ASSESSING LOWER EXTRMITY INTER-SEGMENTAL COORDINATION AND COORDINATION STABILITY IN FEMALE ATHLETES WITH ACL RECONSTRUCTION DURING SINGLE LEG SQUAT

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INTRODUCTION

Female athletes who sustain anterior cruciate ligament (ACL) injuries and undergo surgical reconstruction exhibit deficits in sensorimotor control, which often impairs lower limb movement coordination [1]. The purpose of this study was to investigate inter-segmental coordination while female athletes with ACLr performed single leg squat compared to health female athletes. The hypothesis in this study was that female athletes with ACLr had different and less stable coordination patterns than healthy female athletes.

METHODS

Eighteen female college athletes (9 subjects with ACL reconstruction, 9 health subjects) participated in this study. Subjects reported to the lab and performed eight closed-chain motor performance tests, including a 30 second single leg squat task, which was selected for the current analysis. Each subject was instrumented with 34 retro-reflective markers according to a customized lower body marker system [2]. Three-dimensional motion capture data were recorded using an 8-camera Vicon motion analysis system (Nexus 2.9.3, Vicon Motion System, Centennial, CO; 100 Hz). Three-dimensional raw marker trajectories were processed through CBL3D, which is a custom Matlab program (The Mathworks, Inc., Natick, MA, USA) that was utilized to model the body and calculate kinematic outcome variables. Motion data were filtered using a low-pass Butterworth filter (6 Hz cut-off frequency).

The continuous relative phase (CRP) was used to assess inter-segmental coordination movement patterns of the trunk and lower extremity (i.e., trunk-pelvis, pelvis-thigh, thigh-leg, leg-foot). The CRP was calculated from the phase angle of two adjacent segments (i.e., $\theta_{CRP} = \theta_{\text{Distal Segment}} - \theta_{\text{Proximal Segment}}$) [3]. Deviation phase (DP) was used to quantify the stability of inter-segmental coordination, where a higher DP value indicates less stability in the movement [3]. An independent t-test was used to determine differences between conditions (α=0.05). Statistical analysis was performed using SPSS (version 25.0, Chicago, Illinois).

RESULTS AND DISCUSSION

Descriptive statistics for CRP and DP during the single leg squat were calculated (Tables 1 and 2). Athletes with ACLr exhibited a significantly greater (69.8%) leg-foot CRP ($F(2, 16) = 3.43$, $p < .003$, $\eta^2 = 1.62$) and a greater (62.0%) leg-foot DP ($F(2, 16) = 3.63$, $p < .002$, $\eta^2 = 1.71$) when compared with healthy athletes.

The results support the hypothesis that female athletes with ACLr would present altered patterns of movement coordination and less stable coordination patterns compared to healthy athletes. The high leg-foot CRP in athletes with ACLr indicate that the oscillating segments had a more out-of-phase relationship, meaning that subjects with ACLr had a more rigid and less adaptable pattern of leg-foot coordination [3,4]. The CRP variability corresponds to the capacity of the movement to produce a stable pattern of coordination. Hence, the high DP value indicates a less stable leg-foot movement pattern [3]. The result of leg-foot DP may corresponded to neuromuscular deficit causing a decrease in lower limb stability.

SIGNIFICANCE

The alteration of inter-segment coordination during a dynamic movement such as single-leg squat can be a key factor for determining the appropriate time to return back to sport activities. Lower limb stability could also be an indicator of an athlete's susceptibility to ACL re-injury.

REFERENCES

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Table 1: Descriptive statistics of the CRP during the performance of single leg squat.

	Trunk-Pelvic	Pelvic-Thigh	Thigh-Leg	Leg-Foot
ACL athletes	9.44° ± 4.41	47.08° ± 20.77	14.76° ± 10.71	61.28° ± 19.25[a]
Healthy athletes	8.12° ± 4.33	51.69° ± 16.94	9.48° ± 3.61	36.10° ± 10.73

a = Athletes with ACL had significantly different CRP of Leg-foot (p< .003) from healthy athletes.

Table 2: Descriptive statistics of the DP during the performance of single leg squat.

	Trunk-Pelvic	Pelvic-Thigh	Thigh-Leg	Leg-Foot
ACL athletes	5.52° ± 1.36	54.46° ± 22.86	22.52° ± 18.73	76.78° ± 20.28[a]
Healthy athletes	6.21° ± 1.78	53.59° ± 14.68	17.79° ± 8.67	47.41° ±13.39

a = Athletes with ACL had significant different CRP of Leg-foot (*p*< .002) from healthy athletes.