INFLUENCE OF MIDSOLE BENDING STIFFNESS ON THE METATARSOPHALANGEAL JOINT BASED ON KINEMATIC AND KINETIC DATA DURING RUNNING

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INTRODUCTION

As early as 1982 Bojsen-Møller pointed out that the forefoot probably represents the part of the body which has to bear the highest mechanical stresses. Concerning injury prevention Frederick (1987) and Bojsen-Møller (1982) point out that stiff forefoot flexibility properties could be the reason for overuse injuries. In terms of comfort it is suggested to consider a functional grading pattern of forefoot flexibility properties (Kleindienst et al. 2003). Based on runner's preferences and subjective perception during running in shoes with varying midsole hardness it is recommended to provide lighter female runners footwear with more flexible midsole properties. Regarding performance aspects Stefanyshyn & Fusco (2001) came to the conclusion that increased shoe bending stiffness increases sprint performance. They assume there is an optimal stiffness for each subject.

Therefore the main goal of the present study was to determine the influence of different midsole bending stiffness on the metatarsophalangeal (MTP) joint based on kinetic and kinematic data during running. A possible dependency of gender, bodyweight and running velocity should also be investigated in order to provide guidelines for sport shoe construction with reference to injury prevention.

PROCEDURE

On the study participated 14 male runners with a bodyweight of minimum 80kg (age: 37yr; ht: 184cm; mass 89kg; mileage: 44km/week) and 14 female runners with a bodyweight of maximum 55kg (age: 27yr; ht: 164cm; mass 53kg; mileage: 43km/week). All subjects were injury free during the study. Three shoe types (adidas® Manhattan), differing exclusively in midsole hardness (40 Shore C, 55 Shore C and 70 Shore C) were used for the running trials, sizes varying from UK 4.5 – 12.5.

Prior to the subject study a dynamic material study was performed to determine the mechanical material properties of the used shoe modifications. The test procedure of the forefoot flexibility was in accordance with ASTM 790 (3 point bending) using a servo-hydraulic device (INSTRON 8502). The bending angle was 40° and the machine was driven with 100ms concerning both bending and relaxation. The bending stiffness was calculated within the recorded angle intervals between 4° and 12° (Stiffness I: beginning of push off) and between 22° and 36° (Stiffness II: end of push off).

Kinematic data (200Hz) were collected using a 6-camera 3-dimensional Vicon System. Reflective markers were placed on the pelvis, upper leg, lower leg, rearfoot and forefoot (3 per segment). Kinetic data (1000Hz) were collected using a Kistler force plate. Subjects ran across the force plate in the middle of a 25m runway at two different velocities ($3.0\pm0.2ms^{-1}$, $4.5\pm0.2ms^{-1}$, respectively). Kinematic and kinetic data were collected for 5 valid trials for each subject and condition. An inverse dynamics approach was used to calculate the MTP joint moments in the sagittal plane during stance phase. Within the applied lower body model (Michel et al. 2004) the midpoint between the 1. and 5. MTP marker, which are placed slightly distally of these joint cavities, was chosen to represent the MTP center of rotation. The MTP moment was considered to be zero until the ground reaction forces acted distal to the joint (Stefanyshyn & Nigg 1997). This method is based on the assumption that the inertial forces acting on the phalanges can be neglected. Selected values were determined from each curve and averaged for each condition and subject. Sig. differences between the conditions were detected using non-parametrical tests ($p\leq0.05$).

RESULTS

The results of the dynamic material test (Tab. 1) show an increase of bending stiffness I and II with increasing midsole hardness. The bending stiffness I is always higher than stiffness II.

The subject test indicates that bodyweight and gender as well as running speed effect kinematic and kinetic data during push off phase. Maximum horizontal and vertical GRF and MTP moments are significantly higher for male than for female runners and increase significantly for faster running speed. The GRF show no significant differences between the shoe modifications.

However, different midsole hardness influence MTP plantarflexion moments. At the running speed of 4.5ms^{-1} the hard shoe modification reveals significant higher MTP moments than the moderate and the soft shoe for both genders (Tab. 1, Fig. 1 & 2. For the slow running speed the male group indicates no significant differences between the shoe modifications, but for the females the hard shoe provokes significant higher MTP moments than the moderate and the soft shoe.

Tab. 1: Bending Stiffness and MTP Moments & Angles, Ankle Angle from the sagittal plane (4.5ms^{-1}, mean values)

Shoe Modification	Bending Stiff. [N/mm]		MTP Moment [Nm]		MTP Angle [°]		Ankle angle [°]	
	Stiff. I	Stiff. II	Female	Male	Female	Male	Female	Male
40 Shore C	13.7	6.6	-141.9	-241.1	-24.9	-26.9	16.4	12.7
55 Shore C	19.3	9.7	-143.4	-249.6	-24.8	-24.8	17.4	13.8
70 Shore C	35.6	18.7	-151.0	-255.5	-23.3	-25.4	18.6	15.6

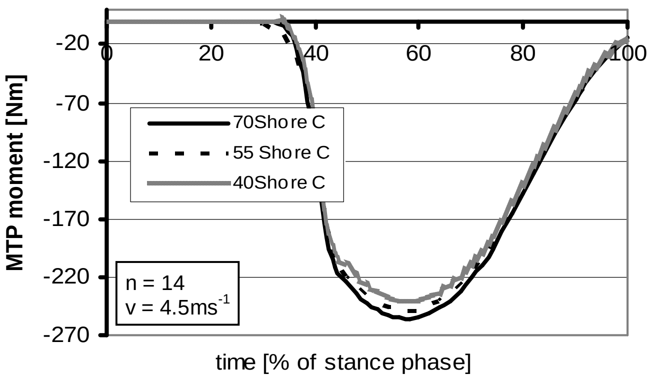

Fig. 1: MTP plantarflexion moments (male)

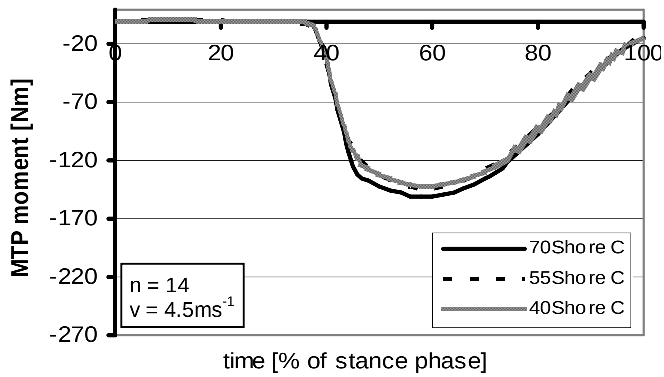

Fig. 2: MTP plantarflexion moments (female)

Analyzing the kinematic data for the female group, only the soft shoe is significantly more dorsiflexed in the MTP joint than the hard one at fast running speed (Tab. 1). For male runners the soft shoe is significantly more dorsiflexed in the MTP joint compared to the hard as well as to the moderate shoe at both running speeds. Moreover only the soft shoe shows a significant greater MTP angle for male athletes compared to female runners. These results could be an indication that the soft shoe is too flexible for heavier male runners. Looking at the ankle, the hard shoe provokes a significantly higher dorsiflexion in the ankle joint than the soft and the moderate shoe (Tab. 1). That's true for both gender and running speed. Female runners are generally more dorsiflexed in the ankle angle than male subjects. These findings could be indications for a gender specific reaction pattern caused by varying bending stiffness of the midsole based on kinematics.

DISCUSSION AND CONCLUSION

The results clearly demonstrate that varying midsole hardness effects MTP moments as well as sagittal plane kinematics of the lower leg during push off phase in running. The results suggest that the bending stiffness of the hard shoe modification is inappropriate for females at both running speeds and for males for faster speed. The findings also indicate that the bending stiffness of the soft shoe provides too flexible characteristics for this group of "heavier" runners. The above mentioned results go hand in hand with runner's preferences and subjective perception (Kleindienst et al. 2003). The application of appropriate bending stiffness could have a positive effect on MTP joint moments and subsequently on injury prevention.

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