoses [5]. We have prescribed this orthosis to children

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(a) (b)

Fig. 1. The carbon fiber spring orthosis (SO): (a) anterior view and (b) posterior view.

with plantarflexor weakness caused by various motor disorders with the aim to improve walking by restoring the second and third foot rockers.

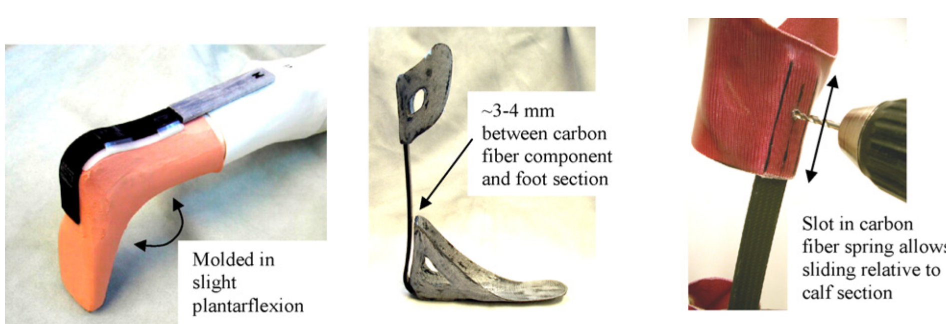
## 2. Methods

### 2.1. Carbon fiber spring orthosis

We constructed the orthosis according to the guidelines of the orthotics company (Gottinger, Zorneding, Germany, personal communication). The carbon fiber spring orthosis (‘SO’, Fig. 1a and b) has a polycentric mechanical ankle joint. It consists of an L-shaped carbon fiber spring component which is lightweight and form- and torsion-stable (Fig. 2a). The spring is made of a pre-impregnated (‘prepreg’) carbon material and is manufactured with autoclave techniques. The carbon fiber component, available for individuals weighing between 12 and 90 kg, is ordered according to each patient’s level of functional ambulation and body weight.

Fig. 3. Ferrari type ankle–foot orthosis, the subjects’ regularly used orthosis type (RO).

The cast model is made in a slightly plantarflexed position to correspond to the 5° plantarflexion of the spring (Fig. 2a). Distally, the carbon spring is embedded in a composite material and is attached to a supramalleolar foot section (Fig. 2b). The carbon fiber spring orthosis is constructed with a few millimeter distance between the carbon fiber spring and the foot section. This construction allows dorsiflexion during the stance phase until the flexion of the spring is stopped by the foot section. Proximally the carbon fiber spring is attached to a calf section that extends to the femoral condyles (Fig. 2b). A vertical slot is drilled into the carbon spring, and the spring is mounted to the calf section via a screw into this slot, allowing relative motion of the carbon fiber component and the calf section. In this way, the calf section can move upwards 1–2 cm during second rocker, and return downwards during heel lift (Fig. 2c). This mechanical solution aims to avoid skin friction when the carbon spring flexes. The sole is made of a composite




(a) (b) (c)

Fig. 2. (a) The carbon fiber spring attached to the cast model in slightly plantarflexed ankle position. (b) The carbon fiber spring attached to the foot and calf sections. (c) The carbon spring attached to the calf section via a screw that can slide along a vertical slot in the carbon fiber spring, allowing some relative motion between the calf section and the spring.