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Comparing standing posture and use of a sit-stand stool: Analysis of vascular, muscular and discomfort outcomes during simulated industrial work

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A B S T R A C T

Sit-stand stools are available for use in industrial settings, but there is a lack of quantitative evidence demonstrating benefits for lower limb, back and/or neck/shoulder outcomes. In this paper we describe an experiment conducted to compare and contrast posture and time-related differences in muscular and vascular outcomes during 34 min of manual repetitive work performed in either standing or sit-standing work posture. We measured vascular parameters in the lower limbs, and muscular parameters in the trunk and neck/shoulder, and discomfort in the three regions as participants accomplished a repetitive box-folding task. Results show that blood flow in the foot ($p = 0.022$) and ankle mean arterial pressure ($p < 0.001$) were greater during standing. Left gluteus medius and external oblique activation was higher during standing, while sit-standing work resulted in higher levels of co-activation between the left erector spinae and external oblique muscle pair ($p = 0.026$). Neck/shoulder muscle activity was not significantly different between the conditions. Reported discomfort did not differ significantly for the trunk and neck/shoulder region, but standing resulted in higher level of reported discomfort in the lower limb. The sit-stand posture used in this experiment appears to prevent the undesirable lower limb outcomes associated with static standing work posture.

Relevance to industry: This work demonstrates quantitative evidence to support the potential use of a sit-stand stool for industrial work operations, at least over relatively short durations.

1. Introduction

In general, seated work is comfortable for workers, but prolonged sitting without the job latitude and/or time to adjust posture and stand at will can lead to reports of discomfort (Messing et al., 2008a). Prolonged seated work has been associated with the development of musculoskeletal disorders (Husemann et al., 2009), typically in the back and neck/shoulder regions (Lehman et alk 2001; Drury et al., 2008). In addition, research has noted that prolonged seated work is associated with risk of developing obesity and associated metabolic and health problems (Choi et al., 2010; Castillo-Retamal and Hinckson, 2011; Ryan et al., 2011). As a result, there has been a trend to increase the amount of time spent in a standing posture at a workstation (Husemann et al., 2009). However, studies also suggest disadvantages to working in predominantly static standing postures.

Prolonged static standing work has been associated with increased discomfort in the lower limb (Messing et al., 2008a; Messing et al., 2009; Reid et al., 2010), symptoms of lower limb vascular disorder (Laurikka et al., 2002; Tuchsen et al., 2005; Raffetto and Khalil, 2008; Sudol-Szopinska et al., 2011) and back discomfort (Messing et al., 2008a; Tissot et al., 2009). A vascular pathway for developing lower limb discomfort during standing work is suggested in epidemiological research, which hypothesizes that the increased incidence of peripheral vascular disorder among

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standing professions is caused by standing-related reductions in venous return, leading to blood pooling and associated increases in hydrostatic venous pressure that cause discomfort and impairment of venous tissue (Kroeger et al., 2004; Tuchsen et al., 2005). Recent work by our research group supports this hypothesis; we have demonstrated that during static standing work tasks, indicators of blood pooling in the lower limbs arise within 30 min of work, and there is a significant association between these indicators and the development of lower limb discomfort (Antle and Côté, 2013; Antle et al., 2013). Repeated exposures to increased blood pooling within a work day, and throughout an individual's working life, might explain the increased incidence of nocturnal leg cramps and increased risk of developing venous disorder among individuals who work in standing professions (Tuchsen et al., 2000; Kroeger et al., 2004; Bahk et al., 2012).

Although back discomfort during standing work is commonly reported, mechanisms underlying this development are poorly understood. A study by Lafond et al. (2009) has shown that low back pain is associated with indicators of postural stiffness. This is supported by recent research that has shown that increased levels of coactivation between bilateral hip muscles and between some trunk flexor and extensor pairs at the outset of a task have an association with the development of standing-related back pain (Nelson-Wong et al., 2008; Nelson-Wong et al., 2009; Nelson-Wong and Callaghan, 2010a,b,c; Nelson-Wong et al., 2010). Together, these studies suggest that postural adaptations and shifting might have benefits, both in terms of having impact on vascular and muscular factors associated with lower limb and back symptoms.

In order to avoid working in prolonged static postures, one approach would be to provide industrial or service employees with a seated workstation and allow frequent opportunities to stand and walk around the workplace. However, production demands and workstations are not typically designed for this situation. This may partially explain why standing is the most commonly used posture in industrial and service sectors within North America (Messing et al., 2005). One postural adaptation that can allow the user to work near their standing height, but remove some of the demands placed on the lower limbs, involves the use of specialized stools that allow a worker to use a hybrid sit-standing posture. Only a few laboratory studies have examined the use of sit-stand stools (Seo et al., 1996; Chester et al., 2002; Taillefer et al., 2011). This research notes that sit-standing postures cause less discomfort in the trunk and upper limbs when compared to standing. Field studies that used sit-stand stools for cashiers also noted improved comfort for the participants when compared to standing (Laberge and Vézina, 1998; Chapados, 2002). However, none of these studies included investigations of muscle activation or co-activation to determine the muscular mechanism underlying the differences in reported discomfort. Moreover, it is important to note that several of these studies did show some negative consequences of using a sit-stand stool, including increased swelling in the lower limb, and reports of discomfort in the hips, thigh and lower limb (Seo et al., 1996; Chester et al., 2002; Taillefer et al., 2011). However, the sit-stand stools tested during these investigations had limited adjustability of support angles of the seat and base (Seo et al., 1996; Chester et al., 2002; Taillefer et al., 2011). Furthermore, there were anecdotal reports of symptoms in the legs that could be attributable to the absence of foot support system in these studies. In two field studies that implemented sit-standing posture for cashiers, participants indeed noted the importance of using a foot support to improve stability of the posture and the comfort of the lower limbs (Laberge and Vézina, 1998; Chapados, 2002). This suggests that sit-stand stool workstations used thus far in the literature might have been sub-optimally adapted, especially with respect to the lower limbs.

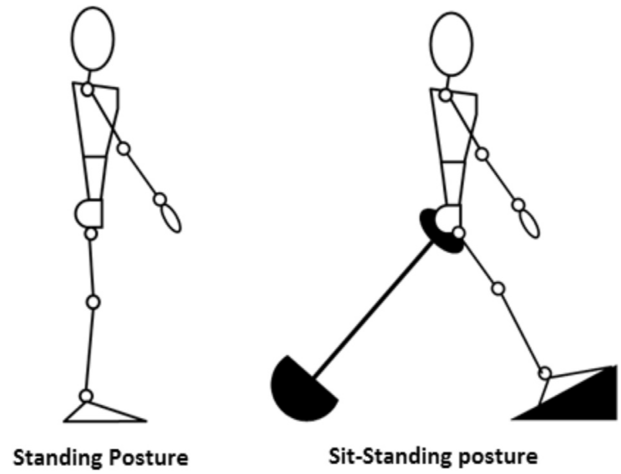

Fig. 1. Model of sit-standing posture.

In this paper we describe an experiment conducted to compare and contrast posture and time-related differences in muscular and vascular outcomes during 34 min of standing and sit-standing work. The sit-standing posture included an adjustable sit-stand stool and foot rest design. We hypothesized that the sit-stand stool and foot rest would result in fewer reports of discomfort and smaller time effects on lower limb and trunk postural and vascular outcomes, but in no impact on upper limb muscular outcomes, compared to those associated with the same work done in standing.

2. Methods

2.1. Participants

15 asymptomatic participants (8 men, 7 women) were recruited for this project. The exclusion criteria were any history of

Fig. 2. Example of the experimental task and use of the sit-stand stool.