The Impact of Running Shoe Midsole Groove Width on Lower Limb Biomechanics During Running

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Summary

The repetitive high-impact ground loads generated during running are one of the key contributors to musculoskeletal injuries in runners.To address this, we developed a running shoe midsole structure aimed at reducing the impact of horizontal anterior-posterior shear forces during foot strike.We used a cutting machine to create six grooves in the forefoot of a standard running shoe midsole, with groove widths of 0mm, 1mm, 2mm, and 3mm. Male running enthusiasts were recruited to wear four different pairs of running shoes for biomechanical testing of forefoot strike at different running speeds. The results showed that the midsole structure of the running shoe primarily affects the biomechanics of the metatarsophalangeal joint. A specific midsole groove width can optimize the biomechanical performance of the metatarsophalangeal joint, enhancing dorsiflexion angles and reducing the toe flexor moment during the push-off phase.

Introduction

Under normal running conditions, runners typically strike the ground approximately 160-180 times per minute, with each vertical ground reaction force (vGRF) peak being about twice the runner's body weight. Although joint structures and soft tissues help attenuate some of the ground impact forces, a significant amount of force still transfers to the skeletal structure of the lower limbs[1]. Evidence suggests that the material and structural design of running shoe midsoles can reduce the likelihood of running-related injuries[2].As an essential piece of running gear, running shoes not only provide significant comfort and functionality for runners but are also closely related to the occurrence of running injuries.Currently, most research on running shoes for injury prevention focuses on the materials used in the footwear, while structural optimization has received comparatively less attention.

Methods

The width of the forefoot grooves in the midsole of the running shoes was altered using a cutting machine to create four different pairs of shoes (C0 representing a standard running shoe, and C1, C2, C3 having forefoot groove widths of 1mm, 2mm, and 3mm, respectively) (Figure 1). Fourteen male running enthusiasts accustomed to forefoot striking were selected for the study. They wore the four different pairs of shoes and ran at speeds of 2.9 m/s, 3.3 m/s, and 4.16 m/s, using a forefoot strike technique. Kinematic data for the lower limbs and ground reaction force parameters were simultaneously collected using an infrared motion capture system and a three-dimensional force platform. Inverse dynamics and biomechanical models were employed to calculate the angles and moment characteristics of the knee, ankle, and metatarsophalangeal joints, as well as ground reaction force parameters. The two-way repeated measures ANOVA was used to analyze the effects of speed and shoe type on lower limb biomechanics and ground reaction force parameters, as well as the interaction between these two factors.

Figure 1: Midsole Forefoot Cutaway.

Results and Discussion

Neither running speed nor footwear showed any interaction effect on lower limb kinematics, dynamics, or ground reaction force parameters.When running in the C0 standard running shoes, the peak dorsiflexion angle of the metatarsophalangeal joint during the support phase was significantly lower than that in the C1 shoes (p=0.01) and C2 shoes (p=0.05). The peak dorsiflexion angle of the metatarsophalangeal joint during the support phase in the C1 shoes was significantly higher than in the C3 shoes (p=0.007). The peak dorsiflexion moment of the metatarsophalangeal joint when running in the C1 shoes was significantly lower than in the C2 shoes (p=0.05). The peak toe flexion moment of the metatarsophalangeal joint when running in the C0 shoes was significantly higher than in the C2 shoes (p=0.016) and C3 shoes (p=0.023), and significantly higher in the C1 shoes than in the C2 shoes (p=0.014).

Conclusions

Compared to standard running shoes, the midsole groove structure of these shoes can increase the peak dorsiflexion angle of the metatarsophalangeal joint during the support phase and reduce the peak toe flexion moment. There exists an optimal groove width that can enhance the lower limb biomechanical performance during running.

References

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