Effects of Footwear Cushioning and Hopping Frequency on Gastrocnemius Medialis Behavior

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Summary

When hopping at an unconstrained frequency and a constrained frequency (2.2 Hz metronome), greater footwear cushioning leads to increased fascicle shortening of the gastrocnemius medialis.

Introduction

Footwear has been shown to lower the energetic cost of running [1]. Midsole cushioning plays a pivotal role in this ergogenic benefit. However, the mechanism by which midsole cushioning lowers energy cost while producing a similar movement is not fully understood and is highly complex. By understanding how midsole cushioning can affect the muscle contractions of the lower leg under different movement constraints, we can better understand the neuromuscular mechanisms that may lead to said ergogenic benefit.

Hopping mechanics shares many characteristics with running mechanics, primarily being modeled as a spring-mass systems. However, hopping requires one less degree of freedom (forward flight) [2], minimizing effects of foot strike pattern, forward propulsion, and shifting ankle moment arm length. In this context, the footwear condition behaves as an additional spring-damper system under the spring mass of the body, The purpose of this experiment was to look at muscle fascicle behavior of the gastrocnemius medialis during constrained and unconstrained hopping.

Methods

8 participants (3M/5F) completed 1 minute of bilateral hopping in two hopping conditions (unconstrained/preferred; constrained/2.2 Hz) and three footwear conditions (barefoot; 30-mm and 60-mm midsole thickness) for a total of 6 trials. A 60-mm linear array ultrasound transducer was placed at the gastrocnemius medialis to image a longitudinal cross-section of the muscle belly. Cine B-mode ultrasound was recorded at 134 frames/s through a depth of 50 mm. A MATLAB-based program (UltraTimTrack) was used for automatic tracking of fascicle lengths over 4.1 seconds (~598 frames). Vertical ground reaction forces (vGRF) were measured and used to calculate hopping frequency, hop height, hop time, and contact time. Linear mixed effects models were used to calculate the effects of footwear and hopping frequency condition on outcome variables

Results and Discussion

Gastrocnemius medialis fascicle length shortening from touch down to toe off was significantly increased as midsole cushioning thickness increased ($p = 0.009$), but there was no effect of hopping frequency condition. Fascicle length changes during positive and negative center of mass work were not significantly different. Hopping frequency was not different between unconstrained (2.28 ± 0.23 Hz) and constrained (2.26 ± 0.12 Hz), though there was increased individual variability during unconstrained. This agrees with previous literature indicating that 2.2 Hz is the preferred hopping frequency for humans [3]. Additionally, even though participants were asked to hop to a metronome in the constrained condition, there was no constraint on hop height (0.083 ± 0.20 m), leading to high variability in task execution between participants. If this task is constrained in hop height instead of/in addition hopping frequency, different muscle fascicle responses may occur.

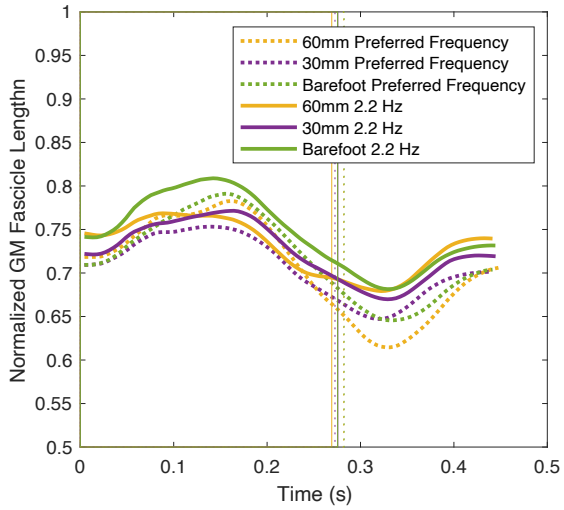

Figure 1: Gastrocnemius medialis (GM) fascicle length during hopping normalized to fascicle length during quiet standing. Vertical lines represent end of stance for respective conditions.

Conclusions

Hopping with greater midsole cushioning thickness led to an increased shortening of the gastrocnemius medialis. Further investigation is needed to understand its relation to series elastic element stretch and metabolic cost.

Acknowledgments

Footwear conditions used in this study were provided by PUMA SE.

References

[1] Hoogkamer, W et al. (2018). *Sports Med*, ***48***(4), 1009–1019.
[2] Gutmann, AK & Bertram, JEA. (2013). *Exp. Physiol.*, ***98***(7), 1178–1189.
[3] Farley, CT et al. (1991). *J. Appl.Physiol.*, ***71***(6), 2127–2132.