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Abstract

The purpose of this study was to look for changes in gluteus medius muscle activity during functional reaches and investigate whether or not anti-fatigue matting affects these changes. Fourteen participants (seven male & seven female) who did not meet any of the exclusion criteria completed forward and lateral reaches at hip and shoulder height on all four floor conditions for a total of sixteen reaches. Four floor types were tested: a control bare force platform, and a low, medium, and high stiffness anti-fatigue mat. Electromyography was applied bilaterally to the gluteus medius muscles, and maximum voluntary contractions were performed so that EMG data could be normalized to this value. Participants stood on two force platforms to get separate measurements under each foot and calculate percent of body weight on each foot. Reach profiles were divided into five phases: standing prior to reach, movement to peak reach, holding peak reach, return to standing, and standing post-reach. Forward reaches showed a main effect of time (p = .004) for peak EMG. Lateral reaches showed interactions between mat and time (p = .02) and height and time (p = .001) for peak EMG. Activity on the hard and medium mats was significantly lower than the soft and control mats at the R2 phase (p = .027). No main effects or interactions were found for percent of body weight shifted during reaches. Gluteus medius muscle activity increased during peak reach in both directions, but only lateral reaches were affected by floor condition and reach height. Future studies should investigate if gluteus medius muscle activity during functional reaches changes after a bout of prolonged standing or in an older population.

1. Introduction

Completing tasks while standing for a prolonged period of time is very common in the workforce. This often corresponds to low back pain, which has been shown by both lab studies (Gallagher, Campbell, and Callaghan 2014) and field studies (Tissot, Messing, and Stock 2009). Anti-fatigue matting is a common recommendation to reduce pain development in the low back and lower limbs during prolonged standing tasks (Cohen et al. 1997). The studies that have assessed these mats have only looked at their influence during constrained standing tasks (Aghazadeh et al. 2015; Cook et al. 1993; Kim, Stuart-Buttle, and Marras 1994). The impact of these mats on the gluteus medius muscles, which are important for remaining upright and balanced during functional reaches, is currently unknown. As a result, the purpose of this study was to assess the influence of mat stiffness on gluteus medius muscle activity during forward and lateral reaches.

Studies that have assessed these mats show conflicting results, and differences in the compressibility of the mats and the materials used has led to mixed results about their effectiveness with respect to muscle activity. As many as seven floor types have been studied at to analyze the effects of thickness and hardness on lower limb and low back discomfort (Cham & Redfern 2001). In general, anti-fatigue mats have led to decreased subjective pain levels for the muscles of the lower back (Aghazadeh et al. 2015). Following two hours of standing, EMG data of the erector spinae muscles showed significantly less fatigue on matted flooring when compared to a concrete floor (Kim, Stuart-Buttle, and Marras 1994). The muscles in the lower limbs, particularly the gastrocnemius muscles, become fatigued during prolonged standing. This was shown by comparing mean frequency values of EMG data for the gastrocnemius and erector spinae muscles (Kim, Stuart-Buttle, and Marras 1994). However, the muscle activity of the lower limbs has not shown to be reduced by anti-fatigue mats, specifically during prolonged standing. During up to four hours of standing, the electromyography of the anterior tibialis and paraspinal muscles showed no differences between the mat and a linoleum-covered concrete floor (Cook et al. 1993). Bilateral co-contraction of the gluteus medius muscles is a strong predictor of low back pain development during prolonged standing (Nelson-Wong and Callaghan 2010); however, anti-fatigue mats have been shown to not affect this muscle co-activation (Aghazadeh et al. 2015). On both a normal firm surface and an anti-fatigue mat, gluteus medius co-activation was not influenced by prolonged standing (Aghazadeh et al. 2015). It is currently unknown how other tasks that may require more gluteus medius muscle activation, such as reaches, would be affected by these mats.

People who are subject to prolonged standing as part of their job commonly complete many different tasks that challenge their balance, such as reaching for an object. Functional reaches, which can vary from person to person based on age and height (Duncan et al. 1990), may alter muscle activity and could play a role in pain development. The gluteus medius muscles are very important for maintaining balance during reaching tasks. This muscle originates on the ilium of the pelvis and inserts on the lateral surface of the greater trochanter of the femur. They aid in maintaining balance while standing and walking because they help to stabilize the pelvis (Gottschalk, Kourosh, and Leveau 1989). While the gluteus medius muscle is typically characterized as a hip abductor, this only occurs when the foot is not planted on the ground. When the foot is planted on the ground, like it is during the stance phase in walking or single leg stance, the gluteus medius muscle of the stance leg stabilizes the pelvis. It is possible that a prolonged standing could affect the ability of these muscles to do so. Secondly, anti-fatigue matting will challenge a person's stability because it is inherently softer than rigid flooring, which could then change the activation levels of the gluteus medius muscles required to stabilize the pelvis. To date, there have been no known studies that have assessed the influence of anti-fatigue mats on hip muscle activity.

The purpose of this study was to determine whether or not gluteus medius muscle activity changes during functional reaches, and to investigate the effects of anti-fatigue matting on muscle activity. In this study, gluteus medius muscle activity was assessed during sixteen different reaches. Our first hypothesis was that the high stiffness anti-fatigue mat would have the lowest level of muscle activity among the four floor types. Our second hypothesis was that reaches at shoulder level would require greater gluteus medius muscle activity. Our third hypothesis was that less body weight would be shifted during reaches on the low stiffness mat.

2. Methods

2.1 Participants

The data were collected using fourteen participants, (7 female, 7 male), between 20-25 years old who did not meet any of the following exclusion criteria: previous history of low back pain that involved medical intervention, any lumbar or hip surgery, employment that required prolonged static standing, an inability to stand for more than two hours, any history of dizziness while standing, or any allergy to rubbing alcohol. Participants were instructed to wear running shoes and gym shorts. Clearance for this study was obtained through the University of Waterloo Institutional Review Board.

2.2 Instrumentation

Participants were instrumented with electromyography on their left and right gluteus medius muscles. The area was shaved with a disposable razor and cleaned with isopropyl alcohol, then gently abraded to remove any residual oils from the skin. Silver-silver chloride electrodes were then placed on the skin approximately half way between the iliac crest of the pelvis and the greater trochanter of the femur to collect gluteus medius muscle activity. Gender specific research assistants were made available to assist with attaching electrodes to the gluteal areas. The participant was asked to perform maximal contractions in a standardized position for the muscle groups being recorded. To do this, the participant was instructed to lie on their side with their legs bent, then open the upper leg towards the ceiling while keeping their ankles together. This was done in order to normalize the EMG data to maximum voluntary contraction (MVC) so that it could be compared between participants. Electromyography data were collected at 2048 Hz and bandpass filtered at 10-1000 Hz. Two force plates were used to get separate measurements under the left and right foot. The force applied to the plate under the right foot and body weight of the participant were used to calculate percentage of body weight placed on the right foot. This is represented in the equation below.

$$[(\text{Force on right force plate (N)} / 9.8) / \text{body weight (kg)}] * 100 = \text{percent body weight on right foot}$$

(Equation 1)

2.3 Flooring conditions

Four different types of flooring were tested in this study. The first was a rigid control floor, and the other three were different types of anti-fatigue matting. They differed by material, thickness, and hardness, and they are presented in the table below.

Table 1. **Floor condition characteristics.**

Floor Type	Material	Thickness	Hardness
Bare force platform	-	-	-
Low Stiffness (bubble down)	Foamed Polyurethane	15 mm	22-30 ShA
Medium Stiffness (infinity smooth)	Foamed Polyurethane	11 mm	37-45 ShA
High Stiffness (nitrile smooth)	Nitrile	11.5 mm	50-60 ShA

2.4 Functional Reaches

The protocol for this study involved several functional reaches on the different floor types. The participant performed maximum forward and lateral reaching at hip and shoulder level. They were instructed to start in a relaxed standing posture, then reach until their perceived limit without moving their feet or losing their balance. They performed the two reaches at two heights on all four floor types, for a total of sixteen reaches.

2.5 Data Analysis

Electromyography data were processed according to standard protocols. The mean was subtracted from the signal; full wave rectified, and filtered using a Butterworth filter with a cutoff of 2.5 Hz. The reach profiles were split into five phases (Figure 1): standing prior to the reach (R1), movement to peak reach (R2), holding peak reach (R3), reach to return to standing (R4), and standing post reach (R5). The phases were defined using the center of pressure profile from each trial. In each phase the following measures were calculated – root mean square of the left and right gluteus, cross-correlation of the left and right gluteus medius, and co-contraction index of the left and right gluteus medius.

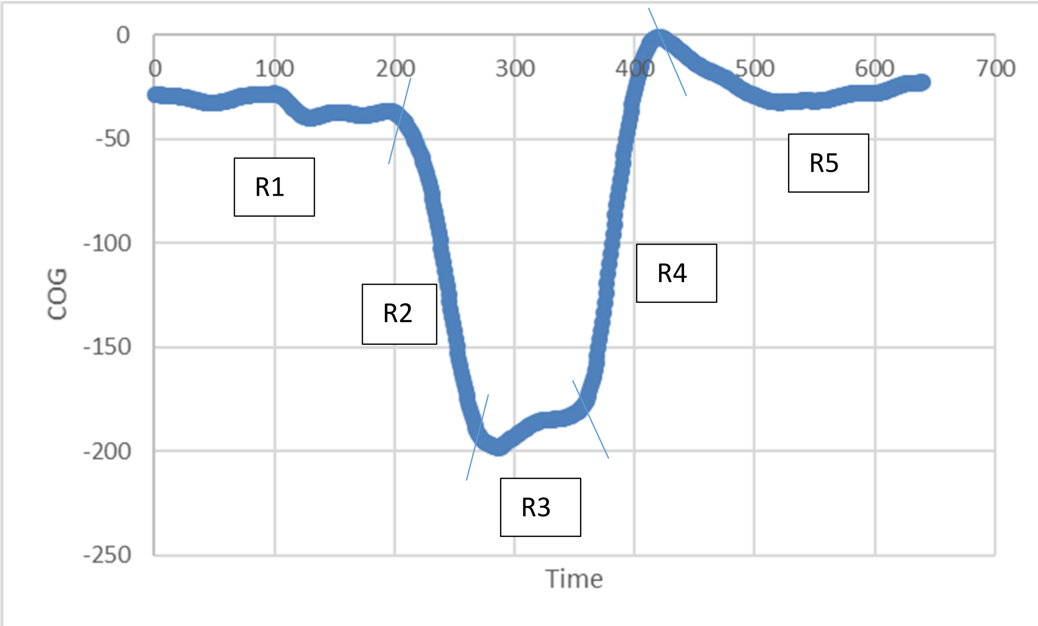

Figure 1: Anterior/posterior and medial/lateral center of gravity (COG) measures were used to divide reach profiles into five phases.

2.6 Statistical Analysis

A three-way general linear model, with factors of floor condition, reach height (hip/shoulder), and time were run on the outcome measures. A two-way ANOVA with repeated measures of floor condition and reach height was run for peak EMG measures. For each outcome measure, separate statistical analyses were run on each phase and reach direction (forward vs. lateral). Tukey post hoc tests were performed on any significant main effects and simple effects analyses were performed on any significant interactions.

3. Results

3.1 Peak EMG Values – Forward Reaches

A main effect of time was found for peak EMG values of forward reaches (p=0.0035). Phases R1 and R5 had peaks of 3.3 (+/-3.4) %MVC and 3.5 (+/-3.2) %MVC, respectively. R3 had an average peak of 7.2 (+/-7.9) %MVC. There was also a trend between peak EMG and floor type, but it was not statistically significant (p=0.081).

3.2 Peak EMG Values – Lateral Reaches

For lateral reaches, there was an interaction between reach height and time (p=0.0007, Figure 2) and mat and time (p=0.0195, Figure 3). The height and time interaction was significant in phases R2 (p=0.0003), R3 (p=0.0125), and R4 (p=0.0046). Shoulder-level lateral reaches had average peak EMG values of 6.7 (+/-5.2), 6.1 (+/-4.6), and 5.7 (+/-4.7) %MVC at R2, R3, and R4, respectively. Hip-level reaches had averages of 5.3 (+/-4.3), 5.3 (+/-4.6), and 4.8 (+/-4.5) %MVC at R2, R3, and R4, respectively.

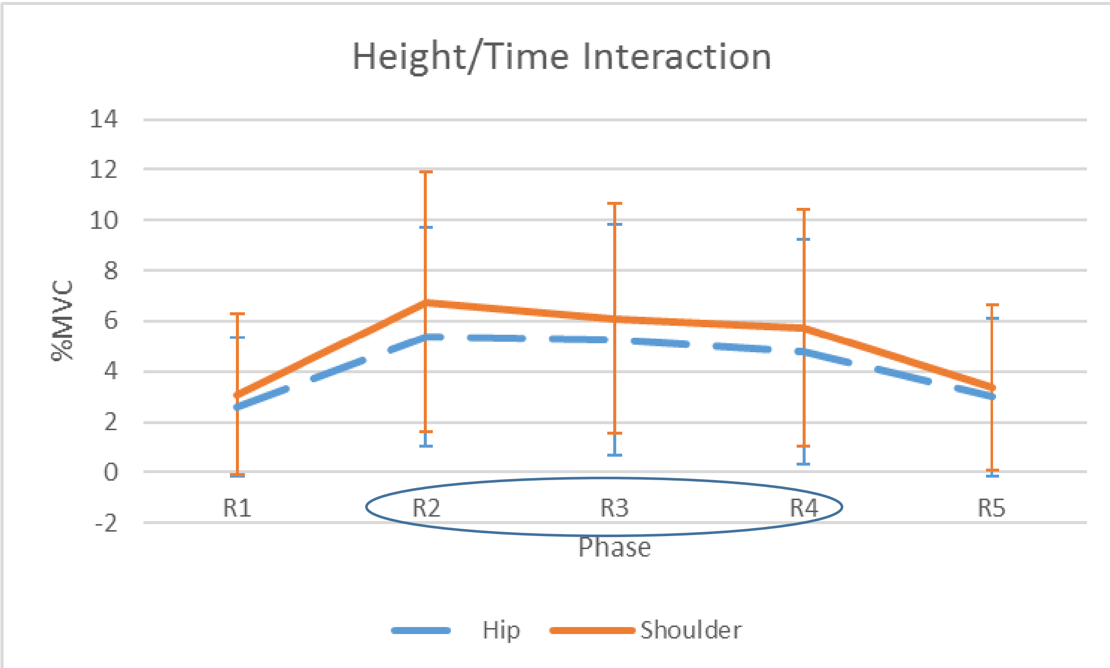

Figure 2. Percent maximum voluntary contraction (%MVC) of peak EMG values for shoulder and hip level reaches. The circled phases demonstrate where there was a significant difference between muscle activity during the hip and shoulder reach heights.

The mat and time interaction was significant during the R2 phase (p=0.0271), with the high and medium stiffness mats showing lower peak EMG values than the low stiffness and control floor conditions. In the R2 phase, the hard and medium conditions had average peak EMG values of 5.2 (+/-4.3) and 5.6(+/-4.3) %MVC, respectively. The soft and control conditions had average values of 6.6 (+/-5.0) and 6.8 (+/-5.5) %MVC, respectively. A similar trend was found during the R4 phase, although it was not statistically significant (p=0.1081). During the R4 phase, the soft condition alone was higher with an average of 6.3 (+/-5.0) %MVC, which the hard, medium and control conditions had averages of 4.7 (+/-4.5), 5.3 (+/-4.4), and 4.8 (+/-4.5) %MVC, respectively.

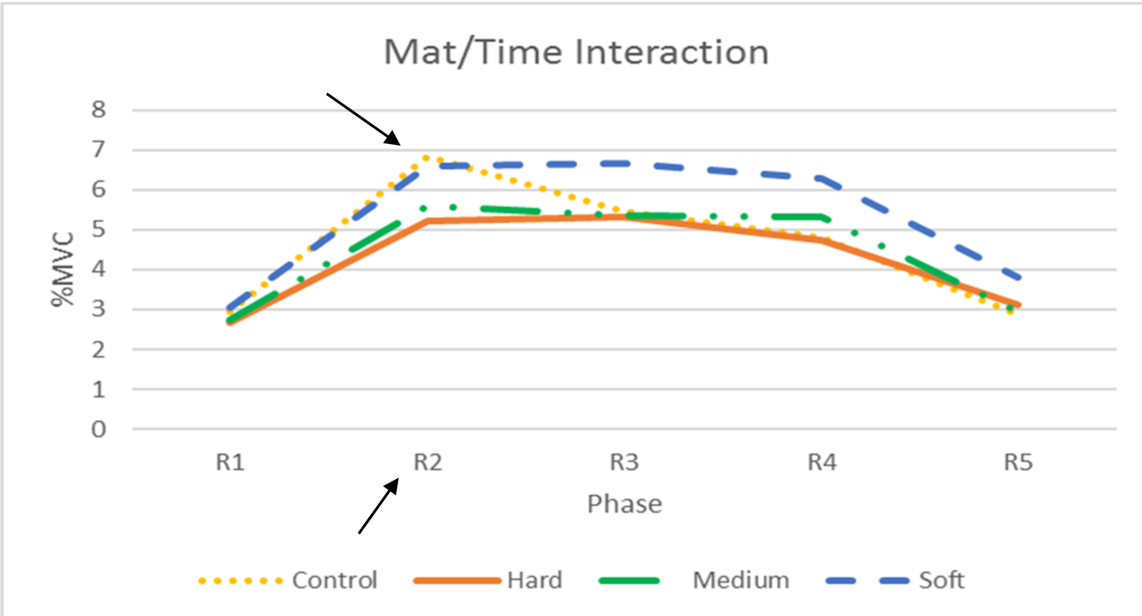

Figure 3. Percent maximum voluntary contraction (%MVC) of peak EMG values on the four different floor conditions. The arrow represents the significant difference between flooring conditions during the R2 phase.

3.3 Percent Body Weight

There were no interactions or main effects found for percent body weight on the right foot during forward reaches. For lateral reaches, there was a main effect of time (p<.0001). The average percentage of body weight on the right foot was 48.3% (+/-2.9) at R1, 79.4% (+/-15.6) at R3, and 47.1% (+/-3.3) at R5. There was no significant difference for the maximum and minimum body weight place on the right foot between the flooring conditions (Table 2).

Table 2. Average maximum and minimum percent body weight on right foot during lateral reaches.

Average Maximum	Standard Deviation	Average Minimum	Standard Deviation
83.7%	15.6%	36.2%	7.7%

4. Discussion

The purpose of this study was to investigate how gluteus medius muscle activity changed during functional reaches on floorings varying in stiffness. Our first hypothesis, that the high stiffness floor condition would have the lowest muscle activity levels, was partially supported. Both the high and medium stiffness floor conditions had peak EMG levels that were significantly lower than the soft and control conditions, particularly during the R2 phase. Our second hypothesis, that reaches at shoulder level would require more gluteus medius muscle activity, was supported. Shoulder height reaches had significantly higher peak EMG levels for the R2, R3, and R4 phases. Our third hypothesis, that less body weight would be shifted on the low stiffness mat, was not supported. There were no statistically significant main effects or interactions found for percentage of body weight shifted during reaches.

We expected gluteus medius muscle activity levels on the control floor condition to be similar to the high stiffness condition; however, it was the medium stiffness condition that remained similar to the high stiffness mat. The higher activity levels of the soft and control conditions during the R2 phase are important because this is the phase when the participant went from standing still to beginning their reach. This means that as the reach begins and the gluteus medius muscles are activated, they are working harder to maintain balance. The soft condition had consistently higher activity levels throughout the reach profile, although it was only statistically significant during R2. This makes sense because less stable surfaces may require more hip muscle activation to stabilize the pelvis.

The magnitude differences found in percent maximum voluntary contraction were only around 1 to 2%. The impact of these small differences on the ability of the gluteus medius muscles to stabilize the pelvis over a prolonged period of time needs to be investigated. Since the gluteus medius co-contraction is a strong predictor of low back pain development during prolonged standing (Nelson-Wong and Callaghan 2010), these small changes could be the difference between developing pain and not developing pain.

As we expected, peak gluteus medius EMG values were higher during shoulder level reaches compared to hip level reaches. Between phases two to four, gluteus medius muscle activity was higher during shoulder level reaches by 1% MVC compared to hip level. When one reaches their arm to shoulder height, the center of mass location will move vertically and anteriorly. As a result, your gluteus medius muscles may be required to contract at a slightly higher activation level to maintain your balance.

This study has shown that certain anti-fatigue mats can reduce muscle activity in the gluteus medius muscles. This agrees with a past study that showed erector spinae muscle activity is reduced by anti-fatigue matting (Kim, Stuart-Buttle, and Marras 1994). The muscles of the legs, specifically the tibialis anterior, seem to be less affected by matted floors because they do not show reductions in muscle activity (Cook et al. 1993 & Kim, Stuart-Buttle, and Marras 1994).

We hypothesized that less body weight would be shifted to the right leg during the reaches when standing on the soft floor condition since it is a less stable surface; however, floor stiffness had no effect on percentage of body weight shifted. During forward reaches, participants kept a mostly even body weight distribution. During lateral reaches, around 80% of their body weight was shifted to the right foot on all floor conditions. It is possible that the unstable surface of the low stiffness mat only increased gluteus medius muscle activation without restricting ability or willingness to shift weight.

Reach distances were assessed separately and were found to not be significantly different between participants. One limitation to this study is that all participants were 25 years old or younger, and gluteus medius muscle activity may change differently during reaches in middle-aged to older adults. A second limitation is that only three different types of anti-fatigue mats were tested in this study, focusing mainly on hardness, but there are many different mat variations (Cham & Redfern 2001) that could change how muscle activity is impacted.

5. Conclusions

Gluteus medius muscle activity was affected differently during forward and lateral reaches. Muscle activity increased during peak reach in both directions, but only lateral reaches were impacted by reach height and floor type. The low stiffness anti-fatigue mat showed higher activity levels than the rigid control floor, while the hard and medium stiffness anti-fatigue mats could potentially reduce muscle activity. It is currently unknown if an increase in muscle activity during these tasks would be beneficial in assisting with stability, or if it could accelerate muscle fatigue during prolonged tasks. Future studies should look at how anti-fatigue matting affects the muscle activity over prolonged periods of time and in older adults who may not be as capable of shifting their full body weight and maintaining their balance.

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