INTRODUCTION

The anterior cruciate ligament (ACL) provides static stability to the knee joint. Non-contact ACL injuries are common in female athletes and are theorized to result from poor neuromuscular control at the knee joint [1]. Variables that have been associated with poor knee joint neuromuscular control include reduced sagittal plane knee excursion and increased normalized vertical ground reaction force (vGRF) [2]. Frontal plane angular knee excursion has also been shown to be higher in females than in males during a single legged hop test [3]. This finding suggests that frontal plane angular knee excursion may play a role in the well-reported increased female injury risk.

The STAtionary Single Leg Hop (STASH) test is a novel and maximal effort task that can investigate the link between generalized neuromuscular control and neuromuscular control at the knee joint. In the STASH the athlete is required to perform three consecutive hops on one leg, jumping as high as possible while attempting to land in the same place after each hop. They are also required to maintain balance on the same leg after the third landing.

METHODS

Center of mass excursion (COM) is the net distance traveled by the COM during a time interval in the x-y plane (Fig. 1). Typically, the analogous center of pressure (COP) excursion measurement is used to assess postural control in static tasks. In a dynamic task, however, a total COM excursion value quantifies neuromuscular control because COP cannot be assessed whilst athletes are airborne.

Figure 1: Depiction of total COM excursion calculation

The purpose of this study was to determine the relationship between generalized neuromuscular control, measured as total body COM excursion, and the injury risk biomechanics including vGRF and knee excursion in the sagittal and frontal planes. Prior to testing, Institutional Review Board approval of the protocol was attained and informed consent was provided to all subjects. Eighteen athletes from a Division I university women’s soccer team (18.94 ± 0.94 yrs, 1.68 ± 0.054 m, 63.68 ± 6.52 kg) with no current lower extremity injury were recorded performing the STASH using tri-axial Bertec 4060 force plates collecting at 1500Hz and a 10-camera Vicon MX-F40 motion capture system collecting at 300Hz. Each athlete performed two repetitions of the STASH on each leg.

49 retro-reflective markers were placed on each athlete using a modified plug-in-gait model. Pelvic markers were used to estimate the COM location, and total COM excursion was calculated for each trial by tracing the total distance traveled between the time points of peak knee flexion at initial takeoff and peak knee flexion on the third landing. Measurement via this method did not allow the elapsed time to obstruct the measurement, which would have been the case if the distances between starting point and COM were summed at each frame for the duration of the STASH.

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Total knee sagittal plane excursion and total knee frontal plane excursion values were calculated by summing the angular excursion differences at each frame during the entire stance phase of each of the three landings. Vertical GRF was normalized by peak potential energy (bodyweight \times \text{jump height before landing}) to account for force generation and force absorption [4], and the three vertical GRF values were averaged for each trial.

RESULTS and DISCUSSION

Moderate correlations driven by two clusters of data points were found between total center of mass (COM) excursion and total knee frontal plane angular excursion (avg.=59.37$^\circ$±17.24; $r=0.62$; $p=0.006$) (Fig. 1), total sagittal plane knee excursion (avg.=265.39$^\circ$±37.34; $r=0.48$; $p=0.046$) (Fig. 2), and normalized peak VGRF (avg.=21.58N/J±2.862; $r=-0.44$; $p=0.065$) (Fig. 3).

A limitation of this novel STASH test assessing knee biomechanics is that COM excursion may not have been the ideal way to assess generalized neuromuscular control because it did not take into account the direction of the COM deviation. Other means of assessing generalized neuromuscular control in a static task include COP 95% ellipse area, standard deviation in the anterior–posterior and medial–lateral directions, and root mean square velocity in the anterior–posterior and medial–lateral directions [5]. These measurements can be applied or adapted to the dynamic STASH test, and their relation to knee joint neuromuscular control can be investigated. Further corroboration of the link between generalized neuromuscular control and knee joint neuromuscular control may provide a basis for more effective, targeted interventions for at-risk athletes.

CONCLUSION

The STASH demonstrates that poor overall neuromuscular control, approximated by total COM excursion, is also associated with injury predicting biomechanical variables at the knee joint that may be useful for ACL injury risk detection. Future studies on the STASH and its abilities to assess injury risk prospectively are needed.

REFERENCES