Wearable trunk accelerometry to estimate running economy: a comparative study of three footwear conditions in highly trained runners

Yoram Müller-Jabsusch[1,2], Davide Petrella[1,2], Toon de Beukelaar[1,2], Benedicte Vanwanseele[1,2]
[1]Department of Movement Sciences, KU Leuven, Leuven, Belgium
[2]KU Leuven Institute of Sports Sciences, Leuven, Belgium

Email: benedicte.vanwanseele@kuleuven.be

Summary

Running economy (RE) is partially determined by running biomechanics. However, there is no consensus on which biomechanical parameters primarily affect RE. Determining RE requires lab-based gas exchange measurements restricting its usage in an ecological environment. An inertial measurement unit (IMU) can assess biomechanical parameters in an ecological environment. This study aims to identify (1) if a single IMU can explain part of the variation in running economy and (2) which biomechanical parameters contribute to RE. RE and running biomechanics of 18 highly trained male runners were measured during treadmill running under three different shoe conditions at two speeds. For both speeds, more than 50% of the variance in RE could be estimated using biomechanical parameters.

Introduction

Running economy (RE) is widely accepted as a key determinant of endurance running performance, yet is a complex, multifactorial phenomenon with numerous anthropometrical, demographic, i.e., age, sex, and ethnic related, physiological, biomechanical, and neuromuscular determining factors [1]. Assessing the RE requires gas exchange measurements restricted to a lab environment. A recent review showed that biomechanical variables can explain 4–12% of the between-individual variance in RE when considered in isolation, with this magnitude potentially increasing when combining multiple variables [2]. Using wearable sensors, simultaneous measurement of multiple biomechanical variables is possible in an ecological environment at a relatively low cost. Therefore, the study aims (1) to identify if a single IMU can explain part of the variation in RE and (2) which biomechanical parameters contribute to RE.

Methods

Eighteen highly trained male runners completed two 5-minute treadmill running trials at 12 (slow) and 16 (fast) km/h in three different shoe conditions: hard midsole (149 N/mm), soft midsole (109 N/mm) and soft midsole with a carbon plate (123 N/mm). Biomechanical data were collected using a single IMU connected to a waist belt (RunEASI, Belgium) while respiratory gas exchange was measured via indirect calorimetry (K5, Cosmed). The last two minutes of each run were used and averaged. Biomechanical data included impact-related parameters (magnitude and duration), stability, and spatiotemporal parameters. All biomechanical parameters were added as independent variables in a stepwise regression model with RE as the dependent variable with separate models for the slow and the fast speeds. All statistical analysis was performed in RStudio (Version 2024.9.0.375).

Results and Discussion

For slow-speed running, an adjusted R-squared of 0.53 was achieved using cadence, braking, ground contact time (GCT), flight ratio, dynamic stability, and impact duration. At faster speeds, an adjusted R-squared of 0.50 was obtained with cadence, braking, GCT, flight ratio, and relative impact score. Differences between estimated and actual running economy across shoe conditions are presented in Figure 1.

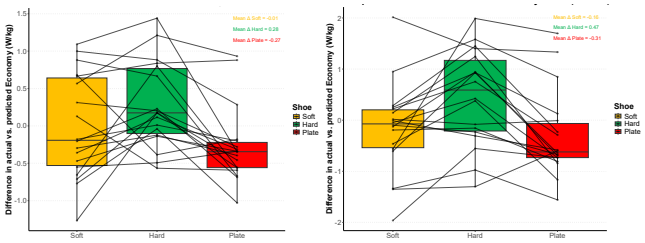

Figure 1: Difference between predicted and actual running economy for the 12 km/h (left panel) and the 16 km/h (right panel).

Key biomechanical parameters influencing RE include cadence, flight ratio, braking, and GCT. While cadence and braking have been previously linked to running economy, flight ratio and GCT were considered irrelevant [2]. Contrary to a previous study [3], dynamic stability emerged as a predictor only during slow running, possibly due to the high training level of our participants.

Conclusions

Despite RE being a complex and multifactorial phenomenon, over 50% of the variance in RE can be estimated through a single IMU on the lower back. This opens opportunities for in-field usage of these IMUs to study different factors that modify RE, such as footwear and running surfaces.

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References

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