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Creating footwear for performance running

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necessary deformation to maintain proper fit throughout the gait cycle. These steps are outlined in Figure 1.

Results

Figure 2 shows example dynamic foot morphology data for the development of a complete digital last.

Discussion and conclusion

The presented methodology provides a workflow for using dynamic foot morphology data to inform the design of better-fitting footwear. The methodology is most useful in applications where the footwear is inherently rigid, such as in a spacesuit, but is also applicable to any footwear design. The process primarily informs the selection of materials which provide proper dynamic fit for the wearer.

Using the methodology to design better fitting spacesuit boots will reduce the risk of injury for astronauts. In addition, its use for terrestrial applications will assist the development of form-fitting custom footwear that is comfortable throughout the gait cycle.

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Introduction

Performance footwear is a system of design attributes intended to deliver biomechanical, physiological, and perceptual benefits. With appropriate footwear samples, attributes such as midsole height, shape, offset, material, etc. can be independently explored. Implications, however, should be considered with reference to the entire system.

Increasing bending stiffness of footwear can improve running economy, yet individual metabolic cost tends to follow a ‘U’ shape across a stiffness range (Oh & Park, 2015; Roy & Stefanyshyn, 2006; Madden, Sakaguchi, Wannop, & Stefanyshyn, 2015). One reason for the increase in cost with high stiffness could be increased leverage for the ground reaction force (GRF) about the ankle, and thus plantarflexor demand. Modifying plate geometry may offer a solution.

Purpose of the study

The purpose of this study was to use precisely designed footwear prototypes to explore the effects of forefoot plate stiffness and curvature on MTP and ankle joint mechanics.

Methods

Footwear with Flat, Moderate, and Extreme curvature carbon fiber plates were created, as well as a no-plate

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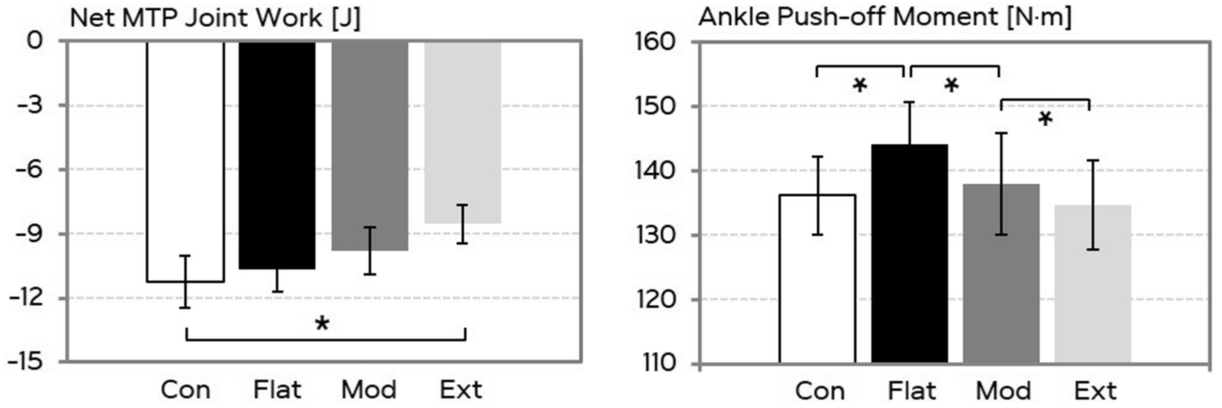

Figure 1. Average mean and standard deviation across runners for net MTP work (net energy loss) and ankle push-off moment (plantarflexor demand defined as the moment at peak ankle power). Con: no plate Control; Flat: Flat curvature; Mod: Moderate curvature; Ext: Extreme curvature. *indicates $p < 0.05$.

Control. Plated samples were constructed with top and bottom foam molds accommodating the plate shapes.

5 male runners (size M10, age 29.5 ± 3.3 yr, height 1.77 ± 0.03 m, mass 73.6 ± 5.8 kg) ran over ground with visual speed feedback (4.47 m/s) for 7 trials in each random footwear condition. Force platform data (Kistler 1250 Hz) and 3 D positions (Motion Analysis 250 Hz) of markers placed on the right lower leg and footwear were captured. Sagittal plane MTP and ankle joint kinetics were determined. Net joint work was used to describe the MTP, as it behaves more like a controlled brake/energy absorber. Since the ankle requires active muscle contraction to produce power during push-off, ankle moment at peak positive power was used as an estimate for demand. This instance is approximately at peak negative MTP power, when the plates have strong influence.

Results

Adding a stiff plate reduced the net energy loss at the MTP (net work; Figure 1) versus a foam Control, yet predominant mechanisms differed across plate curvatures. The Flat plate increased positive work, while the Moderate and Extreme curvature plates decreased negative work.

To change negative MTP work, all plated conditions reduced the negative power phase versus the Control. While the Moderate and Extreme curvature plates also reduced negative power amplitude versus the Control, the Flat plate increased its negative power amplitude.

To change negative MTP power amplitude, all plated conditions decreased in extension velocity versus the Control and increased in flexion moment. For the Moderate and Extreme curvature plates, decreased extension velocity exceeded increased flexion moment. For the Flat plate, increased flexion moment exceeded decreased extension velocity.

For the ankle joint, adding a Flat plate increased push-off moment versus the Control (Figure 1). As plate curvature increased from Flat to Extreme, ankle push-off moment returned to a similar magnitude as the Control, despite the increase in bending stiffness.

Conclusion and discussion

Footwear with an appropriate combination of forefoot plate stiffness and curvature can reduce net energy loss at the MTP without increasing mechanical demand at the ankle.

Increasing forefoot plate curvature from Flat to Moderate to Extreme reduced net MTP work by a combined influence on the duration of the MTP negative power phase, the MTP flexion moment, and MTP extension velocity.

With this understanding of the interaction between plate stiffness and geometry, we are able to tune the mechanics of the ankle and MTP joints to enhance running performance.

Disclosure statement

No potential conflict of interest was reported by the authors.

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