Impact of Midsole Compliance on Leg Stiffness and Running Economy Across Two Running Speeds

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Summary

This study explored how midsole compliance influences leg stiffness and running economy in trained male runners. Nineteen participants ran at two speeds in two shoes designed to only differ in midsole compliance. At both speeds, greater midsole compliance increased leg stiffness and improved running economy, likely through altered knee kinematics.

Introduction

The introduction of supershoes has sparked substantial interest in understanding human-footwear interactions, particularly in relation to enhancing running economy. Prior research has showed that leg stiffness adapts to surface compliance, with compliant surfaces eliciting increased leg stiffness [1]. While increased leg stiffness is associated with improved running economy [2], the extend to which altering a shoe's midsole compliance alone can induce similar effects remains unclear. In this study, we investigated whether midsole compliance induces changes in leg stiffness and running economy at two different speeds.

Methods

Nineteen highly trained male runners participated in a two-session study. In each session, participants ran for 5 minutes at 12 km/h and 16 km/h in two visually identical shoes, each with different midsole compliance: Hard (149 N/mm) and Soft (109 N/mm). In the first session, biomechanical data were collected using 3D motion capture and an instrumented treadmill. Joint angles were determined using OpenSim 4.4, and leg stiffness was calculated as the ratio of peak vertical ground reaction force (vGRF) during stance to the change in leg length measured as distance between the foot's centre of mass and the hip joint centre from initial contact (IC) to midstance (MS). In the second session, respiratory gas exchange was measured via indirect calorimetry using the last 2 minutes of each trial to quantify running economy. A linear mixed model analysed the effects of shoe type, speed, and their interaction.

Results and Discussion

No interaction effect between shoe type and speed was found for either variable, indicating that the effect of midsole compliance is independent of running speed. Running in the soft shoes increased leg stiffness compared to the hard shoe ($p=0.021$) and was accompanied by a decrease in metabolic power ($p<0.001$)(**Figure 1**). This reduction in metabolic power aligns with studies comparing racing flats to supershoes [3], pinpointing midsole compliance as a key factor in improving running economy in supershoes. The increase in leg stiffness coincided with less leg compression from IC to MS, leading to a straighter knee at MS, and an increase in peak vGRF **(Table 1)**. These changes indicate potential mechanisms by which midsole compliance could affect running economy, likely through changes in knee kinematics.

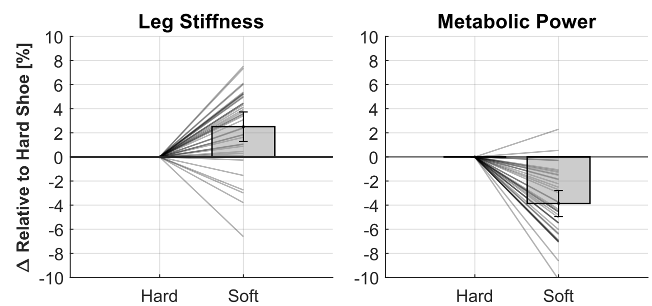

Figure 1. Change in leg stiffness (left) and metabolic power (right) averaged over both speeds, with error bars indicating 99% CI and lines individual data

Conclusions

More compliant midsoles significantly improve running economy and increase leg stiffness, with these effects remaining consistent across speeds. The increase in leg stiffness, primarily influenced by knee kinematics, may be a key mechanism underlying the improved running economy associated with greater midsole compliance.

Acknowledgments

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References

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Table 1. Summary of kinematic and kinetic variables at 12 and 16 km/h for both shoes, including shoe effect p-values.

	12 km/h				16 km/h				
	Hard		Soft		Hard		Soft		p-value
Peak vGRF [BW]	2.72	± 0.19	2.77	± 0.20	2.94	± 0.22	2.97	± 0.22	0.001
Knee angle at MS [°]	47.37	± 4.62	45.72	± 4.47	48.64	± 5.16	47.17	± 5.08	<0.001
Δ Leg length from IC to MS [mm]	91.06	± 10.01	88.53	± 8.87	95.56	± 11.19	93.87	± 9.32	0.029