The Effect of Surface Type and Incline on Walkers from the Ages of 19 to 25: a Study Using EMG to Gastrocnemius Activation

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Abstract

Walking is a popular activity, but factors such as muscle overuse can lead to musculoskeletal injuries [1]. To prevent these injuries, it is important to understand the factors that contribute to muscle activation during walking so that training can be better structured. This study investigates the effects of different surface types and inclines on the average activation of the gastrocnemius using EMG. A digital band-stop filter was used to attenuate noise from electrode movement and an analog bandpass filter was used to isolate frequency bands of interest. Subjects walked on inclines of 15°, 0°, and -6° for ten steps to study the relationship between incline and muscle activation. To compare the relationship between surface type and muscle activation, subjects walked ten steps on a treadmill for the hard surface and sand for the soft surface. The same cohort of healthy participants (N = 13) was used in both experiments. We found a significant increase in muscle activation for 15° and -6° compared to a flat surface. Additionally, we found a significant increase in muscle activation on a hard surface (treadmill) compared to a soft surface (sand). We conclude that there is a relationship between muscle activation with surface type and incline, which is important so that walkers can avoid conditions that would increase the likelihood of overuse injuries.

Introduction

Going on long walks has been an increasingly popular activity but comes with the concern of muscle pain and injuries [1, 2]. Various factors can contribute to these injuries, but muscle overuse is one of the most common and can result in pain while walking for long amounts of time [3]. It is important to understand what factors contribute to muscle activation while walking so that injuries can be prevented. As the body moves forward, the gastrocnemius muscles will have most of the impact during the terminal stance of the gait cycle [4]. We decided to focus on this section of the cycle because the difference between walking on soft vs hard surfaces, and walking on an incline vs decline, will be more noticeable for comparison as the EMG output will be more significant during the terminal stance.

Our first aim is to examine the effect of an incline and decline on the activation of the gastrocnemius muscle. We will analyze the EMG signal at varying inclines and determine the relationship between the average activation of the gastrocnemius muscle and incline. We hypothesize that walking up an incline will increase gastrocnemius activation while walking on a decline will reduce activation. This is because it takes more muscle activation to stiffen one's leg to keep them stabilized on an inclined surface [1, 5]. Previous literature has studied muscle activation while on an incline but has not compared these results to a decline [5]. We will compare muscle activation across a range of percent grades, inclusive of both incline and decline.

Our second aim is to examine the effect of different surface types on gastrocnemius muscle activation. We will determine a relationship between the EMG signal and walking on a hard vs

soft surface. We predict that we will see an increase in muscle activation while walking on soft surfaces compared to harder surfaces. This is due to the activation that stiffening the legs would require to balance on unsteady terrain [1]. We decided to focus on this because there is no literature that investigates the effect of incline and surface hardness on the gastrocnemius. While hard surfaces and soft surfaces have been used for testing in separate independent studies, there have not been any studies comparing gastrocnemius activation between the two.

While there is previous literature, they did not explore the activation for surface hardness and the activation from decline comparing it to the incline and flat surfaces [1, 5]. Knowing these results would allow the people who are at risk of overuse injuries on the gastrocnemius to know what conditions would help them prevent further injury while allowing them to have the opportunity to enjoy their activities.

Materials and Methods

We recorded EMG data at a sampling rate of 1200 Hz and used an analog bandpass filter between 20 Hz and 450 Hz with a gain of 1,729.89 Ω to remove noise [6]. By knowing the length of the trial and the number of steps the participants took, we were able to calculate the frequency of their steps (steps per second). We then used a digital band-stop filter in MATLAB to attenuate signals five percent above and below this frequency. To save the data, we used a Python script to convert the Arduino serial outputs into a text file.

Our experiments consisted of thirteen subjects, including males and females between the age of 19-25 years old, with no current lower leg injuries (Figure 2). We placed the electrode on the

most prominent part of the inner gastrocnemius on their left leg, and another one no more than 20mm away from the first one [7]. We placed a ground electrode on the medial malleolus (Figure 1).

Figure 1: Placement of electrodes on the left inner gastrocnemius and ground on the medial malleolus

For our first aim, we had the subject start their gait cycle with their left leg to ensure that the number of steps that the subject takes will be the same for all subjects. Data was recorded as the subject started walking at one mile per hour, and the recording ceased when the subject took ten steps. Data was collected for percent grades of 15%, 0%, and -6%. The participants were instructed to walk heel first and allowed to freely move their arms. The participants started at a 0% grade, then measured 15% and -6%. The resting period was set to be around 5 minutes between the different grades.

For our second aim, we had the subject start their gait cycle on their left legs as well. They were instructed to walk on the treadmill for ten steps, and then repeat the same process in the sand.

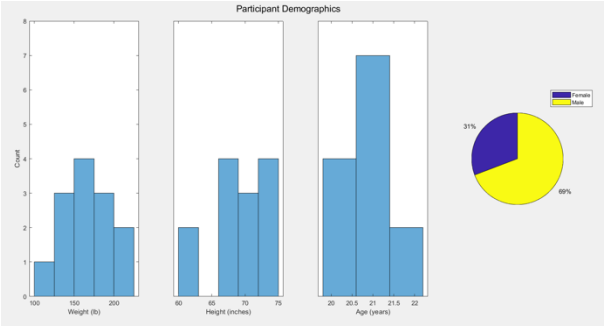

Figure 2: demographics of participants

To process the data, the mean absolute value for each trial in each group was calculated using MATLAB. A one-way ANOVA test and post hoc Tukey multiple comparisons test was used to calculate differences within groups for each aim. A one-way ANOVA was used for aim two and not a paired t-test as the two trials were assumed to be independent. All tests used an alpha value of 0.05.

For aim one, our null hypothesis is that there is no statistical difference in gastrocnemius activation between any of the percent grade groups. Our alternative is that gastrocnemius muscle activation will be least on the -6% grade slope and be the highest on the 15% grade slope. For aim two, our null hypothesis is that there will be no statistical significance in gastrocnemius activation when walking on a soft or hard surface. Our alternative hypothesis is that there will be an increased activation in the gastrocnemius when walking on a soft surface.

Results

For aim 1, the results of the one-way ANOVA revealed a significant effect of incline on mean absolute value ($F(38) = 5.05$, $p = 0.0116$). Tukey's HSD Test for multiple comparisons found that the mean absolute value of incline was significantly different between flat ($p = 0.0335$). Additionally, Tukey's HSD Test for multiple comparisons also found that the mean absolute value of decline was significantly different between flat ($p = 0.0183$). However, there was no

significant difference between incline and decline (p = 0.9659). (Figure 3). A single asterisk denotes a p < 0.05 and p > 0.01.

For aim 2, the results of the one-way ANOVA revealed a significant effect of surface type on mean absolute value (F (25), = 4.36, p = 0.0475) (Figure 4). A single asterisk is used when p < 0.05 and p > 0.01.

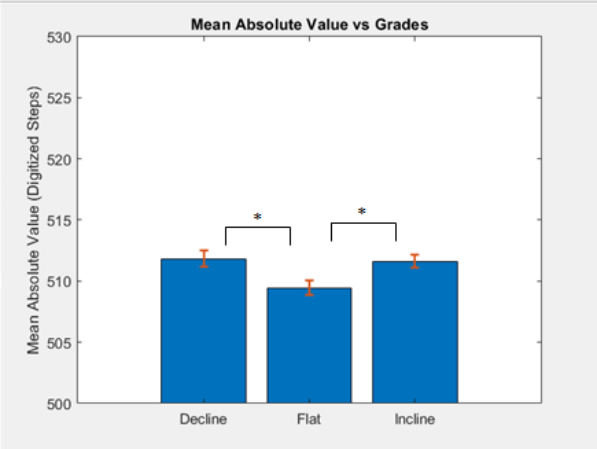

Figure 3: Mean absolute value of EMG data using a one-way ANOVA test (N = 13) comparing –6%, 0%, and 15% grades shows that both –6% and 15% were statistically significant with the 0% incline

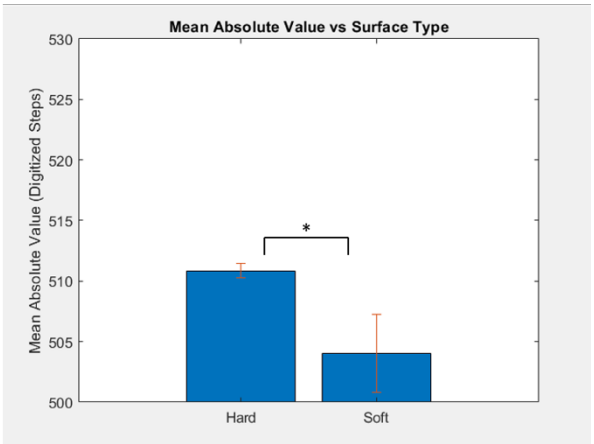

Figure 4: Mean absolute value of EMG data using a one-way ANOVA test (N = 13) shows that gastrocnemius activation between hard and soft surfaces are statistically significant, with a p-value of .047.

Discussion

For our first aim, the results demonstrated that muscle activation of the gastrocnemius increases as the percentage grade of a surface deviates from zero, whether it be in a positive or negative direction. We found that there is a statistical difference between the flat and declined surfaces, and then flat and inclined surfaces. There is no statistical difference between the inclined and declined surfaces. Our results for the inclined surface are consistent with previous literature, which has reported an increase in muscle activation on an incline [5]. Previous literature has not mentioned muscle activation while on a decline. Our alternative hypothesis predicted that gastrocnemius activation would be the smallest on a decline and highest on an incline. However, our results slightly differ from our hypothesis, as gastrocnemius activation increased in both a positive and negative percent grade. We suspect that the increased activation on a decline is due to the increased demand that gravity places on the leg during a downhill segment. Because of this, there is no statistical significance between the inclined and declined groups.

For our second aim, the results demonstrated that muscle activation of the gastrocnemius was greater for hard surfaces than it was for soft surfaces. Our alternative hypothesis stated that gastrocnemius muscle activation would be greater for soft surfaces, while reduced on harder surfaces. The results show the opposite, as muscle activation increased for harder surfaces and decreased for softer surfaces. Previous studies have not examined the effects of surface hardness on gastrocnemius muscle activation, so the yielded results were informative.

We found a 0% incline and soft surface to have the least muscle activation, so we recommend people to walk on these types of surfaces for the lowest chance of injury. For the results of both experiments, we expect that people will be able to better structure their training to avoid injuries.

The knowledge of how surface type and incline affect muscle activation allows athletes or hobbyists to avoid or target specific situations depending on their intent with that specific activity. For example, if an athlete wants to have an easier day as they feel fatigued, they can choose to walk on a soft and/or flat surface to limit the amount of muscle activation or effort they must exert. Quantifying these situations with muscle activations fills the gap in literature and equips athletes with the knowledge of how their training conditions affects them.

While we were able to find significant differences in our experimental groups, there are limitations in the study that could have prevented us from getting the best results. One of these limitations is errors caused by electrodes moving during the gait cycle. We encountered noise in some of the data collections from the EMG, and a lot of them came from the electrodes themselves. We found that simply replacing the electrodes on the participant with a new one was sometimes a way to reduce unwanted noise. Additionally, the alligator clips used were another source of noise that could have disrupted the signal. There was so much resistance in the clips that we were unable to daisy chain them to create longer wires. Doing so would create enough noise that there would be no noticeable difference in signal amplitude when the gastrocnemius was contracted or relaxed. Another limitation of this study is that all participants self-reported their height and weight. This may affect our demographic target by ensuring that we cover a broad range of heights and weights.

For further exploration related to this study, we would like to test various surface elasticities, such as comparing a more elastic surface (rubber track) to a non-elastic surface (concrete). Additionally, adding components including Bluetooth or SD card will make the device more

portable, making data collection cleaner and more efficient. In future studies, we would also like to test under strenuous activities such as running because running requires more activation and would help us see a bigger difference between the different variables. Lastly, we would like to measure activation in other muscles during different sections of the gait cycle because testing during various parts of the gait cycle would help us gain knowledge about the muscles used during distinct parts of the gait cycle.

Conclusion

In this study, we established the relationship between the average activation of the gastrocnemius and the surface hardness and incline using an EMG device. Based on the findings of this study, the gastrocnemius muscle had greater activation when walking on harder and more inclined surfaces. To avoid injuries such as muscle overuse, these results can be used to plan out training and choose surfaces based on the desired training effect. For those who commonly walk as a hobby, these findings can be incorporated into daily life to help ensure the health of their legs and keep injuries subsided while enjoying the outdoors. Lastly, the results of this study fill the previous gap of knowledge on the effects of incline and surface type on gastrocnemius activation.

Citations

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