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A TWO-DIMENSIONAL VIDEO BASED SCREENING TOOL TO PREDICT PEAK KNEE LOADING AND ACL INJURY RISK IN FEMALE COMMUNITY LEVEL ATHLETES

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SUMMARY

Anterior cruciate ligament (ACL) injuries are traumatic and debilitating, with over half occurring during non-contact sidestepping situations. *In-vivo* and *in-silico* research show that the ACL is at greatest risk of injury during the weight acceptance (WA) phase of stance, when the knee is in an extended posture, and valgus and internal rotation moments, combined with anterior drawer are applied to the knee. Simulation research has shown an athlete's technique; more specifically, their upper body motor control can influence knee joint loading patterns during sidestepping manoeuvres. Clinically applicable methods that are capable of identifying community level athletes at increased risk of an ACL injury and that can be administered on a large scale are limited. The purpose of this study was to develop a reliable two-dimensional (2D) video analysis screening tool to predict peak knee loading during change of direction tasks in young female athletes. Significant correlations were found between a number of reliable 2D full body kinematics and three-dimensional (3D) peak knee loading variables. Results indicated that poorer trunk control in the medio-lateral and antero-posterior planes, reduced knee flexion angle at foot strike and high peak knee frontal plane adduction during sidestepping, result in higher peak knee extension and valgus moments. These findings are important as it is the combined external joint loading that predisposes the ACL to the greatest risk of injury. We are currently analysing data from a cohort of junior male athletes to determine the between gender robustness of this 2D screening tool for use in mass screening of community level athletes.

INTRODUCTION

Over half of anterior cruciate ligament (ACL) injuries occur during dynamic sporting tasks such as sidestepping [1,4]. These sporting tasks are common amongst team sports such as football in which approximately 256 million people participate in worldwide [7]. Recovery from ACL rupture is expensive and estimated to cost Australian and American healthcare budgets annually approximately 75 million AUD and 1 billion USD respectively. Personal cost to the injured athlete is also of significant concern with approximately 70% retiring from competition within three years of surgery [8]. When a meniscus injury is concurrently suffered with an ACL injury, athletes are also at significantly greater risk of developing knee osteoarthritis within 10-15 years [8] of the injury event. Previous research has identified causal links between an athlete's trunk and hip neuromuscular control and peak valgus and internal rotation knee loading during dynamic sporting tasks [5]. However, the ability to identify kinematic-kinetic relationships using two dimensional (2D) video analyses is currently limited and consequently, the ability to conduct mass screening of community level athletes to identify individuals with an increased injury risk is significantly hampered. The aim of this study was to develop a reliable 2D video based screening tool that may be used identify the kinematic factors associated with dangerous knee loading patterns that have previously been associated with increased ACL injury risk during sidestepping.

METHODS

Fifteen junior female hockey players (14-17 years) were asked to perform a series of planned and unplanned straight line and change of direction (sidestepping) running tasks (Figure 1) [1,4,6]. 3D marker trajectories were collected using a 12 camera Vicon MX system (Oxford Metrics, Oxford, UK) at 250Hz. The system was synchronized with a 1.2m x 1.2m force plate (AMTI, Watertown, MA) recording at 2,000Hz and frontal and sagittal plane 2D video cameras at 50 Hz. Full body kinematics and kinetics were analyzed during the weight acceptance (WA) phase of the sidestep [1-3].

2D kinematic measures including knee flexion range of motion (ROM), knee flexion at foot strike, peak valgus knee angle, peak dynamic medial knee collapse, trunk lateral flexion, trunk flexion at foot strike, trunk flexion ROM, mid-pelvis to foot displacement and peak thigh abduction were analyzed using Silicon Coach 2D biomechanics software. Peak knee valgus, extension and internal rotation knee moments were calculated using custom lower limb and trunk models in Body Builder (Vicon, Oxford Metrics, Oxford, UK) [1-3,6]. 2D kinematic variables measured during unplanned sidestepping (UPSS) and straight line run trials were placed into a backward stepwise regression ($\alpha=0.05$) to identify 2D kinematic variables that predict the above peak knee loading during UPSS. Intraclass correlations (ICC) and limits of agreement (LoA) were used to test inter- and intra- rater reliability of the nine 2D kinematic measures.

RESULTS AND DISCUSSION

Knee flexion range of motion (ROM) ($p<0.01$), peak knee frontal plane adduction ($p<0.01$) and peak trunk lateral flexion ($p=0.029$) were good predictors of peak extension knee moments, explaining 43.4% of the variability. Knee flexion at impact ($p<0.01$), trunk flexion ROM ($p=0.038$) and peak mid-pelvis to foot displacement (foot placement) ($p<0.01$) proved to be good predictors of peak valgus knee moments, explaining 55.7% of the variability (Table 1). Interestingly, frontal plane kinematic variables were found to explain variability in peak extension knee moments, whereas sagittal plane kinematic variables explained variability in peak valgus knee moments.

Inter-tester reliability of knee flexion, trunk lateral flexion and trunk flexion were moderate to high ($p<0.001$; ICC=0.66-0.8; LoA=3.6-8.3°), as were mid-pelvis to foot displacement and dynamic medial knee collapse ($p<0.001$; ICC=0.78-0.99; LoA=0.02-0.03m). Intra-tester reliability of. knee flexion, trunk lateral flexion and trunk flexion were moderate to high ($p<0.001$; ICC=0.65-0.96; LoA=4.4-7.3°). Mid-pelvis to foot displacement and dynamic medial knee collapse also displayed moderate-high intra-tester reliability ($p<0.001$; ICC=0.68-0.84; LoA=0.04-0.05m).

These results suggest an interplay between an athlete's kinematics in one plane predicting peak knee loading characteristics in another. These findings are consistent with previous simulation research that has shown that kinematic changes in all three planes of motion reduce an athlete's peak knee loading during UPSS [5]. Results also support the rationale that an athlete's upper body kinematics can significantly influence peak knee loading and ACL injury risk during dynamic sporting tasks like unplanned sidestepping. The reliability of the 2D kinematic measures ensure this tool can be used effectively across laboratories and over time. The next step in this research, currently in progress, is to test a group of male team sport athletes to determine the robustness of this clinical screening tool.

Once this tool has been refined it will enable the mass screening of community level athletes. By identifying 'high risk' athletes we can implement subject-specific training protocols to target the individual malingering biomechanical factors predisposing athletes to increased ACL injury risk in sport. This will help in the effective translation of prophylactic training protocols focused on reducing elite and community level ACL injuries.

CONCLUSIONS

A repeatable and reliable 2D video-based screening tool was found to be successful in identifying 2D measures associated with dangerous knee loading characteristics during unplanned sidestepping in female athletes. Movement patterns such as wide foot placement from the midline, a low knee flexion angle at foot strike, a large trunk flexion ROM, trunk lateral flexion away from the intended direction of travel and high levels of knee frontal plane adduction during weight acceptance, effectively predicted peak extension and valgus knee loading during sidestepping.

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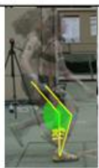
Table 1. Backward stepwise linear regression between peak knee loading ($Nm.m^{-1}.kg^{-1}$) and 2D kinematic variables during the WA phase of UPSS and PSLR conditions.

Peak Extension Moment:				**Peak Valgus Moment:**			
Total Model	**2D Kinematics**	**β**	**p**	**Total Model**	**2D Kinematics**	**β**	**p**
n = 15	(Constant)		.045*	**n = 15**	(Constant)		.001*
p < 0.001**	Knee Flexion ROM 	.336	.002*	**p < 0.001****	Knee Flexion at Foot Strike 	-.385	.000*
R^2= 0.461	Peak Knee Frontal Plane Adduction 	.444	.000*	**R^2= 0.578**	Trunk Flexion ROM 	.182	.038*
Adjusted R^2= 0.434	Trunk Lateral Flexion 	.228	.029*	**Adjusted R^2= 0.557**	Mid-pelvis to Foot Displacement 	.607	.000*

* indicates significance at the 0.05 level. When variables were not significant, they were removed from regression, meaning correlations of significant variables have been adjusted.