LINKING WALKING ECONOMY AND THE METABOLIC COST OF ISOMETRIC PLANTARFLEXOR ACTION

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Introduction

During cyclic movements such as walking, lower limb muscle-tendon units use metabolic energy to generate force and mechanical power. The ankle plantarflexors (PFs) contribute ~35% of lower-limb mechanical energy budget, but with savings afforded by an elastic 'catapult mechanism', may account for only ~18% of the metabolic cost of walking [1]. Indeed, during walking, the stretch and recoil of the Achilles tendon allows the PFs to exhibit strut-like function and produce force isometrically, avoiding the metabolic penalties associated with fast shortening velocities [2](Fig. 1A-B). Despite the presumed role of economical PF force production in shaping the metabolic cost of walking, there exists no formal link between the metabolic cost of isolated, isometric contractions (ISO) of the PFs and whole-body metabolic cost during walking. Understanding the extent to which metabolic cost during ISO PF contractions associates with metabolic cost during walking could inform diagnostic assessments of functional metabolism or mechanisms of reduced walking economy such as age-related reductions in Achilles tendon stiffness. This study aimed to determine the association between whole-body net metabolic power measured during: (*i*) submaximal ISO contractions of the PFs and (*ii*) fixed speed walking. We hypothesized that, due to the importance of economical force production of the PFs in driving whole body energy cost of walking, individuals with greater net metabolic power during ISO would exhibit greater net metabolic power during walking.

Methods

30 young adults (16F/14M, 23±5 yrs, 1.7±0.10 m, 71.7±13.4 kg) performed 1) five minutes of treadmill walking at 1.25 m/s, and 2) a three-minute submaximal isometric ankle plantarflexion contraction. For the ISO contraction, participants used biofeedback to match net ankle moment to a 20 Nm target displayed on a screen. Gross metabolic power (watts) was measured using a portable calorimeter and averaged over the last two minutes of the walking trial, and the last minute of the ISO contraction trial. For both trials, net metabolic power was calculated by subtracting the gross metabolic cost of sitting. Pearson's correlation coefficients (r) determined the association between net metabolic power measured during walking and that measured during sustained ISO contraction (p<0.05) (Fig. 1C). Cine B-mode ultrasound images of the medial gastrocnemius (GAS) were recorded during both tasks. We report the average fascicle length (quantified using Ultratrack [3]) during ISO contractions and during the stance phase of walking.

Results and Discussion

Average PF fascicle length did not differ between the stance phase of walking and ISO contractions (e.g., GAS; walking: 56±7 mm, ISO: 58±9 mm, p=0.90) and maximal voluntary torque (a proxy for force-generating capacity) was not associated with metabolic cost for either task (Walking: r=0.22, p=0.28, ISO: r=-0.4, p=0.85). Contrary to our hypothesis, we found a significant negative association between net metabolic power during walking versus ISO contractions (r=-0.51, p=0.01) (Fig. 1C). That is, individuals with lower net metabolic power during a sustained ISO PF contraction exhibited higher net metabolic power during walking. We offer three possible explanations for this unanticipated outcome. First, individuals with smaller muscle volume may expend less energy during a submaximal ISO task compared to individuals with more muscle volume. Those same individuals may disproportionality rely on proximal muscles during walking (*e.g.,* hip extensors/flexors) for propulsion and swing initiation, increasing walking metabolic cost. Second, given differences in PF muscle morphology, composition, and thus relative metabolic energy costs, our data may allude to a task-specific redistribution of the mechanical energy budget between, the soleus and gastrocnemius. Finally, the mechanism of metabolic energy use between cyclic and ISO contractions is fundamentally different, (*i.e.,* it is more expensive to turn a muscle on/off than to leave it on) [4], which may have implications for how isometric PF muscle actions shape walking metabolic cost.

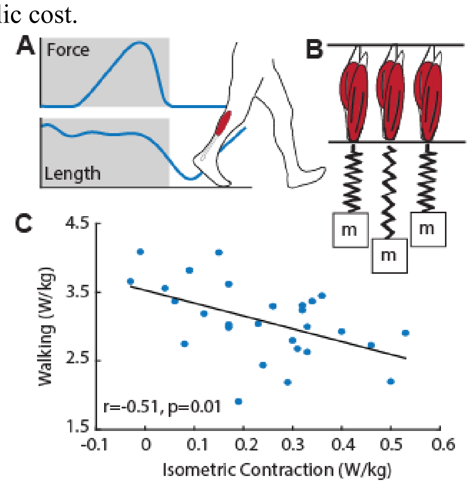

Figure 1: (A) Representative plots of gastrocnemius (GAS) force and length during walking (stance phase shaded). (B) GAS exploits the series elasticity of the Achilles tendon to operate nearly isometrically, as a strut, during walking. (C) Association between net metabolic power during walking versus during isometric contractions.

Significance

Our data represent an important step in understanding the extent to which ISO PF behavior shapes the metabolic cost of walking, which may have important implications for shaping interventions for individuals with reduced PF function, such as older adults.

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References

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