MUSCLE FORCE ESTIMATES DURING THE WEIGHT-ACCEPTANCE PHASE OF 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], with the majority of non-contact injuries occurring during jump landing sport tasks [3, 4]. Low knee flexion angles, elevated knee valgus moments, and anterior tibia translation contribute to elevated ACL strain and injury during landing tasks [5-7]. Muscle forces during landing may determine injury risk.

Muscles support the knee and could potentially reduce ACL injury risk during jump landing tasks. Presently, several methods are available for estimating muscle contributions during sport tasks associated with elevated ACL injury. Surface electromyography (sEMG) [7] and co-contraction indices estimate muscle activity during landing. However, these methods do not account for muscle architecture or changes in muscle moment arms during dynamic sport tasks, preventing these methods from estimating muscle forces. Computed muscle control (CMC) has recently been used to provide valuable insights into the roles individual muscles play during dynamic movements [8, 9].

The purpose of this study was to use CMC to estimate the forces crossing the knee during a single-leg landing tasks. The ability to identify how individual muscles function to support the knee and affect ACL injury risk during a single-leg jump landing may provide researchers with a better understanding of landing biomechanics and the ability to improve methods to reduce injury risk.

METHODS

Experimental kinematic, kinetic and sEMG data for six muscles (vastus medialis, vastus lateralis, medial and lateral gastrocnemius and medial and lateral hamstrings) were recorded from two male Australian football players conducting a single-leg jump landing task. Subject-specific simulations were created in OpenSim for each participant (Fig. 1) [10]. Inverse kinematics was used to derive the joint angles from the experimental kinematic data. Then OpenSim's residual reduction algorithm was used to create dynamically consistent simulations with the experimentally recorded ground reaction forces (peak residual forces less than 4N, peak residual moments less than 8Nm). CMC was used to estimate muscle excitations and subsequently muscle forces during the weight-acceptance phase of single-leg jump landing. During the simulation, minimum excitation levels for six muscles were bounded to excitations observed experimentally from their sEMG measurements. Muscle excitations estimated from CMC were compared to experimentally recorded sEMG data for the six muscles (Fig. 2). Muscle force estimates for nine muscles were normalized with respect to their individual maximum isometric force values used during the simulation (Fig. 3).
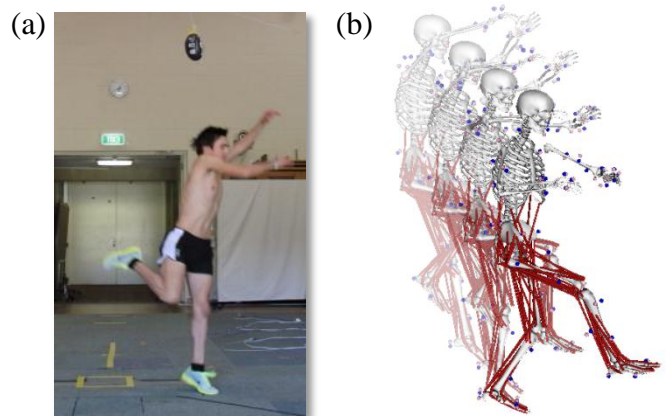

Figure 1: (a) Subject performing single-leg jump landing. (b) Simulation of single-leg jump landing task (model with 23 degrees of freedom and 92 muscle-tendon actuators).
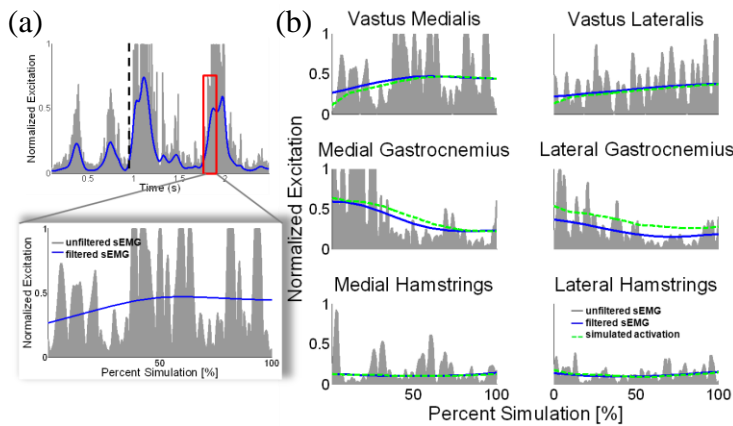
Figure 2: Comparison of sEMG and simulated muscle excitations. (a) Unfiltered and filtered sEMG for the vastus medialis where vertical dashed line indicates start of jump and simulation is during weight-acceptance. (b) Experimental sEMG and simulated muscle excitations estimated during the weight-acceptance phase of single-leg jump landing for subject 1.

Figure 3: Muscle force estimates solved for via CMC during the weight acceptance phase of single-leg jump landing. Muscle forces are normalized to their respective maximum isometric force values used during the simulation for both subjects.

RESULTS AND DISCUSSION

The largest muscle force estimates during the weight-acceptance phase of single-leg jump landing in decreasing order were the quadriceps and gastrocnemius followed by the hamstrings (Fig. 3). This result agrees with the primary motor control task during landing of producing a support moment [11] capable of maintaining the center of mass in an upright position. The gastrocnemius plays a much larger role than the hamstrings muscles in dynamic knee movements during single-leg landing. Further analysis is necessary to determine whether muscles may be selectively recruited [12] based on moment arms to support the knee from externally valgus knee loading during single-leg jump landing.

CONCLUSIONS

Simulations can be used to estimate individual muscle force contributions during the weight-acceptance phase of single-leg jump landing. Currently, these results suggest that the quadriceps and gastrocnemius muscles are the primary muscles utilized to support the knee and may potentially affect ACL injury risk from external knee loading during single-leg jump landing. Additional subjects
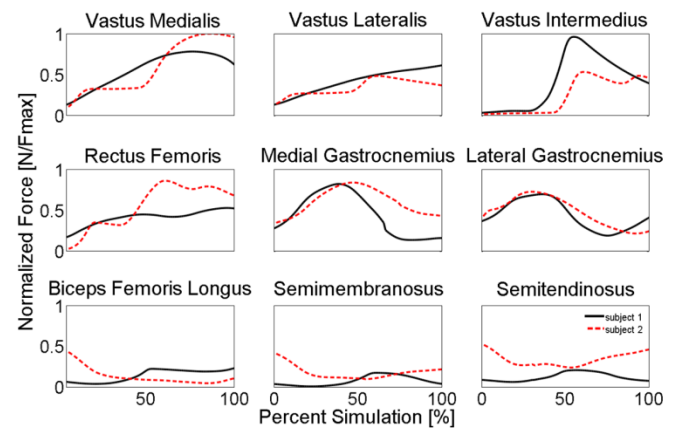
are being analyzed to determine if these muscle strategies are simulation specific or if they can be generalized to the single-leg jump landing sport task.

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