Weight Shifting Strategies and Discomfort during Prolonged Standing

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Over half of the top ten occupations in the United States require prolonged standing, translating to nearly 3.2 million people who spend the majority of their workday standing (*Occupational Employment Statistics*, 2014). Continual exposure to muscle fatigue, blood pooling, and cartilage compression due to prolonged standing may lead to long term injuries and damage. Current interventions show limited effectiveness in situ and in laboratory settings. The goal of this study is to investigate how weight shifting strategies may be used to alleviate discomfort. Seven subjects stood for one hour and reported their discomfort while weight distribution data was collected. Strategy significantly affected discomfort for overall tiredness ($p < 0.0001$), leg tiredness ($p < 0.002$), upper legs ($p < 0.005$), and feet ($p < 0.0024$). Those who use a moderate to full strategy reported less overall discomfort than moderate and full ($p < 0.001$) shifters. Standing strategy may minimize discomfort during the workday.

INTRODUCTION

Many professions—including nurses, doctors, hairdressers, retail clerks, and industrial manufacturers—perform tasks that require a large degree of freedom and mobility that can only be achieved by standing (Halim & Omar, 2011). While standing is the most efficient and safest position to perform tasks, prolonged standing lends itself to discomfort due to blood pooling, muscle fatigue, and joint compression in the lower extremities and low back (Halim & Omar, 2011; Waters & Dick, 2015). Continual exposure to prolonged standing may lead to long term injuries and damage, such as chronic venous disorders and circulatory problems, increased stroke risk, increased risk of birth complications, and degenerative joint damage, which require medical costs and medical support (Halim & Omar, 2011). In fact, injuries due to prolonged standing have been attributed to over 2 million sick days a year in the United Kingdom (Halim & Omar, 2011).

To mitigate these losses, anti-fatigue mats, shoe inserts, and compression stockings have been utilized in the workplace and have been studied in situ and in laboratory settings (Waters & Dick, 2015). Studies use subjective discomfort surveys paired with center of pressure shifting, electromyography, leg volume and leg temperature changes to measure intervention effectiveness, with conflicting results (Cham & Redfern, 1999, 2001; Gregory & Callaghan, 2008; Halim & Omar, 2011; King, 2002; Lin, Chen, & Cho, 2012; Madeleine, Voigt, & Arendt-Nielsen, 1997; Orlando & King, 2004; Wiggermann & Keyserling, 2013; Zander, King, & Ezenwa, 2004). As an alternative, this study investigates weight shifting strategies that those who stand may employ as a method of decreasing discomfort during prolonged standing in the workplace.

Weight shifting is a deliberate behavioral response to standing that has been collected most often in the form of center of pressure (CoP) excursions from a single force plate (Winter, 1995). It has been speculated that weight shifting decreases blood pooling in the lower extremities by engaging venous return pumps in the plantar flexor muscles (Wiggermann & Keyserling, 2013). It may also decrease joint compression to allow synovial fluid return (Goonetilleke, 1999).

A weight shift, according to Duarte & Zatsiorsky, is a "fast disturbance of the average CoP location that shifts the percent bodyweight from one leg to another (Duarte & Zatsiorsky, 1999)." Weight distribution between legs is rarely if ever symmetrical during standing (Murray & Peterson, 1973; Winter, 1995). Therefore, methods to determine whether weight has shifted from one leg to the other have varied (Gallagher, Nelson-Wong, & Callaghan, 2011; Murray & Peterson, 1973; Wiggermann & Keyserling, 2013). Wiggermann and Keyserling have defined weight shifting as a change between one of the following observations that lasts at least 7.5 seconds:

- >80% bodyweight on the left leg,
- >80% bodyweight on the right leg,
- or >20% bodyweight on each leg simultaneously (Wiggermann & Keyserling, 2013).

The percent bodyweight required on one leg to achieve a weight shift, or the duration required to consider the movement a shift, has varied between studies (Gallagher et al., 2011; Murray & Peterson, 1973; Wiggermann & Keyserling, 2013). Cham and Redfern defined a weight shift as a change in lateral CoP beyond 10% of the total distance seen for the trial, with no requirement to maintain the position for a minimum amount of time (Cham & Redfern, 2001).

In most cases, shift frequency and shift duration over time are reported. It has been found that shifts tend to increase frequency over time, but decrease in duration (Cham & Redfern, 2001; Gallagher et al., 2011; Goonetilleke, 1999; Madeleine et al., 1997; Ringheim, Austein, Indahl, & Roeleveld, 2015; Wiggermann & Keyserling, 2013). Furthermore, weight shifting has been positively correlated with discomfort, especially when considering overall fatigue, whole-leg fatigue, the hip, upper legs, ankles, and feet (Cham & Redfern, 2001; Wiggermann & Keyserling, 2013).

For these studies, analysis methods consider shifting as "one size fits all" for healthy controls. It is only when comparing to a subgroup, such as those with chronic or transient low back pain, that a weight shifting strategy has been considered (Gallagher et al., 2011; Gregory & Callaghan, 2008; Ringheim et al., 2015). No study to date has investigated weight shifting strategies employed by healthy standers over time, and how these strategies may impact discomfort.

The goal of this study is to investigate how weight shifting strategies are related to discomfort. This may lead to the possibility of recommending a weight shifting strategy to alleviate discomfort for workers who stand. Various weight shifting strategies (defined in methods) were compared to discomfort ratings over time. It is hypothesized that those who achieve a full spectrum of weight shifting will have increased venous return throughout the testing duration, and therefore will result in the least discomfort overall, as opposed to moderate or moderate to full shifters. By better understanding these strategies, employees may be trained to use a specific weight shifting strategy to decrease discomfort.

METHODS

Testing Protocol

Seven healthy young adults (two females, five males) with age, height, weight, and BMI found in Table 1 participated in this study. Subjects were screened for the following exclusionary criteria: dizziness problems, osteoporosis, recent orthopedic problems, and any neurological, pulmonary, or cardiovascular health problems, and each subject provided voluntary consent in agreement with the University of Pittsburgh IRB before testing. Each subject wore the same brand socks and shoes for testing to control for any variance due to shoe type.

Table 1: Subject Demographics

	Mean ± SD
Age (y)	22.8 ± 2.4
Height (m)	178.6 ± 8.9
Mass (kg)	80.0 ± 14.0
BMI	25.0 ± 4.0

Standing sessions began following a two-minute seated rest. Two balance plates (BP5050, Bertec Corporation, Columbus OH) were used to track postural movements during standing at a sampling rate of 1000 Hz. Each subject stood with a foot on each plate for one hour and were instructed to maintain ground contact with both feet. Subjects were allowed to weight shift, but were not instructed how or when to do so. A standing desk was provided during standing so that subjects could perform a computer task. A CR-10 Borg discomfort survey was administered right after standing, at 30 minutes of standing, and at just prior to finishing the standing trial.

Analysis Methods

Using Matlab 2015a, data was down sampled to 20 Hz for analysis. The force output from each plate was analyzed to investigate the weight endured by the left and right feet during standing. For this study, a weight shift refers to a change in bodyweight percent loaded on the subject's dominant leg for at least 7.5 seconds between the following proportions:

- 0 – 20% bodyweight
- 20 – 40% bodyweight
- 40 – 60% bodyweight
- 60 – 80% bodyweight
- 80 – 100% bodyweight.

We defined four different strategies, three of which were observed during our study:

- Full: >80% bodyweight is observed at least once in the first 30 minutes of standing and the last 30 minutes of standing on either the dominant leg or the non-dominant leg.
- Moderate: >80% bodyweight is not observed at all throughout the duration of standing on either the dominant leg or the non-dominant leg.
- Moderate to Full: >80% bodyweight is only observed during the last 30 minutes of standing on either the dominant leg or the non-dominant leg.
- Full to Moderate: >80% bodyweight is only observed during the first 30 minutes of standing on either the dominant leg or the non-dominant leg. This strategy was not observed during this study.

Discomfort survey data was linearized according to methods described by Borg G (Borg, 1998).

RESULTS

Three different kinds of strategies were observed—full (n = 1), moderate (n = 4), and moderate to full (n = 2). Typical moderate to full subject data is shown in Figure 1. Horizontal lines indicate 20%, 40%, 50%, 60%, and 80% bodyweight placed on the dominant leg. This subject is considered a "moderate to full" shifter because shifts beyond the central 60% bodyweight for over 7.5 seconds does not occur until the end of the standing session.

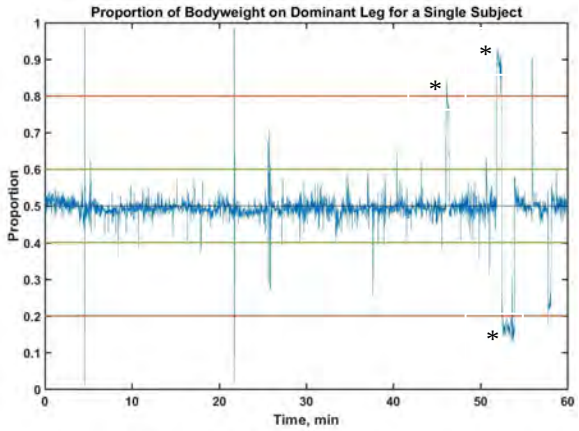


Figure 1: A "moderate to full" shifter does not maintain a weight shift beyond the central 60% bodyweight until the second 30 minutes of the standing session, indicated by *.

Figure 2 displays data for a single full, moderate, and moderate to full shifter. For each type, shift frequency

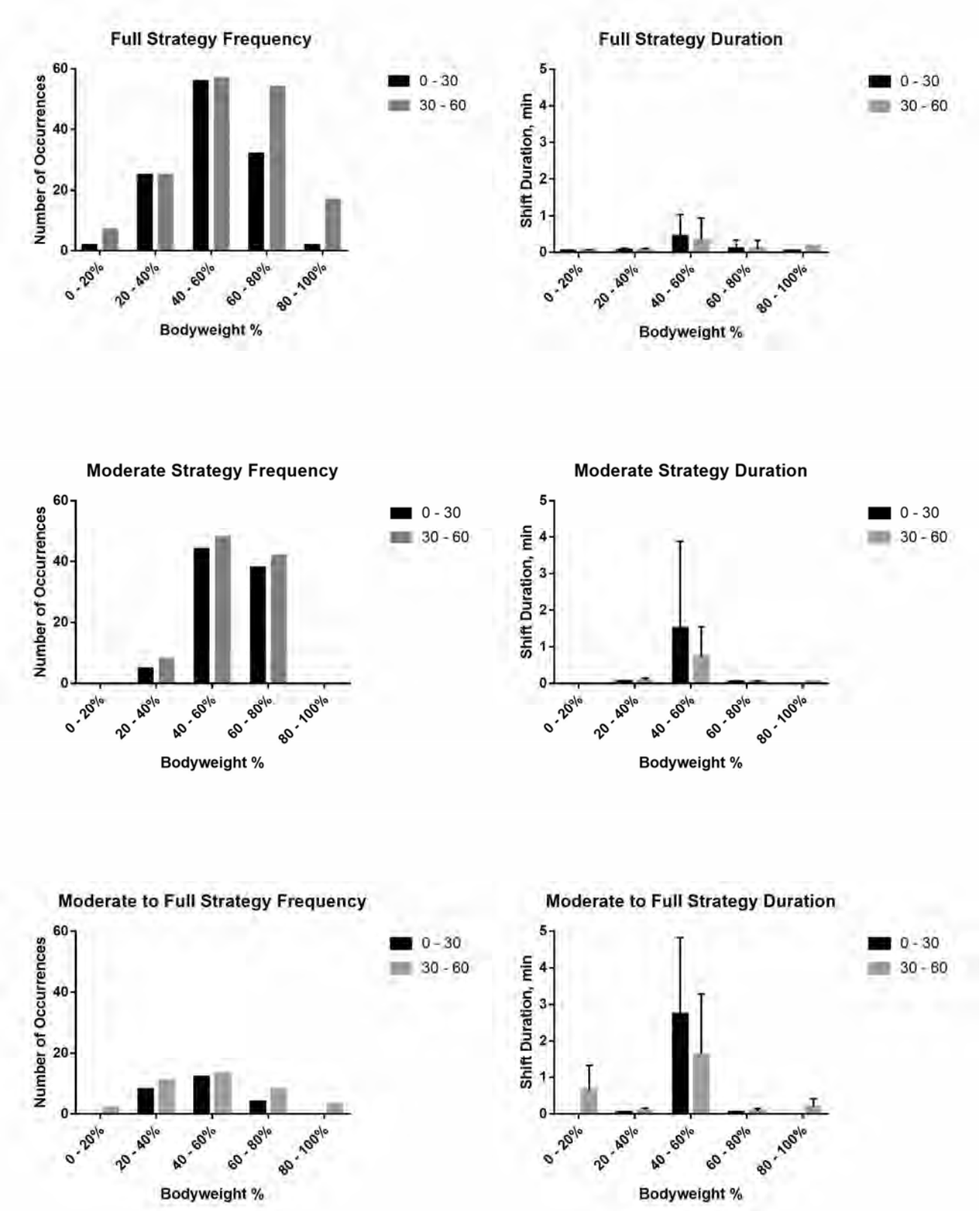


Figure 2: Frequency and duration of shifts for full, moderate, and moderate to full strategies during the first and second halves of the 60-minute standing duration.

increases between the first and second halves of standing. Furthermore, shift duration tends to decrease between the first and second halves of standing, though standing duration shows a relatively large variance.

Overall, the full shifter tended to show more shifts than moderate or moderate to full shifters. Likewise, the moderate to full shifters show the least number of shifts. Consequentially, the full shift duration is less than that of the narrow or

Table 2: Discomfort level versus standing strategy and time during an hour of standing

	Time	Strategy
Overall Tiredness		< 0.0001
Leg Tiredness	0.0264	0.0020
Upper Legs Disc.		0.0050
Feet Disc.	0.0005	0.0024

Interestingly, standing strategy showed more significant outcomes when compared to discomfort level than time. Interactions were considered, but were not significant. Bonferroni post-hoc analyses were performed for the significant results above, with significant differences in Table 3 and Table 4.

Table 3: Significant differences between standing strategy. (M = moderate, F = full, M2F = moderate to full)

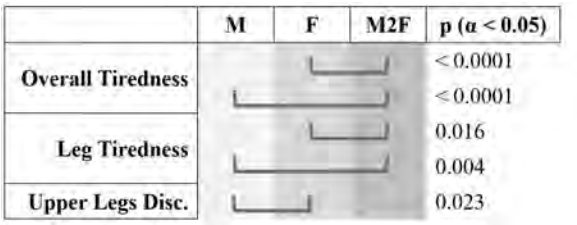
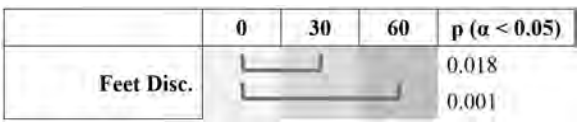


Table 4: Significant differences over time. (0, 30, and 60 minutes of standing)



Post-hoc analyses of strategy suggest that discomfort level is significantly decreased when a moderate to full strategy is used (overall and leg tiredness), as opposed to a moderate or full strategy. Using a moderate strategy showed the largest overall tiredness rating, while using a full strategy showed the largest leg tiredness rating. The upper legs showed significantly decreased discomfort when a full strategy was employed.

Post-hoc analyses of feet discomfort shows a significant increase of discomfort from start to 30 minutes and start to 60 minutes, but no significant change was found between 30 and 60 minutes.

DISCUSSION

This study observed full weight shifting, moderate weight shifting, and moderate to full shifting strategies, which suggests that individuals choose—whether consciously or subconsciously—a strategy that minimizes discomfort as much as possible. Prior studies have speculated that discomfort is the body's way of communicating potential injury to the central nervous system, which elicits a behavioral response to decrease discomfort (Goonetilleke, 1999). While this may be true, studies have approached weight shifting as either a causative or a reactionary mechanism—depending on the outcome variables of the study (Cham & Redfern, 2001; Gallagher et al., 2011; Goonetilleke, 1999; Wiggermann & Keyserling, 2013; Winter, 1995). This study assumes that both of these mechanisms are not mutually exclusive. Therefore, it is possible that a subject may choose a weight shifting strategy and change when discomfort increases to a threshold level, such as with moderate to full weight shifters. Given that discomfort was overall rated least for moderate to full weight shifters, this may be a potential strategy to investigate to decrease discomfort.

We hypothesized that those who achieve a full spectrum of weight shifting throughout the testing duration will result in the least discomfort overall, as opposed to moderate or moderate to full shifters. This hypothesis was derived from data suggesting that asymmetric glute firing for transient low back pain developers decreased pain over time significantly (Gallagher et al., 2011). More dramatic weight shifting over time requires more asymmetric glute firing, which was thought to decrease discomfort.

However, those who performed a moderate to full weight shifting strategy tended to report less discomfort. When weight shifting occurs, venous return is initiated and pressure is relieved from the joints through the use of repeated low-level contractions of the plantar flexor muscles (Winter, 1995). Performing full weight shifts over the duration of standing may fatigue the plantar flexors more quickly, which lends itself to increased discomfort (Goonetilleke, 1999). If full weight shifting is only initiated once a certain blood pooling threshold is achieved, fatigue may be minimized and pooling may be decreased most efficiently.

Consistent with prior studies, visual investigation of our graphs indicate that weight shifting frequency increases over time, and duration decreases over time—especially as discomfort increases (Cham & Redfern, 2001; Gallagher et al., 2011; Goonetilleke, 1999; Madeleine et al., 1997; Ringheim et al., 2015; Wiggermann & Keyserling, 2013). More between-subjects analysis is being performed to better understand links between discomfort, strategy, duration, frequency, and time. Furthermore, discomfort increased over time, which is consistent with other studies (Cham & Redfern, 2001; Gallagher et al., 2011; Goonetilleke, 1999; Madeleine et al.,

1997; Ringheim et al., 2015; Wiggermann & Keyserling, 2013).

Interestingly, when strategy was considered as part of the ANOVA model we chose (as opposed to just time as an independent variable), strategy showed more significant results as an indicator of discomfort than time. This may be due to a small sample size and will require more investigation.

The main limitation of this study is the low sample size (n = 7). Despite the small sample size, there were some patterns that suggest a need for further investigation. Another limitation was that no instructions were given to the subjects on *how* to weight shift. While this makes the study's data more authentic for the subject's own weight shifting strategy, it does not test discomfort level differences within subjects based on different strategies.

CONCLUSION

The overall goal of this study was to investigate how weight shifting strategies may alleviate discomfort. While the study indicates that there may be some connections between standing strategy and discomfort, more research is required to determine how these strategies and discomfort are related. Future studies may consider using EMG's to measure muscle fatigue of the plantar flexors to compare to shifting strategy as well. Hopefully, with added research in this area, standing strategies could be added to the list of methods to mitigate discomfort in the workplace—and chronic injuries over time.

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