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The effect of standing interventions on acute low-back postures and muscle activation patterns

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ABSTRACT

Occupations requiring prolonged periods of constrained standing are associated with the development of low back pain (LBP). Many workplaces use improvised standing aids aimed to reduce LBP. Unfortunately, there is little scientific evidence to support the use of such standing interventions in effectively reducing LBP. To assess some commonly implemented standing interventions, thirty-one participants stood in four different standing positions (Level Ground (control), Sloped, Elevated, and Staggered) for 5 min each. The use of an elevated surface changed the lumbar spine posture of participants such that participants stood in a more flexed lumbar spine posture. This change in lumbar spine posture may be an indication that the elevated standing aid intervention can positively impact lumbar spine posture in standing pain developers and potentially reduce LBP.

1. Introduction

Occupations requiring prolonged static standing are associated with low back pain (LBP) development (Andersen et al., 2007; Tissot et al., 2009). Approximately 50% of individuals (Marshall et al., 2011; Nelson-Wong et al., 2008; Nelson-Wong and Callaghan, 2010b; Gallagher et al., 2014) are susceptible to acute LBP development during prolonged standing (pain developers, PDs). Those identified as PDs have a 3 times higher likelihood of seeking clinical care for LBP within 2 years (Nelson-Wong and Callaghan, 2014). Many workplaces have begun using improvised standing positions aimed to reduce LBP and standing aids are commonly recommended by various occupational health and safety associations (Canadian Center of Occupational Health and Safety (CCHOS), 2008, Occupational Safety & Health Administration (OSHA), 2012). Unfortunately, there is little scientific evidence to support the use of such standing interventions in effectively reducing LBP during prolonged standing. Therefore, the purpose of this work was to investigate the short-term differences in lumbar spine posture and muscle activation patterns between PDs and non-pain developers (NPDs) utilizing a variety of commonly implemented standing interventions.

PDs have been shown to stand with greater lumbar lordosis (extension) than NPDs during a prolonged standing task (Sorensen et al., 2015). A positive relationship was displayed between lordosis angle and maximum reported low back pain scores on a visual analog scale. A radiographic study that imaged the sagittal lumbar spine found that PDs stood closer to the maximum extension angle of their lower lumbar arc (L3-S1) than NPDs (Gallagher et al., 2014). Seated breaks between prolonged bouts of standing have also been shown to help temporarily alleviate LBP development, a movement that also induces lumbar spine flexion movement (Gallagher et al., 2014). Based on these postural characteristics of PDs when compared to NPDs, inducing flexion in the lumbar spine via an altered standing position could provide a means to mitigate LBP development when standing.

Motor control patterns also differ between PDs and NPDs during prolonged periods of level ground standing. PDs demonstrate increased bilateral gluteus medius muscle co-activation, while NPDs tend to exhibit reciprocal firing of these muscles (Nelson-Wong et al., 2008). In two follow up studies, gluteus medius co-contraction indexes (Nelson-Wong and Callaghan, 2010b) were higher, and cross-correlations values (Marshall et al., 2011) were higher and positive in PDs compared to NPDs, indicating gluteus medius co-activation. This co-activation response is hypothesized to be a potential pre-disposing factor or symptom of pain development since it is evident at the start of a standing task prior to pain development (Nelson-Wong and Callaghan, 2010b).

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Alternate standing positions have been recommended in attempt to reduce LBP and help workers tolerate prolonged bouts of standing. To date, recommended standing interventions have attempted to incorporate posture and movement into the design of the intervention (Table 1). The majority of standing investigations have focused on postural changes associated with standing interventions and little work has looked at the influence of standing interventions on muscle co-activation patterns. Muscle activation patterns are a distinguishing feature between PDs and NPDs (Nelson-Wong et al., 2008), and therefore it is important to consider when evaluating the successfulness of a standing intervention. By examining the influence of alternative standing positions on key variables that differentiate PDs from NPDs, we can gain insight into what standing interventions could be helpful at reducing or preventing LBP. A change in muscle co-activation in PDs, resulting in a decrease in muscle co-activation, may be an indication that an alternative standing position could be effective at reducing LBP across PDs.

The purpose of this study was to evaluate alternate standing positions based on how they impact lumbar spine posture and muscular activity. We hypothesized that the use of standing interventions, sloped surface, elevated single foot rest, and staggered stance will move participants into a more flexed lumbar posture compared to level ground standing with a subsequent increase in muscle activation. Results from this study may explain if recommended standing interventions can positively change motor control strategies and lumbar spine posture previously linked to low back pain development during prolonged standing. In this study, lumbar spine angle and hip and trunk muscle activations were measured while participants stood on level ground and the three alternate standing positions.

2. Methods

2.1. Participants

Twenty-three participants (11 male, 12 female) between the ages of 18–35 participated in this study. Exclusion criteria included any previous history of low back pain that was significant enough to seek medical intervention or that resulted in greater than three days off work or school, previous lumbar or hip surgery, employment in a task that required prolonged static standing during the past 12 months, and the inability to stand for at least two hours. All participants had previously participated in a prior prolonged standing simulation that categorized participants as either PDs (11 participants) or NPDs (12 participants) based on self-reported visual analog scores (VAS). A participant was considered a PD if they reported any change in VAS score greater than 10 mm from baseline during the prolonged standing simulation (Gallagher et al., 2014; Marshall et al., 2011; Nelson-Wong et al., 2010). Ethics approval for research involving Human Subjects was obtained from the Office for Research Ethics at the University of Waterloo.

2.2. Instrumentation

Four pairs of disposable surface EMG electrodes (Blue Sensor, Ambu A/S, Denmark) were placed on the lumbar erector spinae (LES, above and below the third lumbar spinous process) and gluteus medius muscles (GM, approximately 50% of the distance between the iliac crest and greater trochanter). The GM muscle was chosen because GM activation patterns are a distinguishing feature between PDs and NPDs during prolonged standing. PDs tend to display gluteus medius co-activation, meaning that both muscles are activated together. NPDs tend to display gluteus medius reciprocal firing, meaning that one muscle is being activated while the contralateral muscle is not (Nelson-Wong et al., 2008). As a result the goal of monitoring GM activations was to examine the influence of different standing interventions on activation patterns across PDs and NPDs. A reference electrode was placed over the spinous process of the seventh cervical vertebrae. EMG signals were differentially amplified using a common mode rejection ratio of 115 dB (at 60 Hz; input impedance of 1010 Ω), analog band-pass filtered from 10 to 500 Hz and gained by a factor of 500–5000 (AMT- 8, Bortec, Calgary AB, Canada). The specific gain used was tailored to each individual muscle using sub-maximal test contractions and real-time visual feedback to best fill the input range of

Table 1
A summary table of commonly implemented standing interventions and previous studies' general findings.

Study	Evaluated standing intervention	Assessment	Findings of standing intervention
Dolan et al., 1988	One leg elevated onto a 20 cm platform	Compared low back muscle activity when level standing to standing with one leg elevated on a platform.	Standing with one leg elevated and resulted in increased lumbar flexion and increased low back muscle activity when compared to level standing.
Gallagher and Callaghan (2016)	Declining sloped surface of 16°	Compared the posture differences between level standing and standing on a declining sloped surface during prolonged standing.	Sloped standing reduced LBP scores by 59.4% for PD when compared to level ground. All participants showed hip joint flexion, trunk- to-thigh angle flexion, and posterior translation of the trunk center of gravity towards the ankle joint when standing on the sloped surface compared to level ground.
Nelson-Wong and Callaghan (2010a)	Self selected alternation between standing on a 16° incline and decline surface	Compared differences between using a sloped surface during prolonged standing and level ground prolonged standing.	Using a sloped surface reduced LBP scores by 59.4% for PD when compared to level standing and decreased gluteus medius co-activation levels. NPDs showed increased bilateral gluteus medius co-activation of these muscles.
Gallagher et al. (2013)	Short-term differences between standing on incline and decline sloped surfaces	To examine the short and long term responses to standing when using a sloped surface on pelvis, lumbar, and trunk angles.	Using a sloped surface increased trunk flexion and posterior rotation of the pelvis.
Gallagher (2014)	Posture differences between standing on a declining sloped surface and standing with one foot elevated on a platform.	Radiographic assessment of sagittal lumbopelvic postures between PDs and NPDs when standing on level ground, standing with one leg elevated and standing on a sloped surface	The elevated surface was most effective at causing lumbosacral lordosis flexion, and the declined sloped surface was more effective at inducing L1/L2 intervertebral joint flexion.