MUSCULAR CONTRIBUTIONS TO KNEE ACCELERATIONS DURING SINGLE-LEG JUMP LANDING IN AUSTRALIAN FOOTBALL PLAYERS

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INTRODUCTION

Australia reports one of the highest rates of ACL injury in the world at 52/100,000 people annually [1, 2]. Approximately 60% of ACL injuries are non-contact injuries, the majority occur during single-leg jump landing (SLJL) [3, 4] when the knee is near full extension, experiences anterior tibial translation and under an external valgus load [5-7]. While previous studies have defined kinematic and kinetic characteristics of ACL injury, the muscular mechanisms behind ACL injury prevention are not well understood as indicated by the 50% increase in ACL injuries over the last decade [8]. ACL injury prevention programs are aimed at altering muscle force and activation patterns to circumvent the ACL injury mechanism; however, they are limited by their inability to assess individual muscle contributions to resist excessive knee loading during movement. This lack of understanding has limited the progress of the current ACL injury research.

Identifying how muscles contribute to movement during SLJL may help to mitigate injury risk. Muscles accelerate joints and determining how they accelerate the knee during landing may be the key to understanding ACL injury prevention. Induced acceleration analysis (IAA) determines the accelerations caused or "induced" by individual muscle forces acting on a model (e.g., contribution of muscle forces to knee accelerations). Hence, the contribution of each individual muscle to frontal, sagittal and transverse plane knee accelerations can be established and determine which muscles are responsible for resisting certain elevated knee accelerations and better understand the cause-effect relationship (i.e., muscle contributions to movement) between muscle forces and joint biomechanics specifically with regard to ACL injury risk.

METHODS

A subject-specific simulation was created in OpenSim of a male Australian football player conducting a SLJL task (Fig.1). Experimental kinematic, kinetic and sEMG data for six muscles (medial and lateral vasti, gastrocnemii and hamstrings) were recorded for each subject. A musculoskeletal model with 23 degrees-of-freedom (dof) and 92 muscle actuators was scaled to represent the size of the subject. The model included a 3 dof knee actuated by muscles and ideal torque actuators. Inverse kinematics and a residual reduction algorithm were used to generate the simulation of the weight-acceptance (WA) phase of SLJL that was dynamically consistent with experimental measured ground reaction forces (GRFs) (peak residual forces and moments < 4N and 8Nm, respectively). Computed muscle control estimated muscle excitations and subsequently muscle forces during landing. Then, IAA was conducted to compute individual muscle contributions during landing [9-11]. For muscles crossing the knee, their contribution to accelerating the knee in the frontal, sagittal, and transverse planes during the WA phase of SLJL were compared.

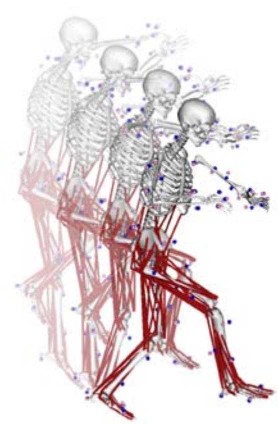

Figure 1: Simulation of SLJL task (model with 23 degrees of freedom and 92 muscle-tendon actuators).

RESULTS AND DISCUSSION

The muscular contributions to knee accelerations varied widely during the WA phase of SLJL (Fig. 2). In the frontal plane, the muscles that contributed to knee adduction based on peak and mean acceleration in descending order were the medial gastrocnemius, vastus medialis and medial hamstring muscles. The lateral gastrocnemius and hamstring muscles opposed adduction. In the sagittal plane, the muscles that accelerated the knee into extension in decreasing order were the vastus medialis, medial hamstring, lateral hamstring and vastus lateralis muscles. The gastrocnemii muscles resisted extension. In the transverse plane, the vastus medialis and medial hamstring muscles mainly contributed to internal knee rotation and the medial gastrocnemius muscle was the strongest contributor to external knee rotation.

The objective of this study was to understand how muscles contributed to accelerating the knee and mitigating injury risk. Thus muscles that opposed knee extension, abduction and also internal rotation could potentially reduce injury risk [6]. The results indicated that strong force production by the medial muscles served to counteract the early force production of the lateral gastrocnemius to adduct the knee and potentially mitigating ACL injury risk. Additionally, the gastrocnemii muscles flexed the knee to oppose the quadriceps muscles and increase knee flexion during landing also potentially reduce injury risk. However, the lateral gastrocnemii role in internally rotating and abducting the knee may mitigate its positive effect on flexing the knee.

This analysis was performed on one individual and future work will analyze additional subjects to determine if these trends are common across all individuals. Additionally, future analyses will investigate the contributions of muscles that do not cross the knee to knee accelerations in the frontal, sagittal and transverse planes.

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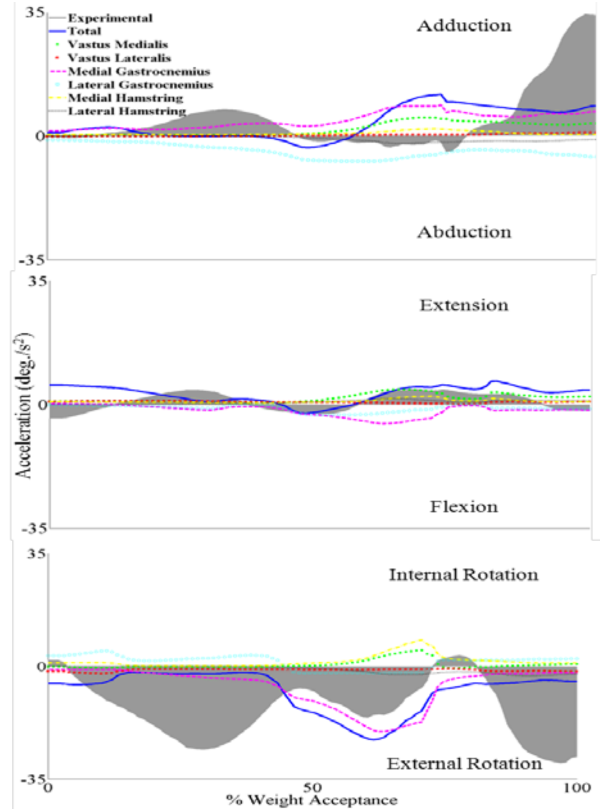

Figure 2: Muscle contributions to experimentally measured knee frontal, sagittal and transverse plane accelerations (shaded regions) for six muscles crossing the knee and the summation of the contributions of the six muscles (solid lines) during the WA phase of SLJL.

CONCLUSIONS

Based on these results, the medial gastrocnemius may be the best target for prevention programs to reduce ACL injury risk as it generated the strongest accelerations to oppose knee abduction and internal rotation. The lateral gastrocnemius was useful as a knee flexor and in this capacity could potentially resist the anterior translation of the tibia; however, its contributions to abducting the knee may diminish its role in lowering ACL injury risk.

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