The Impact of a Sloped Surface on Low Back Pain During Prolonged Standing Work: A Biomechanical Analysis

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Background: Occupations that require prolonged periods of standing have been associated with increased reports of musculoskeletal disorders including low back pain. Previous work has utilized a prospective design of functionally inducing low back pain in previously asymptomatic individuals during a prolonged standing task. Increased trunk and gluteus medius muscle co-activation has been found in previously asymptomatic individuals who developed pain during standing compared with individuals who did not develop pain.

Purpose: The purpose of this study was to investigate the subjective and biomechanical responses of known pain developers and non-pain developers (previously determined during level standing) when exposed to the same prolonged standing task protocol completed while standing on a 16° sloped surface.

Results: Males appear to favorably respond to the sloped surface, regardless of whether they have low back pain associated with standing or not, whereas females exhibited a more variable response. Overall low back pain scores were reduced by 43.5% for the pain development group, identified in level standing, when using the sloped surface. There was a marked decrease in the co-activation of the bilateral gluteus medius muscles in the known pain developers when standing on the sloped surface compared with level standing. However the non-pain developer group responded in the opposite direction by having an increase in the co-activation of these muscles, although they did not have a commensurate increase in low back pain. There were changes in both the postural and joint-loading variables examined. These changes were minimal and in most cases the sloped surface produced responses that bracketed the postures and loading magnitudes found in level standing depending on whether the participant was standing on the incline or decline surface.

Conclusions: The sloped surface introduced biomechanical changes that resulted in beneficial reductions in low back pain during prolonged standing. These findings were most prevalent in the male participants examined in this study. These positive findings were supported in an exit survey satisfaction rating with 87.5% indicating that they would use the sloped surface if they were in an occupational setting that required prolonged standing work.

Keywords: *low back pain, occupational standing, ergonomic intervention*

1. INTRODUCTION

It has been well established that occupations requiring prolonged periods of static standing are associated with development of musculoskeletal disorders including low back pain (LBP)[1, 2]. A high prevalence of musculoskeletal disorders has been documented in workers across several different industries that require standing for more than 4 hours continuously [1]. Research that has investigated the impact of ergonomic measures such as anti-fatigue mats, different flooring surfaces and shoe insoles has shown mixed results for effectiveness at alleviating or preventing musculoskeletal pain that is aggravated by prolonged standing [1, 3, 4].

Previous work in our lab has investigated the modulation of biomechanical factors during the development of acute LBP during standing. This is a novel approach that utilizes a prospective design by functionally inducing LBP in previously asymptomatic individuals. We have found that 47-64% of previously asymptomatic individuals will develop clinically significant levels of LBP during a protocol that involves standing at a work station for a 2-hour period. This approach has allowed us to identify factors that are associated with the development of LBP during standing by comparing the characteristics of the pain developers and non-pain developers. Through identification of the factors that appear to predispose the development of LBP during standing, we are also able to investigate how different interventions may impact those factors[5-7].

The eQuilibrium® (eQ) Almond (Deltabalance, Inc., Edmonton, Alberta, Canada) is a platform for standing with a sloped surface of 16º that allows for standing with the feet in an inclined or declined position.

The purpose of this experimental study was to provide an assessment of the subjective comfort associated with standing on a sloped surface (eQ Almond) and to determine to what extent usage of the sloped surface alters muscular activity, spine and pelvis postures during prolonged standing. We hypothesized that individuals who previously developed LBP during level standing would have a subjective decrease in pain reporting when standing on a sloped surface, and would also show a decrease in trunk and hip muscle co-activation with sloped surface standing. A third hypothesis was that there would be kinematic and kinetic differences between the different available standing positions.

2. METHODS

Sixteen volunteers, 8 male and 8 female (average age 22.2 ± 3.06 years, female mass 62.49 ± 9.3 kg, male mass 83.13 ± 9.4 kg, female height 1.64 ± 0.07 m, male height 1.85 ± 0.07 m, BMI 23.6 ± 2.34 kg/m^2) were recruited from the University of Waterloo student population. Participants had previously undergone the standing protocol as part of a larger study, and had therefore already been identified as pain developers (PD) or non-pain developers (NPD). There were 5 PD and 3 NPD participants for each gender entered into this study. Exclusion criteria included any prior lifetime history of LBP requiring medical treatment or that resulted in more than 3 days off work or school, any previous hip surgery, inability to stand for greater than 4 hours, and having an occupation requiring static standing. The study protocol received approval from the University Office of Research and subjects gave informed consent before testing began.

Volunteers participated in two data collection days. On one day participants completed the 2-hour standing protocol on a level surface and on a second day completed the same protocol while standing on the sloped surface. Specific protocols for each testing day are detailed below.

2.1 Data Collection - Level Standing

After informed consent was obtained, participants completed a baseline measure of current LBP symptoms on a 100-mm visual analogue scale (VAS) with end-point anchors of 'no-pain' and 'worst pain imaginable'. The VAS has been found to have good construct validity [8] and reliability [9].

Muscle activation of the trunk flexors, extensors, and hip abductors were monitored continuously throughout the 2 hours of standing work. Six pairs of disposable electromyographic (EMG) Ag-AgCl electrodes (Blue Sensor, Medicotest, Inc., Olstykke, Denmark) were affixed to the skin with a 2 cm centre-to-centre inter-electrode distance over the muscle bellies of the following bilateral muscle groups: Thoracic Erector Spinae (5 cm lateral to T_9 spinous process) [10], Lumbar Erector Spinae (above and below L_1 spinous process) [11], Rectus Abdominus (1 cm above umbilicus and 2 cm lateral to midline) [12], Internal Oblique (1 cm medial to anterior superior iliac spine (ASIS) and beneath a line joining bilateral ASIS) [12], External Oblique (below the rib cage, along a line connecting the inferior costal margin and the contralateral pubic tubercle) [12], and

Gluteus Medius (1 inch distal to the midpoint of the iliac crest) [13]. All electrode placements were also confirmed through palpation and manual resistance.

Maximal voluntary contractions (MVC) were collected for EMG normalization. Manual resistance was applied to obtain MVC's in the following positions: Beiring-Sorensen [14], sidelying hip abduction, supine straight-leg curl up and diagonal curl-up to the left and right [14]. 'Rest' trials were collected in supine and prone positions so that the muscle activation levels above a resting level could be assessed. Raw EMG was amplified (AMT-8, Bortec, Calgary, Canada; bandwidth = 10-1000 Hz, CMRR=115 db at 60 Hz, input impedance = 10 GΩ) and collected with a sampling frequency of 2048 Hz using a 16-bit A/D card with a ± 2.5 V range.

Participants then entered into the prolonged standing task. A standing table was positioned in front of an in-floor force platform (Advanced Mechanical Technology, Inc., Watertown, Mass.) and adjusted to a height of 5-6 cm below the wrist of the participant when the elbow was flexed to 90° (Figure 1). Participants were instructed to stand 'in their usual manner as if they were standing for an extended period' with the only stipulation being that they could not rest their foot on the standing table frame, and they could not lean on the table surface with their upper extremities to support their body weight. Another baseline VAS was collected prior to the start of the 2-hour standing period.

Three different tasks were selected to simulate light occupational activities. These included a 'sorting' task; a small object 'assembly' task; and a 'boredom' task where participants were asked to stand without activity or social interaction. This task was included in an attempt to assess the effect of distraction on a participant's pain ratings. Tasks were presented in a semi-random block fashion using a random number generator, with 30-minute blocks for each task. There were two blocks of boredom, and task order was a partially controlled randomized design in that two boredom blocks could not be adjacent to each other. At the end of each 15-minute block, participants were asked to complete a VAS for the low back resulting in a total of 9 pain measures over the 2-hour period.

Lower body and trunk segment positions were measured using an optoelectronic motion analysis system (Optotrak Certus, Northern Digital Inc., Waterloo, ON) at a sampling frequency of 32 Hz. 46 markers were placed bilaterally on each participant's body to track movement of the following eight segments: feet, legs, thighs, pelvis, and thorax. Force plate, sampled at 1024 Hz, and kinematic data were entered into a 3-dimensional inverse dynamic model using Visual3D software (C-Motion, Inc., Kingston, ON) to calculate forces and moments at the L_5S_1 joint, and joint angles for the lower extremity and trunk. A standing calibration trial was collected and all joint angle data were normalized to a neutral level standing posture.

2.2 Data Collection – Sloped Surface Standing

The same data collection processes were repeated for the same 16 participants on a separate day at a similar time of day to the first session. There were several differences in methodology from the level standing trials aimed at quantifying the response of the participants to the inclined and declined surfaces. These differences included:

i. The sloped surface had markers placed on the longitudinal midline and was placed on the force platform.
ii. Prior to and following the 2-hour standing protocol, participants completed three 1-minute standing postures in: level standing, incline standing, and decline standing (Figure 2) in randomized order.
iii. Participants were instructed to stand wherever they were most comfortable on the sloped surface during the 2-hours. The standing table was fit with a pullout tray for participants to position the work surface at an appropriate distance for their standing position.
iv. Participants were asked to complete an Exit Questionnaire to record their opinions about the sloped surface.

2.3 Signal Post-Processing and Data Analysis

Participants were considered to be pain developers (PD) if they reported any absolute VAS score greater than 10 mm during the 2-hour level standing period. These threshold VAS values were chosen since 9 mm has been found to be the minimum clinically significant difference in VAS, representing a small treatment effect, with greater than 20 mm differences representing a large treatment effect [15]. The PD group were further sub-categorized as 'responders' and 'non-responders' based upon their VAS scores during the sloped surface standing. The 'responders' were defined as those individuals that switched from a PD group during level standing to a NPD group during sloped surface standing using the same threshold of greater than 10 mm maximum VAS to determine PD group. ‘Non-responders’ were those individuals who did not switch from a PD to a NPD group when using the sloped surface during prolonged standing.

EMG post-processing was coded in Matlab version R2008a version 7.6.0.324 (The Mathworks, Inc., Natick, MA, USA) using the built in signal processing toolbox. All EMG had any systematic bias removed and then was low-pass filtered (dual-pass, 4^{th}-order, zero lag Butterworth, effective cutoff frequency of 400 Hz) to remove high frequency noise components. When heart rate contamination was observed by visual inspection of the raw EMG and confirmed through spectral analysis, EMG was band-pass filtered (dual-pass, 4^{th}-order, zero lag Butterworth, 35-400 Hz)[16]. All EMG then received the same post-processing treatment of full-wave rectification followed by low-pass filtering (dual-pass, 4^{th}-order, zero-lag Butterworth effective cutoff frequency of 2.5 Hz), normalization to % MVC, and subtraction of resting activity level [17]. EMG data were then down sampled to 32 Hz prior to further analysis as a data reduction measure and to align temporally with the kinematic data.

Co-activation coefficients (CCI)[18] were calculated for all possible muscle pairs (a total of 16 x 16 possible combinations with 120 unique comparisons) using the equation:

Equation 1 $$CCI = \sum (EMG_{low}/EMG_{high})*(EMG_{low} + EMG_{high})$$

The CCI provides a quantitative measure of the degree of co-activation for a pair of muscle groups over a specified number of data points. ‘EMG_{low}’ and ‘EMG_{high}’ in this equation denote the relative magnitudes of the muscle activation for the two muscle groups at that point. A custom program was written in Matlab to compare the magnitude of EMG activation (%MVC) on a point-by-point basis for determination of ‘EMG_{low}’ and

'EMG_{high}' values for entry into Equation 1. CCIs were calculated over 1-minute windows (1,920 data points) for the eight 15-minute blocks. As a data reduction measure, data were collapsed by taking an average of the 1,920? CCI values for each block to yield 8 CCI values for the 2-h standing period for each pairing of muscle groups.

Marker and force platform data were used to develop a 3-dimensional inverse dynamic model with the Visual3D software. The model was used to calculate forces and moments at the L_5S_1 segment, and to determine the relative joint angles at the ankle, knee, hip, and trunk as well as the global pelvis angle. The neutral level standing position was used as a zero reference position for reporting all postural changes. Joint angles during the incline and decline standing positions were expressed as the difference in degrees from angles calculated for the neutral level standing posture. L_5S_1 forces are expressed as a percentage of the individual's body weight in order to allow for comparisons between people of different weights. L_5S_1 moments were normalized to the moment calculated during the neutral level standing position and are therefore expressed as a percentage of the neutral standing moment. Marker data from the participant's feet and the sloped surface midline were used to determine where the participants were standing throughout the 2-hour protocol and to track the number of times they changed positions between the two surfaces (incline and decline).

2.4 Statistical Analysis

SPSS version 16.0 (SPSS, Inc., Chicago, IL, USA) was used for all statistical analyses. Independent t-tests were conducted to ensure equality of groups on the personal characteristics of age, body mass index (BMI), and activity level. Independent t-tests were also conducted on the Baseline VAS scores to ensure there were no group differences in pain level prior to the standing period. To compare differences between standing positions on the sloped surface, dependent variables were entered into a 3-way general linear model with between factors of gender (M/F), group (PD/NPD) and a within factor standing position (Level/Incline/Decline). Dependent variables measured during the prolonged standing period were entered into a mixed general linear model with between factors of gender (M/F) and group (PD/NPD), and a within factor of standing condition (level/sloped surface). To examine differences between the responders and non-responders, measures for the PD group were also run separately with between factors of gender (M/F) and responder category (responder/non-responder) and a within factor of standing condition (level/sloped surface). Pairwise comparisons with Bonferroni corrections were made when post-hoc tests were required. The level for significance was set at $p < 0.05$ for all statistical tests.

3. RESULTS AND DISCUSSION

3.1 Subjective Pain Scores During Standing

All participants were similar in baseline VAS ratings prior to the prolonged standing exposures ($p > 0.05$). Participant characteristics of age, BMI and activity level were also statistically similar ($p > 0.05$).

Ten of the 16 participants developed LBP during level standing with the magnitude of pain reported by the PD and NPD groups being significantly different ($p < 0.01$). There were no gender differences in the VAS scores reported. Individuals who were categorized as PD during level standing reported an average maximum VAS score of

20.89 (± 3.5) mm. Individuals who were categorized as NPD during level standing reported an average maximum VAS score of 1.33 (± 4.5) mm. The PD group showed a significant decrease ($p < 0.01$) overall in VAS scores during sloped surface standing, with no significant effect of gender. Average maximum VAS scores for the PD group decreased to 11.80 (± 3.4) mm (from 20.89 ± 3.5 mm) during sloped surface standing (Figure 3).

When the PD group was examined separately, there was a significant interaction between standing condition, gender and responder category ($p < 0.01$). Male and female responders demonstrated similar decreases in maximum VAS scores from level to sloped surface standing (average decrease of 10.3 mm, or 68.8% for males and 11.5 mm, or 74.2 % for females) (Figure 4). All 5 of the male individuals who developed pain during level standing had a significant decrease in their subjective pain reports, although only 3 of these were classified as 'responders'. The 2 male 'non-responders', whose maximum VAS scores remained above 10 mm, still had a clinically meaningful decrease in pain (average decrease of 45.8%, or 19.5 mm on VAS). Female pain developers showed a less favorable subjective response to the sloped surface. Of the 5 female individuals who developed pain during level standing, 2 had a decrease in their subjective pain reports and were classified as 'responders', while 3 had no change or a slight increase (average increase of 4.2%, or 0.7 mm on VAS) in their pain reports when standing on the sloped surface. A limitation of this study is that when the PD group is further subdivided into responder and non-responder categories, the sample sizes are very small, so findings related to responder category may have limited generalizability to different populations.

When VAS scores from the sloped surface standing condition were analyzed using the original threshold criteria for being a pain developer or non-developer, 6 of the 16 participants were classified as LBP developers, with VAS scores above 10mm with significant differences between groups ($p < 0.01$) and no differences between genders. Of these 6 individuals, 5 were previously classified in the PD group during level standing (and are therefore considered 'non-responders'). One previous female non-pain developer actually became classified as a pain developer during sloped surface standing. It should also be noted that for the 5 other non-pain developers in level standing (3 male and 2 females), the levels of discomfort remained at the same or lower levels of discomfort when using a sloped surface.

3.2 Kinematic and Kinetic Differences Between Standing Positions

As expected, there were postural differences in both the kinematics and kinetics of individuals when standing in the Level, Incline and Decline positions. Significant differences ($p < 0.05$) between standing positions were observed in global pelvis, lumbosacral, knee and ankle angles (Table 1). The global pelvis angle had increased flexion (anterior tilt) during the incline standing position and no difference from level standing in the decline position. Participants had increased knee extension ($p < 0.05$) during incline standing, and no significant change from level during decline standing positions. As expected, the ankle angles closely follow the slope of the standing surface for both incline and decline positions ($p < 0.001$).

There was an increase in lumbosacral extension angle during incline standing with a commensurate increase in estimated L_5S_1 anterior shear and compression forces when compared with level standing. Shear and compression forces at L_5S_1 were not different between the incline and decline positions. While the shear and compression estimates at L_5S_1 during sloped standing were significantly higher than in level standing, these increases were only on the order of 3-5% of body weight. For this sample, with a range of body weights from 52.2 to 95.9 Kg, this would correspond to a range of shear and compression increases of only 1.6 to 4.8 N. These are extremely small magnitudes from a clinically meaningful perspective and are unlikely to be contributory to low back pain development.

There were significant differences in the estimated lumbar flexion-extension moment between the standing positions, with the decline standing position creating an extensor moment approximately 1.4 times that in level standing and the incline position reducing extensor moment to approximately 0.6 of that in level standing. The average magnitude of the estimated extensor moment was 21.1 ± 3.2 N-m in level standing, 15.3 ± 2.9 N-m in the incline position and 27.1 ± 3.1 N-m in the decline position. While this has an influence on the amount of muscle activity that is necessary to balance the moment to maintain static equilibrium in standing, the differences are on the order of approximately 6 N-m, and are very low when compared to the population 50% percentile trunk extensor strength limits of 234 N-m for males and 184 N-m for females [21].

3.3 Pre-Post Standing Differences in Joint Angles and Loading

Exposure to a prolonged period of standing on the sloped surface over 2-hours did result in some postural changes with participants having an increase in lumbosacral extension in the incline position only. Because there was no change in the global pelvis angle, this difference must be driven by an adjustment of the thorax position on the pelvis. L_5S_1 compression estimates significantly increased in all 3 positions following the 2-hours of standing, although again the magnitudes of these increases were extremely small, (on the order of 5-6 N), and would not be considered to be clinically relevant or of a concern in a task exposure risk assessment.

3.4 Foot Position on Platform During Standing

There were no gender or group differences in the self-selected foot position over the 2-hour period of standing. Participants, on average, showed a preference for a decline position as evidenced by the fact that they spent approximately 72% of the 2-hours in that position compared with only 28% in the incline position. On average, individuals changed position quite frequently over the 2-hour period of standing with an average of 85 position shifts during the 2-hours. There were no significant differences between genders or groups in the position shifts.

3.5 Muscle Co-activation Patterns During Standing

Previous work has linked increased muscle co-activation in the early stages of prolonged standing with development of LBP [6]. A sloped surface appears to have an influence on modifying the muscle co-activation levels present during standing. There was a significant interaction between group and standing condition on the 2-hour CCI average for bilateral gluteus medius ($p < 0.05$) (Figure 5). The PD group responded to standing on the sloped surface by showing a marked decrease in the co-activation of the bilateral gluteus medius muscles, with co-activation levels becoming similar to the profiles seen in the NPD group during level standing. However the NPD group responded in the opposite direction by having an increase in the co-activation of these muscles, which was on the same order of the values seen in the PD group during level standing, although they did not also have a commensurate increase in LBP.

There were significant group differences for trunk flexor-extensor co-activation between standing conditions. There was no change in the trunk flexor-extensor co-activation in the PD group, however the NPD group again responded with an increase in co-activation of the left lumbar erector spinae (LLES) and left external oblique (LEO) and the LLES and right external oblique (REO) muscle pairs ($p < 0.05$) during sloped surface standing (Figure 6).

There were no significant gender differences in muscle co-activation. When the PD group was examined independently, there were no significant differences between responders and non-responders in muscle co-activation during level or sloped surface standing.

3.6 Exit Questionnaires

In general, participants rated standing on the sloped surface favorably, with 14 of the 16 participants indicating they would adopt this as a work station device for greater than 50% of the time if they worked in an occupation that required standing. Two of the 16 participants (1 female, 1 male) indicated they would choose not to use sloped surface in a work environment at all. Surprisingly, those 2 participants were PD and classified as ‘responders’ with decreased low back VAS scores when standing on the sloped surface.

4. CONCLUSIONS

There was a positive effect of reduced LBP during standing for pain developers when a sloped standing surface was compared to standing on a level surface. Over 2-hour periods of standing exposure the sloped surface reduced perceived discomfort, primarily for male users. It appears that there are both gender and pain developing profile influences on the subjective response to the sloped surface as an intervention for LBP, and this should be a consideration when recommending this as an intervention for people in the workplace. Males appeared to more favorably respond to the sloped surface, regardless of their LBP development status when standing, whereas females exhibited a more variable response.

The effect of the sloped surface was seen in the reduced discomfort scores for the lower back with the pain development group identified in level standing reducing their perceived discomfort by 43.5% on average. There were corresponding changes in the postural and joint loading variables examined. The joint loading changes were minimal and in most cases the sloped surface resulted in changes in joint position and joint loading that bracketed the postures and loading magnitudes found in level standing. In other words, the incline and decline surfaces resulted in higher magnitudes for one direction compared to level standing and lower magnitudes than level standing for the other surface. The only variable that was consistently increased by both incline and decline surfaces was joint compression, which was higher when standing on the sloped surface compared to level standing. These changes were of a very small magnitude and are of no concern when compared to risk of injury threshold limit values. The sloped surfaces create a favorable postural variability in both pelvic and lumbar spine angles. The incline surface resulted in flexion or anterior rotation of the pelvis and a corresponding increase in lumbar spine extension. The decline surface created the opposite postural shift with extension or posterior rotation of the pelvis and an increase in flexion of the lumbar spine. These motions were on the order of 1 to 2 degrees and would be classified as small postural adjustments. Similar small changes in muscular activation profiles have been shown to be beneficial in reducing pain reporting in assembly workers [22] and in prolonged seated exposures less frequent lumbar and pelvis postural adjustments were associated with higher low back discomfort [23, 24]. The variability in posture is supported by the finding that participants tended to alter position on average once every 84 seconds, or 85 postural shifts in total over a 2-hour period. The decline surface was preferred and 72% of the total time was spent standing on this slope.

Trunk and hip muscle co-activation during standing have previously been associated with susceptibility to pain development. Standing on the sloped surface did modulate this muscle activation pattern, however the finding of increased muscle co-activation in the NPD group (to PD levels) without increased pain, is intriguing and requires further study as a potential pathway to pain development. This is also of potential concern if there is a direct response between these co-activation patterns and pain development as the NPD group exhibited a pattern that would be indicative of identifying high-risk individuals for developing LBP in level standing.

The sloped surface appears to introduce changes in standing style that result in beneficial reductions in LBP during prolonged standing exposures. These findings were most prevalent in the male sample of participants examined in this study. The positive outcomes were supported in the satisfaction rating of the participants, with 87.5%

indicating that they would use a sloped surface if they were in an occupational setting that required prolonged standing work.

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Table 1. Kinematic and Kinetic Differences Between Standing Positions

Note - Angle data expressed as difference from neutral standing in degrees	**Mean**	**SE**
Global Pelvis Flexion Angle (°)	*+ve* = Extension	
Incline	-2.65 [a, b]	0.495
Decline	0.072 [c]	0.604
Lumbosacral Angle Flexion Angle (°)	*+ve* = Extension	
Incline	1.71 [b]	0.86
Decline	-1.03 [a, c]	0.96
Left Ankle Dorsi/Plantar Flexion Angle (°)	*+ve* = dorsiflexion	
Incline	16.6 [a, b]	0.48
Decline	-16.6 [a, c]	0.29
Right Ankle Dorsi/Plantar Flexion Angle (°)	*+ve* = dorsiflexion	
Incline	17.2 [a, b]	0.58
Decline	-16.6 [a, c]	0.32
Left Knee Flexion/Extension Angle (°)	*+ve* = Extension	
Incline	2.37 [a, b]	0.68
Decline	-0.22 [c]	0.39
Right Knee Flexion/Extension Angle (°)	*+ve* = Extension	
Incline	3.2 [a, b]	0.97
Decline	0.22 [c]	0.44
L_5S_1 AP Shear – *normalized to % Body Weight*	*+ve* = anterior	
Level	21.0 [c]	1.04
Incline	25.5 [a]	0.99
Decline	22.8 [*NS*]	1.12
L_5S_1 Compression – *normalized to % Body Weight*	*+ve* = upwards	
Level	-54.5 [b, c]	0.66
Incline	-58.0 [a]	0.62
Decline	-59.0 [a]	0.65
L_5S_1 Flexion/Extension Moment – *normalized to Level Standing Value*	*+ve* = extensor	
Level	1.0 [b, c]	
Incline	0.71 [a, b]	0.048
Decline	1.142 [a, c]	0.09

a. = Different from Level Standing at the $p \leq .05$ level

b. = Different from Decline Standing at the $p \leq .05$ level

c. = Different from Incline Standing at the $p \leq .05$ level

NS = Not significantly Different From Other Positions

Figure 1. Experimental set-up for level standing data collection.

Figure 2. a) Level Standing Position b) Decline Standing Position c) Incline Standing Position

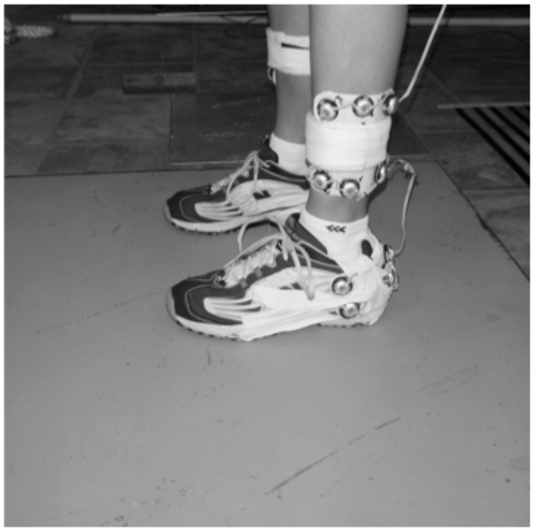
Figure 3. Pain Developers showed a significant decrease in low back VAS during sloped surface standing.

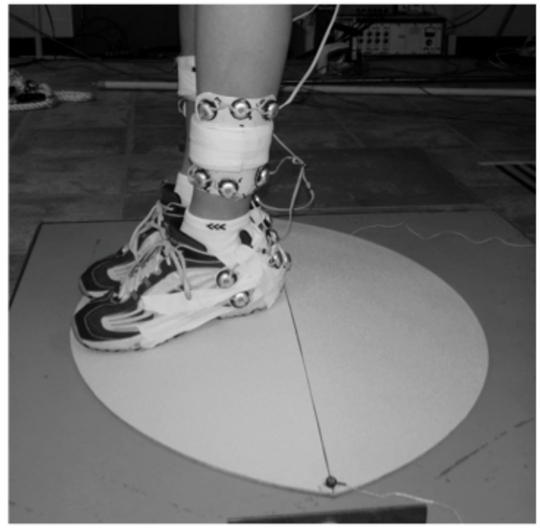
Figure 4. Male and female responders had similar decreases in VAS when standing on the sloped surface. Male non-responders had a decrease in VAS, while female non-responders had a slight increase in VAS.

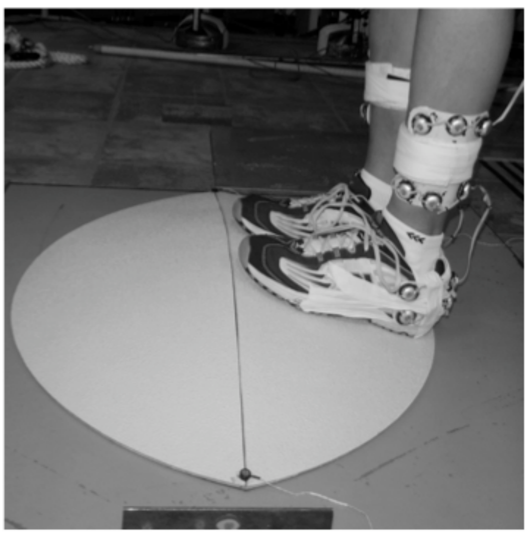
Figure 5. Differences in bilateral Gluteus Medius Co-Contraction Index (CCI) between standing conditions. PD group had a decrease in CCI with sloped surface standing while NPD group had an increase from the level standing condition.

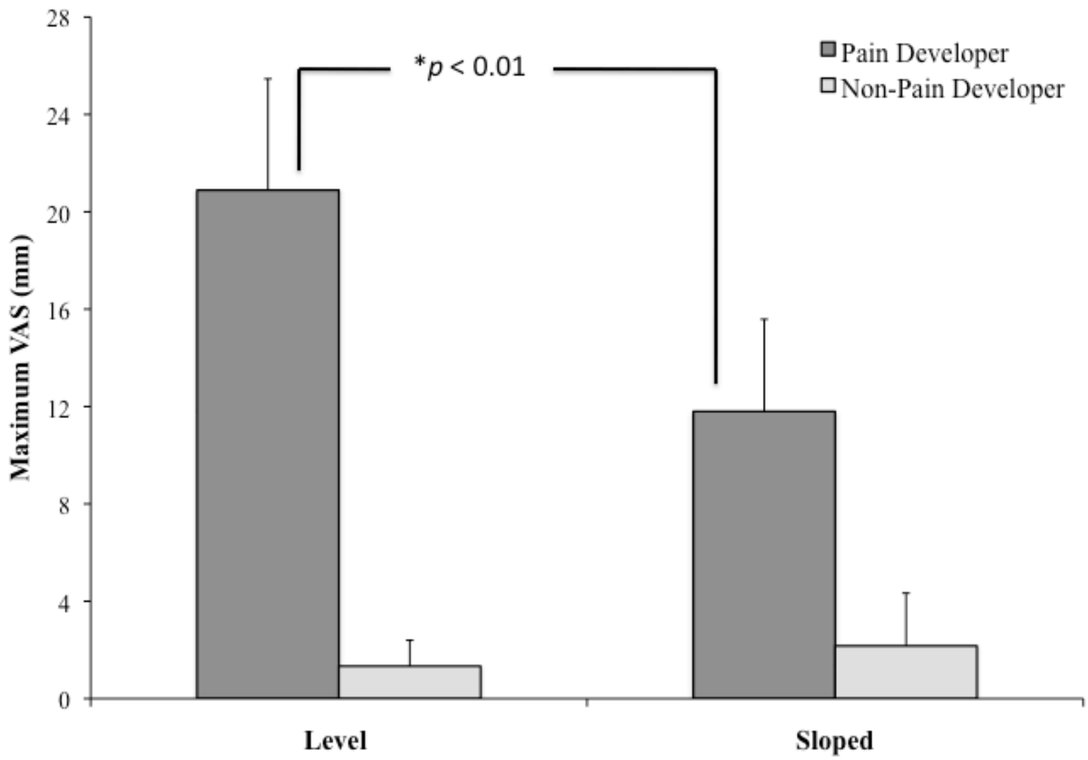
Figure 6. Differences in left lumbar erector spinae and left external oblique (LLES-LEO) Co-Contraction Index (CCI) between standing conditions. PD group showed no differences in CCI between standing conditions while NPD group increased LLES-LEO CCI in sloped surface standing.

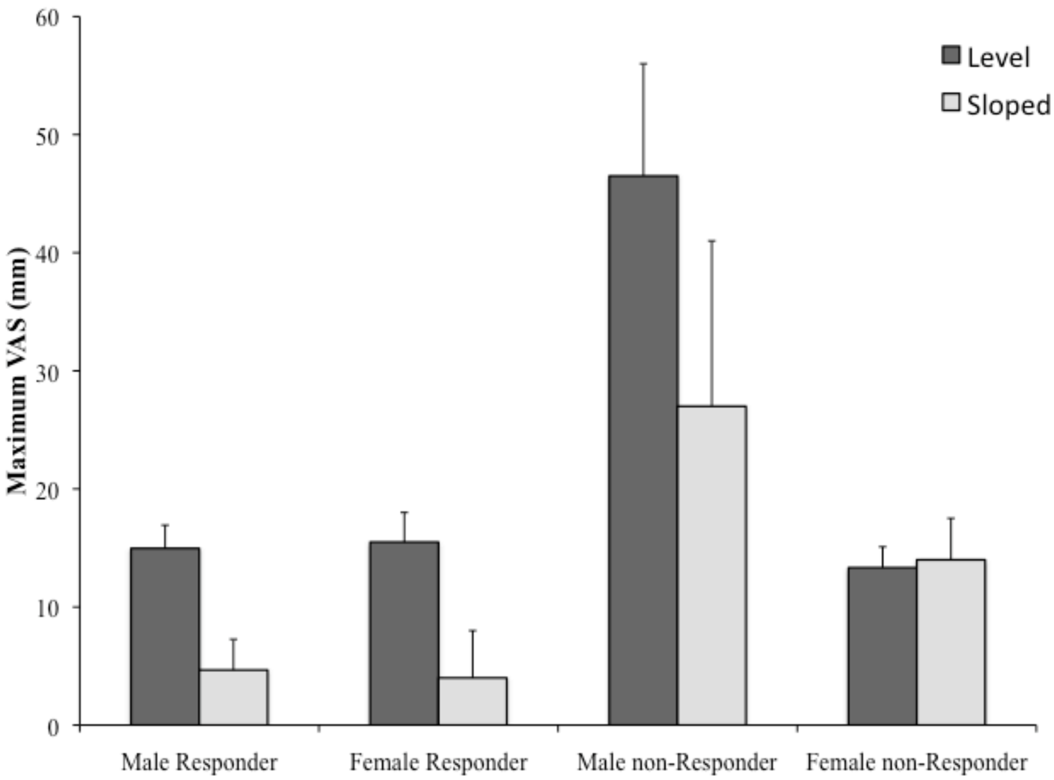
Table 1. Kinematic and Kinetic Differences Between Standing Positions


a)

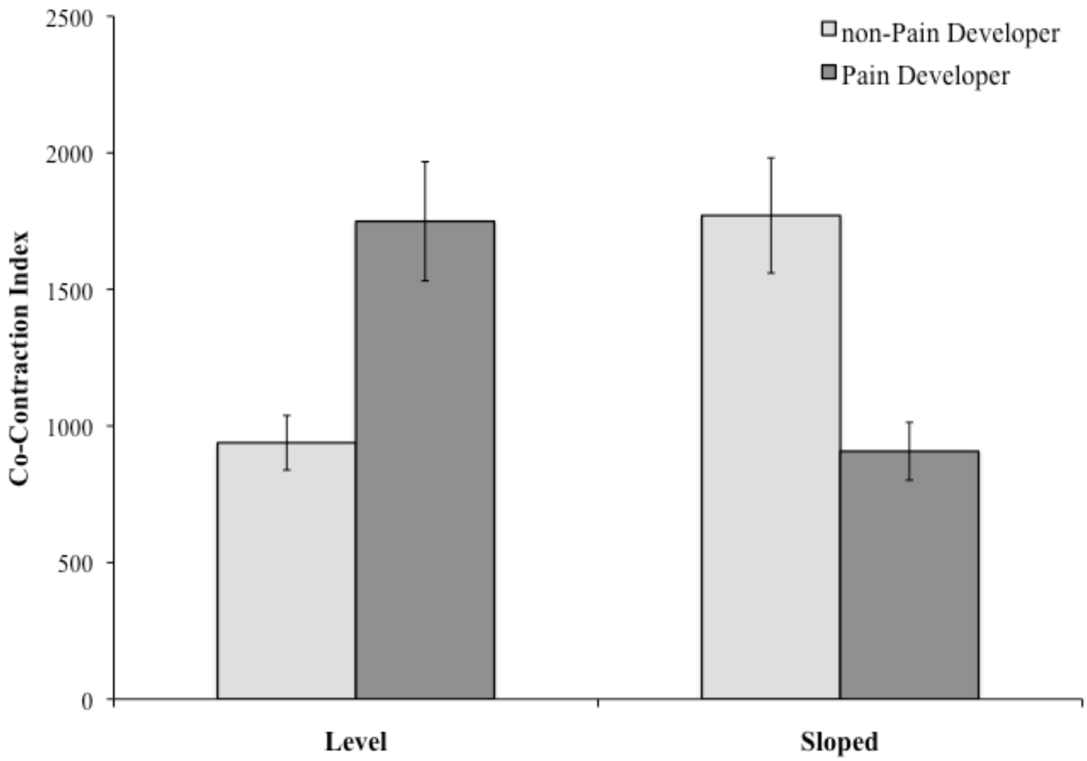

b)


c)

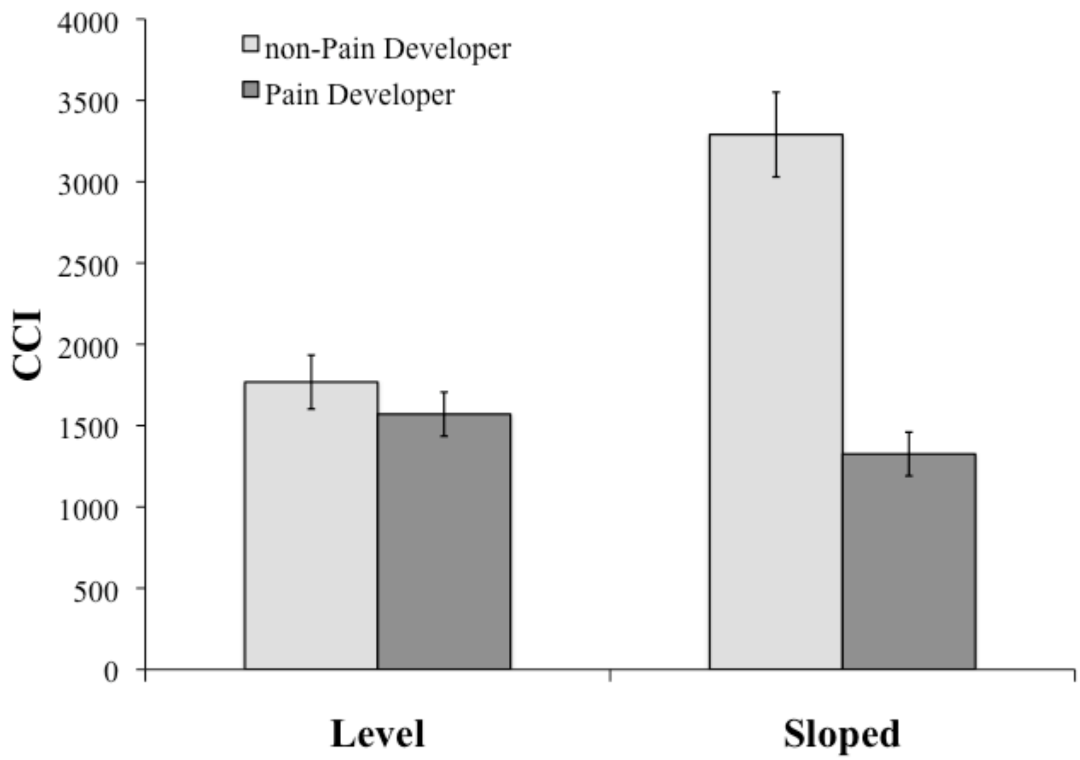

Pain Developer
Non-Pain Developer
*p < 0.01
Maximum VAS (mm)
0
4
8
12
16
20
24
28
Level
Sloped



Level
Sloped
Maximum VAS (mm)
60
50
40
30
20
10
0
Male Responder
Female Responder
Male non-Responder
Female non-Responder



2500
2000
1500
1000
500
0
Co-Contraction Index
non-Pain Developer
Pain Developer
Level
Sloped



non-Pain Developer
Pain Developer
CCI
4000
3500
3000
2500
2000
1500
1000
500
0
Level
Sloped