INTRODUCTION

Lower extremity injuries have been linked to hip muscle weakness in both cross-sectional studies and theoretical papers [1,2]. However, studies on the link between hip muscle strength measures and kinematic variables have been inconclusive or inconsistent [3]. In studies examining hip strength and the effect on mechanical variables, participants were generally given preplanned tasks to perform, allowing them time to plan coordinated motions and responses to the tasks [4]. Performing these tasks under unanticipated conditions elicits more high-risk biomechanics than when performed under preplanned conditions [5,6]. The effects of the maximal strength of hip muscles may also be more apparent under unanticipated conditions than preplanned conditions, as participants have to react in a shorter time frame without the ability to adjust body trajectory to the desired path, and where athletes generally adopt more of a co-contraction strategy in their controlling musculature [7].

METHODS

Twenty-three female D1 soccer players were recruited. Maximal isometric hip abduction and external rotation strength were measured with a standard protocol [4]. Participants then performed three randomly cued tasks: 1) single-leg land, 2) single-leg land and cut, and a single-leg land and forward run. Participants began each task by standing on a box, initiating a forward jump, and landing with their dominant limb on a force plate. Box height and forward jump distance were normalized to each participants’ maximum vertical jump height and maximal single-leg stride distance, respectively. The random cue to perform each task was triggered from a switch mat placed on the takeoff box.

A 14-camera Vicon motion analysis system was used to collect position data from thigh, shank, and heel marker clusters [4]. Hip, knee, ankle, and foot markers were positioned for a standing trial and used to define joint centers for each lower extremity joint. Motion data were processed with Visual 3D to calculate 3-D knee joint angles and moments [4]. Force plate data were used to determine initial foot contact during each landing.

Measured maximal isometric hip strength values were multiplied by segment length to calculate joint torque, and normalized to body mass. For the movement trials, hip and knee excursion, defined as initial contact angle minus the maximum angle during the landing phase, were calculated for each trial, averaged for each participant, and exported for analysis. Peak hip and knee moments in each plane were also identified during the same phase, averaged across trials, and exported for analysis. Moments reported are internal moments. Left lower extremity values were inverted in the frontal and transverse plane so the signs of all data are presented as right lower extremity data. No differences were found in the landing phase biomechanics between the three tasks, so data from all three tasks were pooled for statistical analysis.

The effects of hip strength on landing mechanics were investigated with simple linear regressions. The level of statistical significance was set at $\alpha = 0.05$.

RESULTS
Hip abductor strength did not significantly correlate with any variables. Hip external rotation strength, however, correlated significantly with frontal-plane excursion of the hip into adduction (Figure 1; $R^2 = 0.24$; $p = 0.017$), peak hip external rotation moments in the transverse plane (Figure 2; $R^2 = 0.22$ $p = 0.021$), and with knee internal rotation moments in the transverse plane (Figure 2; $R^2 = 0.17$; $p = 0.048$).

**Figure 1**: Hip Excursion in the frontal plane (degrees) plotted against measured Hip External Rotation static strength (N-m/kg).

**Figure 2**: Hip ($\times$) and Knee ($\circ$) transverse plane moments (N-m) plotted against measured Hip External Rotation static strength (N-m/kg).

**DISCUSSION**

Greater isometric hip external rotation strength correlated with a greater hip external rotation moment in women’s D1 soccer players. In all participants, the femur was internally rotating after ground contact. The greater external rotator moment in those participants with greater hip strength suggests that those individuals controlled the femoral internal rotation with a stiffer landing strategy in that muscle group.

Further, participants with greater hip external rotator strength had a greater internal knee rotation moment. Oh et al [8] noted that an externally applied internal rotation moment contributed significantly to the loading of the ACL when combined with tibial abduction and axial loading. The participants in this study with greater hip external rotation strength had greater knee moments in the opposite direction, which would suggest that greater hip external rotation strength may ameliorate high-risk knee kinetics during unanticipated single leg landings, and therefore may have a protective effect at the knee.

**CONCLUSIONS**

The current findings suggest that hip external rotation strength affects the movement and loading of the lower extremity during the landing phase of unanticipated single leg activities. Individuals with greater static hip external rotator strength generated greater transverse plane moments at the hip during landing, possibly to counter deleterious externally applied internal rotation moments of the lower extremity while absorbing forces during impact.

**REFERENCES**
