INTRODUCTION

Intersegmental acceleration and velocity profiles help dictate body movement stability and resultant success. This will be particularly true for high-impact movement scenarios where kinematic transmissions across segments return high magnitudes. These large magnitudes increase the likelihood of “noisy” and potentially inaccurate precision movement responses. Degradation in precision will likely be exacerbated with the onset of fatigue, where sub-optimal muscle activation allows for greater mechanical transmission and adaptive/corrective responses up the kinetic chain. As an initial step in elucidating the contributions of intersegmental dynamics to performance, this study aimed to examine the effects of neuromuscular fatigue on segment specific angular velocity and acceleration profiles of a jump-landing task relevant to athletic activity.

METHODS

Subjects
Seven females (21.6 +/- 0.5 yrs.) were recruited to participate in this pilot study. Inertial measurement units (IMUs; Yost Engineering, Portsmouth, OH), containing tri-axial gyroscope and accelerometers, were secured to the dominant foot, shank and thigh, and the trunk (Figure 1). Prior to testing, sensors were time-synchronized via oscillating the dominant lower limb about the hip joint in the frontal plane.

Experimental Design
Subjects performed an initial series of jump-landing tasks to establish baseline pre-fatigue performance. Specifically, they executed six successful trails each of: 1) stationary double-leg front jump to dominant leg stabilization; 2) dominant leg cut-jumps (Figure 1); and 3) 0.6-m high box elevation jumps to dominant leg stabilization.

Subjects performed alternating jump-landing tasks and fatigue exercises until fatigue was reached. The fatigue protocol included three sets of specific exercises, with each set consisting of: 1) ten 0.6-m high box step-ups; 2) 10 double-leg squats; and 3) 20 stationary lunges (10 on each leg). Maximal fatigue was qualified as the inability to consistently perform fatigue exercises with proper athletic form. A single examiner determined when fatigue was achieved, and was denoted by any of the following: 1) inability to perform more than five full double-leg squats with knees flexed to 90-degrees; 2) inability to keep knee from touching the floor during five or more stationary lunges; and/or 3) inability to maintain constant frequency of step-up exercises. After maximal fatigue, subjects repeated the jump-landing tasks to assess post-fatigue performance.

Data Processing
Following testing, raw IMU data were processed within custom Matlab (Mathworks, Inc.) programs to extract segmental peak acceleration and angular velocity magnitudes during each baseline and post-fatigue jump-landing task. Average peak magnitudes were calculated for each jump-landing task from the six successful
trials for each subject. After considering results, only data from elevation jump-landings was used in further analysis due to distinct impact peaks and the highest level of landing consistency across subjects. Paired two-tailed t-tests (SPSS Statistics 20) were conducted between baseline and post-fatigue kinematical measures.

RESULTS AND DISCUSSION
Peak resultant angular velocity occurred at initial ground contact and increased significantly post-fatigue for the thigh (25.3%; \( p=0.003 \)) and trunk (65.8%; \( p=0.0004 \)) segments compared to baseline. Foot angular velocity similarly peaked at initial contact, trending towards a post-fatigue increase (7.6%; \( p=0.057 \)) (Figure 2). Peak resultant acceleration was significantly greater post-fatigue for the shank (13.2%; \( p=0.04 \)) and trunk (35.9%; \( p=0.015 \)) segments compared to baseline. Peak resultant acceleration again demonstrated an increasing trend post-fatigue for the foot segment (6.6%; \( p=0.057 \)) (Figure 3).

Fatigue increases the prevalence of lower limb overuse injuries such as stress fractures [1,3], due, in part, to the neuromuscular system’s decreased ability to attenuate impact-induced accelerations [4]. Current outcomes support this tenet, with increased tibial accelerations being evident post fatigue for our dynamic landing task [2]. Increased kinematic transmission was also observed higher up the kinetic chain (thigh and trunk). Larger peak angular velocity and acceleration magnitudes evident in these segments in the presence of fatigue may directly impact their ability to stabilize and control movements requiring a high-degree of postural precision. This decreased dynamic stability may additional pre-empt additional joint injury scenarios, where passive joint structures must necessarily compensate for a compromised overarching neuromuscular strategy.

The current pilot study, while providing important baseline information, is limited in its ability to identify key mechanical predictors of successful/degraded movement responses. Future efforts will expand on these initial efforts by additionally considering progressive fatigue contributions and assessments of explicit task accuracies with and without fatigue. Further, fatigue and movement tasks will continue to be refined to minimize confounding inter-subject neuromuscular control variations.

CONCLUSIONS
The influence of fatigue on performance is multi-factorial and detrimental to the overall ability to stabilize the body in an efficient manner. The data presented demonstrate increased acceleration and angular velocity transmission higher up the kinetic chain once fatigue sets in. The result of this increased transmission will likely be a decreased capacity to control movement precision, effectively reducing overall movement performance.

REFERENCES