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Possible mechanisms for the reduction of low back pain associated with standing on a sloped surface

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ABSTRACT

Prolonged standing in an occupational setting has long been associated with the development of low back pain. In response to this, researchers have investigated various interventions that can alleviate low back pain and discomfort, such as anti-fatigue mats, shoe insoles, and more recently, sloped platforms. The purpose of this study was to investigate the effects of a sloped surface on kinematics and trunk muscle thickness during quiet and prolonged occupational standing. Eleven participants performed 1-min quiet standing tasks on three surfaces – level ground, incline, and decline – followed by 16-min of prolonged standing in each condition. Trunk, lumbar, and global pelvis angles were measured during each standing condition, and muscle thickness measurements of erector spinae and the lateral abdominal wall were taken during the quiet standing task. During quiet standing, there were systematic changes in trunk, lumbar, and pelvis angles with the different surfaces; however, these changes were not accompanied by systematic changes in muscle thickness. The responses found during the quiet standing were consistent during prolonged standing. As a result, the reduced perceived low back pain found when using sloped platforms is likely not the result of changes in morphology of the trunk musculature, but might be related to the altered kinematics caused by standing on these platforms.

1. Introduction

Prolonged standing in occupational environments has been associated with the development of low back pain [1–3]. Not only can individuals develop chronic low back pain, but a portion of the population can be categorized as "pain developers" – individuals who have not previously had a low back injury, but develop pain during bouts of prolonged standing [4,5]. In response to this, interventions for use in industry have been developed, such as anti-fatigue mats and shoe insoles [6–8], and more recently, sloped platforms [9]. Previous research on these sloped platforms has shown that individuals who developed low back pain during standing demonstrated a 59.4% reduction in their subjective low back pain ratings [9]. Given the positive response to standing on a sloped surface, the purpose of this study was to investigate potential mechanisms that allow for this reduction in low back pain during prolonged standing by looking at both quiet and prolonged bouts of standing on flat and sloped surfaces.

A majority of the work related to standing on sloped surfaces has been centered on high-heeled shoes or heel supports [10–13], while some have investigated standing on platforms [9,14]. The results of these studies have been mixed; however, many studies demonstrate a similar general trend. When compared to level ground standing, standing on a decline (with the toes pointing down) has been shown to causes a flattening of the lumbar spine [10,12–14] and posterior rotation of the pelvis [9,12,13], while standing on an incline generally causes the opposite response – increased lumbar lordosis [12,14] and anterior rotation of the pelvis [9,14]. In studies that have investigated muscle activity, there is slight increase in muscle activity of the erector spinae when standing on a sloped surface [14]; however, there is no influence of the slope angle/height on erector spinae activity [12].

With the use of these sloped surfaces in industrial settings, it is important to understand the effects of standing on these surfaces may have over a long period of time. Only one study has investigated the prolonged effects of standing on a sloped surface [9], which compared asymptomatic individuals who developed low back pain over a 2-h standing protocol to those who did not. When standing on a sloped surface, pain developers demonstrated

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decreased gluteus medius co-contraction, which became comparable to non-pain developers, and an overall decrease in their pain ratings over the 2-h [9]. While these are positive results and point to the use of a sloped surface during occupational standing tasks, participants were allowed to freely move between incline and decline positions during the protocol. As a result, it is unknown whether the differences in pain reporting from this study were due to changes in posture caused by the sloped platform, or if they were the result of participants cycling between the incline and decline positions.

It has previously been shown that posture has an effect on muscle thickness. Ultrasonography has been used to measure muscle thickness as indicator of changes in morphology in different postures [15–17]. When placed in a relaxed posture, there is a decrease in erector spinae (ES) thickness with lumbar extension and an increase with lumbar flexion [16,17]. A difference in erector spinae thickness has also been noted across the upper and lower lumbar spine [16]. During neutral upright standing and sitting postures, the transversus abdominis muscle significantly increased in thickness compared to sway back or slouched sitting [15]. A relationship between erector spinae thickness changes and hemodynamics has also been found, with relaxed lumbar extension resulting in an increase in tissue blood volume and oxygenation during extension, and a decrease during flexion [17] As a result, any changes in muscle thickness noted when standing on a sloped surface could point to potential differences in muscle oxygenation and tissue blood volume, which could provide evidence for changes in these variables as a mechanism for the altered pain development patterns noted when standing on a sloped surface.

The purpose of this study was to examine both the short and long term responses to standing using a sloped surface on pelvis, lumbar, trunk, and lower limb kinematics and muscle thickness measurements of the lateral abdominal wall (external oblique, internal oblique and transversus abdominis) and erector spinae. It was hypothesized that (i) kinematic variables would differ between standing conditions; (ii) changes in muscle thickness would accompany any changes in kinematics during sloped standing; and (iii) there would be no changes in kinematics and muscle thickness over time during the prolonged standing task.

2. Methods

2.1. Participants

Eleven participants, six male and five female (female 22.4 ± 1.1 years, male years 23.7 ± 2.0 years, female mass 59.3 ± 7.7 kg, male mass 80.5 ± 8.4 kg, female height 1.64 ± 0.08 m, male height 1.80 ± 0.06 m) were recruited from the University of Waterloo student population. Those with past or present cardiovascular or neurological illnesses, who could not stand for a 48 min period, had seen a medical professional for previous back injury or pain, wore high heels daily or worked in environments where prolonged standing was required, were excluded from the study. The Office of Research at the University of Waterloo approved this study protocol and participants gave informed consent before testing began.

2.2. Protocol

Three standing conditions were assessed in this study – standing on level ground, a decline (toes pointed down) surface, and an incline (toes pointed up) surface (Fig. 1). For each condition, participants stood in two types of standing tasks: quiet and prolonged. For the quiet standing task, participants stood for 1-min with their gaze fixed forward and their arms at their sides in each of the three standing conditions. For the prolonged standing task, participants were required to stand for 16 min in each of the three standing conditions, for a total of 48 min. For both the quiet and prolonged tasks, the order of the standing conditions was randomized between participants. During the prolonged standing task, the participants performed a light assembly task on a table located approximately 5–6 cm below the radial styloids when the elbow was flexed at 90°. For each of the standing conditions, distance from the table was standardized to the distance to the middle of their forearm when the elbow was flexed at 90°.

2.3. Kinematic measurements

Lower body and trunk segment kinematics were measured using an optoelectronic motion analysis system (Optotrak Certus, Northern Digital Inc., Waterloo, ON) at a sampling rate of 32 Hz. Thirty-six markers were placed bilaterally on the foot, shank, and thigh segments and rigid bodies with four markers each were placed on the thorax (T9), upper lumbar spine (L1/2), and pelvis. Within each of these rigid bodies, four anatomical landmarks were digitized to define the end points of each segment. Lumbar and trunk angles were calculated as the angle between the pelvis and lumbar (tracked with rigid body at L1/2) or trunk (tracked with rigid body at T9) segment, respectively. Pelvis angle was calculated with respect to the global coordinate system. Marker data was imported into Visual 3D (C-Motion, Kingston, ON) to calculate sagittal joint angles of the lower extremities, pelvis, lumbar spine, and trunk. Each marker's coordinate data were filtered at 6 Hz using a second order dual pass Butterworth filter. Mean trunk, lumbar, global pelvis, and bilateral hip, knee and ankle angles were determined using a ML-AP-Axial rotation sequence. During the quiet standing task, averaging over each 1 min trial was performed to provide an average angle in each of the standing conditions. For the prolonged standing task, the mean of each angle during the first, sixth, eleventh, and sixteenth minute in each standing condition was

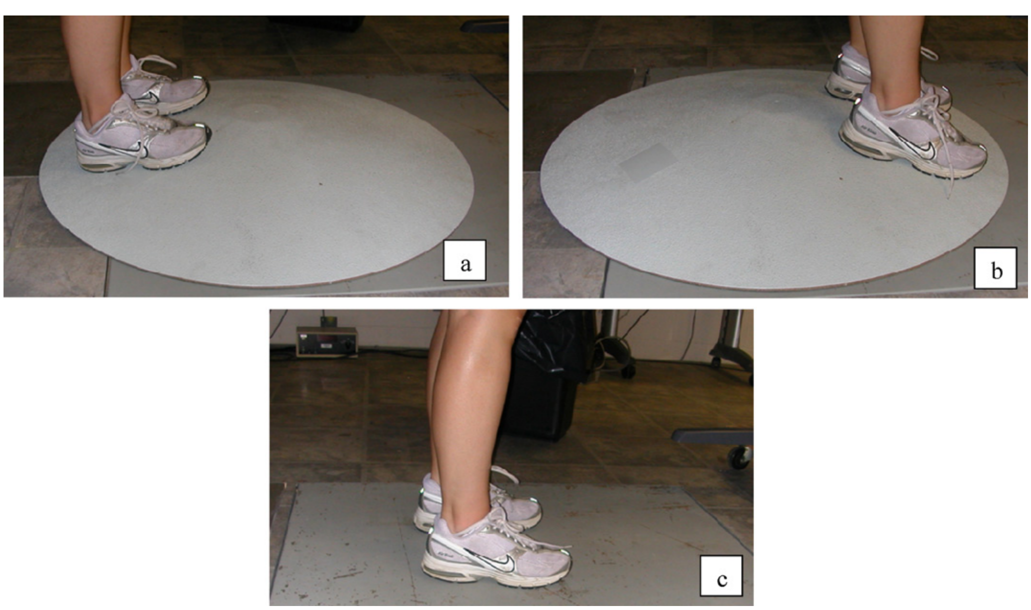

Fig. 1. Example of the three standing conditions: (a) incline (b) decline, and (c) level ground.