EFFECTS OF HEEL HEIGHT ON STIFFNESS IN THE GASTROCNEMIUS OF YOUNGER WOMEN

by

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Introduction

In years past, numerous studies have been completed on footwear products, but are typically only limited to athletic type shoes and their benefits to increasing abilities on and off the field. Not much research has been done on the negative effects of professional shoes and how they play a role in the changing structures of the lower extremities that result in pain for the wearer. Anecdotally, studies that have been completed by the research team have suggested that women generally have stiffer calves than men. A likely mechanism for this is that high heeled shoes keep the gastrocnemius muscle in a shortened position for great lengths of time leading to increased stiffness.

High heeled shoes are very common among women, in fact 72% of women wear high heeled shoes at some point in their life. Aside from its popularity, wearing high heeled shoes has been associated with instability of the ankle muscles, shortening of calf muscles and even back pain and muscle fatigue. While wearing high heeled shoes the foot is fixed at an angle; the belly of the calf muscle condenses and stiffness increases. Long-term use of wearing high heels could alter the shape of the muscle and change its functionality.

Background

According to recent studies, of those 72% of women who wear high heeled shoes at some point in their life, 40% wear them on a daily basis and 10% wear them for more than eight hours a day. Some studies have shown an increase in heel height up to 8 cm, has altered the posture and gait of women by shortening the medial gastrocnemius muscle by up to 12%. Studies have shown that high heeled shoes increased knee flexion while decreasing ankle eversion. Another indicated, when the heel is elevated, it requires more work from the muscles of the lower leg, which relates to decrease in balance. The reduced range of motion increases the risk of ligament sprains and decreased shock absorption.

Furthermore, the annual health care cost as a result of high-fashion footwear is estimated to exceed $3 billion.

One study even found that the length of calf muscle fibers were up to 13% shorter in those who wore high heels compared to those who do not. These shortened fibers can affect how a muscle contracts, resulting in less force production when walking. As a result of the shortened fibers, those who wear heeled shoes over long periods of time can even begin to experience discomfort and pain when they do not wear heeled shoes because of the alteration of the muscle. Researchers suggest that those who wear heeled shoes should adequately stretch their calves and feet often to avoid the permanent change of the muscles. Overall, studies have concluded chronic wear of high heel shoes can permanently alter musculature in the leg and contribute to muscle overuse and overcompensation, increased stiffness, and decrease in balance.

Based on these studies, researchers for this study have designed specific research questions to guide the study to focus on how stiff the gastrocnemius muscle becomes throughout an eight-hour workday. These questions can be crucial to understanding how heels effect women over the course of a single day and interpret the results to how these heels can affect women if they continue to wear heels for extended periods of time over the course of their lives.

Purpose of the study

Researchers will be examining the effects of heeled shoes and how they play a role in calf stiffness, and potentially leading to increasing pain. Studies have also shown that there is a direct correlation between pain and stiffness in muscles, so the purpose of this study will be to determine how heeled shoes effect women's pain and stiffness and, if possible, attempt to change designs or workplace policies regarding what is deemed as a "professional" shoe.

Research questions

This research is based much more on guiding questions than it is on a single hypothesis. These guiding questions help keep researchers focused on what we are researching, why we are researching it, and why it is important.

The guiding questions for this project are as follows:

1. By what value does stiffness increase in the gastrocnemius muscle throughout an eight-hour workday while wearing heeled shoes?
2. Does wearing heeled shoes contribute to stiffness significantly more than other shoes?
3. How can we use this research to change how often women wear heeled shoes, and if needed, how do we change workplace policies to redefined what is deemed as a "professional" shoe for women?

Methodology

This study will be conducted by using shear wave ultrasound imaging of the medial and lateral gastrocnemius of each leg by showing change in stiffness from the beginning to end of a typical eight-hour workday. The purpose of shear wave ultrasound imaging is to send sound waves through tissue of the body and observe how quickly it moves. These shear waves sent through relaxed muscles tend to move much slower than in stiff muscles. Once sheer modulus is determined by the reading on a relaxed muscle at the beginning of the day, another reading will be taken at the end to determine how stiff the gastrocnemius actually became throughout the day. In order to definitively state that heeled shoes play a negative role in calf stiffness, researchers will be examining numerous women, with ultrasounds taken at both the beginning and end of the day. This methodology will allow researchers to determine by what

value of shear modulus the heeled shoes really cause throughout an eight-hour workday that leads to immense stiffness and pain.

The methodology for the study will be as follows. Twelve participants will be recruited by poster advertisement and word of mouth. The participants must be between 18-50 years of age, wear high heeled shoes at or above 2 inches, wear high heeled shoes regularly (at least 8 hours a week), and have no previous foot/ankle surgery or current lower extremity injuries. During the visit, each participant in the experimental group will read and sign an informed consent form, have their height and weight measured, and undergo panoramic ultrasound, which will determine the beginning and end of the Gastrocnemius belly, and have length the of Gastrocnemius measured with measuring tape and marked.

The participant will then have ultrasound elastography performed in the middle of the measured section at the beginning of the simulated eight-hour workday. They will then put on high heel shoes with a desired heel height. Participants will participate in several activities while wearing the heels. These activities include level surface walking and walking up and down the stairs. The remainder of the day will be spent seated at a computer. Participants will be instructed to keep their shoes on but can use this time at their leisure. Breaks will also be freely available for lunch and restrooms trips. At the end of the simulated eight-hour workday, the participants will have ultrasound elastography performed at the same location of the gastrocnemius as they did at the beginning of the day. Researchers will then take the average of the ultrasound elastography readings from both the beginning and end of the day and analyze the data. Data will be analyzed using graphs and paired sampled T-Tests with an alpha level set at 0.05. This test will take into account the averages of each muscle over all the participants. If the alpha value is determined to be less than 0.05, then the data will be classified as statistically significant.

Closure

Results:

At the conclusion of participant readings, researchers compiled the data into a chart consisting of all the shear modulus readings from each participant from both before and after their simulated eight-hour workday. Based on the data, researchers can see a clear increase in the Kilopascal readings of each muscle from each participant.

Structure	Beginning of Day (kPa)	End of Day (kPa)
Lateral Gastrocnemius (Left)	14.1	18.1
	17.1	23.7
	13.9	17.3
	13	20
	11.2	14.9
	12.9	15.1
Medial Gastrocnemius (Left)	19.8	20.8
	17.9	21.4
	12.7	20.8
	12.8	20.4
	14.1	18.7
	12.9	18.5
Medial Gastrocnemius (Right)	16.2	26.1
	16.8	25
	11.1	19
	10.5	17.4
	12	19.9
	13.3	20.2
Lateral Gastrocnemius (Right)	15.5	16.9
	15.4	18.2
	11.2	18.6
	12.6	18.6
	17.4	21.9
	16.2	22.6

Figure 1: Kilopascal Readings Taken from Each Participant Before and After Research

Researchers used this data to form different charts used to visualize change. The first of these charts is a line graph, where each dot on the graph represents a participant's specific muscle that is being measured, both before and after the experiment. This graph does however

violate the independence of samples. Due to the small sample size, numerous readings were taken of each participant. In the graph, every two dots represent two readings from a single participant.

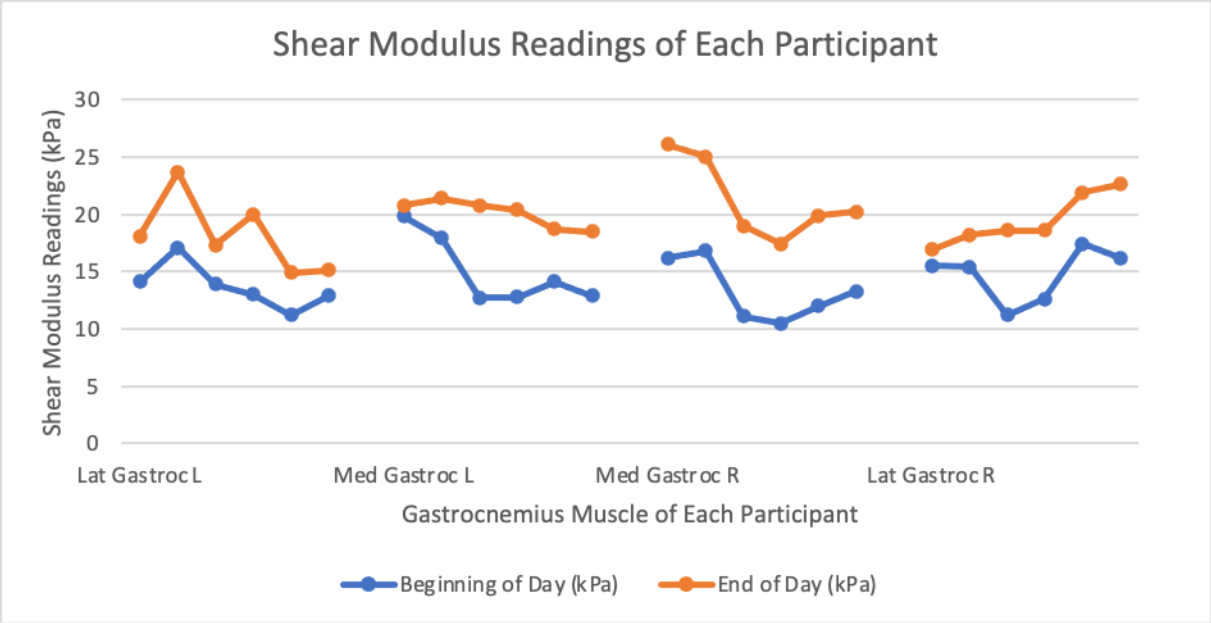

Figure 2: Shear Modulus Readings of Each Participant Before and After Research

Because of the violation of independence of samples, researchers analyzed paired sampled T-Tests with an alpha level set at 0.05. If the data shows that the alpha level is less than 0.05, then the data will be classified as statistically significant.

T-Test	Alpha Level
Lat Gastroc Left	0.00218
Med Gastroc Left	0.00542
Lat Gastroc Right	0.00001
Med Gastroc Right	0.00389

Figure 3: T-Test Data of Individual Muscles for Combined Participants

The third graph created shows a visualization of the data in the form of a box plot. This chart allows researchers to combine the data of each muscle from each participant with both the average readings and the outliers at both points of data collection.

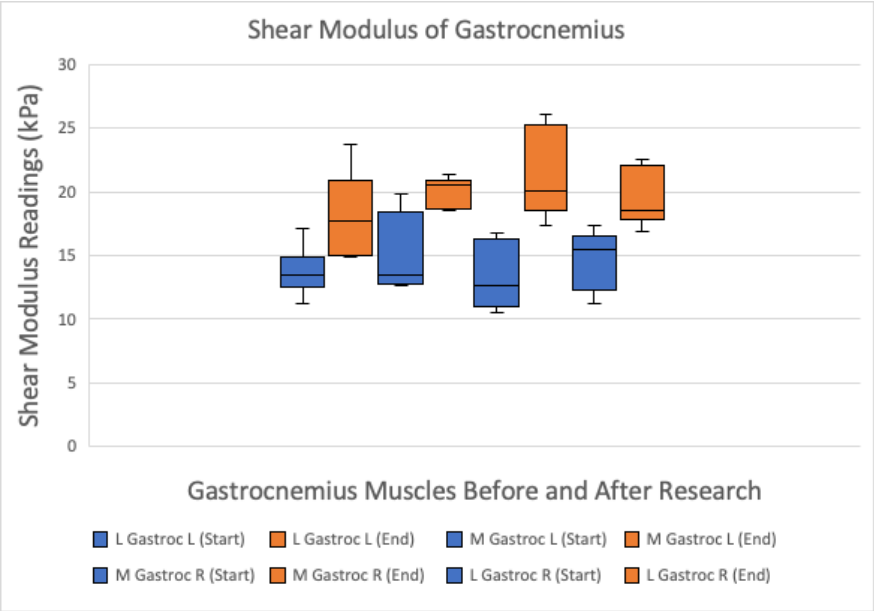

Figure 4: Combined Shear Modulus of Gastrocnemius Based on Individual Muscle

The final chart that was created shows the combined averages of all readings from before and after experimentation. The four muscles being examined from all participants were compiled into one box plot reading showing the mean and outliers taken at the start of the experiment. This same process was also completed for the end of the day readings.

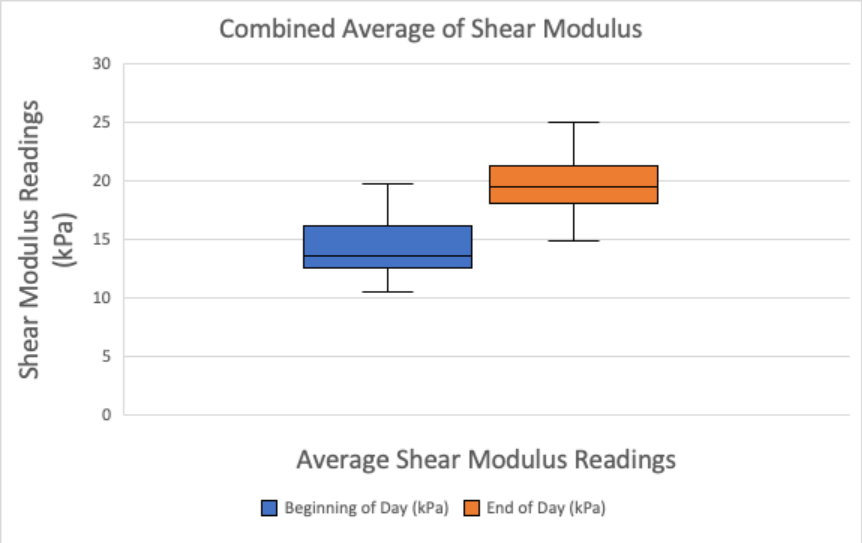

Figure 5: Combined Average of All Shear Modulus Readings

Discussion:

After the conclusion of the study, the data collected shows that shear modulus increases in all gastrocnemius muscles throughout an eight-hour workday as a result of heeled shoes. Based on the findings of the study, the lateral and medial gastrocnemius muscle have changed in stiffness by varying rates among each participant, but all of the participants showed increase in stiffness. The lowest change researchers observed was only 1 kilopascal, while the greatest change was 9.9 kilopascals. After the compilation of all readings, researchers found that each muscle increased by an average of 5.56 kilopascals. The T-Tests also prove that the data collected can be deemed as statistically significant as all the Alpha values are significantly less than 0.05.

These findings are important because they show that even wearing heeled shoes for as short of time as a single workday has drastic impact on the stiffness of the lower extremities.

Based on other research, it has been found that this change in shear modulus can permanently alter women's musculature. One day of wearing heeled shoes will not lead to lasting effects, but this research should show women that they need to be more selective about how often they do wear heeled shoes. These findings can also be used to continue research. Such studies could be as follows: "By what value does wearing heeled shoes contribute to increased stiffness over heelless shoes", "What other lower extremities are effected by wearing heeled shoes", "How many companies require heeled shows and what is the quality of life of their employees compared to companies who do not require heeled shoes."

There are a few limitations of this study. The main limitation is the sample size. Due to the short timeline of the research study, researchers found it hard to acquire an ample number of participants. Because of this, researchers were unable to perform the necessary requirements of all the participants to conclude the study. To make a definitive claim, researchers aimed to complete the study on at least four participants. If all four results point in the same direction, researchers can hypothesize that the other eight will continue on that trend. Researchers also encountered numerous cancelations of the participants leading to only three participants actually participating in the research. Because of the small sample size, researchers were formed to violate the independence of samples. Another limitation is that this study did not have a control group. In order to make a more accurate claim, a control group would help researchers decipher whether heeled shoes contribute heavily to gastrocnemius stiffness or if these muscles just become stiffer throughout the day regardless of the shoe type. The final limitation is the population of the participants. Since researchers are young adults at ECU, the easiest way to get participants to partake in the study is by asking peers. This results in a relatively specific population of females between the ages of 18-25 years old.

The first presentation of this research will be completed at the RCAW on April 3rd, 2023. The second presentation will be completed on May 4th in front of numerous professors and researchers in the Kinesiology Department of ECU.

Even though my career path no longer takes me down the path of research, I greatly enjoy studying the human body and how it functions. This research will help me in future endeavors as it has taught me the value of listening to those who are more experienced than you, as well as the willingness to adapt your methodology if it will yield better results; even if that means the path is challenging and takes more time.

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