Effect of Cardiovascular Fatigue on Postural Stability

Hamid Bateni, PhD; Gina Leno, MPT; Rebeca Manjarres, MPT; Bailey Ouellette, MPT; and Mark Wolber, MPT • Northern Illinois University

Context: Previous research has demonstrated that localized leg muscle fatigue induced by lower extremity exercises (e.g., squat jumps, sprints, and treadmill running) has an adverse effect on postural stability. Objective: To assess the effect of cardiovascular fatigue induced by upper extremity exercise on postural stability. Design: Repeated measures. Participants: Fourteen healthy young adults between the ages of 22 and 30 years (7 male and 7 female). Intervention: Participants performed an exercise protocol on an upper-body ergometer to induce cardiovascular fatigue. Main Outcome Measures: Postural sway, represented by center of pressure excursion, during bilateral standing in two different foot positions. Results: In a tandem standing position, mediolateral mean distance, root mean square distance, resultant power, and centroidal frequency increased significantly after inducement of cardiovascular fatigue. Conclusion: Cardiovascular fatigue adversely affects postural stability. Key Words: postural balance; postural sway

Muscle fatigue can be defined as a decrease in the ability of a muscle to generate a required force. Research has demonstrated that muscle fatigue has an adverse effect on physical performance and postural control. Specifically, fatigue of the ankle plantar flexors and dorsiflexors, as well as the hip flexors and extensors, impairs postural control. A fatigue-inducing protocol that consisted of squat jumps, sprints, and treadmill running was found to produce a significant negative effect on the performance of the balance error-scoring test. A model of postural control has been developed on the basis of the effects produced by a decline in the force output of fatigued muscle groups.

Recent research has demonstrated that prolonged exercise can decrease the force output of muscles through more than one mechanism, including metabolic influences and changes in central nervous system information processing. Metabolic and neural factors may influence the performance of numerous muscles simultaneously. For example, repeated heel raises that fatigue the ankle plantar flexors also may have an effect on the knee extensors, and thereby increase risk for falling. Because a decrease in postural stability might not be due solely to the inability of a specific muscle group to generate a sufficient amount of force, the purpose of this study was to assess the possible adverse impact of generalized cardiovascular fatigue on control of posture.

Procedures and Findings

Fourteen healthy young adults (22–30 years of age; 7 male and 7 female) participated in the study. Exclusionary criteria included visual or vestibular deficits and history of injury or surgery involving the lower extremity within the previous six months. A force platform (Model 9287BA, Kistler Co., Winterthur, Switzerland) was used to acquire center of pressure (COP) data at 100 Hz. Postural sway was related to the mean position of the COP in terms of COP excursion distance and the root mean square (RMS) of the distance.
Participants stood on the force platform with bare feet and were instructed to stand as motionless as possible, while looking straight ahead at a point on the wall (eye-level, 1-inch diameter, six feet away). Prior to the performance of fatiguing exercise, force platform data were collected for two 30-second trials in both of two standing conditions (i.e., heels-together and tandem; random performance order). To distract the participants from excessive focus on the task, they were asked to count backward by threes from a randomly chosen three-digit number during performance of the tests.

Following the initial testing sequence, the participants performed fatiguing upper extremity exercise to achieve a consistent level of cardiovascular fatigue. A target heart rate was computed for each participant using Karvonen’s formula as follows:

$$\text{THR} = \frac{70 \times (220 - (\text{AGE} + \text{RHR}))}{100} + \text{RHR}$$

Where:

THR = target heart rate  
RHR = resting heart rate  
AGE = participant’s age

Each participant exercised on an upper-body ergometer until the target heart rate was reached, and then maintained the target heart rate for two minutes. Throughout the exercise session, a finger pulse oximeter (Model 8500AW, Nonin Medical Inc, Plymouth, MN) was used to monitor the heart rate, and verbal encouragement was provided. Postexercise postural balance was assessed again in the same manner as the initial procedure. Thus, each participant performed a total of eight postural balance trials (i.e., two trials in both of two standing positions before and after exercise).

Anteroposterior and mediolateral COP data were filtered through a fourth-order zero-phase Butterworth low-pass filter, with a 5-Hz cutoff frequency. The first 10 seconds and the last 2 seconds the trial data were excluded from the analysis. A detailed explanation of time and frequency domain variables computed in this study has been provided in the literature.

The dependent variables were overall and directional mean distances of COP excursion, RMS, 95% confidence circle area, and centroidal frequency, each of which were analyzed separately. Pre- and postfatigue trials were compared for both stance conditions through paired t-tests ($\alpha = 0.05$).

No significant pre- to postfatigue differences were apparent for any of the dependent variables for the heels-together position. For the tandem-standing position, the mean COP excursion distance significantly increased after the exercise session ($p = 0.011$). Analysis of the directional mean distance demonstrated that changes primarily occurred in the mediolateral direction. Similarly, the RMS distance demonstrated a significant increase following cardiovascular fatigue ($p = 0.047$). The resultant power demonstrated a significant increase following the cardiovascular fatigue exercise ($p = 0.027$), and centroidal frequency increased significantly ($p = 0.041$). There was no significant difference in the 95% confidence circle area in the tandem standing condition.

Discussion

Our findings indicate that cardiovascular fatigue adversely affects postural stability, despite lack of fatigue inducement in muscles that are known to affect postural control (i.e., ankle plantar flexors and dorsiflexors). Previous studies have demonstrated that mean closed-eyes postural sway distance increases in older adults and following fatigue of the knee extensors and ankle plantar flexors. The level of cardiovascular fatigue that we induced was not strong enough to affect balance in the heels-together standing position, but it did alter balance in the tandem condition, which provides a more narrow base of support. Our findings were consistent with those of other researchers who have documented an increase in RMS in the eyes-closed condition. Our finding of an increase in the power of postural sway, combined with changes in time and frequency domain variables, indicates diminished muscular control of postural position.

The exercise protocol was identical for all participants, but variation in fitness levels may have resulted in different levels of fatigue inducement. Measurement of heart rate, or perceived exertion (e.g., Borg Scale rating), during performance of the exercise would have provided a means to assess variation in the extent to which the protocol imposed differential cardiovascular demand among the participants. Measurement of postexercise pulmonary ventilation rate also might have demonstrated a relationship with postural sway oscillations. Electromyography could have been used to monitor the respective activation levels of the different
leg muscles during performance of the postural balance trials.

**Conclusion**

Cardiovascular fatigue adversely affects postural stability, despite lack of localized fatigue inducement in muscles that are known to affect postural control (i.e., ankle plantar flexors and dorsiflexors).

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**References**


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**Hamid Bateni, Gina Leno, Rebeca Manjarres, Bailey Ouellette, and Mark Wolber** are with the Allied Health and Communicative Disorders School at Northern Illinois University in Dekalb, IL.

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