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The effect of task type and perceived demands on postural movements during standing work

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ABSTRACT

This study investigated how task demands affect postural behaviour during standing. Twenty-four participants completed three different 12-min tasks: (1) a cognitive task that involved answering questions based on a written passage; (2) a light manual assembly task; and (3) standing quietly with no secondary task. The manual task was associated with the lowest amount of postural movement and a more static pose than the other two conditions. Specifically, postural variability of the lumbar ($F = 5.8$; $p = 0.01$) and thoracic ($F = 4.2$; $p = 0.03$) spine, and fidgets and shifts of the spine ($F = 3.2$; $p = 0.048$), were lowest in the manual task. Additionally, individuals perceiving tasks to be more demanding—regardless of task type—tended to move less ($p = 0.049$) than those perceiving lower demands. These findings provide important initial evidence that the type and perceived demands of standing work tasks can affect postural movement.

1. Introduction

Standing is very common in the workplace and on the rise with the recent attention to the negative health impacts of sitting (Baddeley et al., 2016). While some occupations require individuals to stand when performing their duties (e.g., nursing, assembly work, and retail service), many others (e.g., office jobs) are beginning to voluntarily implement standing as an active alternative to sitting (Tissot et al., 2005; Alkhajah et al., 2012). Regardless of motivation, standing for prolonged periods—especially without the opportunity to sit or walk around—is associated with health concerns such as low back pain (LBP) and leg discomfort (Tissot et al., 2009; Ryan, 1989; McCulloch, 2002; Waters and Dick, 2015). Recent findings suggest that postural movements (i.e., periodic deviations from sustained, static positions) occurring early in standing exposures may play a role in reducing eventual pain development (Gallagher and Callaghan, 2015). While the presence of these postural movements is well documented, little is known about how they are controlled or how the demands of different workplace tasks affect the frequency, amplitude, and type of movements generated. As stand and sit-stand workstations become more common, understanding the interaction between specific task demands and postural movements during standing could be critical to informing job/task rotation, sequencing, and distribution guidelines aimed at reducing pain and discomfort.

Growing evidence suggests that an absence of whole body movement while sitting or standing may predispose individuals to LBP (Tissot et al., 2009; Antle et al., 2013). In laboratory studies of prolonged standing (~2 h), between 40% (Nelson-Wong et al., 2010) and 70% (Marshall et al., 2011) of participants with no history of LBP report transient pain in their low back that exceeds clinically significant levels (Hagg et al., 2003; Kelly, 1998). This subgroup of individuals, referred to as pain-developers, tend to stand more statically than their non pain-developing counterparts. These static postures are marked by fewer lumbo-pelvic flexion/extension fidgets and a lower frequency of side-to-side body weight transfers from one foot to the other (Gallagher and Callaghan, 2015). Interestingly, these differences between pain and non-pain developers exist only during the first 15 min of standing—before any pain has developed in either group—highlighting the role that movements may play in preventing standing-induced LBP. The mechanisms by which postural movements reduce pain development have been postulated to involve: redistributing joint capsule fluids (Alexander, 1992; Duarte and Zatsiorsky, 1999), reducing blood pooling (Brantingham et al., 1970), and decreasing soft tissue strain (Vergara and Page, 2002). Through these mechanisms, pain may be attenuated, ultimately allowing individuals to work productively and comfortably for longer periods while standing.

The control of posture during upright standing can require non-trivial attentional resources (Woollacott and Shumway-Cook, 2002). Dual task paradigms have demonstrated this phenomenon, whereby a cognitively demanding secondary task can detrimentally affect the 'primary' task of postural control (Kerr et al., 1985; Teasdale et al., 1993; Lajoie et al., 1993; Rankin et al., 2000). Such interference implies

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that central processes controlling the separate tasks may compete for the same attentional resources. Moreover, these attentional resources may modulate the postural movements introduced above, and thus the cognitive work demands could affect standing postural movements with either beneficial or detrimental consequences. Postural movements of interest in this study included: whole body movements and localized thoracic and lumbar spine responses. Body weight transfers, measured using separate force platforms under each foot, were also monitored to capture the loading and unloading of the lower limbs (Carlsöö, 1961; Prado et al., 2011). Fidgets and shifts (Duarte and Zatsiorsky, 1999) were measured at the foot-floor interface (using the centre of pressure (COP)) and higher in the kinetic chain (lumbar spine). Fidgets are a common movement pattern involving fast and large displacements of the COP—or deviations of lumbar spine angles—that return to a similar location or angular orientation (Duarte and Zatsiorsky, 1999). Shifts are also fast displacements or deviations but differ from fidgets as they involve moving to a new location or angular orientation (Duarte and Zatsiorsky, 1999). Together all of these measures provide a thorough overview of an individual's movement patterns during standing.

The purpose of this study was to determine how differing task demands affect postural behaviour during standing work. We presented individuals with three standing work conditions: (1) a cognitive task that involved reading a technical passage and answering comprehension-based questions; (2) a manual handling task involving assembly of industrial fasteners; and (3) standing quietly without a secondary task. We hypothesized that postural movements, namely measures incorporating (i) body weight transfers and (ii) fidgets and shifts of the spine and COP, would be highest with no external task and lowest during the manual handling task. The precision demands associated with reaching, grasping, and assembling materials in the manual task would likely require a stable lower body and torso, resulting in fewer postural movements (Bertenthal and Von Hofsten, 1998) than the cognitive or no secondary task conditions. We also hypothesized that individuals who perceived the secondary tasks to demand greater levels of effort would exhibit fewer postural movements than those perceiving lower task demands.

2. Methods

2.1. Participants

Twenty-four young adults (12 male; 12 female), recruited from a university population, participated in the study (mean (SD) age = 21.9 (1.7) years; height = 1.72 (0.11) m; mass = 73.2 (16.4) kg). Participants were excluded if they had a history of LBP, were pregnant at the time of the study, or had any musculoskeletal or neurological impairments that could affect their ability to stand. The University of Waterloo Office of Research Ethics approved this study and all participants provided informed written consent prior to the experiment.

2.2. Instrumentation

Three Optotrak Certus motion capture units, utilizing 9 cameras (Northern Digital Inc., Waterloo, ON), were used to track spine motion. Infrared light-emitting diode markers arranged on rigid clusters were affixed to the skin over the posterior aspect of the sacrum and spinous processes of L1 and T5 to track the position and angular orientation of the sacrum, lumbar spine, and thoracic spine, respectively (Fig. 1). A digitizing probe was used to identify relevant anatomical landmarks defining the endpoints of each spine segment. Separate force platforms measured ground reaction forces and moments under the left (50 × 50 cm; OR6-7) and right feet (90 × 90 cm; BP900900; both plates manufactured by Advanced Medical Technology, Inc., Watertown, MA). Participants were asked to rate their level of pain upon arriving to the laboratory and every 6 min during the experiment on a 10 cm visual analogue scale (VAS) anchored by the endpoints: "No pain (0 cm)" and "Worst pain imaginable (10 cm)". Regional pain levels were reported for the low back, upper back, neck, and bilaterally for the lower limbs and shoulders during each survey. Upon completing the experiment, participants were asked to rate their perceived level of cognitive and physical effort for each task from 0% to 100% effort on an 11-point numeric rating scale with 10% intervals.

2.3. Experimental protocol

Once instrumented, participants performed a 5-s quiet standing trial to establish a reference posture for subsequent spine angle calculations. Individuals then performed the following three 12-min standing tasks, in a random order: (1) cognitive task (COG), consisting of reading two excerpts from academic publications and typing answers to comprehension-based questions on a computer; (2) manual materials handling (MMH), consisting of assembling and disassembling a series of bolt-washer-nut combinations; and (3) quiet standing, consisting of standing naturally in front of the desk no secondary (NS) task (Fig. 1).

For each condition, participants were instructed to stand comfortably with each foot on a force platform. Individuals were allowed to move each foot around within its respective force platform, but could not cross their feet or contact either the surrounding laboratory floor or the force platform under the other foot. For the COG and MMH tasks, the standing desk was positioned 5–6 cm below elbow height. In both of these tasks, participants could rest their hands gently on the work surface to interact with the keyboard & mouse (COG) or the fasteners they had to work with (MMH), but were told to avoid leaning on the surface to support their body weight. In the COG task, the monitor was placed at eye level. This physical interaction between the hand and work surface was not directly quantified or controlled, as the intention was for participants to complete the simulated work tasks as they naturally would in the workplace. In the MMH task, tape secured to the work surface and clearly labelled bins demarked the work area, which was within the primary reach zone for each participant (Fig. 1). In the NS task, participants were instructed to stand naturally with hands either relaxed at their sides or in front of them and their gaze focused forward on the wall in front of them.

2.4. Data processing

Time-varying motion capture data were used to calculate spine angles in rigid-link modelling software (Visual 3D, version 5, C-Motion Inc. Kingston ON). The Thoraco-Lumbar angle (TL) was defined as the orientation of the T5 cluster relative to the L1 cluster, and the Lumbo-Sacral angle (LS) was defined as the orientation of the L1 cluster relative to the S2 cluster. Angles were computed using a Flexion-Lateral Bend-Axial Twist rotation sequence with only the flexion component from both angles being extracted for further processing.

Time-varying force plate data were used to compute COP in the anterior-posterior and medial-lateral directions for both feet using Equations (1a) and (1b). The subscript *ML* refers to the medial-lateral component, *AP* refers to the anterior-posterior component, and *V* refers to the vertical component of the measured moments (*M*), forces (*F*), and offset of the origin relative to the top-centre of the force plate (*O*).

$$COP_{AP}(t) = \frac{M_{ML}(t) - F_{AP}(t)O_V}{F_V(t)} \tag{1a}$$

$$COP_{ML}(t) = \frac{F_{ML}(t)O_V - M_{AP}(t)}{F_V(t)} \tag{1b}$$

Kinematic variables from the spine (TL and LS flexion angles) and foot-floor interface (AP and ML COP) were used to quantify three measures of postural behaviour: (1) static postures, (2) postural variability, and (3) transitions between postures. Mean TL and LS angles over each 12-min task represented the static posture of a participant's trunk during that task. Standard deviations of these angles represented gross