The effect of plantarflexor fatigue on positive joint work distribution during running

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Summary

Exhaustive running causes a proximal shift in positive joint work that may impair performance. We investigated the effect of local plantar flexor (PF) fatigue on this shift. Running with PF fatigue akin to that experienced over a 10 km race decreased positive ankle work and increased positive knee work. Thus, local PF fatigue may lead to a potentially suboptimal gait strategy.

Introduction

Exhaustive running (e.g., 10 km race) causes a proximal shift in positive joint work, from the ankle to the knee and hip, which may impair performance [1,2]. It has been suggested that PF fatigue (reduced force output) may play a role in the observed shift, however this remains untested. Therefore, we aimed to determine the effect of PF fatigue on lower limb positive joint work distribution in exhaustive running. We hypothesised that, compared to an unfatigued running bout, there would be an increase in proximal positive joint work when running with PF fatigue.

Methods

Eleven male recreational runners (mean age: 25) provided their informed consent to participate in this study which was approved by the University of New South Wales Human Research Ethics Committee. Females were excluded due to known effects of sex on fatigue [3] and our inability to control for this in the current study. After a warm-up, we determined the PF maximum voluntary contraction (MVC) of participants on a custom-built dynamometer. Following this, they completed a baseline run (BR) on an instrumented treadmill (Motek) at their individual 10 km race speed, which was immediately followed by another PF MVC. Next, participants underwent a fatigue protocol consisting of bilateral calf raises, performed in sets to failure. MVC was periodically assessed until fatigue reached 70-80% of the initial baseline value [4,5]. Next, a fatigued run (FR) was undertaken, again at the participants same 10 km race speed. The FR was immediately followed by a post-fatigue MVC.

3D motion capture (Vicon) and force plate data (Motek) were collected during each run. Inverse dynamics models (MATLAB) were used to calculate kinematic and kinetic variables. Positive ankle (shank-calcaneus), knee, and hip work during stance phase were calculated by integrating the power-time curve. Power data were non-dimensionalised by $Mg\sqrt{gL}$ and work data were non-dimensionalised by MgL were M is body mass, g is acceleration due to gravity, and L is leg length. Non-dimensionalised work was then divided by non-dimensionalised stride length ($stride\ length/L$) to account for potential variations in distance travelled between the BR and FR. Linear mixed effects models were used for statistical analyses (RStudio).

Results and Discussion

The target level of fatigue was obtained for all runners. PF force was 87.0 N [-138.1, -35.9] lower following the FR than the BR ($p<0.001$), indicating that the experimentally induced fatigue did not fully recover during the FR. Yet, a force increase of 58.2 N [7.08, 103.3] from the start to the end of the FR does suggest some level of recovery was present ($p=0.014$).

Positive ankle work was greater during the BR (0.032 [0.029, 0.035]) than the FR (0.030 [0.027, 0.034]; $p=0.015$; Figure 1). Conversely, positive knee work during the BR (0.011 [0.009, 0.014]) was less than during the FR (0.0140 [0.011, 0.017]; $p=0.015$). No change in positive hip work was found between the BR and FR ($p=0.437$). The positive joint work percentage redistribution observed in this study (ankle: -4%, knee: +3%, hip: +1%) is similar but slightly less than previous research on exhaustive 10 km running (ankle: -5-8%, knee: +3-5%, hip: +0-3%) [1,2].

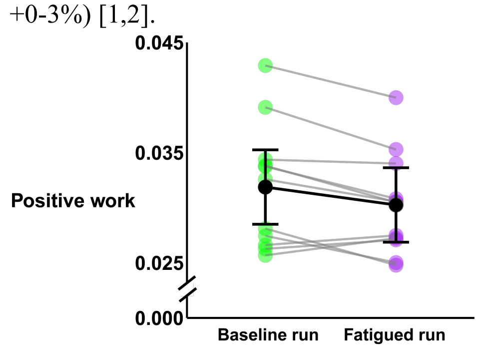

Figure 1 Group mean (±95%CI) and individual data points for ankle power over the stance phase of the baseline (BR; green) and fatigued (FR; purple) run.

Conclusions

PF fatigue causes positive joint work to redistribute proximally during exhaustive running. It likely acts in conjunction with other factors to drive redistribution over the course of a 10 km run as the observed redistribution in this study was less than previously reported.

References

[1] Sanno M et al (2018). *Med Sci Sport Exer*, **50**: 2507–2517
[2] Cigoja S et al. (2022). *J Sports Sci*, **11**: 293–302
[3] Finni T et al (2004). *J Sports Med. Phys Fitness*, **43**: 411–417.
[4] Girard, O. et al (2011). *Euro J Appl Physiol*, **112**: 2323–2330.
[5] Sarwar, R. et al (1996). *J of Physiol* ***493***: 267–272.