DIFFERENCES IN MUSCLE FUNCTION BETWEEN WALKING AND RUNNING AT THE PREFERRED WALK-RUN TRANSITION SPEED

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INTRODUCTION

Walking and running are the two most common forms of human gait. Understanding differences in muscle function between the two gait modes would further our understanding of the neuromotor control principles that govern human locomotion. Recent modeling and simulation studies have identified individual muscle contributions to the body mechanical energetics during normal walking [1]. However, it is unclear whether these contributions are preserved when the gait mode switches from walking to running. Therefore, the objective of this study was to use forward dynamical simulations of walking and running at the same speed and assess whether individual muscles contribute to the same body segment mechanical energetics during the two gait modes.

METHODS

Forward dynamical simulations of walking and running at the preferred walk-to-run transition speed (~2 m/s) were generated using dynamic optimization such that the simulations reproduced the averaged experimental kinematic and ground reaction force data collected from 10 healthy subjects. A 2D musculoskeletal model with nine degrees-of-freedom (trunk anterior-posterior tilt, horizontal and vertical translation, hip, knee and ankle flexion-extension for both legs) consisting of a trunk and two legs (femur, tibia, patella and foot for each leg) and seventeen individual muscle actuators per leg was developed using SIMM [2]. The muscles included the gluteus maximus, anterior and posterior gluteus medius, adductor magnus, iliacus, psoas, biceps femoris long head, medial hamstrings, biceps femoris short head, vastii, rectus femoris, tibialis anterior, soleus and medial and lateral gastrocnemius. Thirty visco-elastic elements were attached to each foot segment to model the foot-ground contact [e.g. 1]. Individual muscle excitation patterns were derived from EMG data collected from the same subjects. Parameter optimization using a simulated annealing algorithm was used to fine-tune the onset, duration and magnitude of the EMG patterns to produce well-coordinated movements. A state-space segment power analysis was performed to quantify how individual muscles contribute to the body segment energetics [3].

RESULTS AND DISCUSSION

The primary difference in how individual muscles distribute body segment mechanical power between walking and running was observed in the soleus (SOL). In walking, SOL absorbed ipsilateral leg power and transferred much of that power to the trunk from mid to late stance, then in late stance simultaneously generated power directly to the trunk (Fig. 1: SOL, Walking, 25-50% gait cycle). In running, SOL absorbed power from both the leg and trunk in the beginning of stance and then generated power to both the leg and trunk in mid stance (Fig. 1: SOL, Running, 0-30% gait cycle). In addition,

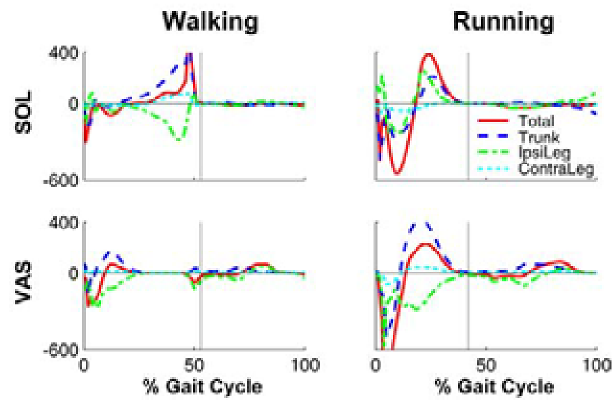

Figure 1: Distribution of total musculotendon power (*Total*) to the trunk (*Trunk*), ipsilateral leg (*IpsiLeg*) and contralateral leg (*ContraLeg*) during walking and running over the gait cycle. The vertical lines indicate toe-off. SOL: soleus; VAS: vasti. Units are in watts.

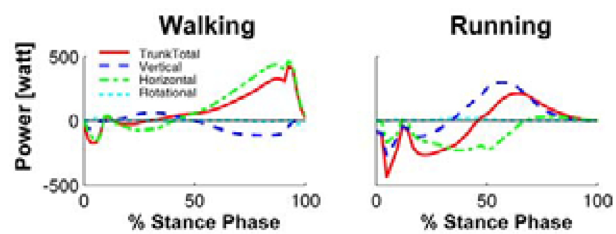

Figure 2: Trunk mechanical power generated by the soleus (SOL) during stance in walking and running. *Total*: total power; *Vertical*: vertical kinetic and potential power; *Horizontal*: horizontal kinetic power; *Rotational*: rotational power.

the power generated to the trunk by SOL exhibited different patterns between gait modes (Fig. 2). In walking, SOL provided positive horizontal and negative vertical power in late stance, which indicated that SOL acted to accelerate the trunk forward and decelerate the downward motion of the trunk. In running, near mid-stance SOL absorbed power from the trunk in the horizontal direction (i.e., decelerated its forward motion) while providing positive power in the vertical direction for body support. All other muscle contributions to body segment power were similar between walking and running, although the magnitudes and durations often differed between the two modes (e.g. Fig. 1: VAS).

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