INTRODUCTION

Various techniques have been developed and used to understand the effects of perturbations and injuries on lower extremity joint couplings through the calculation coordination variability within a particular task [1, 2]. Previous investigators used continuous relative phase [1], a modification of relative motion plots analysis, to examine joint couplings. However, this technique is designed for sinusoidal movement patterns and often requires normalisation of data which often hinders the ability to interpret the findings as they relate to injury. To overcome these limitations, a vector coding (VC) method [2] was developed to allow for the simultaneous comparison of multiple trials through the use of angle-angle plots created between two segments.

Females exhibit a reduced variability in couplings that involved either the transverse or frontal planes [3, 4]. Specifically, the knee flexion-extension/knee rotation and knee flexion-extension/hip rotation couplings were reduced compared to males during the first 40% of stance in an unanticipated side step cut. From these data, it was hypothesized that a decrease in coordination pattern variability in particular joint couplings may help explain the increased risk of lower extremity injury in females [3].

Neuromuscular fatigue was shown to alter lower extremity kinematics, which may increase the risk of injury in female collegiate athletes [5]. Specifically, these athletes landed in a more extended position when fatigued, showing that fatigue had a detrimental effect on lower limb biomechanics at discrete time points. The purpose of this study was to improve our understanding of the effects of fatigue on the coordination variability of lower extremity joint couplings.

METHODS

Fifteen NCAA Division I female soccer players (mean age = 19.2 ± 0.8yrs; height = 1.67 ± 0.05m; mass = 61.7 ±8.1kg) were selected to participate in this study. In a previously published study, kinematic and kinetic data were collected for each participant as they performed four trials of an unanticipated side step cut using their dominant leg for both pre- and post-fatigue conditions [5]. The fatigue protocol consisted of dynamic movements such as sprinting, cutting, jumping and squatting at varying intensities within a short period of time.

A modified VC technique [2] was used to analyze variation between the pre- and post-fatigue trials, where zero and one represents no variability and high variability [6]. A custom MATLAB program (Mathworks, Inc., Natick, MA, USA) imported the kinematic data and performed the VC calculations. Four trials of the side step cut were analyzed for each subject for both the pre- and post-fatigue conditions. The stance phase of each trial, consisted of heel strike to toe-off and was normalized to 101 points.

Inter- and intra-limb couplings of the entire group between the hip and knee joints were analyzed using curve analysis during the deceleration phase (i.e., first 50% of stance). The pre- and post-fatigue variation curves along with their respective standard error bands were plotted simultaneously and areas of non-overlap were considered to be areas to investigate further. An area of non-overlap exists when the standard error bands of both curves do not intersect.

RESULTS AND DISCUSSION

An area of non-overlap was found in the hip flexion/hip rotation coupling during the first 5% of
stance, where pre-fatigue presented higher variation values than post-fatigue (Fig. 1). This suggests that the athletes in this study are able to employ multiple movement strategies to accomplish the preliminary stage of the cutting task in an un-fatigued state. Many of the other couplings involving knee motion exhibited an opposite trend between 20-30% of stance. This suggests that the motion of the hip joint during the first 5% of the task may affect the motion of the knee joint at a later time period of the stance phase.

From the previously published study, significant differences were found for hip flexion-extension and rotation at initial contact after fatigue [5]. A direct comparison between the kinematics and joint coupling variation values cannot be made yet. However, the changes in planar kinematics along with the coupled motions with fatigue suggest that the deceleration around initial contact during cutting should be further investigated.

A decrease in variation in a fatigued state in the hip flexion-extension/hip rotation coupling may be responsible for the increase in post-fatigue variation in many couplings involving knee flexion-extension. This may be a compensatory mechanism that the athletes are employing to accomplish the deceleration phase of the cutting task, however, the interpretation of these findings require further investigation.

CONCLUSIONS
Vector coding may be a useful technique that can be used to determine coordination variation during a particular task. Future studies should combine vector coding along with kinetic and neural assessments to help provide further insight into the non-contact ACL injury mechanism.

REFERENCES

Table 1: Chart indicating areas of non-overlap, where blue and red represent greater variability in pre- and post-fatigue, respectively. There were no areas of overlap beyond 50% of the stance phase of cutting.