Investigating in-vivo motion of the medial longitudinal arch with different orthotic types using lateral fluoroscopy images during dynamic gait

1Megan Balsdon, 1Kristen Bushey, 2Colin Dombroski and 1,3Tom Jenkyn

1Dept. of Mechanical and Materials Engineering, Faculty of Engineering, The University of Western Ontario, London, ON, Canada
2Sole Science, Fowler Kennedy Sports Clinic, The University of Western, Ontario
3School of Kinesiology, Faculty of Health Sciences, The University of Western Ontario
e-mail: mbalsdon@uwo.ca

INTRODUCTION

Foot orthotics are commonly prescribed as a conservative treatment for many musculoskeletal disorders such as pes cavus and pes planus. It is commonly thought that they mechanically change the positions and motions of the foot bones by applying forces or constraint to the plantar surface. Although there are many studies using fluoroscopic imaging to evaluate the movement of the bones of the medial column of the foot during functional activity [1], there has yet to be a study of the affect of foot orthotics on the physiologically loaded foot.

The motion of the bones of the medial longitudinal arch (MLA) has been examined in static weight bearing conditions. However, these analyses were limited from providing information regarding its dynamic function during gait. Elongation of the arch has been noted to correspond with ground reaction peaks during stance phase of walking. The shortening of the MLA coincided with increased flexor muscle activity [1] during stance. The use of orthotics may change this motion during stance phase, by constraining and supporting the bones of the medial column and limiting the elongation of the arch with loading.

X-ray fluoroscopy has recently been demonstrated to be a feasible method for measuring foot bone motions during in-vivo weight bearing gait [2]. To the authors’ knowledge, a fluoroscopic study of the foot during orthotic use has not yet been done. In this study, x-ray fluoroscopy is used to compare the medial longitudinal arch during orthotic use. Four conditions were tested: barefoot walking, soft and rigid orthotic walking and proprioceptive feedback influenced walking during weight bearing gait. It was hypothesized that the lowest arch would occur during barefoot walking, and the highest during walking with the rigid orthotic.

METHODS

Eighteen volunteers (6 controls, 6 with diagnosed pes cavus, and 6 pes planus) were fitted for custom-made orthotics by a Canadian Certified Pedorthist using the foam box technique with plastazote (soft) and subortholen (firm) material as per usual clinical practice. Each volunteer walked along a custom-made wooden platform that raised their feet to the height of a single fluoroscope (SIREMOBIL Compact-L; Siemens, Malvern, PA). On the platform, each volunteer was able to walk normally and fully weight bearing past the fluoroscope. The left foot was imaged during stance phase from a sagittal plane view.

Volunteers were first instructed to stand in quiet, full weight bearing double limb stance and a static weight bearing image was taken of the left foot. The volunteers were then instructed to walk along the platform past the fluoroscope at their preferred pace, placing their left foot in the view with the heel aligned with a mark on the platform. The fluoroscope recorded moving images at 30 frames per second. Each trial condition was repeated twice, ensuring that the entire hindfoot, tarsus and first metatarsal were visible at all times. There were four conditions tested: 1) barefoot, 2) shoed with a soft custom-made orthotic, 3) shoed with a rigid custom-made orthotic and 4) shoed with a proprioceptive feedback-type orthotic (PFO, Barefoot Science; Mississauga, ON, Canada). The two custom-made orthoses were constructed with an aggressive support for the medial longitudinal arch.
The PFO device had a soft dimple under the middle of the plantar surface of the foot.

The fluoroscopic images were digitized in the control PC and stored as mpeg format. Each frame was post-processed using custom-written software (Matlab; Mathworks Inc., Natick, MA). In each image two landmarks were identified on the plantar aspect of the calcaneus, at the most posterior and anterior corners (Figure 1). These landmarks were then connected with a line. A line running along the dorsal aspect of the first metatarsal was then identified and the angle between these two lines were determined (Figure 1). This calcaneal-first metatarsal angle (CFMA) defined the convexity of the medial longitudinal arch as described in Murley [3]. A smaller angle indicated a higher arch.

![Figure 1: Sagittal fluoroscopic image of the left foot showing the lines defining the alignment of the calcaneus and the first metatarsal. The angle between the two defined the convexity of the medial longitudinal arch (calcaneal-first metatarsal angle, CFMA).](image)

The CFMA was measured at midstance and compared between the four test conditions. It was hypothesized that the CFMA would be reduced (i.e. higher arch) with the soft orthotic compared to the barefoot condition. The CFMA was expected to be even less (i.e. even higher arch) with the rigid orthotic. The PFO device was hypothesized to have a slightly higher angle (i.e. lower arch) than the rigid orthotic, but to be similar to the soft orthotic.

**RESULTS**

There was a trend of decreased CFMA angle across subjects (mean 4.63±2.4 degrees) when comparing the soft orthotic to the barefoot condition. This is consistent with the hypothesis. The PFO devices showed an increased CFMA compared with the barefoot case (mean 1.61±1.3 degrees). The rigid orthotic did not show a clear trend across the test volunteers.

**DISCUSSION**

As was expected, the soft orthotic provided support to the medial longitudinal arch compared to barefoot and restricted the drop of the arch at midstance. However, the affect of the rigid orthotic was less clear, showing no clear trend of either raising or lower the arch compared to barefoot. This was unexpected, but it is anticipated that a trend will appear as more volunteers are recruited into this study. The PFO device showed an unexpected trend of lowering the medial longitudinal arch compared to barefoot at midstance. However this effect was very small and is not statistically significant.

Possible reasons for inconsistent data may be due to slight differences in foot structure of the test volunteers. ‘Control’ subjects are not classified as normal based on their arch, but because they are asymptomatic. Therefore some controls may actually have an asymptomatic pes cavus or pes planus that respond differently to the orthotics. Despite these results being preliminary, the use of fluoroscopy to measure CFMA during in-vivo gait appears to be feasible. Further analysis, including three-dimensional investigation, needs to be completed before conclusions can be drawn.

**REFERENCES**