ESTIMATION OF EXTRINSIC FOOT MUSCLE FORCES USING A MUSCULOSKELETAL MODEL

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INTRODUCTION

Excessive foot pronation is believed to lead to overuse running injuries by causing high stresses in the muscles of the leg. However, it remains unclear exactly how these muscles (particularly the extrinsic foot muscles) respond to foot pronation during running. The eleven extrinsic foot muscles originate proximal to the foot and insert on the foot. While forces in some of these muscles have been estimated through musculoskeletal modeling (e.g., Scott & Winter, 1990), there are no studies that have investigated the effect of perturbations on these muscle forces. This could be critical in understanding how interventions such as orthotics alter the muscular loading in the leg. The purpose of this study was to develop a musculoskeletal model to study the force contributions of the extrinsic foot muscles during the stance phase of running under perturbation conditions.

METHODS

One subject ran in shoes with a normal midsole, a varus-wedged midsole, and a valgus-wedged midsole (Milani et al., 1995). A four-segment, three degree-of-freedom model was developed using the SIMM software package. The thigh, shank, talus, and calcaneus were modeled with articulations at the knee, ankle, and subtalar joints. Knee data were used to more accurately estimate length changes in the medial and lateral gastrocnemius. Eleven Hill-type muscle-tendon actuators represented the extrinsic foot muscles. Muscle parameters were based on the work of Delp (1990).

Three trials (one in each shoe condition) from the single subject were used as input to the model. The subject was asked to run across a force plate while kinematic, kinetic, and EMG data (on six muscles) were collected. Three-dimensional kinematic and kinetic data for the knee, ankle, and subtalar (axis estimated) joints were calculated.

A static optimization approach was used to estimate the force in each muscle based on a criterion of minimization of muscle activation squared such that the net moments matched the experimentally derived ankle and subtalar moments.

Confidence in the model was evaluated using three criteria. First, the modeled muscle forces should result in joint moments that matched those calculated from the experimental data. Second, the model force profiles should be consistent with the EMG data. Third, the model and EMG should have responded similarly to the perturbation conditions.

RESULTS AND DISCUSSION

The model was successful in meeting the first two criteria (match joint moments and muscle forces consistent with EMG). However, there were some timing discrepancies between model activation and
EMG (Figure 1). There was general agreement in the relative magnitudes of model force and peak EMG across conditions, which supports the third criteria (Figure 1).

One interesting finding was that the soleus was a major contributor to foot supination, which is generally attributed mainly to the tibialis posterior. The soleus provided 60% of the peak supination moment about the subtalar joint. This strengthens the idea that excessive pronation of the foot may contribute to overuse injuries such as shin splints that have been associated with the origin of the soleus on the tibia.

SUMMARY

This model may be useful in examining the load sharing between the extrinsic foot muscles and allow estimation of energy absorption of muscle and tendon units. The next step in model development will be to perform a sensitivity analysis before proceeding with application to a larger population.

REFERENCES


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**Figure 1:** EMG profiles, modeled activations, and modeled forces for the soleus, tibialis posterior (TP), and medial gastrocnemius (MG) while running in each shoe condition. These muscles were the largest contributors to the joint moments. Legend: thin – varus, dashed – neutral, thick – valgus. Note: EMG profile for the tibialis posterior in the valgus shoe was not obtained. Temporal data are reported relative to percent stance.