Joint energetic and spatiotemporal differences between elite and well-trained distance runners

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Summary

The study of joint work during running allows for the determination of individual joint contributions for propulsion. Here we compare stride parameters and lower limb joint work between eight elite and eight well-trained distance runners during a graded exercise test to identify factors that may explain improved running performance. Our data indicates that elite runners can maintain a higher proportion of ankle work relative to total work performed as they reach progressively higher speeds, which likely has implications for improved economy.

Introduction

Running is a cyclic task, and small differences at the stride level may have significant consequences for both performance and/or risk of injury. Few studies have examined biomechanical differences between elite and well-trained distance runners [1,2], and how these may be related to performance outcomes. The aim of this study is to compare the absorption and generation of mechanical work across joints with increasing running speed in elite versus well-trained runners. A comparison of these groups may aid in understanding some of the factors that separate world-class runners from amateur performance.

Methods

Eight elite distance runners (5 km in less than 15:00 min) and eight well-trained distance runners (5 km between 15:00 and 20:00 min) completed a submaximal six-stage graded exercise test on a treadmill. Initial velocity was set as 72% of each participant's 5 km season-best time, with velocity increasing by 3% during each subsequent stage. Kinematic and kinetic data were collected in 3 x 10-s periods using a combination of marker-less motion capture (Theia Markerless Inc., Kingston, ON) and force data from an instrumented treadmill (AMTI Tandem Treadmill, Watertown, MA).

Stride parameters, joint angles and joint moments were calculated using inverse kinematics and dynamics (Visual3D, C-Motion, Inc., Germantown, MD) from an average of 84 ± 4 strides (left and right legs combined). Joint work was calculated as the time integral of the joint power curve, and relative joint work as the percentage of the total lower limb joint work (ankle, knee and hip combined).

Data was analysed using a Two-Way ANOVA with group (elite vs well-trained) as the between-subject variable and speed as the time variable. Significance was set at the $p \leq 0.05$.

Results and Discussion

The initial running velocity for the elite group was 4.17 ± 0.27 m/s and 3.89 ± 0.36 m/s for the well-trained group. A significant increase in stride length and frequency was observed across the six stages for both groups, with a significantly larger increase in stride frequency observed in the elite group ($p = 0.03$, $\varpi^2 = 0.159$).

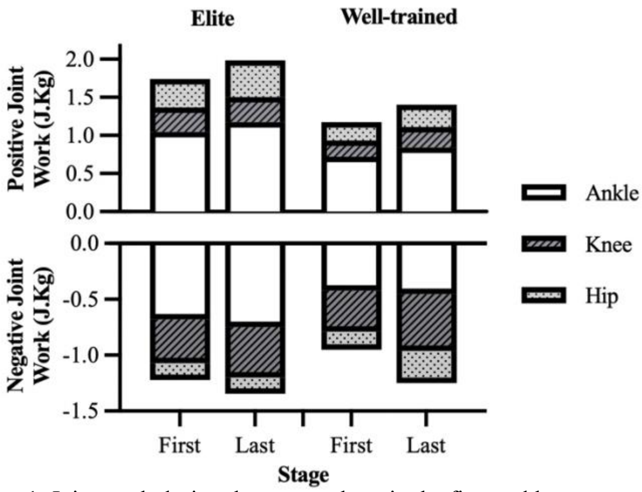

Figure 1. Joint work during the stance phase in the first and last stages of a graded exercise test.

There was a significant increase in joint positive and negative work during the stance phase with increasing velocity with the exception of negative hip work during the stance phase for both groups (Figure 1). When considering the proportion of total joint work for each joint across stages, there was a significant interaction effect for negative ankle work ($p < 0.01$, $\varpi^2 = 0.35$) during the stance phase, where the elite group increased and well-trained group decreased the contribution of the ankle joint to total negative work in the stance phase (Figure 1).

Conclusions

The observed change in relative negative ankle work during the stance phase likely represents an increased capacity of the elite group to produce sufficient plantar flexor torque to absorb energy in the Achilles tendon, rather than absorbing via muscles at other joints. This would increase the amount of strain energy stored and subsequently released in the Achilles tendon, which has been associated with a lower metabolic cost of transport [3].

References

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