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# Muscle activity during backward and forward running with body weight support

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ABSTRACT

We investigated muscle activity during backward (BR) and forward (FR) running with body weight support (BWS). Ten participants completed BR and FR on a lower body positive pressure treadmill while selecting a preferred speed (PS) for different BWS conditions (0%, 20%, 40%, 60%, and 80%BWS). Muscle activity from the rectus femoris (RF), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius (GA), rating of perceived exertion (RPE), preferred stride frequency (PSF), and PS were measured. Magnitude of muscle activity (BF, TA, and GA), RPE, PSF, and PS were not influenced by the interaction of direction and BWS ($P > 0.05$). BF, TA, and GA were not different between directions ($P > 0.05$) but were different between BWS conditions ($P < 0.01$). RF was influenced by the interaction of direction and BWS ($P < 0.01$). RF, BF, TA, and GA during BR were lower with increasing BWS. RF during BR was 59–86% higher than that of FR within BWS condition. RPE was lower with increasing BWS ($P < 0.001$), regardless of direction of locomotion. PSF was lower and PS was higher during BR and FR with increasing BWS (both $P < 0.001$). PSF during BR was 6–9% higher than that of FR. PS during BR was 24–31% lower than that of FR. These observations demonstrate that a change in BWS influences magnitude of muscle activity, PS, PSF, and RPE for both BR and FR. However, a change in direction of locomotion may not influence magnitude of muscle activity or RPE during running for a given BWS, even though muscle activity pattern, PS, and PSF were different between BR and FR.

## 1. Introduction

Running is a popular mode of exercise that can lead to positive health benefits but also comes with a high risk of injury. For example, the incidence of running-related lower extremity injuries ranges from 19% to 79% (van Gent et al., 2007). In general, moderate mechanical loading is required for maintaining a healthy musculoskeletal system (Griffin & Guilak, 2005). Although mechanical loading is necessary for positive bone health, magnitude of impact forces on the lower extremity during running may play a major role in the development of lower extremity injury (Edwards, Taylor, Rudolphi, Gillette, & Derrick, 2009).

Reducing the impact forces on the lower extremity can be accomplished through a variety of changes to running. For example, manipulations of stride frequency (Hamill, Derrick, & Holt, 1995) and running speed (Mercer, Vance, Hreljac, & Hamill, 2002) has been proposed as simple and effective means to reduce the magnitude of impact forces on the lower extremity during treadmill running. However, it should be noted that the physiological demands during treadmill running decreases with decreasing running speed (Mercer et al., 2002). Other possible strategies for the reduction in the magnitude of impact forces on the lower extremity

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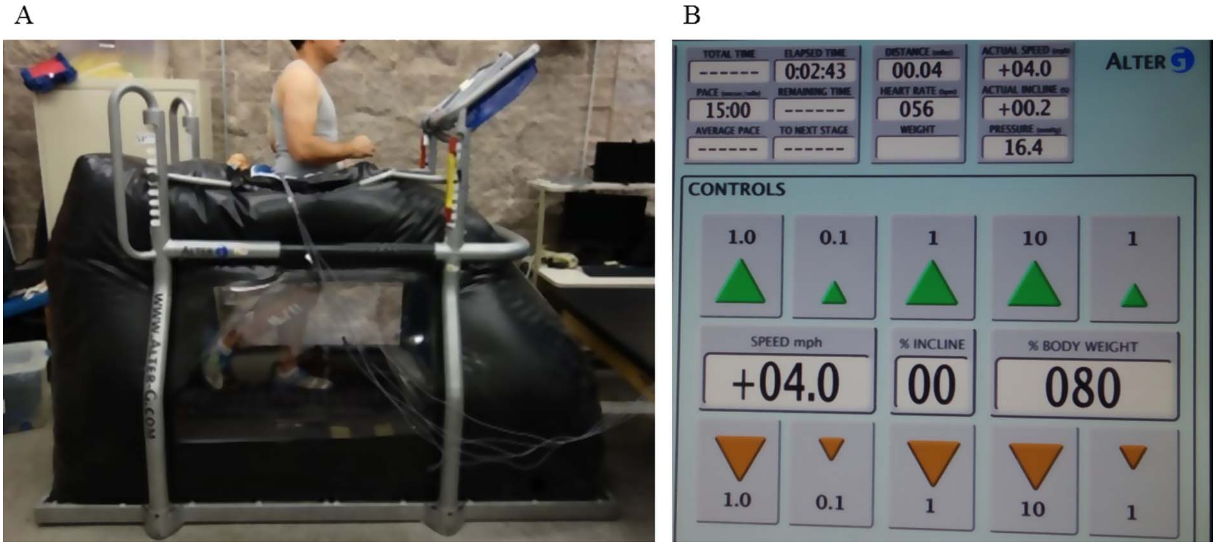


**Fig. 1.** Pictures of a lower body positive pressure (LBPP) treadmill (A) and a control display (B) of the LBPP treadmill.

include running with body weight support (BWS) and backward running (BR).

Recently, a lower body positive pressure (LBPP) treadmill which provides BWS during running has become commercially available. The LBPP treadmill consists of a regular treadmill enveloped by a chamber that can be pressurized while a person's lower extremity is secured within the chamber. This design provides the ability to control the amount of BWS and speed of treadmill independently (Fig. 1). The LBPP treadmill has become a widely used tool for physical fitness enhancement (Gojanovic, Shultz, Feihl, & Matheson, 2015) in addition to its uses in lower extremity rehabilitation (Saxena & Granot, 2011).

An advantage of the LBPP treadmill is that movement patterns (e.g., muscle activity patterns) during running at increased BWS are similar to that of treadmill running with no BWS (Liebenberg et al., 2011; Mercer, Applequist, & Masumoto, 2013, 2014). Furthermore, individuals can reduce vertical ground reaction force while maintaining an aerobic stimulus by running at fast speeds with increased BWS during running on the LBPP treadmill (Kline et al., 2015; Raffalt, Hovgaard-Hansen, & Jensen, 2013). Therefore, running on the LBPP treadmill can be used as a cross-training alternative to running on dry land with effective running speed and BWS combinations while minimizing a change in the movement patterns.

Separate from BWS, BR has been reported to induce reduced vertical ground reaction force (Threlkeld, Horn, Wojtowicz, Rooney, & Shapiro, 1989) and patellofemoral joint forces (Roos, Barton, & van Deursen, 2012) than that of FR at the same speed. Additionally, BR has been shown to produce higher physiological responses (e.g., an increase of 31% in oxygen uptake: Flynn, Connery, Smutok, Zeballos, & Weisman, 1994) than FR at the same speed. Therefore, BR may be another possible cross-training alternative to FR because it produces higher physiological responses with reduced impact forces on the lower extremity than that of FR. Furthermore, BR with BWS may also be a potential useful exercise. However, there are no data on any parameter during BR with BWS.

Changes in BWS and direction of locomotion may influence muscle activity during running. For example, Masumoto, Bailey, and Mercer (2015) reported that the mode-specific preferred stride frequency and muscle activity during FR in water were lower than that of FR on dry land. Furthermore, it has been reported that knee extensor musculature was active for a longer percentage of the stance phase during BR than that of FR at mode-specific preferred speed (Flynn & Soutas-Little, 1993). However, no research is available regarding the influence of BWS and direction of locomotion on magnitude and pattern of muscle activity, preferred stride frequency, and rating of perceived exertion (RPE) during running, while measuring each individual's actual preferred speed at various BWS conditions. Such information is important if human locomotion is to be better understood, and if individuals use these techniques as alternative cross-training methods for physical fitness enhancement.

Accordingly, the purpose of this study was to determine the magnitude and pattern of muscle activity, knee angular kinematics, preferred stride frequency, preferred speed, and RPE during BR and FR at different BWS conditions. We hypothesized that the two modes of exercise may interact with BWS in some way to change the responses for each variable.

## 2. Methods

### *2.1. Participants*

Ten participants (6 males and 4 females: means ± standard deviation: age = 23.1 ± 3.5 years, height = 169.6 ± 5.7 cm, body mass = 70.9 ± 7.4 kg) participated in this study. Their typical training distance, training duration, and training frequency were 11.6 ± 11.2 km $week^{-1}$, 27.6 ± 10.2 min $session^{-1}$, and 3.4 ± 1.1 sessions $week^{-1}$, respectively. They were free from acute or chronic cardiopulmonary and musculoskeletal diseases and injuries at the time of data collection. This study was approved