

# DECREASED STABILITY OF MULTISEGMENTAL POSTURAL COORDINATION IN ACL-INJURED FEMALE ATHLETES

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## INTRODUCTION

Bilateral proprioceptive deficits result from anterior cruciate ligament (ACL) injury and may persist up to two years after ACL reconstruction (e.g., Corrigan et al. 1992). Proprioception plays a key role in neuromuscular control, as indicated by performance impairments resulting from perturbations of proprioception (e.g., Serrien et al. 2001). High levels of neuromuscular control are important for athletic actions such as landing and cutting, which are associated with ACL injury (Boden et al. 2000). Because deficient neuromuscular control has been implicated as contributors to ACL injury risk (Hewett et al. 2002, 2005), proprioceptive deficits following ACL reconstruction may place athletes at risk for a second ACL injury.

Standard tests of proprioception may not capture the functional deficits that contribute to ACL injury (Co et al. 1993). In this study we determined whether a dynamic postural coordination task was sensitive to the proprioceptive and neuromuscular deficits that characterize ACL-injured subjects. The task (Bardy et al. 2002) required subjects to track the position of an oscillating visual target by keeping the head at a fixed position relative to the target. This is achieved by coordinating sagittal-plane rotations of the body about the ankle with sagittal-plane

oscillation of the trunk and upper body about the hips. This coordination is mediated by proprioceptive feedback, so proprioceptive deficits were expected to manifest as decreased stability of the coordination pattern.

## METHODS AND PROCEDURES

Twenty-two females participated in the current study (11 ACL injured; 11 controls). The ACL-injured subjects were medically cleared to return to sport. Four trials (two low-frequency, two high-frequency) of anterior/posterior target oscillation were examined. Front-to-back ankle and hip angular displacement was recorded using a 10-camera motion analysis system (Motion Analysis Corp., 60 Hz sampling rate). All trials lasted for 10 front-to-back-to-front oscillations that took approximately 15 s and 1 min to complete for the high and low frequency conditions, respectively.

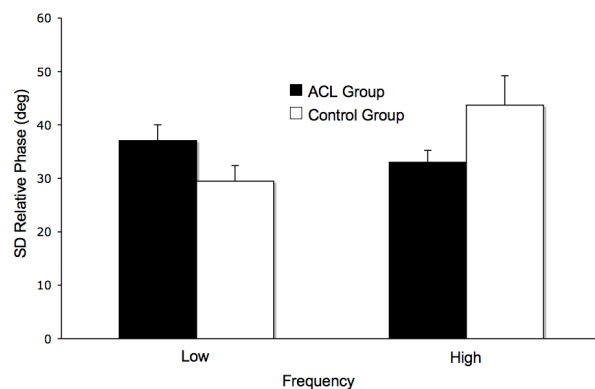
Subjects stood on either the left or right leg with their arms crossed in front of them. The computer-generated, oscillating target was displayed on a monitor placed 1 m from the participant. Participants were instructed to use body movements to track the front-to-back oscillations of the target, doing their best to move in phase with the target, which oscillated at either 0.2 or 0.7 Hz. Motion data

were filtered using a low-pass Butterworth filter (4<sup>th</sup> order, 5 Hz cut-off frequency).

Postural coordination was indexed on each trial by continuous relative phase ( $\phi$ ), the difference between the ankle and hip phase angles  $\theta$  (i.e.,  $\phi = \theta_{ankle} - \theta_{hip}$ ). Relative phase variability ( $SD\phi$ , the within-trial standard deviation of  $\phi$ ) quantifies the stability of ankle-hip coordination—higher  $SD\phi$  indicates more variability in the phase relation, hence lower coordination stability—and was the dependent variable of interest.

## RESULTS

A group (ACL injured vs. control)  $\times$  leg (injured vs. non-injured)  $\times$  frequency (low vs. high) mixed-model ANOVA revealed a significant group  $\times$  frequency interaction (see Figure 1),  $F(1,25) = 10.03$ ,  $p < .01$ . Follow-up tests revealed significantly higher  $SD\phi$  for the control group in the high frequency than the low-frequency condition ( $p < .05$ ;  $M = 43.70^\circ$  vs.  $29.49^\circ$ , respectively), and significantly higher  $SD\phi$  for the ACL injured than the control group in the low frequency condition ( $p < .05$ ;  $M = 37.03$  vs.  $29.49$ , respectively).



**Figure 1.** Group  $\times$  frequency interaction for standard deviation of relative phase ( $SD\phi$ ).

## DISCUSSION

Postural coordination was affected differently for the ACL-injured and control groups by the

frequency manipulation. ACL-injured subjects exhibited significantly greater variability than controls in the low-frequency condition. The stability of the postural coordination decreased significantly in the high-frequency condition for controls, but not for the ACL-injured subjects. The low-frequency condition required slow, controlled muscular contractions to oscillate the body in the sagittal plane so as to track the looming target—arguably this presented a greater challenge in terms of neuromuscular control. The multi-segmental, dynamic postural coordination task, which depends heavily on proprioceptive feedback, may have utility in predicting risk for ACL re-injury.

## SUMMARY

ACL-injured subjects exhibited less stable hip-ankle coordination when performing a postural coordination task that required slow oscillations about the ankle and hip.

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## ACKNOWLEDGEMENTS

Supported by NSF grants 0432992 and 0716319, NIH/NIAMS grant R01-AR049735-01, and a University Research Council grant from the University of Cincinnati.