Midsole Cushioning Affects Joint Coupling Patterns in Running

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Summary

Using continuous relative phase (CRP) methodology, we quantified shank-foot couplings in time periods surrounding initial ground contact in runners wearing two shoe conditions with extreme differences in midsole cushioning levels. Non-linear mixed effects modeling was used to examine for differences of relative phase coupling plots between footwear. Shank-foot coupling patterns were found to be significantly different between shoes with high vs low amounts of midsole cushioning.

Introduction

Faulty inter-segment kinematics during running, have been identified as a risk factor for sustaining musculoskeletal injury [1,2]. Continuous relative phase (CRP) analysis has been used to describe joint couplings across time, and allow for a quantification that includes both the angular position and angular velocity of the two segments in relation to each other [3]. Midsole cushioning has been incorporated into running shoes in an attempt to mitigate the transmission of GRFs to the lower limb during ground contact. However, it is not known how different levels of midsole cushioning affect lower-limb joint couplings. Therefore, the purpose of this investigation is to use CRP techniques to quantify joint coupling patterns in time frames surrounding the initial impact period when running in footwear conditions with minimal (LW) and maximal (HI) levels of midsole cushioning. It was hypothesized that differences in midsole cushioning would significantly alter adjacent segment coupling patterns.

Methods

Data were collected from ten pain-free rearfoot (RF) runners (age 26.4 ± 6.6 years, height 163 ± 11 cm, mass 64.6 ± 12.2 kg) with no history of running-related injuries. The shoes chosen for this study were the New Balance Minimus (NB) and the Hoka Stenson One One (HK) for their large difference in midsole thickness (24mm) and their similar heel-toe drop (4mm). Subjects ran on a treadmill at 5 mph (2.24 m/s) in each shoe condition and 50 consecutive footstrikes of the right leg were captured for analysis. Reflective marker trajectories modeling the limb segments were collected with a 16-camera (MX-T40S) Vicon motion capture system sampling at 500 Hz. Joint angles were calculated in Visual 3D v. 6 using an X-Y-Z Cardan sequence, and angular velocities were derived from segment angles. Transitioning to a custom C# program built in Visual Studio 2010, CRP was then calculated following the method described by Hamill et al. [3] for shank flexion/extension vs foot flexion/extension (S/F-X) and for shank internal/external rotation vs foot internal/external rotation (S/F-Z) couplings. A nonlinear mixed effects model was used to determine the effects of shoe (HK, NB) on CRP, in 20 ms intervals for 100 ms before and 100 ms after ground contact. Random intercepts and slopes were estimated using an AR1 var/cov matrix, and within subject correlations were estimated using an UN matrix.

Results and Discussion

S/F-Z (Figure 1a) and S/F-X couplings both displayed significantly different relative phase motions across the 100ms pre-contact time period between shoes ($p<0.001$). The S/F-Z coupling motions were also significantly altered between shoes ($p<0.001$) post-contact, while S/F-X couplings were found to be no different ($p>0.05$) (Figure 1b).

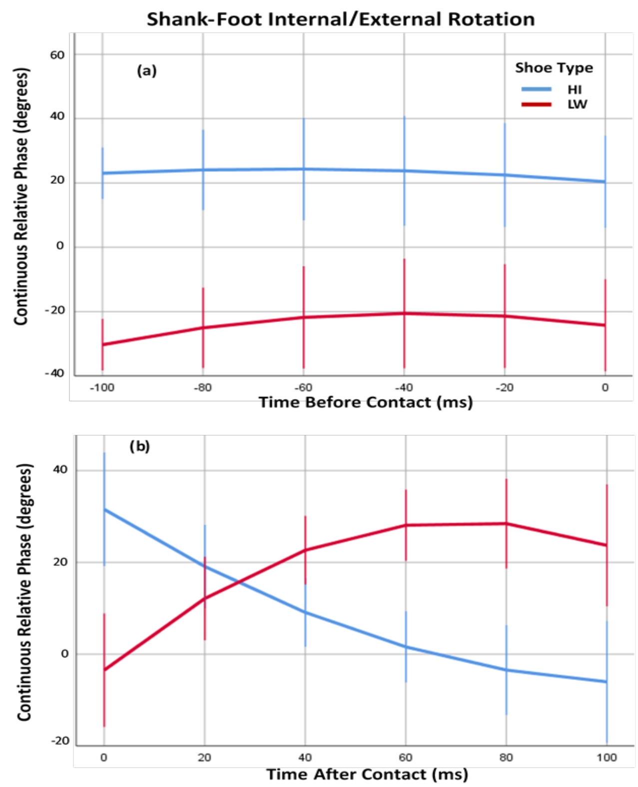

Figure 1: Mean ± 95% CI CRP plots for HI and LW cushioning conditions 100ms before (a) and after (b) initial ground contact.

Conclusions

Altered levels of midsole cushioning affect shank-foot coupling patterns not only in the rapid-loading impact period of stance, but also immediately prior to ground contact, pointing to an influence of cushioning on control of limb segment coordination.

References

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[3] Hamill J et al. (1999). *Clinical Biomechanics*, **14**:297-308.