Muscle Forces During Single-Leg Jump Landing

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INTRODUCTION

Over 200,000 anterior cruciate ligament (ACL) injuries occur in the United States every year [1, 2] and these injuries often occur in sports where dynamic movements, such as jump landings, place high loads on the ACL ligament [3,4]. Small knee flexion angles, increased knee valgus moments, and anterior tibia translation contribute to ACL injury during landing [5-7]. Muscle forces impact changes in these knee kinematics and kinetics.

There are several methods to evaluate muscle contributions to dynamic knee movements with high risk for injury. Some have analyzed various roles that muscles play in landing biomechanics by evaluating muscle activity recordings such as electromyography (EMG) and co-contraction indices [7]. However, muscle activity does not provide a muscle's relative contribution to the movement, but computer simulations may provide additional insights [8]. For example, algorithms (e.g., computed muscle control) can estimate muscle forces required for the desired movement given kinematic and kinetic data [9].

In this study, we used computed muscle control (CMC) to estimate forces for muscles crossing the knee joint during single-leg jump landing. Identifying muscle contributions to landings may provide researchers with better understanding of landing biomechanics and injury prevention.

METHODS

We used experimental kinematic and kinetic data collected at the University of Western Australia to study the effectiveness of balance and technique training. One athlete from this study was selected and a subject-specific simulation was created for this subject in OpenSim (Fig. 1).

A subject-specific simulation of single-leg landing was created by using the following four steps. First, a generic musculoskeletal model was scaled to the size of the subject by specifying mass properties and segment dimensions obtained from experimental exams and marker data [10]. Second, inverse kinematics was used to derive the joint angles from the marker data obtained during jump landing. Third, simulated kinematic errors were minimized (RMS < 1.5N) to be dynamically consistent with experimental ground reaction forces by using the residual reduction algorithm. Fourth, CMC was used to estimate muscle excitations during jump landing. Associated forces for muscles crossing the knee joint required were recorded. These muscle forces were normalized with respect to maximum vastus lateralis muscle force during the simulation, similar to Besier, et al. [11].
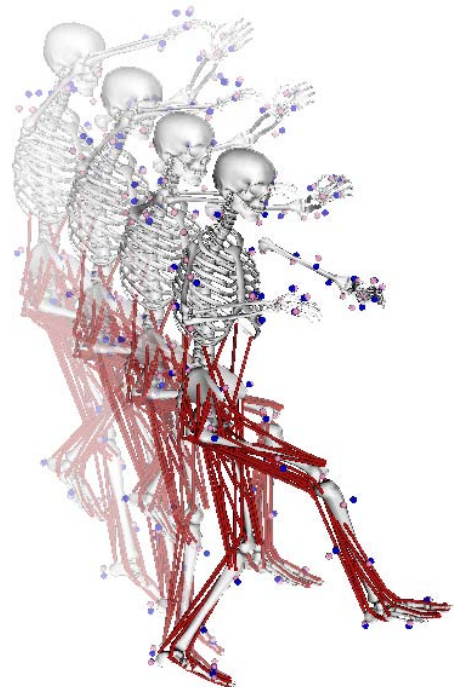

Figure 1: Series of images for a subject-specific simulation during single-leg jump landing using a musculoskeletal model with 37 degrees of freedom and 94 muscle-tendon actuators.
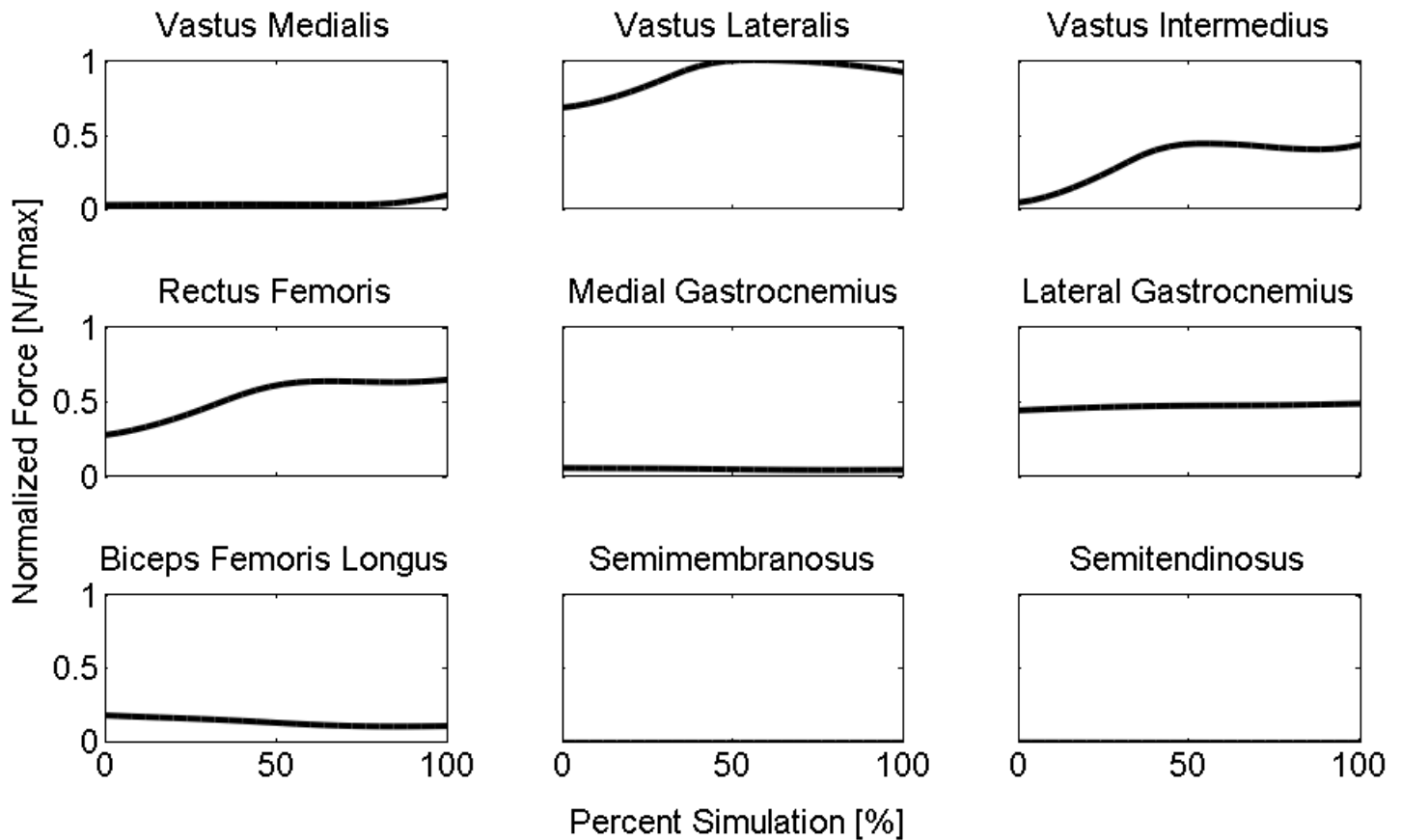
Figure 2: Forces for muscles crossing the knee joint normalized by maximum vastus lateralis force (Fmax) during single-leg jump landing

RESULTS AND DISCUSSION

Muscle contributions during single-leg jump landing resulted in a variation of normalized forces for muscles crossing the knee joint (Fig. 2). Vastus lateralis had the largest muscle force contribution. Normalizing the muscle forces with respect to the vastus lateralis muscle illustrated relative muscle contributions to single-leg jump landing. Our results are consistent with others showing lateral gastrocnemius had increased activity during landing [12]. Our findings for individual muscle forces add to previous work which combined these muscles into two synergistic groups [7].

CONCLUSIONS

Unlike EMG data for limited muscles, computer simulation provides information about several individual muscle force contributions to a dynamic movement. Future work will analyze additional subjects to determine if the trends reported here are truly representative of muscle force contributions in single-leg jump landings.

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