Effect of footplate stiffness on push off power when walking with posterior leaf spring ankle foot orthoses

Han Houdijk  
*dept. of Human Movement Sciences*  
University Medical Center Groningen,  
University of Groningen,  
Groningen, the netherlands  
h.houdijk@umcg.nl

Yvette Kerkum  
*Faculty of Sciences*  
REVAL Rehabilitation Research Center,  
Hasselt University  
Diepenbeek, Belgium  
yvette.kerkum@uhasselt.be

Wieke Philippart  
*dept. of Human Movement Sciences*  
Faculty of behaviour and Movement Sciences,  
Vrije Universiteit  
Amsterdam, The Netherlands  
wiekephilippart@gmail.com

I. BACKGROUND

Ankle foot orthoses (AFOs) are prescribed for patients with neuromuscular impairments to support the function of foot and ankle complex and improve walking ability. In the design and evaluation of AFOs much emphasis is put on finding optimal stiffness of structures around the ankle joint. But it can be argued that stiffness of the footplate can be just as important, as the foot can also store and return energy during walking [1,2] and acts as a lever that determines the mechanical advantage of the structure around the ankle [3]. In this study we investigated the effect of footplate stiffness on push power of the foot and ankle during walking with posterior leaf spring orthoses in able-bodied persons.

II. METHODS

Twelve able-bodied participants walked at a fixed speed (1.2 m·s⁻¹) on an instrumented treadmill in four conditions: shod without AFO, and with a posterior leaf spring orthosis with a flexible (0.04 Nm·deg⁻¹), stiff (0.45 Nm·deg⁻¹) or rigid (0.95 Nm·deg⁻¹) footplate. For each condition ankle and foot kinematics and kinetics were calculated and averaged over one-minute walking. Separate contributions of the ankle joint complex (AJC; 6DOF between shank and hind foot) and distal hind foot (DHF; 6DOF between hind foot and ground) to total ankle-foot power and work were calculated using a deformable foot model [4].

III. RESULTS AND DISCUSSION

Peak AJC-power was significantly higher with the rigid footplate compared to the flexible and stiff footplate and not different from shod walking. The stiff footplate increased peak DHF-power compared to the flexible and rigid footplate and shod walking. Total ankle-foot power showed a significant increase with increasing footplate stiffness, where walking with the rigid footplate was comparable to shod walking (Fig. 1). Similar effects were found for positive mechanical work.

Net ankle internal plantarflexion moment increased with footplate stiffness and was significantly different between successive footplate stiffness conditions and significantly higher in the rigid footplate condition compared to shod walking. This coincided with an increased forward progression of the center of pressure under the foot with increasing footplate stiffness.

IV. CONCLUSION

A rigid footplate increases the lever arm of the foot, resulting in an increased ankle moment and consequently increased energy storage and release of the AFO’s posterior leaf spring as reflected in higher AJC power. This effect dominates changes in the power generation of the foot, which was highest with the intermediate footplate stiffness. This study demonstrates that foot plate stiffness should be taken into account when optimizing properties of ankle foot orthoses.

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**Fig 1:** The posterior leaf spring AFO could be equipped with different footplates and was worn inside a flat neutral sneaker. Ankle Joint Complex power ($P_{AJC}$) and Distal Hind Foot power ($P_{DHF}$) were separately calculated and summed to obtain Total Ankle Foot power ($P_{TFP}$) for shod walking without an AFO (control) and with the AFO with a flexible, stiff and rigid footplate.

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REFERENCES


