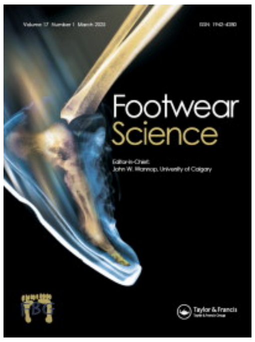

Footwear Science

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/tfws20

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To cite this article: Cagla Kettner, Bernd J. Stetter & Thorsten Stein (24 Apr 2025): Changes in centre of mass variability and its structure with different shoe stack heights at different running speeds, Footwear Science, DOI: 10.1080/19424280.2025.2489686

To link to this article: https://doi.org/10.1080/19424280.2025.2489686

Published online: 24 Apr 2025.

FOOTWEAR SCIENCE
https://doi.org/10.1080/19424280.2025.2489686

ABSTRACT

Changes in centre of mass variability and its structure with different shoe stack heights at different running speeds

Cagla Kettner, Bernd J. Stetter and Thorsten Stein

Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Karlsruhe, Germany

ARTICLE HISTORY Received 19 February 2025; Accepted 1 April 2025

KEYWORDS Stack height; midsole thickness; running shoes; advanced footwear technology; motor control; movement variability

Introduction

Stack height is a highly discussed design feature of running shoes, especially since World Athletics restricted it. A high stack may enhance running performance, but it may also lead to instabilities (Barrons et al., 2023), i.e. the effects on running coordination are not yet fully understood. To understand running coordination in the context of stack height, the analysis of movement variability is important, since even experienced runners exhibit variations across multiple running strides. Movement variability is differentiated between execution and outcome variability. Outcome variability can be operationalised with the Tolerance, Noise and Covariation (TNC) approach (Müller & Sternad, 2004), which quantifies structural changes in outcome variability. The centre of mass (CoM) movement is important in running and can be used as a task-relevant outcome variable (Möhler et al., 2021).

Purpose of the study

This study aimed to investigate the effects of different shoe stack heights on 3D CoM variability and its structure during running at different speeds.

Methods

The study involved 17 experienced male runners (age: 25.7 ± 3.9 yr; height: 1.77 ± 0.04 m; mass: 68.1 ± 6.0 kg). After warm-up, participants ran with three shoes in a parallelised order (H: 50 mm; M: 35 mm & L: 27 mm, measured at heel). For each shoe, the protocol began with shoe familiarisation followed by two 90 s runs alternating between 10 and 15 km/h.

Full-body marker data were collected by 3D motion capturing (Vicon, Oxford, UK, 200 Hz). Inverse kinematics was performed with OpenSim Hamner running model. Coefficient of variation (CV) of CoM was calculated for three directions (anterior-posterior (AP); medial-lateral (ML); vertical (VER)) separately as the ratio of standard deviation of the CoM to its mean position in % of stance phase to assess CoM variability. A TNC approach with a 3D full-body model was applied to assess the structure of the CoM variability. 3D joint angles were chosen as the elementary variables and 3D CoM as the outcome variable (Möhler et al., 2021). Statistical parametric mapping (SPM) rmANOVA was calculated to compare stack height (H, M & L) and speed (10 & 15 km/h) conditions with SPM paired *t*-tests at *post-hoc*. Pairwise shoe comparisons for two running speeds performed individually to decompose CoM CV differences into T, N, C components. T, N and C were tested against zero by one-sample SPM *t*-tests. The significance level was set *a priori* to $\alpha = 0.05$.

Results

AP CoM CV showed significant interaction effect between stack height and speed ($p = 0.001$). L led to a higher AP CoM CV than M at 10 km/h ($p < 0.001$). The factor T for VER CoM CV was higher with H compared to M at 10 km/h ($p = 0.021$) and compared to L at 15 km/h ($p = 0.016$).

Discussion and conclusion

This study showed that first, AP CoM CV was higher for L than M at 10 km/h. Previous research highlighted the importance of AP CoM movement particularly for forward propulsion (Möhler et al., 2021). Possibly more constrained running conditions (i.e. slow speed and lower stack) increased the requirement for control, therefore resulted in higher variability (Lindsay et al., 2014). In AP, the structure of CoM variability did not change. Possibly the summation of non-significant changes in each factor led to a significant modulation of AP CoM CV. Second, H changed the task tolerance in VER, which may reflect a modulation of spring-mass behaviour (Möhler et al., 2021). Differences in factor T did not change CoM CV, possibly due to compensation through other factors N and C (Müller & Sternad, 2004).

To sum up, the tested shoes changed CoM CV and its components, which may indicate that the motor control system reacted to different stack heights. However, it should be noted that the differences were small (<1%).

CONTACT Cagla Kettner cagla.kettner@kit.edu

Disclosure statement

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

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