Prescribed Ankle-Foot Orthoses Alter Tibiotalar Joint Angles in Adults with Cerebral Palsy During Walking

Emily M. Smith[1,2], Robert Chauvet[1,2], Ben Lutzko[2], Janae Ruzicki[1,2], Elizabeth Condliffe[3], Koren E. Roach[1,2,4]

[1]Schulich School of Engineering, University of Calgary, Calgary, Canada
[2]McCaig Institute of Bone and Joint Health, Calgary, Canada
[3]Alberta Children's Hospital Research Institute, Calgary, Canada
[4]Cumming School of Medicine, University of Calgary, Calgary, Canada

Email: emily.smith1@ucalgary.ca

Summary

Individuals with cerebral palsy (CP) are at high risk of early-onset osteoarthritis (OA) believed to be caused by the impact of foot deformities and altered gait on joint loading. Ankle-foot orthoses (AFOs) may be prescribed to correct foot deformities, stabilize the ankle joint, and alter range of motion (ROM), though little is known about how the AFO impacts the motion of individual joints (e.g., tibiotalar joint). This study employs dual fluoroscopy (DF) to accurately measure ankle bone motion while using AFOs. The preliminary results of this study suggest that personalized AFO prescription alters tibiotalar joint angles.

Introduction

Individuals with CP have a higher prevalence and earlier onset of OA [1]. This may result from gait abnormalities and foot deformities (e.g., equinus and planovalgus) [2], which can contribute to abnormal joint loading and subsequent OA. AFOs may be clinically prescribed to correct foot deformities and alter range of motion (ROM) [3], though little work has been done to quantify their effect on ankle joint kinematics. Further, AFO research often considers the ankle joint complex as one segment [4], neglecting independent bone movement. This limitation may be overcome by using dual-fluoroscopy (DF), which employes two orthogonal X-ray videos to accurately measure 3D in-vivo joint kinematics [5]. The purpose of this feasibility study was to evaluate how tibiotalar joint kinematics in adults with CP are altered by AFOs compared to barefoot walking.

Methods

Three participants with CP and planovalgus (CP1, CP2) or equinus (CP3) foot deformity and three typically developed controls were enrolled following informed consent (REB23-1432). Computed tomography (CT) scans of the tibia through toe-tips were acquired (Revolution GSI HD, GE Healthcare, USA). DF images were acquired of the foot and ankle at 120 Hz while participants walked overground under two conditions: 1) barefoot; and 2) shod with their AFO. The tibia and talus were segmented from the CT images to create 3D bone models (3D Slicer, 2024). 2D-3D registration was used to align the 3D bone models with the DF images (Autoscoper[6], 2024) and determine bone position and orientation throughout walking under both conditions. Bone positions were used to calculate tibiotalar joint angles.

Results and Discussion

CP1 was planovalgus, had ankle pain, and used a rigid AFO designed to stabilize ankle dorsi/plantarflexion motion. CP1 dorsi/plantarflexion ROM during stance was similar in both conditions; however, the AFO altered the timing of motion, which may alleviate ankle pain. CP2 was planovalgus, with crouch gait, resulting in increased dorsiflexion in the barefoot condition compared to controls. CP2 used a semi-rigid stock AFO and exhibited decreased dorsiflexion in the AFO condition compared to barefoot during a majority of stance. CP3 was equinus, with increased plantarflexion in the barefoot condition compared to controls and used a rigid-articulated AFO. CP3 exhibited increased dorsiflexion and plantarflexion ROM in the AFO condition compared to barefoot.

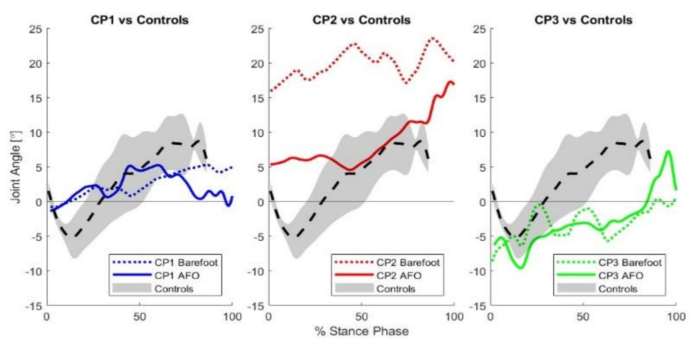

Figure 1: Tibiotalar dorsiflexion(+)/plantarflexion(-) of participants with CP walking barefoot (dash) and shod with an AFO (solid).

Conclusions

Based on preliminary results, proper AFO prescription for adults with CP may promote a tibiotalar joint angle that is more similar to controls, compared to barefoot walking. This manipulation of joint angles may decrease the joint load and degeneration that leads to early onset OA. These results demonstrate that differences in ankle joint motion between AFO and barefoot trials can be measured using DF.

References

[1] French ZP et al. (2019). *J. Rehabil. Med.* **51**: 575–581.
[2] Wright E et al. (2020). *Phys. Med. Rehabil.* **31**: 69–89.
[3] Sees, JP et al. (2021). *Foot Ankle Clin.* **26**, 639–653.
[4] Richardo D et al. (2021). *Children.* **8**: 903.
[5] Chauvet R et al. (2024). *CSB Conference Proceedings.*
[6] Akhbari B et al. (2019). *J. Biomech.* **92**: 120–125