INTRODUCTION

The most salient feature of the running gait has often been considered to be the generation of vertical forces in opposition to gravity. In comparison, horizontal ground reaction forces (GRFs) have traditionally been thought to play a much smaller role in running economy and muscle function. However, Chang and Kram (1999) found that by varying horizontal GRF demands, the energy cost of running could be reduced by one-third.

The purposes of this study were to find out which lower extremity muscles actively contribute to horizontal ground reaction force (GRF) production during running and to what degree muscle-tendon units use concentric or eccentric function.

METHODS

Fourteen subjects participated in this study, seven men and seven women between 20 and 39 years old. The group included sprint and endurance athletes of recreational to sub-elite ability. All were accustomed to running at least an hour per week for the past 3 months.

Each subject ran on a treadmill at 3.35 m/s while horizontal loads were applied via a waist belt attached to elastic tubing; Horizontal loads ranged from -8% body weight (BW) resistance to +12% BW assistance. Practice was given with this at least six days prior to the experimental session. A forward-directed or assistive pull increases braking impulses and reduces propulsive impulses. A rearward or resistive pull decreases braking impulses and increases propulsive impulses (Chang & Kram, 1999).

Muscle activities were measured in the soleus, gastrocnemius, tibialis anterior, vastus lateralis, rectus femoris, biceps femoris, and gluteus maximus. A sagittal plane video was recorded and combined with the regression equations of Hawkins and Hull (1990) to estimate muscle velocities.

The dependent variables for each of seven muscles were average stance activation and percent of total stance activation in concentric function. A one-factor repeated measures ANOVA was used to assess the significance of horizontal load effects (\(\alpha = .05\))

RESULTS

The gastrocnemius and soleus exhibited significantly lower mean stance activations with horizontal assistive loads (figure 1). Therefore, these two muscles contribute to propulsive impulses. The tibialis anterior had a significantly larger mean stance activation with horizontal assistance. All the muscles except the biceps femoris significantly increased their mean stance activation with increased horizontal resistance. Therefore all
muscles except the biceps femoris may contribute to horizontal force production during faster running.

![Mean Soleus Activation Graph](image)

![Mean Gastrocnemius Activation Graph](image)

**Figure 1:** Mean stance activations of the soleus and gastrocnemius muscles

To address the question of whether muscles tended to function eccentrically or concentrically in producing braking and propulsive forces, integrated concentric stance activations were expressed as a percentage of the integrated stance activations. Few significant changes were observed across different horizontal loads. The idea that propulsive forces are generated concentrically and braking forces eccentrically is not supported by this study.

**DISCUSSION**

The gastrocnemius and soleus could potentially account for most of the energy cost of generating propulsive forces during moderate speed running, and by extension up to a third of the total cost.

Regarding eccentric/concentric function, muscles seem to rely more on adjusting activation levels generally in response to different horizontal GRF requirements than on changing shortening and lengthening activation levels independently. A potential consequence of this is that more economical runners may rely more on eccentric activations to generate propulsive forces.

A limitation was the inability to manipulate braking and propulsive forces independently. Also, only the stance leg was examined.

**SUMMARY**

The gastrocnemius and soleus muscles contribute to propulsive impulse generation during running. For all the other muscles measured, no results conclusively demonstrated involvement in propulsive or braking force production. Also, contrary to common assumption, braking forces do not necessarily have to be created through eccentric actions, and propulsive forces do not necessarily require concentric activation.

**REFERENCES**


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