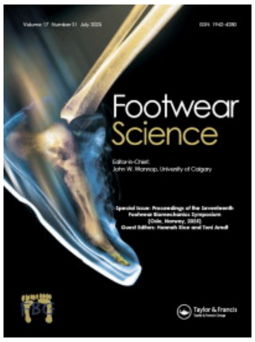

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ABSTRACT

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Advanced footwear technology does not affect local dynamic stability during treadmill running

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KEYWORDS Advanced footwear technology; local dynamic stability; running; running economy; lyapunov exponent; cost of transport

Introduction

Advanced footwear technology (AFT) running shoes have a thick midsole of highly compliant and resilient foam, contributing to improved running economy (RE) of, on average, 2–4% (Burns & Joubert, 2024). However, this thick layer of compliant foam may result in reduced stability (Burns & Joubert, 2024), which in turn has been linked to a worsening of RE (Schütte et al., 2018). This effect, termed the 'cost of instability', has been suggested to partially explain why RE does not improve when increasing stack height beyond 40 mm (Burns & Joubert, 2024). One method to assess running stability is through local dynamic stability (LDS), which can be quantified by calculating the maximum Lyapunov exponent (LyE) of any stationary kinematic time-series signal and describes the ability to withstand small perturbations (Winter et al., 2023). Although LDS has proven valuable in clinical gait research, it has received limited attention in footwear science with only one study investigating footwear effects on LDS (Frank et al., 2019; Winter et al., 2023). Despite a hypothesised reduction in stability caused by AFT, no study has investigated the effects of AFT running shoes on LDS directly.

Purpose of the study

The aims of this study are 1) to determine effects of 4 different AFT running shoe models on LDS during treadmill running and 2) to investigate if LDS is associated with RE.

Methods

12 male and 9 female trained runners ran for 3 consecutive 3-minute trials at individually standardised velocities of increasing intensity on a treadmill, wearing 1 of 4 different pairs of AFT running shoes (AFT1-4) and their own habitual simple footwear technology (SFT) running shoes in randomised order. Inertial measurement units were attached at both tibiae to measure triaxial angular velocities. Pulmonary gas exchange data were collected using a breath-by-breath metabolic cart and used to calculate RE as cost of transport (COT; $kJ \cdot kg^{-1} \cdot km^{-1}$). LDS was quantified by calculation of LyE from angular velocities of the tibial rotations of the final 100 strides of each trial using Rosenstein's algorithm after time-normalization, Euclidian norm transformation and state-space reconstruction using method of delays (high LyE values indicate low LDS and vice versa). LDS values of left and right tibiae were averaged to attain a single value per subject and condition. LDS results were statistically analysed using repeated measures ANOVA with condition and velocity category as within-subject factors. Due to non-normality of COT data, correlation between LDS and RE was determined using Spearman's r ($\alpha = 0.05$ for all tests). All participants provided written informed consent and measurements were approved by the Ethics Committee of Magdeburg-Stendal University of Applied Sciences (EKIWID-2023-09-001RM).

Results

There were no significant main effects of condition ($p = 0.591$) or velocity category ($p = 0.160$) on LyE (Figure 1). No significant interaction between condition and velocity category was found either ($p = 0.349$). However, LyE and COT showed a weak but significant negative correlation ($r = -0.18$, $p = 0.003$; Figure 2).

Discussion and conclusion

LDS did not differ significantly between any AFT model and runners' habitual SFT running shoes at any velocity, providing evidence that stability may not be as affected by AFT features as previously hypothesised (Burns & Joubert, 2024). These results are in line with previous work showing that midsole thickness and compliance of traditional running shoes do not influence LDS (Frank et al., 2019), and indicate that running stability should not be a primary concern when

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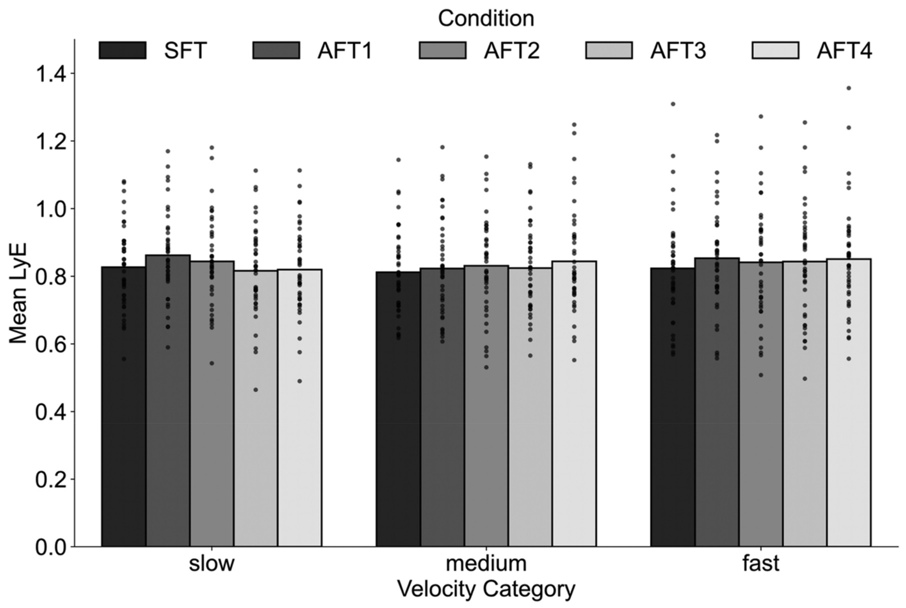

Figure 1. Mean LyE derived from gyroscope data of both tibiae according to condition and running velocity.

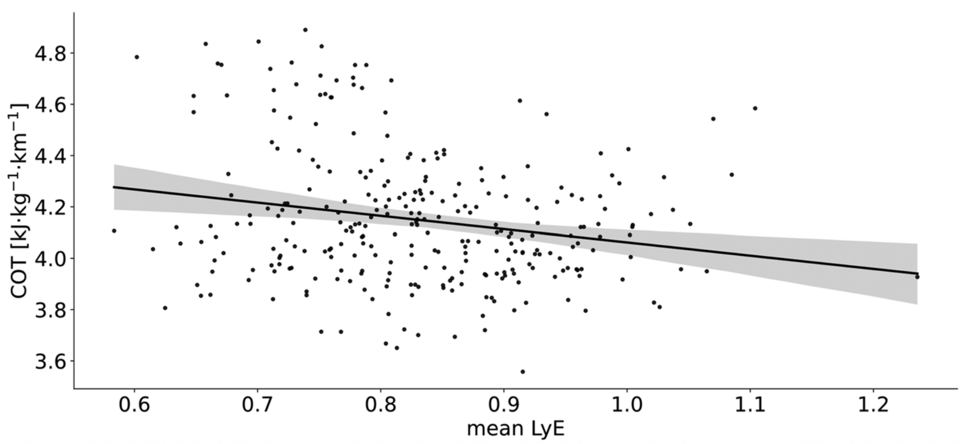

Figure 2. Correlation between COT and LyE. Shaded area displays the confidence interval.

designing AFT running shoes. Further, increased LDS showed a weak association with a worsening of RE, hinting that higher LDS might not be energetically favourable.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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