PLANTAR PRESSURE MEASUREMENTS DURING BAREFOOT AND SHOD RUNNING – RELATIONSHIPS TO LOWER LIMB KINEMATICS

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INTRODUCTION

The kinematics of barefoot (BF) and shod (SH) running have been examined in the literature (e.g. Stacoff et al., 2000 and DeWit et al., 2000) and movement adaptations such as foot/lower leg posture at ground contact, and coupled movement behaviour of the rearfoot and tibia have been investigated. McClay and Manal (1997) found good relationships between the internal rotation of the tibia (TIR) and eversion of the rearfoot but these rapid lower limb movements that contribute to the bodies' natural load attenuation mechanisms during locomotion are not easy to quantify (Digby et al., 2005). Plantar pressure measurements provide a good indication of how the foot or shoe contacts with the ground and transfers load during ground contact and fast lateral to medial plantar loading transitions have been related to rearfoot motion (Hagman, 2002). Plantar pressure measurement systems are now able to record plantar loading transitions at high data acquisition rates and therefore have the potential to predict rapid movement characteristics of the foot and lower leg. This would open up the possibility of using a relatively simple measurement approach (pressure mat) to estimate movement transients during running that may be associated with the risk of overuse injury. This study examined how the medial and lateral heel pressures taken from a pressure plate and a pressure insole were associated with TIR.

METHODS

Seven male subjects (age 27.50±11.33years, height 1.75±0.72m, mass 72.86±8.26kg) all with size 9 feet participated and completed ten trials of BF and SH (cushioned running shoe) running at 4-4.5m.s^{-1}. A six-degrees of freedom, multi segment foot model was produced with heel, midfoot and forefoot segments along with motion of the tibia. Kinematic data (Qualysis, Sweden) was collected simultaneously with pressure plate (RSscan International, Belgium) data. In the SH condition a pressure insole (Footscan® Insole system) was also worn. All equipment sampled at 500Hz. Localised areas of pressure under the medial and lateral heel and the metatarsals were used to give accurate indications of the rapid transitions in pressures throughout stance. The medial and lateral pressure changes across the heel and metatarsals were termed were quantified into several indices of medial loading transition. Each were normalised to the average Fz force of the trial allowing comparison between subjects. A Pearson's correlation was performed on the barefoot and shod tibial internal rotation kinematics and the barefoot, shod and insole pressure heel medio-lateral loading (heel balance) curves. The average velocity of the increase in internal rotation after contact was related to corresponding 'heel balance' velocities.

RESULTS AND DISCUSSION

Highly negative correlations were found in the barefoot and shod heel balance data, but no significant correlation was found for the insole (Table 1). This indicates that as TIR increases, medial pressure under the heel increases (Figure 1a) and would support previous research demonstrating that eversion of the heel is closely related to tibial internal rotation (DeLeo et al., 2004). The best correlation of heel pressure transition velocity results to TIR velocity was obtained for the pressure information at the shoe-ground interface rather than the foot-shoe interface (which were collected simultaneously). This can be explained by the constant orientation of the insole flat against the heel and perhaps it is not surprising that movement aspects of the foot-ankle complex are not well predicted. It is established that instrumented insoles provide important information regarding the localised loading of the plantar tissues inside the shoe but the insole loading transitions do not appear to be well linked to movement kinematics in this investigation.

Table 1. The correlation coefficients and corresponding p-values for the three correlations performed.

	Correlation coefficient	P –value
Barefoot TIR velocity vs Barefoot Heel Balance velocity	-0.812	**0.026**
Shod TIR velocity vs Shod Heel Balance velocity	-0.891	**0.007**
Shod TIR velocity vs Insole Heel Balance velocity	-0.324	0.478

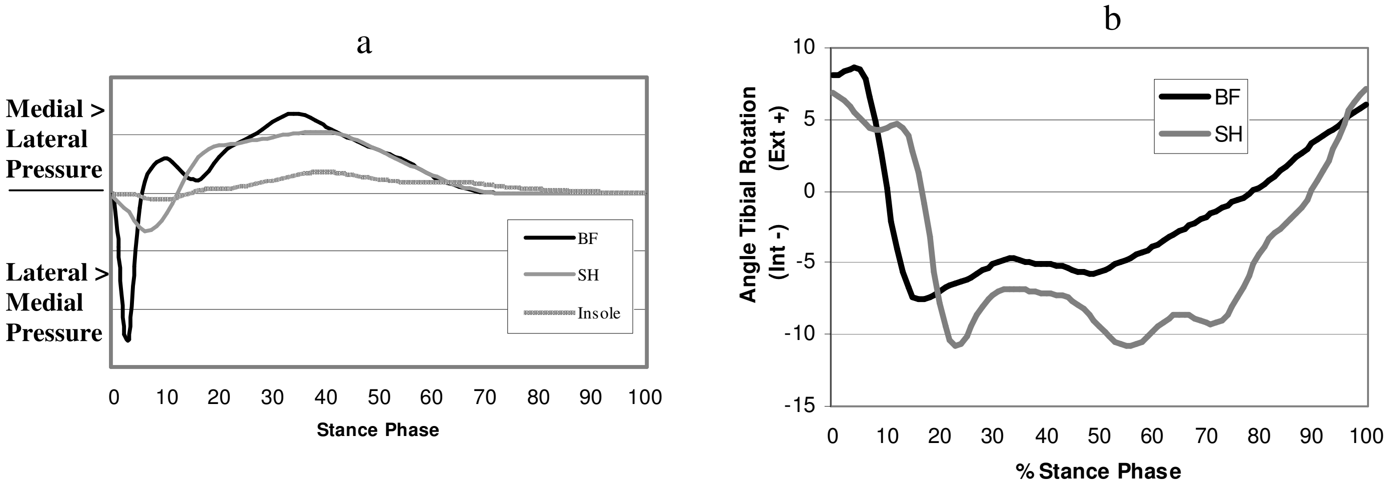

Figure 1a. Heel balance velocity for the barefoot (BF), shod (SH) and insole conditions taken from one representative subject.
Figure 1b. Transverse plane kinematics of the tibia relative to the lab during shod and barefoot running

CONCLUSIONS

The high-speed pressure mat measures of barefoot and shod running (shoe-ground interface) were shown to be predictive of tibial internal rotation velocity. This suggests that the pressure mat alone may have the potential to predict important movement transients during locomotion that are otherwise difficult to measure using traditional methods.

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