Lower limb blood flow and mean arterial pressure during standing and seated work: Implications for workplace posture recommendations

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A B S T R A C T

Sit-stand workstations are a popular workplace intervention. Organizations often require a medical professional's guidance for implementation. Therefore, it is important to understand potential negative outcomes associated with standing work, such as lower limb discomfort and peripheral vascular issues. The objective of this study was to compare changes in lower limb discomfort, blood pressure and blood flow accumulation during a light-load repetitive upper limb work task accomplished from seated and standing postures. At the Jewish Rehabilitation Hospital (Laval, Quebec, Canada), 16 participants were outfitted with Laser Doppler Flow (LDF) electrodes to measure blood flow in the lower limb, and a sphygmomanometer to measure lower limb mean arterial blood pressure (MAP). Participants completed simulated work over 34 min in standing and seated conditions. Repeated measures ANOVAs (Posture x Time) were used to assess the differences. There were significant effects for both Posture (p = 0.003) and Time (p = 0.007) for LDF-measured of blood flow accumulation in the soleus and the foot, with a mean increase of 77% blood flow over time in the standing posture, when compared to seated work. There was a significant ‘Posture × Time’ (p = 0.0034) interaction effect and a significant Posture (p = 0.0001) effect for MAP, with higher values in the standing posture by a mean of 37.2 mmHg. Posture had a significant effect (p < 0.001) on lower limb discomfort, with standing posture reporting higher levels. These results suggest that recommendations for using static standing work postures should be tempered, and physicians' guidance on workstation changes should consider the impacts on the lower limb.

1. Introduction

Sedentary workplace sitting has become associated with musculoskeletal pain, obesity, cardiovascular disease, diabetes and other chronic health concerns (Buckley et al., 2015; Choi et al., 2018; Wilmot et al., 2012). Media coverage of the impact of sitting at work on an individual's health and wellness has led to a proliferation of height adjustable sit-stand workstations as an intervention to improve health outcomes (Callaghan et al., 2015; Karol and Robertson, 2015). To control costs for new workstations, many organizations require a medical recommendation from an employee outlining why they require control costs for new workstations, many organizations require a medical professional's guidance from an employee outlining why they require.

Despite standing work having an association with a reduction in upper limb and trunk musculoskeletal symptoms (Callaghan et al., 2015; Husemann et al., 2009), strong causal links between occupational sitting and development of cardiovascular disease and other morbidities have not been conclusively proven (Hayashi et al., 2016; Van Uffelen et al., 2010), and seated work was noted to have no association with all-cause mortality in a recent review (Pulsford et al., 2015). It is likely that there is no extra cardio-metabolic benefit from sedentary standing work compared to sedentary sitting (Tudor- Locke et al., 2014). This has led to calls to temper recommendations for reducing seated behaviour as a means of improving health and reducing mortality (Pulsford et al., 2015). Instead, a focus on physical activity levels both in and outside the workplace form a better set of recommendations (Pulsford et al., 2015; Tudor- Locke et al., 2014). Still, standing work interventions to replace sitting remain very popular workplace health initiatives.

While there may be comfort and musculoskeletal benefits for the trunk and upper limb associated with standing work, physiological outcomes in the lower limb during prolonged standing are often overlooked. Prolonged standing is associated with increased discomfort in the lower limb (Antle et al., 2015; Messing et al., 2008, 2009; Reid et al., 2010), symptoms of lower limb vascular disorder (Laurikka et al., 2002; Raffetto and Khalil, 2008; Sudol-Szopinska et al., 2011; Tuchsen et al., 2002). Media coverage of the impact of sitting at work on an individual's health and wellness has led to a proliferation of height adjustable sit-stand workstations as an intervention to improve health outcomes (Callaghan et al., 2015; Karol and Robertson, 2015). To control costs for new workstations, many organizations require a medical professional's guidance from an employee outlining why they require control costs for new workstations, many organizations require a medical professional's guidance from an employee outlining why they require.
et al., 2005), and varicose veins (Kroeger et al., 2004; Tuchsen et al., 2005). Standing has been previously noted to cause marked increases in mean arterial pressure (MAP) in the lower limb, and it was noted that such increases may lead to peripheral arterial disease (Malhotra et al., 2002). However, these changes in lower limb blood pressure were not tracked during work tasks. Earlier work tracking brachial blood pressure changes during standing occupations did note a reduction in MAP in the upper limb (Ngomo et al., 2008), but such benefits may be offset if there are increases in MAP in the lower limb. In addition to increases in arterial pressure in the lower limb, we must also consider venous back flow and pooling in the lower limb due to gravity during standing work. Standing longer than 75% of the average workday leads to increased hydrostatic venous pressure (Kroeger et al., 2004), which may in turn lead to biochemical changes that cause venous valves and surrounding tissues to become damaged and less functional (Bergan et al., 2006; Raffetto and Khalil, 2008). Increased arterial and venous blood pressures and pooling are likely to induce discomfort, and may contribute to vascular damage and diseases that are often reported in epidemiologic literature (D’Souza et al., 2005; Tabatabaeifar et al., 2015). It is reasonable to assume that seated work would lead to reduced levels of lower limb vascular pooling and pressure, as muscle recruitment demands would be reduced or absent while sitting when compared to static standing. Therefore, less pressure from lower limb musculature would lead to reduced opposition to blood flow in the surrounding vasculature. From a lower limb vascular perspective, seated work may therefore be preferred to standing work. However, studies have yet to evaluate lower limb blood pressure and pooling changes during prolonged standing and seated work postures, and without a comparison it is difficult to include lower limb outcomes in the assessment of appropriate workplace posture interventions.

The objective of this study was to quantitatively compare changes in lower limb MAP and measures of blood pooling during a light-load repetitive upper limb work task accomplished from seated and stationary standing postures. These results are intended to inform further research and considerations for policies around workplace posture adaptations and the impact that such changes might have on physiological changes that may link to health outcomes.

2. Methods

2.1. Participants

16 participants (8 men, 8 women) were recruited for this project and completed the protocol in 2012 or 2013 at the Occupational Biomechanics Laboratory within the Jewish Rehabilitation Hospital in Laval, Quebec. The exclusion criteria were any history of neurological, musculoskeletal, or vascular disorders during the 3 previous years, or currently pregnant. Participants signed an informed consent form, approved by the ethics committee of the Centre for Interdisciplinary Research in Rehabilitation (CIRIR) of Greater Montreal. Mean age was 32.4 years (SD = 8.7 years), mean weight was 76.2 kg (SD = 8.9), and mean height was 172.4 cm (SD = 10.7). All participants worked in sedentary desk-based occupations, and potential participants were excluded if they worked in in an occupation which required them to stand for > 25% of their working time. While this sample size is not extensive, the experimental research approach allowed for high resolution data using a repeated-measures approach. Adequacy of the data collection procedures and sample size are detailed in previous publications and pilot work (Antle et al., 2013a; Antle et al., 2015; Antle et al., 2013b).

2.2. Apparatus and procedures

Participants were barefoot and outfitted with Laser Doppler Flowmetry (LDF) (floLAB Monitor, Moor Instruments, Devon, England, sampling frequency: 1080 Hz) electrodes to measure skin blood flow; one electrode was placed on the distal third of the soleus, and another over the 4th metatarsal of the foot. This measure provides indication of blood flow and pooling from arterial and venous sources. Lower limb arterial blood pressure, measured as MAP, was measured using an automated digital sphygmomanometer at the left ankle region, which has been noted as having adequate reliability and validity (MacDonald et al., 2008; Verberk et al., 2012). This measure was used to assess arterial pressures as a potential risk factor for peripheral arterial disease.

Participants completed a repetitive box-folding task as the experimental task. This task was selected because it included very light weight loads (< 200 g/box), and it would be representative of light repetitive work in both office and industrial work contexts. Participants performed this task during two randomly assigned sessions on separate days within a 2-week timeframe; one session in the seated posture and one in a standing posture. Participants practiced the box-folding task for 10 min prior to beginning the standardization procedure. After a 5-minute rest period following the practice session, participants were instrumented and reference levels for each measure were taken. Baseline measures for blood flow and blood pressure were taken in the seated position, after the subject was seated for 5 min in a chair, with their back and feet supported.

After the standardization procedures, a comfortable work posture was determined. A work surface was placed in front of the participants and adjusted to their knuckle height, based on workstation design guidelines for non-precision work in both standing and seated positions. (Kromer and Grandjean, 2005). The participants then began the experimental work task. For both the standing and seated postures, the task required participants to construct one box every 9 s during four, 8.5 minute work bouts, totaling 34 min. Participants reached for individual pieces of cardboard placed 30 cm to their left, moved it in front of them, folded it into a box, and placed the completed box on a line 30 cm from the near edge of the work table. For standing work, we attempted to control for the effect of different levels of stepping and movement between participants by setting the task to be a stationary standing task. Participants were instructed that while they could shift their weight distribution between the feet at will, they could not move their feet or lift them from their set standing position during the 34 min of work. After each 8.5 minute work bout, the participants were asked to stop working and remain static for 30s, with both arms abducted 45°, to allow collection of vascular data. Movement of the feet was also not allowed during these collection periods. Participants rated their level of reported lower limb discomfort using a 10-point visual analog scale with rooted verbal anchors, which was included in previous publications (Antle et al., 2015).

2.3. Data analysis

Data collected from the LDF at each collection period were normalized to the levels measured during the seated standardization trial. After normalization, the data were integrated over non-overlapping 3s windows for the 30s time series. The ten 3s windows were averaged to attain one value representing blood flow accumulation levels, which would be analogous to accumulation, for each of the work bouts. Ankle blood pressures were reported using the mean arterial pressure (MAP).

Changes in blood flow and blood pressure were assessed using repeated measures ANOVAs with two within-subject factors: Posture and Time. Post-hoc tests (Tukey) were used to identify time(s) when outcomes significantly changed from their time 1 values. Changes in discomfort in the lower limb were assessed using Friedman ANOVAs. Mann-Whitney tests were used as post-hoc tests to determine where significant postural and time-based changes occurred.
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