DYNAMIC FOOT MOBILITY IN HIGH AND LOW ARCHED INDIVIDUALS

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INTRODUCTION

Evidence relating injury to any one foot type is limited (Kaufman et al. 1999). However, a higher incidence of shock-related bony injuries have been reported in high arched (HA) runners (Williams et al. 2001a). This incidence may be linked to the higher observed loading rates in this population (Williams et al. 2001b). During early stance the foot pronates, a tri-planar motion consisting of dorsiflexion, eversion and abduction. Pronation has been suggested to serve as a shock attenuation mechanism. Perry and Lafortune (1995) reported increased impact loading when normal pronation was restricted. Given this, one may expect the range of motion within the joints of the foot to be crucial in determining its shock attenuation ability. The purpose of this study was to compare the relative foot mobility and tibial shock in those with HA and those with low arches (LA). More specifically, it sought to test the hypothesis that those with LA have more mobile feet and are better able to absorb shock dynamically than more rigid HA feet. It is suggested that those with greater range of motion at the joints of the foot (LA) will have lower tibial shock compared to those with more rigid feet (HA).

METHODS

After ethics approval, 101 male participants (age 20.0±2.8, height 176±19 cm, mass 76.9±10.5 kg) gave informed consent to take part in the investigation. Measurements were taken on the right foot of participants at 90% of weight bearing, using dorsum height at 50% of foot length divided by truncated foot length to give a measure of arch height index (AHI) (Williams and McClay, 2000). This population was used as a normative database from which participants in the upper (HA) and lower (LA) most quartiles were selected for further analysis and comparison. The study included seven LA (age20.2±2.2 yrs, height 179±5 cm, mass 75.4±4.5 kg, AHI 0.316±0.014) and eight HA (age 19±0.9 yrs, height 177±5 cm, mass 82±11 kg, AHI 0.383±0.014) participants. A measure of arch stiffness taken between 10% and 90% of weight bearing (Williams and McClay, 2000) was calculated and normalised to body weight (STFF). A lower STFF score indicated a more flexible arch structure, and a higher score indicated a more rigid arch. Participants completed 10 good trials of running (3.5m/s ±5%) wearing gait sandals (Bite, Orca). A three segment model (adapted from Carson et al. 2001) comprising the shank, rearfoot and forefoot was used, where markers were fixed directly to the skin. All three dimensional kinematic data were collected using an eight camera motion capture system (Motion Analysis Corporation), sampling at 500Hz. A force platform (Kistler, 9281CA) and uniaxial accelerometer (PCB, piezotronics) mounted on the anterior medial aspect of the distal tibia were sampled simultaneously at 1000Hz. Tibial acceleration data were filtered (50Hz) and corrected for angular motion and gravity (Lafortune and Hennig, 1991), before peak positive acceleration (PPA) was calculated. The raw coordinate data were filtered (8 Hz), and cropped to the stance phase of gait using the force data (15N threshold). Rearfoot motion was calculated relative to shank, and forefoot relative to rearfoot, using a joint coordinate system adapted from Cole et al. (1993). Rearfoot (RFDF) and forefoot (FFDF) dorsiflexion excursion were defined from initial maximum plantarflexion to maximum dorsiflexion during stance. Rearfoot eversion (RFEV), rearfoot abduction (RFABD), forefoot eversion (FFEV) and forefoot abduction (FFABD) excursion were all defined from footstrike to peak values during stance. Cohen's *d* values were calculated as a measure of effect size. The following classifications were used to interpret effect values: *d*=.20 small, *d*=.50 medium, *d*=.80 large.

RESULTS

Results of all variables for both LA and HA groups can be seen in Table 1. PPA was found to be greater in the HA group, with a *d* value approaching a medium effect (*d*=0.49). A higher STFF score was also seen in the HA group with a large effect (*d*=1.80). Greater range of motion was seen in the HA group for RFABD (*d*=0.52), FFEV (*d*=0.69) and in particular FFABD in which a large effect was observed (*d*=1.18).

Variable	LA	HA	*d*
PPA(*g*)	6.1(1.8)	6.9(1.5)	0.49
STFF	780(256)	1261(270)	1.80
RFDF(°)	13.0(2.6)	11.8(3.2)	0.41
RFEV(°)	14.4(4.2)	13.7(3.2)	0.19
RFABD(°)	5.5(1.8)	6.7(2.5)	0.52
FFDF(°)	7.9(2.2)	8.1(1.8)	0.01
FFEV(°)	2.6(1.5)	3.9(2.2)	0.69
FFABD(°)	3.7(0.8)	5.3(1.7)	1.18

Table 1. Means (SD) of variables for LA and HA groups, as well as effect sizes (*d*).

DISCUSSION

The purpose of this study was to compare foot mobility and tibial shock during running in those with HA and LA. Results show the HA group exhibited a higher mean tibial shock than the LA group. This finding is supported by the higher loading rates previously reported in HA individuals (Williams et al. 2001b), and may offer some explanation for the higher incidence of shock-related bony injuries (Williams et al. 2001a). A stiffer arch structure was observed in the HA group, evidenced by the higher STFF score. This supports the theory that HA feet are stiffer, and LA feet are more flexible. Although this may offer some explanation for the higher tibial shock in the HA group, the STFF score is based solely on static measures and does not reflect dynamic foot function. However, the assessment of dynamic foot mobility in the present study does not provide a clear explanation for the higher tibial shock measured in HA individuals. Sagittal (RFDF, FFDF) and frontal (RFEV) plane excursions were similar between groups. This does not support the findings of Williams et al. (2001b), who reported greater RFEV in LA (13.9°) compared to HA (11.9°) individuals. This difference may be due to the sampling of more extreme foot types (very LA and very HA) than in the present study. Contrary to expectation, greater excursions were seen for RFABD, FFEV and FFABD in the HA group. This may be due to a limited available range of motion for these rotations in LA individuals. LA feet exhibit a more pronated foot position than HA feet during running. Therefore, as the foot is loaded and pronation occurs, the joints in LA feet have less range of motion through which to pass, thereby limiting excursion for these rotations. These findings suggest the relationship between arch height and foot mobility to be complex, and one which certainly warrants further investigation.

SUMMARY

Tibial shock was greater in HA compared to LA individuals. While LA feet were more flexible (lower STFF), increased excursions within the feet of LA individuals were not found.

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