EXTRINSIC FOOT MUSCLE FORCES DURING RUNNING WITH DIFFERENT FOOTFALL PATTERNS

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INTRODUCTION

Humans run with a variety of footfall patterns such as a rearfoot/heel-toe (RF) or forefoot (FF) pattern of initial contact with the ground. It has been suggested that runners who run with a RF pattern have a lower $VO_{2submax}$ [5]. It has also been shown that the control strategies for these footfall patterns are different [1]. Since the extrinsic foot muscles play an integral part in controlling the foot during running, it is necessary to understand the contibution and the action of the extrinsic foot muscles to each of these footfall patterns. Therefore, the purpose of this study was to investigate the extrinsic foot muscle forces during running with a HT and FF footfall patterns using a static optimization model.

METHODS

Five healthy, college-aged males participated in this study (average age=31.2±4.9years; average mass=77.8±10.69kg; average height=1.77±0.08m). All of the subjects were natural RF runners. Each gave approval for participation in this study in accordance with University IRB policy.

The experimental set-up consisted of eight Qualysis motion capture system cameras (240 Hz). The motion capture system surrounded an AMTI force platform (1200 Hz). Markers for a 3-D analysis were placed on the pelvis, thigh, leg and foot of the right limb. Participants ran at their preferred speed (3.75±0.43 $m \cdot s^{-1}$). Ten trials in each condition were collected. Kinematic and kinetic data were used to calculated 3-D lower extremity moments about the sub-talar and talocrural joint axes using an inverse dynamics procedure. Moment arms for the extrinsic foot muscles were derived from OpenSim 1.5.5 [2] for muscles that were plantar/dorsiflexors (talocrural joint), those that were invertors/evertors (sub-talar joint) and those that were both.

A musculoskeletal model was developed and consisted of two joints (talocrural and sub-talar) and six extrinsic foot muscles extensor digitorum longus (EDL), gastrocnemius (GASTROC), peroneals (PER), soleus (SOL), tibialis anterior (TA), and tibialis posterior (TP). Muscle forces were determined using a 3-D static optimization procedure with a cost function that minimized the cubed muscle stresses [3]. The sum of the individual extrinsic foot muscle forces was constrained to equal the net moment at the talocrural and sub-talar joints. The model was scaled to the body mass and leg length of each subject.

Peak muscle forces were estimated and averaged for all trials in each footfall pattern for each participant. To illustrate clinically relevant differences between footfall patterns, effect sizes (ES) were calculated with ES>0.8 considered large and clinically relevant.

RESULTS

Figure 1 illustrates the peak muscle forces for the extrinsic foot muscles. In these muscles, the RF footfall pattern exhibited greater peak forces than the FF footfall pattern. Three muscles (EDL, PER and TA) had ES>0.8 indicating clinically relevant differences between RF and FF footfall patterns.

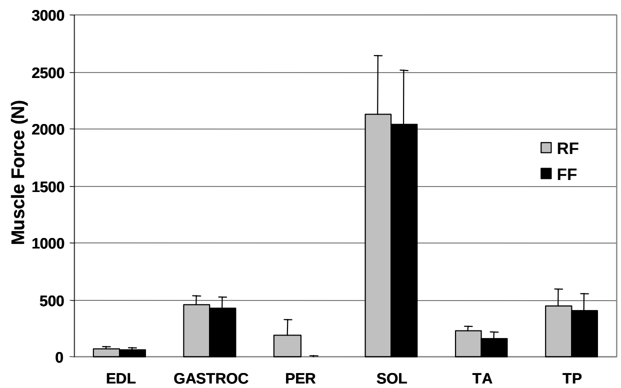

Figure 1: Ensemble averages of peak muscle forces (mean+SD).

The time of occurrence of the peak force resulted in moderate to large differences (ES>0.5) for all muscles. The time when EDL and TA muscles reached their peak force occurred later in support in the FF condition while the PER peak force occurred earlier in support.

DISCUSSIONS and CONCLUSIONS

The EDL and TA are muscles that primarily control foot PF/DF while the PER acts in ankle eversion. It appears that, by changing footfall patterns, the actions of these muscles change significantly with the RF pattern exhibiting greater forces in these muscles than the FF pattern. The GASTROC and SOL muscles act primarily as plantar flexors while the TP acts as an invertor. These muscles did not show large difference in muscle force between the two patterns. Surprisingly, the differences in muscle forces between the footfall types were very small.

An MRI study by O'Connor and associates [4] demonstrated that a relatively extreme orthotic perturbation did not alter the amount of work done by the extrinsic foot muscles. The results of the present study indicate that there are indeed some changes in the actions of the extrinsic foot muscles with a perturbation such as altering one's footfall pattern.

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