Kinematic and metabolic analysis of the uphill walk-run transition with constant vertical meter speed in mountain/trail runners

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Summary

Understanding when to walk or run uphill is crucial for trail runners during races. The transition between these locomotion modes occurs at a specific speed, driven by multiple mechanisms. This study aimed to integrate biomechanical aspects to provide a more comprehensive understanding of the uphill walk-to-run transition on wide angle range and at a constant vertical speed. Results showed that biomechanical parameters, such as internal and total mechanical work, did not significantly influence the transition. Instead, energetic cost was the primary determining factor, followed by heart rate and ventilation. Additionally, findings indicated that at a constant vertical speed of 800 m/h, walking becomes the optimal strategy for inclines steeper than 7.4°.

Introduction

As humans increase their walking speed, they naturally transition to running at a characteristic speed known as the preferred transition speed (PTS). Near this threshold, running becomes more metabolically efficient than walking, a point referred to as the energetically optimal transition speed (EOTS). On level ground, research consistently shows that PTS occurs before EOTS [1]. Various hypotheses, such as muscle limitations, neuromuscular control, and anthropometric factors, have been proposed to explain this phenomenon, with no clear consensus [2]. Uphill locomotion, compared to level walking and running, involves a higher energetic cost, different muscle activation patterns, and distinct kinematics [3]. Moreover, understanding the mechanisms triggering transitions is important for performance and strategic management in trail racing. The few studies that have investigated PTS during uphill locomotion have primarily focused on physiological aspects [4]. This study aims to investigate the metabolic (VO_2, VE, HR) and biomechanical (energetic cost, internal and total work) factors influencing the walk-to-run transition during uphill locomotion at a constant vertical speed.

Methods

19 healthy, experienced trail and mountain runners participated in this study. Participants completed eight randomized walking trials (2–9 km/h) and nine randomized running trials (2–14 km/h) of six minute each and all conducted at a constant vertical speed of 800 m/h. PTS was assessed using incremental walk-to-run and run-to-walk tests and averaged. For each variable, the speed range with no significant difference between walking and running was identified by checking if zero fell within the 5th to 95th quantile of the walking-running difference.

Results and Discussion

Results showed that PTS converged to OTS during uphill locomotion but occurred sooner than expected compared to previous studies [4]. Energetic cost (Figure 1A) appeared to be the primary factor explaining PTS, along with heart rate and ventilation. Oxygen uptake alone (Figure 1B) could not fully account for PTS. Internal work (Figure 1C) and Total work (Figure 1D) during uphill locomotion did not influence PTS as it did on the flat [1].

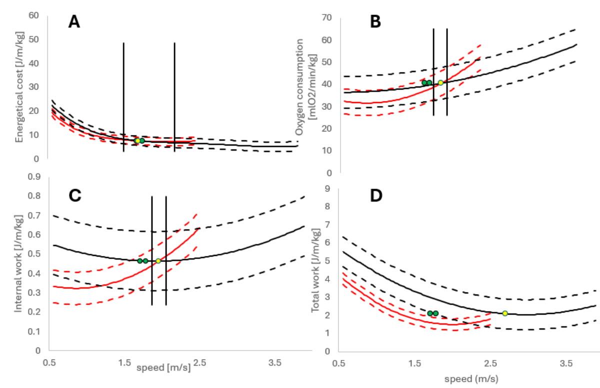

Figure 1: All figures display the preferred transition speeds (PTS) for both walk-to-run and run-to-walk transitions (green dots), as well as the intersection between the running and walking models (yellow dots). The black bars represent the confidence intervals, within which no statistical differences between the two locomotion modes are observed. Figure A represents the energetic cost (J/m/kg), Figure B represents oxygen consumption (ml O_2/min/kg), Figure C represents internal mechanical work (J/m/kg), and Figure D represents total mechanical work (J/m/kg).

Conclusions

This study demonstrated that PTS was not influenced by mechanical work but was primarily determined by energetic cost, with heart rate and ventilation also playing a role. It also revealed that for slopes steeper than 7.4 degrees at a vertical speed of 800 m/h, running is no necessary. These findings provide valuable strategic insights for race management and contribute to a better understanding of uphill PTS.

References

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