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

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A R T I C L E   I N F O

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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 x 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. Research on the potential medical recommendation from an employee outlining why they require control costs for new workstations, many organizations 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 x 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.

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., 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.

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et al., 2005), and varicose veins (Kroeger et al., 2004; Tuchsen et al.,
2002). However, these changes in lower limb blood pressure were not
tracked during work tasks. Earlier work tracking brachial blood pres-
sure 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 sur-
rounding 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 con-
tribute to vascular damage and diseases that are often reported in
epidemiologic literature (D’Souza et al., 2005; Tabatabaeeifar et al.,
2015). It is reasonable to assume that seated work would lead to re-
duced 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, se-
ated 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 sta-
tionary 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 physio-
logical 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, ap-
proved by the ethics committee of the Centre for Interdisciplinary
Research in Rehabilitation (CRIR) 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 se-
dentary desk-based occupations, and potential participants were ex-
cluded if they worked in an occupation which required them to stand
for > 25% of their working time. While this sample size is not ex-
tensive, the experimental research approach allowed for high resolution
data using a repeated-measures approach. Adequacy of the data col-
lection 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) (fLOAB 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 au-
tomated 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 dis-
ease.

Participants completed a repetitive box-folding task as the experi-
mental 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 per-
formed 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 ex-
perimental 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 indi-
vidual 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 30 s, 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 publica-
tions (Antle et al., 2015).

2.3. Data analysis

Data collected from the LDF at each collection period were nor-
malized 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 re-
peated measures ANOVAs with two within-subject factors: Posture and
Time. Post-hoc tests (Tukey) were used to identify time(s) when out-
comes significantly changed from their time 1 values. Changes in dis-
comfort 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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