A minimal set of screening activities to characterize anterior cruciate ligament injury risk

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Summary

A wide variety of movement patterns are associated with inciting mechanisms of anterior cruciate ligament (ACL) injuries across sports, but a more comprehensive assay is needed to better capture and isolate all athletes at risk. We identified a set of four screening tasks (double and single-leg squats, drop cuts and run cuts) from six of the most studied activities that best characterize injury-linked biomechanics captured in our comprehensive literature review.

Introduction

Anterior cruciate ligament (ACL) injuries are catastrophic, yet 72-88% are non-contact injuries indicating a majority are likely preventable with appropriate screening and targeted neuromuscular training [1,2]. While prevention strategies have been studied extensively, no consensus exists for the best tasks to screen athletes for injury risk. We aimed to identify a minimal set of screening activities, drawing from those most studied in literature, that maintain comprehensive characterization of mechanistic risk factors.

Methods

Female adolescent (n = 27; 15.7±1.2 yrs) recreational soccer, basketball, and volleyball athletes performed six ACL injury risk screening tasks (double and single-leg squats, double and single-leg drop jumps, drop cuts, and 90° run cuts) [3]. We collected motion capture and ground reaction force data and calculated 34 biomechanical features—such as peak joint angles and moments—associated with ACL injury risk, including 2-9 features per activity [4]. We pooled dominant and non-dominant limbs for single-leg activities. We used a statistical technique called column subset selection (CSS) to identify a set of tasks that best linearly reconstructed the biomechanical features from the left-out activities [5]. First, we evaluated the performance of all single activities, then all two-activity sets that included the best single activity, and so on. We assessed performance of reconstructing the features of left-out activities using average normalized root mean squared error, with leave one subject out cross validation across 100 bootstrapped samples. We normalized feature errors by the maximum value in the full dataset and compared activity sets with Mann Whitney U tests (α=0.05).

Results and Discussion

CSS identified a set of four screening activities (Figure 1) with the lowest predictive error on biomechanical features from the left-out activities (i.e. double and single-leg drop jumps). Predictive performance statistically improved ($p<0.001$) with each additional activity until a fifth was added wherein no new meaningful injury characteristics were emerging. Double-leg squats were the most predictive followed by drop cuts, single-leg squats, and run cuts.

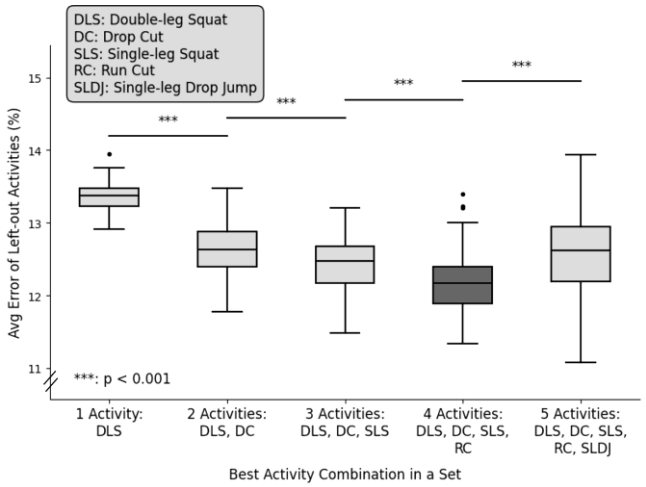

Figure 1: The best activity combination for a given set is compared using average normalized root mean squared error of biomechanical features from left-out activities. The minimal activity set (dark gray) has the lowest prediction error and includes four activities.

Conclusions

Four activities (double and single-leg squats, drop cuts, and run cuts) capture the biomechanical ACL injury risk information from six commonly studied screening activities. Despite frequent use in the ACL literature, double and single-leg drop jumps provide little unique or additive biomechanical risk information beyond this set of four activities. These data may inform consensus for screening activities and efficiency of risk assessments.

Acknowledgments

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