Effects of Localized Muscle Fatigue and Whole Body Fatigue on Postural Control during Single-Leg Stance

Chang-Hong Youm¹ · Joong-Dal Shin¹ · Joong-Sook Lee² · Kook-Eun Seo³ · Jong-Jin Park⁴

¹Department of Coaching, College of Sport Sciences, Dong-A University, Busan, Korea
²Division of Physical Education, College of Medical and Life Sciences Silla University, Busan, Korea
³Division of Sport Sciences, Pusan National University, Busan, Korea
⁴School of Sports and Health, College of Arts, Kyungsung University, Busan, Korea

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ABSTRACT

The purpose of this study was to investigate the effects of localized muscle fatigue and whole body fatigue on postural control during single-leg stance after impairment induced by heel raise and the Harvard step test. Thirty-eight university students (19 men: age, 20.1±0.2 yrs; height, 175.0±5.23 cm; weight, 66.8±5.6 kg; body mass index, 21.8±1.7 kg/m², 19 women: age, 20.6±1.1 yrs; height, 163.6±6.7 cm; weight, 58.8±4.6 kg; body mass index, 22.0±2.2 kg/m²) were participated in this study. Subjects performed a series of single-leg postural tasks prior to, following, and 24 hours after completing: heel raise or the Harvard step test. This study showed that the root mean squared distance and velocity in the anteroposterior and mediolateral planes of the center of pressure decreased significantly due to heel raise exercise-induced fatigue. Furthermore, the root mean squared distance in the anteroposterior and mediolateral planes, and the 95% confidence ellipse area of the center of pressure also decreased significantly 24 hours after completing the Harvard step test. In conclusion, this study showed that both heel raise exercise- and Harvard step exercise-induced fatigue affects postural control during single-leg stance. Also vision can attenuate the postural deficits associated with the fatigues. In order to clarify these results, further studies using other equipment and variables are necessary.

Keywords : Muscle Fatigue, Single-leg Stance, Center of Pressure, Heel Raise, Harvard Step Test

I. Introduction

Postural control is maintained by the dynamic integration of internal and external forces(Massion, 1994; Yaggie & McGregor, 2002), which involves harmonious control of the musculoskeletal, visual, vestibular, and somatosensory systems(Hall & Brody, 1999; Shumway-Cook & Woollacott, 2000). For the assessment of the postural control, the force platform is primarily utilized, and the center of pressure (COP) is determined to quantify body sway (Winter, 1995). The COP assessments have been used to investigate changes in postural control in a variety of healthy and special populations (Dolye, Hsiao-Wecksler, Ragan, & Rosenberg, 2007). The single-leg stance is used as a clinical and experimental tool to assess static postural control in various groups (Bohannon & Leary, 1995; Frzovic, Morris, & Vowels, 2000), since this stance is required to perform many everyday motor tasks, including turning, climbing stairs, and walking (Jonsson, Seiger, & Hirschfeld, 2004).

Measurement of postural control is one approach to quantify neuromuscular control (Gribble & Hertel, 2004b). Fatigue has been shown to have an adverse effect on neuromuscular control (Gribble & Hertel, 2004a). Moreover, fatigue and postural control deficits can lead to musculoskeletal injury (Gribble & Hertel, 2004b). This increased postural sway can increase the risk of musculoskeletal injuries such as ankle sprain (Christina, White, & Gilchrist, 2001; Letafatkar, Alizadeh, & Kordi, 2009; Rozzi, Lephart, Gear, & Fu, 1999; Urabe et al., 2005).

Muscle fatigue relates to a decline in performance during high-intensity exercise. The fatigue-induced changes in per-
formance include reduced force production, decreased shortening velocity, and slowed relaxation (Allen & Westerblad, 2001). Factors contributing to muscle fatigue are divided largely into 2 groups: the central factor generates fatigue as a result of the disorganizing of neuromuscular transmission between the central nervous system and the muscular membrane, whereas the peripheral factor leads to alteration within the muscle (Giannesini, Cozzone, & Bendahan, 2003). Muscle fatigue depends on the type of exercise and its various causes, and its behavior is based on the manner in which it is induced (Giannesini et al., 2003; Letafaktar et al., 2009).

Many researchers have examined the relationship between lower leg muscle fatigue and COP sway (Adlerton & Moritz, 1996; Cobeil, Blouin, Bégin, Nougier, & Teasdale, 2003; Gribble & Hertel, 2004a, 2004b; Shin & Youm, 2011; Yaggie & McGregor, 2002; Youm & Kim, 2012). Lundin, Feuerbach, and Grabiner (1993) studied how postural control during single-leg stance was affected by plantar flexor and dorsiflexor fatigue in 8 healthy men, and found that both mediolateral and anteroposterior sway increased significantly. Similarly, Yaggie and McGregor (2002) investigated how postural control during single-leg stance was impacted by plantar flexor and dorsiflexor fatigue in 24 healthy men, and reported that mediolateral sway increased significantly. Gimmon, Riemer, Oddsson, & Melzer (2011) reported that localized plantar flexor fatigue caused impairment to postural control in the sagittal plane. Lin et al. (2009) investigated that acute effects of fatigue location and age on changes in postural control induced by localized muscle fatigue, and reported that the acute effects of fatigue differed between joints. And ankle joint fatigue resulted in significant effects on postural control.

On the other hand, Adlerton and Moritz (1996) examined the effect of calf muscle fatigue on postural control during single-leg stance and found no significant reduction. Gribble and Hertel (2004a) studied the effects of ankle, knee, and hip joint fatigue on postural control during single-leg stance in 4 men and 10 women, and reported that localized muscle fatigue in the anteroposterior plane affected the postural control of the lower limbs. In another study by Gribble and Hertel (2004b), which examined the effects of hip and ankle muscle fatigue on postural control during single-leg stance in 4 men and 9 women, they discovered that hip muscle fatigue affected postural control in the anteroposterior and mediolateral planes but ankle muscle fatigue did not produce any significant effect. Although most investigations concluded that ankle muscle fatigue negatively affects postural control; however, some studies reported no changes in postural control after fatigue of the ankle muscles, which may be due to a differences of methods and protocols (Adlerton & Moritz, 1996; Gribble & Hertel, 2004b). In addition, some studies have been conducted on the effects of peripheral localized muscle fatigue on postural control using an isokinetic dynamometer; however, studies focusing on the differences in the types of exercise-induced fatigue, such as a comparison of the effects of heel raise and the Harvard step test on functional movements, rarely have been performed. In addition, the effect of post-fatigue recovery on postural control has been poorly documented.

Therefore, the purpose of this study was to investigate the effects of localized muscle fatigue and whole body fatigue on postural control during single-leg stance after impairment induced by heel raise and the Harvard step test in healthy university students.

II. Methods

1. Participants

Thirty-eight university students (19 men: age, 20.1±0.2 yrs; height, 175.0±5.23 cm; weight, 66.8±5.6 kg; body mass index, 21.8±1.7 kg/m\(^2\); 19 women: age, 20.6±1.1 yrs; height, 163.6±6.7 cm; weight, 58.8±4.6 kg; body mass index, 22.0±2.2 kg/m\(^2\)) in sports-related departments participated in this study. None of the subjects presented with any history of injury of the lower limb that could affect their ability to perform the experiment. Informed consent was obtained from each participant after the purpose of the study and its procedures was explained.

2. Experimental procedures

Subjects participated in 2 experimental sessions, separated by approximately 1 week, and were asked to refrain from performing physical exercise and to maintain their regular daily activity level during the study period. During each session, subjects performed a series of single-leg postural tasks prior to, following, and 24 hours after completing 1 of 2 randomly ordered conditions: heel raise or the Harvard step test.

All single-leg postural trials lasted above 70 seconds immediately following each condition, with the patients’ eyes open on the platform (Figure 1). During the stance, subjects were instructed to stand barefoot with their preferred leg, with arms crossed at their chest and the knee of the opposite leg in a flexed position, and to visually fixate on the target in front of them. Subjects were instructed to sway as little as possible while single-leg standing.

3. Fatigue protocol

The fatigue protocol involved a heel raise and the Harvard step test (Figure 2). The heel raises were performed on a board with an approximately 10° posterior slope in order to increase the subjects’ range of motion. Subjects were