



How does the slope gradient affect spatiotemporal parameters during running? Influence of athletic level and vertical and leg stiffness

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ABSTRACT

Background: The current evidence leaves certain questions unanswered, including whether well-trained athletes adapt to different slope gradients in the same way as amateurs, and whether stiffness influences spatiotemporal adaptations during uphill running.

Research question: This study aimed to determine the effect of different slope gradients (0%–11%) on spatiotemporal gait characteristics during running, taking into account the influence of athletic level, vertical and leg stiffness.

Methods: Male endurance runners (12 amateurs, 10 highly-trained) performed a running test on a motorized treadmill. The running velocity was set at 12 km/h, and participants completed six different running conditions (0, 3, 5, 7, 9 and 11% gradients). Spatiotemporal parameters were measured using the OptoGait system. Vertical (Kvert) and leg (Kleg) stiffness were calculated according to the sine-wave method.

Results: A 2 (amateur; highly-trained) × 6 (running conditions) ANOVA found no significant between-group differences in spatiotemporal parameters at any gradient ($P \geq 0.05$); however, significant Kvert and Kleg differences ($P < 0.05$) were found within both groups with increasing gradients. Stepwise linear regression analysis showed that Kleg was strongly associated with contact time ($R^2 = 0.797$, $P < 0.001$), whereas Kvert was associated with spatiotemporal adaptations to different slope gradients ($R^2 = 0.547$, $P = 0.002$).

Significance: An increased slope gradient (0–11%) at a given running velocity (12 km.h⁻¹) caused spatiotemporal adaptations (i.e., increased CT and SF and decreased FT, SL and SA) regardless of the athletic level of the runner, although a non-significant trend differentiated the adaptations between the amateur and highly-trained groups. The results also indicated that leg stiffness plays a key role in the characteristics of spatiotemporal gait during level running, whereas vertical stiffness is strongly associated with spatiotemporal adaptations when running uphill.

1. Introduction

It is well-known that running biomechanics can favour or limit running performance by influencing the economy and efficiency of running [1–4]. Nevertheless, despite trail running has become increasingly popular and it includes a broad range of distances and slope variations, the majority of running biomechanics studies have

only considered flat (level) running. Running speed was reported to decrease by 0.1–0.3 km.h⁻¹ per every 1% increase in gradient [5], which led to important biomechanical, neuromuscular and physiological changes. Thus the study of the physiological and biomechanical changes associated with graded running is important, as the ability to appropriately regulate locomotor behaviour in response to gradient changes is fundamental to the understanding of human locomotion control [6].

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