How does shoe midsole energy return and bending stiffness affect running economy and ankle joint mechanics? A systematic review and meta-analysis

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Summary

This systematic review and meta-analysis investigated the effects of advanced footwear technology (AFT), longitudinal bending stiffness (LBS), and midsole energy return on oxygen consumption and ankle joint mechanics. AFTs significantly decreased oxygen consumption and ankle joint moments, work, and power compared to traditional running shoes. However, independently increasing shoe LBS and midsole energy return had no significant effect on oxygen consumption or ankle joint mechanics. Results suggest that reductions in oxygen consumption while running in AFTs are due to the interaction of LBS and midsole energy return rather than either feature in isolation.

Introduction

The introduction of AFTs has improved season best performances among the top 100 male and female long-distance runners globally [1]. Compared to traditional running shoes, AFTs have greater midsole energy return and LBS. For some runners, these mechanical properties improve running economy translating to improved performance. However, not all runners benefit from AFTs, and of those that do, the magnitude of benefit varies between individuals [2].

Individual improvements in running economy may be linked to biomechanical changes at the ankle. Ankle plantar flexor muscles play a key role in power generation during running, contributing ~45% of whole body work [3]. Therefore, altering ankle joint mechanics may improve running economy.

The current literature includes heterogenous cohorts (e.g., running experience) and study designs. The aim of this study was to synthesize the current literature on the effects of AFTs, LBS, and midsole energy return on oxygen consumption and ankle joint mechanics, and to explore potential moderators of their effects.

Methods

A systematic search of six databases identified studies examining oxygen consumption and ankle joint mechanics and energetics during running in AFTs or shoes with altered LBS and/or energy return properties. Data on oxygen consumption, ankle joint work, power, moments, and angular velocity were extracted for analysis. A three-level random effects meta-analysis was performed on extracted data. Subgroup analyses and meta-regressions were conducted to explore the moderating effects of training status, sex, running speed, and change in LBS and energy return.

Results and Discussion

Forty-eight studies with a total of 878 participants were included. Across studies, running in AFTs were associated with reductions in oxygen consumption (standardized mean difference (SMD) = -0.44, 95% confidence interval (CI) [-0.60, -0.28]), peak ankle joint moments (SMD = -0.59, 95%CI [-1.00, -0.19]), positive work (SMD = -0.75, 95%CI [-1.14, -0.36]), positive power (SMD = -0.98, 95%CI [-1.46, -0.51]), negative work (SMD = -0.63, 95%CI [-1.05, -0.20]), and negative power (SMD = -0.80, 95%CI [-1.21, -0.39]) compared to traditional running shoes (Figure 1). Meta-regressions found the greatest reductions in oxygen consumption from AFTs at faster running speeds and in highly trained runners.

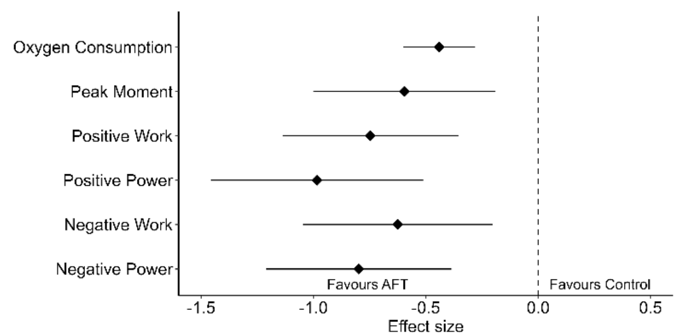

Figure 1: Summary of meta-analyses for AFTs.

Meta analyses of studies increasing LBS found significantly increased negative ankle power (SMD = 0.29, 95%CI [0.05, 0.53]), with no changes in other variables. Increasing energy return had no significant effects on any variable, suggesting that the benefits from AFTs result from the combined effects of LBS and energy return, rather than either in isolation.

Conclusions

AFTs enhance running economy and alter ankle joint mechanics. The effects of AFTs are moderated by running speed and training status, indicating that highly trained runners who can maintain faster running speeds experience the greatest benefits. Neither LBS nor energy return independently improved running economy. Therefore, rather than either feature in isolation, the interaction of these features may be responsible for the ergogenic effects of AFTs.

References

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