INTRODUCTION

The metatarsophalangeal joint (MTP) has been reported to absorb large amounts of energy while generating very little during running [1]. Existing studies have investigated the effects of longitudinal bending stiffness of footwear on MTP mechanics and energetics [1,2]. However, none of these studies have reported MTP joint stiffness changes at various running speeds.

METHODS

To date, three male runners (average 20yr, 175cm, 58.5kg, 15:20min 5000m best, 67mi/wk) have been enrolled in this ongoing study. Written informed consent was given by the subjects prior to the IRB-approved protocol. Running trials were conducted at 3.89, 4.44, 5.00, 5.56, and 6.11 m/s on an instrumented split-belt treadmill (Bertec, Inc., Columbus, OH). These velocities were chosen as they are representative of relevant training and racing paces for competitive distance runners. Rest between conditions was self-determined, to reduce any effects of fatigue. Subjects all wore the same footwear (Brooks Launch 4) to control for the effects of varied longitudinal bending stiffness among shoe types. Windows were cut in the shoes at the hallux, first and fifth metatarsals, and the medial, lateral and posterior calcaneus, to allow for direct application of retro-reflective markers to the skin. Marker coordinate data were collected at 200Hz using an 8-camera motion capture system (Motion Analysis Corp., Santa Rosa, CA). Ground reaction force data were collected at 2000Hz using a force-instrumented treadmill and then imported from Cortex to Visual3D for kinematic and kinetic analysis. A two-segment foot model was defined, with an MTP pin joint defined by a vector between the 1st and 5th metatarsal markers.

RESULTS AND DISCUSSION

Data presented from three of the five running speeds are preliminary and part of an ongoing study. Joint stiffness values represent the combined effects of the foot-shoe complex. The load-displacement relationship of the MTP joint widens as running speed increases (Figure 1). The MTP joint does not elicit a similar load-displacement relationship pattern to that of the ankle, knee, and hip, where stiffness calculations tend to be synchronized with the energy absorption phase of stance while joint flexion is occurring [3].

A prominent amount of hysteresis was exhibited by the load-displacement curve of the MTP joint during running.

Figure 1. Metatarsophalangeal joint stiffness across running speeds (m/s). SD: initial dorsiflexion, PM: peak plantar flexor moment, MD: max dorsiflexion.

This suggests that a large amount of elastic energy is dissipated, rather than utilized for plantarflexion. The amount of hysteresis increased as running speed increased, indicating that the MTP joint dissipates more energy at faster running speeds. This loss of mechanical energy may negatively impact running economy.

Energy dissipation at the MTP joint may also inhibit forward propulsion. The plantar aponeurosis actively contributes mechanical strain energy to shortening the longitudinal arch and assisting foot push-off [4]. Similar mechanical contribution may occur from the toe-flexor musculature. If so, then there may be decreased mechanical contribution of the foot to forward propulsion at faster running speeds.

CONCLUSION

Initial examination of these preliminary findings indicates that the MTP joint may in fact decrease in efficiency as running speed increases. Ongoing investigation should lead to future development of methodologies to enhance function of the MTP joint during running to increase performance.

REFERENCES


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