Fatigue Effects on Lower Extremity Coordination and Coordination Variability During Multi-joint Ballistic Movement

Adam E. Jagodinsky, Christopher Wilburn, Lorraine Smallwood and Wendi H. Weimar

Auburn University, Auburn, AL, USA
email: aej0015@auburn.edu

INTRODUCTION

Lower extremity multi-joint movements are abundant in sport and sport-related training, often occurring in a repetitive, ballistic nature. When fatigue is evident, understanding coordination strategies adopted by an athlete during ballistic tasks has implications for performance outcomes and injury prevention. As a tenet of dynamic systems theory, variability in coordination patterns is thought to provide information regarding the state of the motor system during a given task and can be used to describe the integrity of a given movement strategy [1]. However, application of such concepts to lower extremity ballistic movements related to sport is lacking. Therefore, the purpose of this project was two fold: (1) to assess coordination and coordination variability (CV) during a repetitive lower extremity ballistic motion; and (2) to investigate the influence of fatigue on lower extremity coordination patterns while performing a ballistic movement.

METHODS

Five healthy and currently resistance training males (age: 23.4±3.4yrs; weight: 89.73±10.5kg; height: 1.75±0.1m) participated in the study, which was approved by the Institutional Review Board. Participants were asked to report on Day 1 for familiarization of the experimental task. During Day 2, participants performed the experimental protocol. The experimental protocol asked the participant to perform kettlebell swings using a 24kg load. The specific movement consists primarily of a loading phase (flexion at the hip, knee, and dorsiflexion at the ankle) followed by a propulsion phase (extension at the hip and knee with ankle plantar flexion), similar to a vertical jump motion. The protocol consisted of one continuous set of repetitions of the experimental movement until the participant reached self-reported exhaustion. Each repetition represented one cycle of movement and data from each cycle was interpolated to 150 points to allow comparison between cycles. To avoid including unrepresentative cycles related to movement initiation and cessation, the first and last three trials were excluded from analysis. Subsequently, the first ten (T1) and last ten (T2) cycles represented movement from a pre-fatigue and fatigue state respectively.

A ten-camera optical motion capture system (VICON Technology, Los Angeles, CA) was used to obtain kinematic measurements during the experimental protocol. Lower extremity joint angles and velocity were calculated from marker data and used to construct phase portraits (joint angular displacement versus its rate of change) for the hip, knee and ankle joints. Continuous Relative Phase (CRP) was used to assess the relative motion of the hip, knee and ankle throughout the entire movement cycle [2]. From the phase portrait, phase angles were obtained and relative phase angles were calculated for knee-hip (K-H), ankle-hip (A-H) and ankle-knee (A-K) by subtracting the proximal joint phase angle from the distal joint phase angle at each point within the time series. The relative phase angle represents the spatial/temporal disparity or congruity between joints within a cycle of movement. Mean absolute relative phase (MARP) was calculated as the average absolute value of relative phase mean ensemble. Larger MARP values indicate more sequential or out-of-phase relative motion while smaller values indicate more simultaneous or in-phase relative motion. Deviation Phase (DP) was calculated to assess the stability of the organization of the neuromuscular system and was determined by taking the mean of the standard deviations of the
ensemble relative phase points. Lower DP values indicate a more stable joint coupling relationship while larger DP values suggest reduced stability joint coupling relationship.

RESULTS

Results from paired-samples t-tests indicated that for all joint couplings, changes in coordination (K-H, p=0.30; A-H, p=0.49; A-K, p=0.49) and CV (K-H, p=0.38; A-H, p=0.53; A-K, p=0.26) from T1 to T2 were not statistically significant.

![Mean Absolute Relative Phase During T1 and T2](image1)

Figure 1: Mean absolute relative phase, as a measure of joint coordination for each joint coupling at T1 and T2.

![Deviation Phase During T1 and T2](image2)

Figure 2: Deviation phase for each joint coupling as a measure of coordination variability at T1 and T2.

DISCUSSION

This project adopted a novel approach to assess coordination and CV during a repetitive ballistic movement. Although the data failed to reach statistical significance, this project has yielded some interesting findings. First, statistical outcomes suggest that from a pre-fatigued to fatigue state, lower extremity coordination patterns during a ballistic movement are similar. However, for all three joint couplings a considerable difference is noted for the MARP (Figure 1). Data presented in Figure 1 indicates a trend of more in-phase relative motion during pre-fatigue cycles. However, each joint coupling exhibited more out-of-phase behavior with fatigue, suggesting more independent joint motion. In general, lower extremity coordination strategies were highly flexible for each joint coupling (Figure 2), which may be beneficial when high loads are imposed on the system. However, with fatigue A-H and A-K motion became less variable. The less flexible arrangement between A-H and A-K was contrasted by greater variability between K-H during T2. This could be explained by the reduced capacity of the motor system to control more distal joints with fatigue while great flexibility in K-H motion was required for satisfying task requirements.

To account for limitations, expansion of this project will consider the loading and propulsion phases independently in addition to increasing the sample size.

REFERENCES