GÖTEBORGS UNIVERSITET

INSTITUTIONEN FÖR KOST-
OCH IDROTTSVETENSKAP

Effects of foam rolling on ankle joint ROM and hamstring flexibility

Oskar Brengesjö
Jonathan Lohaller

Kandidatuppsats 15 hp
Program: Sports Coaching
HT 2017
Handledare: Lennart Gullstrand
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Abstract

Foam rolling is a popular tool among athletes and recreationally active individuals. The manufacturer's promises athletic improvements but little is known what benefits the foam roller gives. In this intervention study, we will explore self-myofascial release with foam rolling. 17 recreationally active subject foam rolled the hamstring muscle, calf muscles, and plantar fascia for 60 seconds with one leg, the other leg was used as the control group. The ROM and flexibility in the ankle and hip joint were measured with the mobee device, before and after the intervention. SPSS was then used to calculate the differences achieved after rolling. Influencing factors such as gender and activity type were also looked at to find variables that influence the result. No significant results were found when comparing the foam rolling group to the control group, responses to the rolling vary greatly, much like previous research. More research is required to understand why the individual responses differ, research should focus on what effect foam rolling has on muscle and surrounding tissue.

Sammanfattning

Foam rolling är ett populärt verktyg bland idrottare och fritidsaktivister. Tillverkarens löften är atletiska förbättringar men vilka fördelar som foam rolling ger är inte klarlagt. I denna interventionsstudie utforskar vi self-myofascial release med foam rolling. 17 rekreationsaktiva deltagare foam rollade hamstringsmuskeln, vadmuskeln och plantar fascia i 60 sekunder med ett ben, det andra benet användes som kontrollgrupp. Rörelseförmågan i fotleden och höftleden mättes med mobee-enheten före och efter interventionen. SPSS användes för att beräkna skillnaderna efter foam rolling passet. Påverkande faktorer som kön och aktivitetstyp betraktades också för att hitta variabler som kan påverka resultatet. Inga signifikanta resultat hittades när man jämförde foam rolling gruppen med kontrollgruppen, resultaten varierar kraftigt likt tidigare forskning. Mer forskning krävs för att förstå varför de individuella resultaten skiljer sig, forskning bör fokusera på vilken effekt foam rolling har på muskel och omgivande vävnad.

Acknowledgement

Task assignment	Percent performed by Oskar/Jonathan
Planning of the study	50/50
Search of literature	50/50
Data collection	50/50
Analysis	50/50
Writing	40/60
Layout	60/40

First, we would like to thank our supervisor Lennart Gullstrand at the University of Gothenburg for his support and guidance. We would also like to thank Stefan Grau along with Elias Johannesson at CHP at the University of Gothenburg for their knowledge and constructive feedback with the statistical analyses. We also want to thank our coworker during this study, Florian Birk for his commitment and teamwork during the process of this study. At last special thanks to all the subjects that joined our study, making the study possible.

Table of contents

Introduction

There is a constant striving in competitive sports to improve their opportunities for better performance and results. By streamlining the training method, using the right materials and tools, keeping track of the diet and try to influence the rehabilitation, it is believed to affect the performance for the better. To practice a physical activity, it is necessary to have functional skeletal muscles that can perform the required work. The muscles of the body are surrounded by a fascia whose main task is to keep the respective muscle groups in place and facilitate the muscular movement pattern (Myers, 2014). This, in turn, has led to the attempt to find methods where one can affect the tenderness and stiffness of the fascia. According to Freiwald, Baumgart, Kühnemann, and Hoppe (2016), problems with fascia have been treated with methods such as osteopathy, massage, and physiotherapy where the goal is to bring the muscle and fascia back to normal condition. One type of such a method is self-myofascial release (SMR), which means a type of self-massage where you put pressure on the fascia so that it changes the formation into a normal and elastic condition (Curran, Fiore & Crisco, 2008). A type of SMR is the use of foam rolling that may have different effects on performance, flexibility, range of motion (ROM), reduction of delayed onset of muscle soreness (DOMS) and perceived pain (Freiwald et al., 2016; Schleip & Müller, 2012). The use of foam rolling is a relatively new phenomenon and although studies have not shown that foam rolling has an absolutely positive effect, the sports world has already embraced the use of foam rolling into their specific sport. A problem with the research of foam rolling is that it is limited and inconclusive. Most of the available research use different methods, for both the foam rolling protocols and to measure expected effects. Research done has a lack of guidelines and proof of the effects of foam rolling, meaning researching foam rolling without addressing these problems, will be of limited value. The answers of what may be influenced from foam rolling could lay in the fascia and how different properties of the fascia respond to foam rolling. Understanding of how the foam rolling effects fascia and its effects on flexibility, ROM would contribute to an understanding which in turn could help athletes in their pursuit to achieve greater performance and results in their sport. By conducting a study with clear parameters so intend this study to provide clarity in this area to eventually can provide guidelines for different sports for which foam rolling is suitable for. Today there is a lack of research around which foam rolling targets and, above all, the effects that can be predicted before starting a session foam rolling.

Aim

The aim of this study is to analyze the effects of foam rolling on the range of motion in the ankle joint and the flexibility in the hamstrings. The study also strives to clarify if gender, the amount of force exerted, type of activity and time spent exercising have an impact on the effects of foam rolling. Last, this study is meant to give suggestions for areas that future research should focus on and methods that should be used when doing the intervention with a foam roller.

Research questions

1. Does foam rolling have an acute effect on range of motion at the ankle and hip joint?

2. Is the result influenced by gender, type of recreational activity, time spent exercising or force exerted when foam rolling?

Background

Anatomy of the fascia

Fascia is a three-dimensional organ that envelopes the contents within the body, from head to toe it surrounds organs, muscles, and bones. The fascial network is built as a tensegrity structure, distributing loads and forces along the whole network (Myers, 2014). The definition of fascia differs from the sources. But fascia refers to connective tissue that mainly consists of layers with collagen fibers, separated by adipose tissue. The connective tissue is mainly made of collagen, elastin and ground substance. Collagen provides support and structure, elastin provides flexibility and ground substance surrounds cells, determining their function (Barnes, 1997). The fascia is complex, appears and functions differently depending on where it is located, commonly mentioned in the literature is the superficial fascia and the deep fascia. Simply put the superficial fascia is a loose connective tissue, can be found just below the skin. The deep fascia is a very dense connective tissue that envelops muscles and bones, it is commonly found deeper below the skin. Both are also divided into layers, separated by adipose tissue that can be seen in figure 1 (Stecco, Porzionato, Lancerotto, Stecco, Macchi, Ann Day & De Caro, 2008). To complicate things the distinction is not always clear. Langevin & Huijing, (2009) reports that the superficial fascia is at places as dense as the nearby deep fascia, making the distinction between superficial fascia and deep fascia difficult and changing how the superficial fascia responds depending on where it is stimulated.

The viscosity of connective tissue varies from firm to gel form (Paoletti, 2006). The viscosity of the connective tissue is determined by the loading or stress history of the area. Viscosity is important in sliding filament, a more gel-like connective tissue allowing the layers of fascia and muscles to slide along each other, providing greater flexibility. It might also improve circulation within the fascia (Schleip and Müller, 2012).

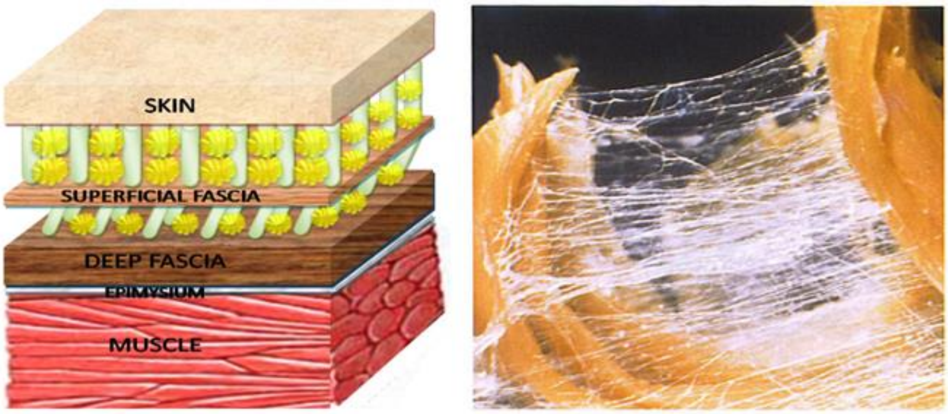

Figure 1. Subcutaneous tissue (Stecco et al., 2008) and connective tissue (Myers, 2014)

Function of the fascia

The main function of the fascia is to provide stability to all structures inside the body, while also absorbing external forces. It also acts as a force transmitter between bones and muscles, allowing movement such as walking and running. It has a tensegrity structure that allows it to distribute pressure along its entire structure (Myers, 2014). The fascia also plays an important role in communication. Through its tensegrity structure, it adapts to loading and stress without any interaction from the brain (Myers, 2014). It also interacts with the autonomic nervous system with its abundance of nerve endings. The fascia acts as an important sensory organ with its numerous mechanoreceptors. This allows the fascia to actively contract through smooth muscle cells, influencing the musculoskeletal system and changing the viscosity of the fascia (Schleip, 2003a; Schleip, Klingler, & Lehmann-Horn 2005). Thus, changes in the substance and viscosity from the likes of trauma, overstretching or overload can lead to adhesions or scar tissue to form. This is due to the fibrous connective tissue stiffening, making it harder for the muscle and the layers of fascia to slide along each other. In turn, this is reducing elasticity, causing pain and discomfort (Barnes, 1997) and can lead to chronic pain and limit extensibility of muscles (Schleip, 2012). Patients with chronic back pain suffer from an immobile fascia compared to healthy volunteers (Langevin et al, 2011). This creates the assumption that a movable fascia is a healthy fascia (Griefahn, Oehlmann, Zalpour & Piekartz, 2015).

Myofascial release

Myofascial release (MFR) is a manual therapy technique aimed to loosen up and stretch restricted fascia. The procedure is done by applying pressure over time to trigger points in the fascia, releasing tension as a result (Barnes, 1997). MFR in fascia supposedly stimulates the mechanoreceptors, which in turn relaxes the fascia and change fluid dynamics and tissue metabolism (Schleip, 2003a). The warmth generated from stimulation could also have a positive effect on the viscosity of the fascia (Barnes, 1997). The relaxation effect is thought to be a neurophysiological one while the influences in the viscosity of the fascia might be because of changes in the ground substance from the stimulation and warmth (Simmonds, Miller & Gemmell, 2012).

Self-myofascial release and foam rolling

Self-myofascial release (SMR) is the usage of a tool to achieve the results of myofascial release without the help of a manual therapy. There are different methods of doing SMR, one of the most popular being foam rolling. The foam roller consists of a cylinder-shaped tube surrounded by a softer layer that is either smooth or with points and curves aimed to treat so-called trigger points. The goal with foam rolling is to use one's own body weight to roll out muscles and connected fascia. By rolling out these layers a it is suggested to have similar effects as myofascial release.

Research on MFR suggests it positively affects fascia in several ways, so it is suggested that SMR could work in the same way. These effects are divided in mechanical and neurophysiological. The mechanical includes thixotropy, stating that when pressure or heat is applied the fascia will become less dense and more fluid (Schleip, 2003a). The piezoelectric effect states that stimulation of fibroblast that is responsible for producing collagen will improve with an electric charge created by outside pressure (Schleip, 2003a). MFR is also supposed to release fascial adhesion, this is done by the pressure applied to the fascia, releasing the layers of fascia and allowing them to slide against each other again (Paoletti, 2006). The fluid model states that when the fascia is rolled with a roller it extrudes water like a sponge before it then rehydrates. This probably has a positive effect on tissue mobilization and stiffness. Inflammation that occurs in the fascia is proposed to be released by the increased blood flow following a rolling of the muscle and surrounding fascia, this is further helped by the release of myofascial trigger points (Findley, Chaudhry, Stecco, & Roman, 2011).

The neurophysiological theories are divided in two: the Golgi reflex arc and stimulation of the mechanoreceptors. MFR probably stimulates the Golgi tendon organs inside the connective tissue, reducing motor firing rate and thus reducing muscle tension (Schleip, 2003a). MFR supposedly stimulates the mechanoreceptors located in the connective tissue, which in turn relaxes the fascia and change fluid dynamics and tissue metabolism (Schleip, 2003a). From these mechanisms, it is believed that SMR increase muscle flexibility, extensibility and reducing delayed onset muscle soreness (DOMS). For these improvements to occur it is probably required to reach and stimulate the deep fascia since there are limited results when treating the superficial fascia (Simmonds et al., 2012). Schleip (2003b) shows that an unrealistic amount of pressure or time would be needed to change the properties in the deep fascia.

The anatomy of the fascia is different depending on where it is located (Langevin & Huijing, 2009), leading us to believe that the fascia might also respond differently depending on what a large amount. Even if the goal of foam rolling is to influence the fascia, it might be unrealistic to assume it will change the properties of the deep fascia. This in turn questions all these positives effects of foam rolling, or at least that the positive effect is due to changes in the deep fascia.

Range of motion

ROM is the measurement of a muscles extensibility, it refers to the distance a joint can move in flexion and extension. ROM is the variable used when measuring flexibility. It is measured in angle or length, depending on the measurement used.

Research on the effects of foam rolling on range of motion is still in its infant stage, the topic has some research behind it but there is a lack of standardized methods used, and thus the results vary. The research mainly focuses on what effect foam rolling have on range of motion, not why or how it affects the muscles and fascia. The combination of these factors makes the validity of the current body of research low and it hinders future research. Earlier research has all found significant changes between the control group and the intervention group (MacDonald, Penney, Mullaley, Cuconato, Drake, Behm & Button, 2013; Griefahn et al., 2015; Behara & Jacobson, 2015; Junker & Ströggl, 2015). Three studies did not find any significant results (Couture, Karlik, Glass & Hatzel, 2015; Miller & Rockey, 2006; Škarabot, Beardsley & Štirn, 2015).

Four studies did not find a significant result between group but did find a significant result within the intervention group (Bushell, Dawson & Webster, 2015; Kelly & Beardsley, 2016; Markovic, 2015; Mohr, Long & Goad, 2014). is likely because of increase in the control group. This could be because of stretching when measuring or in the case of the control group being another limb (leg or foot), the change could be contributed to stretching during the intervention or a crossover effect of the foam rolling.

In addition to the varied results, most of the studies show a high standard deviation, suggesting a difference in responses after foam rolling. This is furthered strengthened by illustrative charts and confidence intervals highlighting the high variance in responses, some subjects even respond negatively after foam rolling. Due to the lack of standardization and the different method used it is not possible to say if these difference in responses are due to the foam rolling itself. The variance in methods and subjects used, also makes it difficult to find an eventual cause for the difference in responses.

Method

The study was done at the Center of Health and Performance (CHP) at the University of Gothenburg. As part of a larger project, this study collaborated with another study which examined the effects of the use of foam rolling on the stiffness of the calf muscles by using elastography before and after the intervention. Both studies were done at the same time and share the same study procedure (figure 2). However, the result of processing of its data will not be treated in this study. This is because it is not relevant in terms of our research questions. The study aims to be a basis for future studies.

Design

An experimental design was pre- and post-intervention measurements were performed to examine the effects of SMR by foam rolling on the parameters of ankle ROM, hamstring flexibility and calf muscle stiffness of the gastrocnemius medialis and lateralis. This study involves the first two-part was the last part of measuring calf muscle stiffness is part of another study that was made at the same time during our process. The intervention was made on one leg, was the other leg was used as a control group. The leg used during the intervention was randomly chosen. The study procedure is divided into five steps were step 1 involved the measurement of muscle stiffness of gastrocnemius medialis and lateralis on both legs. Step 2 where ROM of the ankle joint and the flexibility of the hamstring was measured. Directly after the 3rd part started where the participant foam rolled the lower parts of the superficial back line, with each muscle group to roll for one minute. After the foam rolling, the first two pre-intervention measurements were performed again. Starting with the ROM and flexibility test (step 4) and ending the study procedure with the Elastography of the gastrocnemius medialis and lateralis (step 5). After the intervention, the time was recorded to enable the Elastography measurement always 10 minutes post-intervention (see figure 2).

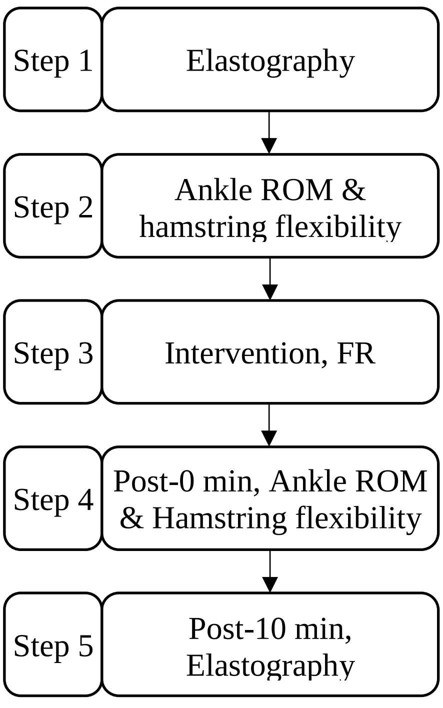

Figure 2. Study procedure

Sample

In the study 17 recreationally active participants (13 males, 4 females) were recruited and included in this study (age: 27.53 ± 2.94 years, age range: 22-36 years, weight: 76.24 ± 15.89 kg, height: 175.47 ± 8.41 cm, BMI: 24.55 ± 3.6 $\frac{kg}{m^2}$). The inclusion criteria were: at least 18 years old, at minimum 3 hours of training per week, healthy, and no heavy exercise the previous 48 hours before the intervention. If the participants have previous injuries in the lower body that could impact the results of the study, they were excluded. In the process of recruiting participants for the study, friends, colleagues and known recreational athletes were asked to join the study. A total of 18 different people responded and took part of the intervention, but as a result due to errors in the collected data, one of the subjects had to be excluded. Therefore, only 17 subjects were included in the final analysis.

Before the participants came to the CHP to take part of the study, information about the study was served to them either by Information sheet (see Appendix 1) or verbally. This included the criteria previously mentioned. On the day of testing the study procedure always started with a short moment of information and run through of the study. And before taking part of Step 1 (Figure 2), a health survey and consent were filled (see Appendix 2). Afterwards, anthropometric data were collected, determining the weight using a force plate (Kistler, Switzerland), and the height with the use of a permanently place measurement board on the wall.

Table 1. Subject demography, Data: mean ± SD

Participants	Male	Female	Overall
Age (years)	27 ± 2	30 ± 4	28 ± 3
Weight (kg)	82 ± 13	57 ± 3	76 ± 16
Height (cm)	179 ± 6	164 ± 2	176 ± 8
BMI ($\frac{kg}{m^2}$)	25.7 ± 3.4	20.9 ± 0.6	24.6 ± 3.6

Data collection

The data collection for the study was made during June in 2017 at CHP at the University of Gothenburg. The collection period lasted all month as the study's design enabled only one test person to do the tests at a time. Each test session took between 60-90 minutes. All data were collected through excel sheets and software linked to the different steps in the study procedure (figure 2) and then used in the results analysis.

Elastography

The step 1 in the study procedure (figure 2) were measured with the ultrasound device (Toshiba Medical Systems Corporation, Japan, Aplio 500) to measure the subjects muscle stiffness. The same step was made post-10 intervention. Before the measurements were made, Gastrocnemius Medialis and Lateralis were marked with crosses to help during the measurement to get clear pictures. While the subject lied in a relaxed position, the ultrasound gel was put on the markings and a total of four images were taken (figure 3). The data was collected by the Toshiba Aplio 500 and stored on a USB-drive. This study is not using the data from the elastography in the analysis of the results.

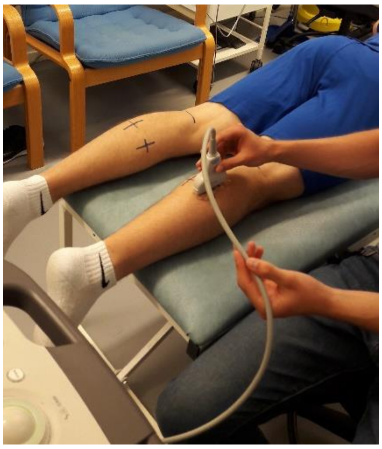

Figure 3. Elastography

Figure 4. Ankle joint ROM

Figure 5. Hamstring flexibility

ROM and flexibility

ROM and flexibility measurements were used during step 2 and step 4 (figure 2) since it's an effective way to detect a response in the tissue after an intervention (Vaughan & McLaughlin, 2014). Both the ankle joint ROM and hamstring flexibility were made with a Mobee device (SportMed AG, Germany), which is a device along with a software that is excellent for measurements of ROM and flexibility. The choice for using the Mobee device was made since the CHP already had access to the software and it is easy to learn for unexperienced users. The test was made on both the experimental leg and the control leg. For the two measures using the Mobee device, the subject lied supine on the bench with straight arms beside the upper body and the knees fully extended. For the Ankle joint ROM, a "Blackroll Duo ball" was put under the examined legs knee to enable a maximum ankle joint ROM (figure 4). The Mobee device was placed on the foot sole, while the foot held at the starting angle 90°. During the ankle joint ROM measurements, the software $\text{Mobee}_{\text{med}}$ was used, which allowed measuring dorsi- and plantarflexion and the total ROM of the movement. From the starting position the test leaders provoked a maximal dorsi- and plantarflexion by holding one hand on the examined ankle joints foot heel and the other hand steady around the foot while not touching the Mobee device (figure 4). This movement was made twice and made without causing any pain to the subject. The software $\text{Mobee}_{\text{med}}$ collected and stored all the data for further use in the analysis.

For the Hamstring flexibility test, the Mobee device was fixed in a proximal direction from the ankle (figure 5). For this test, the software Mobee$_{fit}$ was used and measured from the initial value of zero degrees. For this test, two test leaders were needed. The first held the leg with one hand underneath the foot and the other hand over the knee, to keep the leg straight during the leg raise. The second test leader held the other leg down to prevent pelvic movement, which could affect the results. Every subject was instructed to inform the test leaders if the perceived pain was beyond stretching. As for the ankle joint ROM measurements, this test was made also made twice to enable a maximum range of feasibility. The data from the Hamstring flexibility test was collected and stored in the Mobee$_{fit}$ software which was later used in the analysis.

Figure 6. Foam rolling equipment during the intervention

Intervention

The step 3 (figure 2) was made using foam roll equipment from Blackroll (Blackroll, Germany). That included two different types of black roll where the first is a “Blackroll ball”, with an 8-cm diameter which was used to roll the plantar fascia. The second was the “Blackroll Standard” which was used for rolling the lower leg and hamstring (figure 6). The session of foam rolling was made on a force plate (Kistler, Switzerland), which the subjects were instructed to only be in contact with by using the foam rollers. Besides the force plate, a mat was placed to avoid slipping on the floor and to reduce the pressure on the hands while foam rolling (figure 7-9). The foam rolling was divided into three parts: plantar fascia, lower leg, and hamstring. Each session was rolled for 60 seconds with a 15-second rest between the bouts. Since the foam rolling was made on a force plate the analysis program MARS (Measurement, Analysis and Reporting Software, Kistler, Switzerland) recorded the amount of force that was used on the muscle and fascia by the subject.

Figure 7. Foam rolling the plantar fascia

Figure 8. Initial position for the lower leg. Underneath the achilles tendon

Figure 9. Initial position for FR hamstring with two legs

Before starting the session, the subjects were instructed on how to foam roll. Even if it is almost impossible to maintain through all the subjects, the aim was to instruct the subjects so that their posture and speed would be the same. The subjects were also instructed to regulate their rolling so that the perceived pain would be maximum 7 on a 0-10 VAS scale were 10 is the worst perceived pain and 0 represents no pain. During the intervention, the subjects were also instructed to look for trigger points during their roll. If a trigger point was made, they were instructed to stay on that point for 6-7 seconds as this could loosen fascial adhesions. The order of the foam rolling session was always starting with plantar fascia, followed by the calf and at last the hamstring.

During each session, the subject started beside the force plate. One test leader managed the software from the computer while another test leader managed the clock and gave feedback to the subjects if they were slipping away and when to start and stop rolling. During the first 60 seconds, the subjects rolled the “Blackroll ball” from the base of the calcaneus to the metatarsal heads with either circular or side movement to find trigger points of the foot sole (figure 7). After 15 seconds rest the subjects started to foam roll from the distal end of the lower leg towards the most proximal in a frequent range using the “Blackroll Standard” (figure 8). After foam rolling the lower leg for 60 seconds the subject had another rest for 15 seconds. The final foam rolling set started at the distal end of the back thigh. During this set the muscle group is quite large and hard to foam roll which means that some of the subjects either used one leg on the foam roller and the other beside the force plate for balance or used the control leg to put more force on the foam roller by putting it over the experimental leg (figure 9). After the intervention, the test leader started a clock and immediately started the ankle joint ROM and Hamstrings flexibility measurement tests (step 3). At post-10 minutes the subjects got another elastography (step 1) to once again measure the stiffness of the calf muscles.

Data processing and analyze

The data that was collected from $Mobee_{Med}$, $Mobee_{Fit}$ and MARS were after the last subject collected and processed so that it could be analyzed in IBM SPSS Statistics (SPSS, version 24). Other data such as height, weight, age and gender that were collected in the health survey was also processed and mapped into a large file in SPSS. With all the data stored in one file a lot of different statistical analyses were performed concerning the effect on of foam rolling on ankle ROM, hamstring flexibility. The Shapiro-Wilk test that was used showed the normality of all data. The usage of The Shapiro-Wilk test is a powerful tool for a set significance (Nornadiah & Bee, 2011). To investigate the correlation of the foam rolled and control leg a paired samples t-test was made. The paired samples T-Test was also used to calculate the correlation coefficient for the pre- and post-intervention measurement results within a group. Another test that was used was the Fisher's Exact Test, to prove if the variables of foam rolling and control leg are dependent on one another or not. Pearson Chi-Square test was also used during the analyses to compare with the Fisher's Exact Test to find the test that gave the most exact p-value. During the tests, the significance level was set to 0.05. Using the software Excel (2016) allowed to describe the data in a graphical way through the usage of charts and plots.

Methodological considerations

Even if the chosen time to foam roll only lasted for 60 seconds for each are, it is said to still have an impact (Grieve, Goodwin, Alfaki, Bourton, Jeffries & Scott, 2015; MacDonald et al., 2013). Another methodological consideration we made during the intervention was the choice of foam rolls. At first, we investigated different foam rollers to find the ultimate choice for the study, only to realize that the CHP has some sort of collaboration with Blackroll. This meant that we easily could use a foam roller with the right amount of density for our study. The "Blackroll Standard" was chosen since its density is recommended for sports.

When the study was outlined arguments about the amount of areas that should be rolled during the intervention. And under guidance from workers at the CHP that were more familiar into foam respond the three do (hamstring, lower leg, foot sole) were chosen. An argument for this cause is that larger number of rolled areas could have an impact on the result. This could mean that the correlation between foam rolling and ROM/flexibility in the different joints would be even more unclear.

Throughout the study, the aim was to follow the research ethical principles (Vetenskapsrådet, 2002). By sending out an information sheet to the intended participants, the purpose of the study and the study procedure were clarified before the participant agreed to participate. The information sheet and the health survey, clarified that participants participated voluntarily and at any time they could cancel the study if they wanted to. (See Appendix 1 & 2). Similarly, it was clarified that all data collected that may be linked to the participant is not available to anyone unauthorized and will not be used in any other study without their permission.

Results

Table 2. Descriptive statistic. Displaying the pre- and post-values of both the intervention and control group

	Intervention group				Control group			
Parameters	Pre	95%CI	Post	95%CI	Pre	95%CI	Post	95%CI
Ankle ROM	74.71±11.58	69.20–80.09	77.18±13.09	71.06–83.50	73.71±9.41	69.33–78.17	74.65±11.43	69.29–80.07
Hip ROM	88.41±11.41	82.88–93.75	90.12±11.20	84.85–95.25	87.71±13.36	81.44–93.64	89.94±13.21	83.77–95.87

Research question 1

Ankle joint range of motion

An independent sample T-Test showed no significant ($p<0.05$) difference between the intervention group and the control group. The difference was 1.5±1.6 degrees in favor of the intervention group (table 3).

Paired sample t-test showed there was a significant change ($p<0.05$) recorded in the intervention group. Range of motion increased in the ankle joint by 2.4±4.6 degrees. There was no significant ($p<0.05$) difference noted in the control group (table 4). Within-group changes illustrated further in figure 14 and 15.

Hip joint range of motion

An independent T-Test showed no significant ($p<0.05$) differences between the groups. The difference was 0.5±2.2 degrees in favor of the control group (table 3). Between-group differences further illustrated in figure 10-13.

Paired sample t-test showed there were no significant changes ($p<0.05$) to be found when looking at the changes within the groups. The intervention group gained 1.7±5.1 degrees and the control group gained 2.2±7.6 degrees (table 4). Within-group changes illustrated further in figure 14 and 15.

Between-group differences further illustrated in form of different responders with the help of Z-score. Figure 10 & 11 illustrate the results according to the mean value, where 0 is the mean value. Figure 12 & 13 categories the responders in a bar chart, showing the number of positive and negative responder in each group.

Table 3. Independent t-test. Displaying the differences between the intervention group and the control group (Post-Pre)

Parameters	Differences between groups	95%CI	P-value
Ankle joint ROM	1.52 ± 1.6	-1.37–4,61	0.351
Hip joint ROM	-0.52 ± 2.2	-4.92–3,73	0.815

Table 4. Paired t-test. Displaying the differences within each intervention group (Post-Pre)

Parameters	Differences within groups	95%CI	P-value
Ankle joint ROM	2.47 ± 4.65	0.25-4.57	0.046
Ankle Control	0.94 ± 4.78	-1.35-3.13	0.136
Hip joint ROM	1.70 ± 5.19	-0.76-4.06	0.195
Hip Control	2.24 ± 7.64	-1.36-5.93	0.815

Comparing the groups through z-score

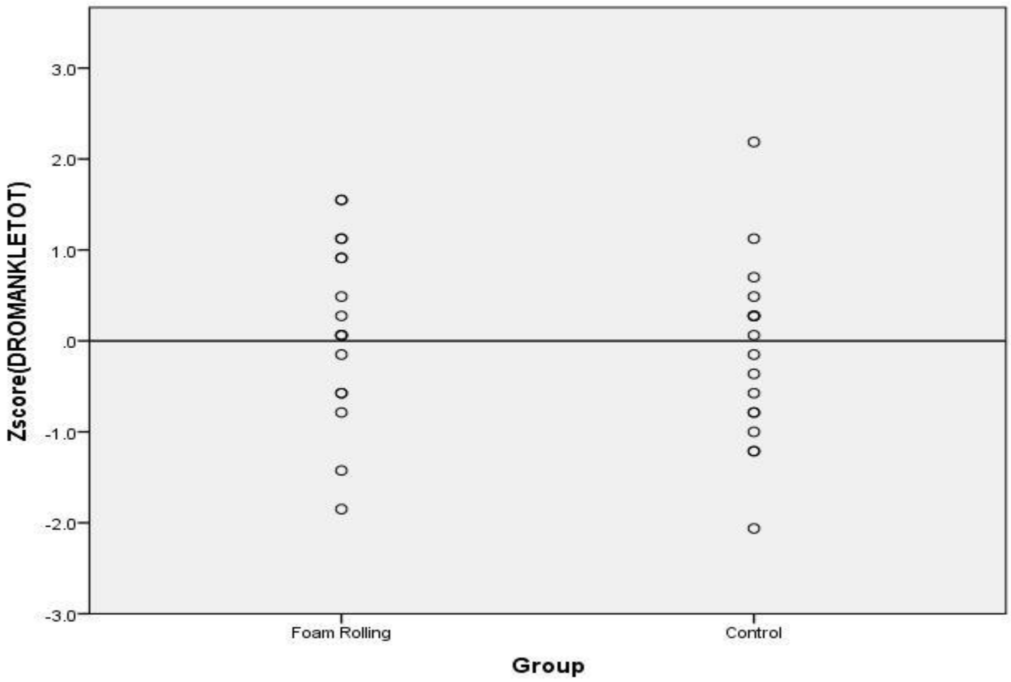

Figure 10. Illustrating the responses compared to the mean value in ankle joint range of motion. Y-axis shows the responses in ROM compared to the mean value, where 0 is equal to the mean difference post-intervention (Post-Pre).

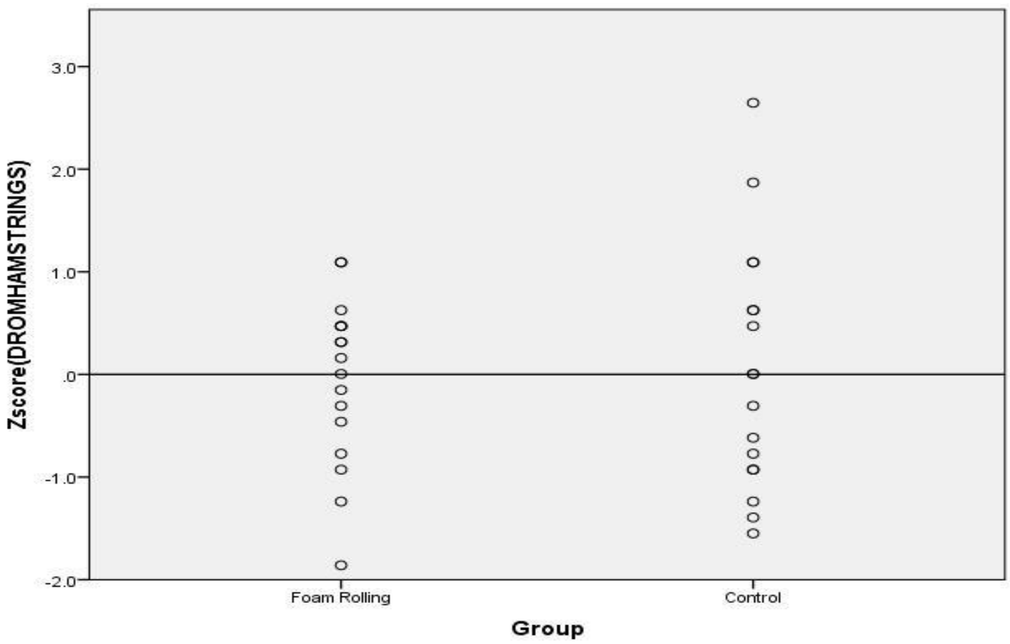

Figure 11. Illustrating the responses compared to the mean value in hip joint range of motion. Y-axis shows the responses in ROM compared to the mean value, where 0 is equal to the mean difference post-intervention (Post-Pre).

Different responses post intervention

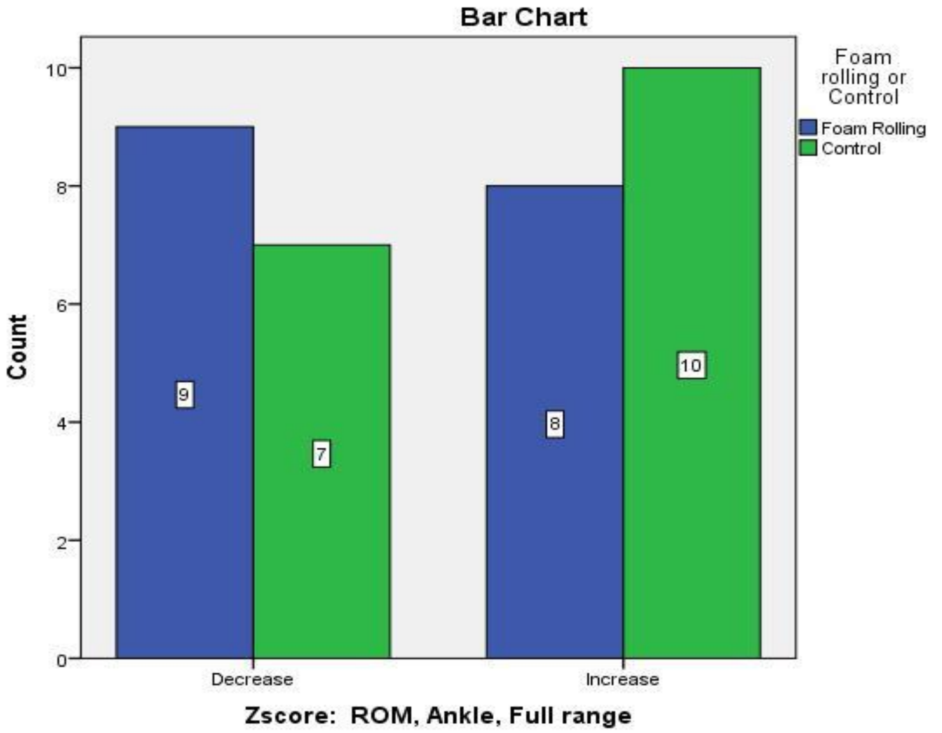

Figure 12. Illustrating positive and negative responders based on z-score in ankle joint range of motion. Increased/decreased is based on the mean value post-intervention (Post-Pre).

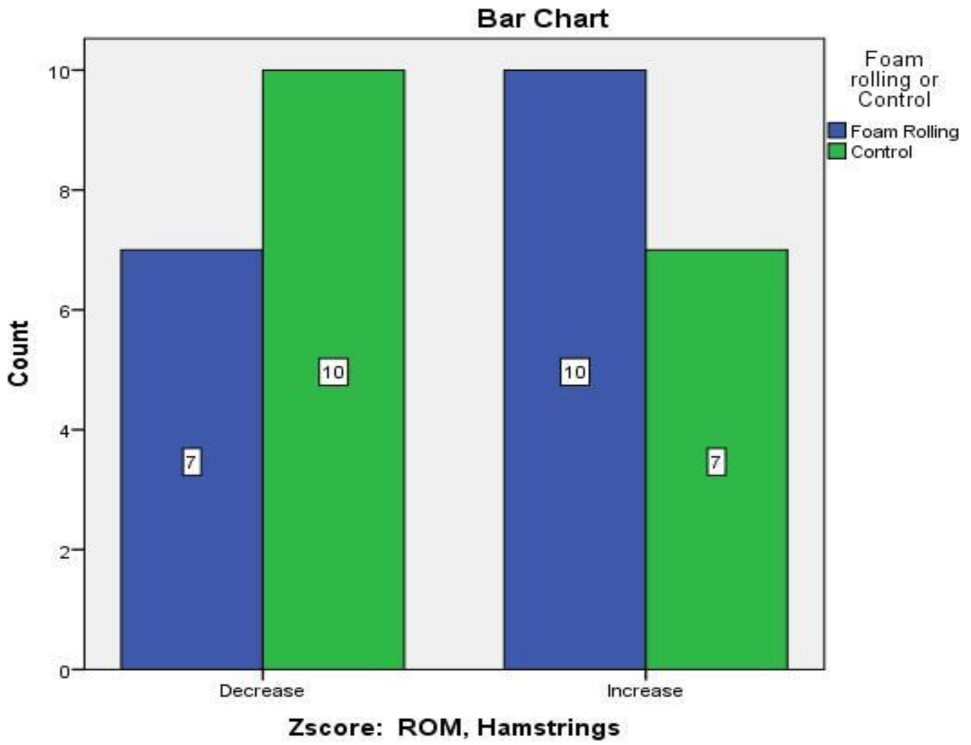

Figure 13. Illustrating positive and negative responders based on z-score in hip joint range of motion. Increased/decreased is based on the mean value post-intervention (Post-Pre).

Differences within intervention groups

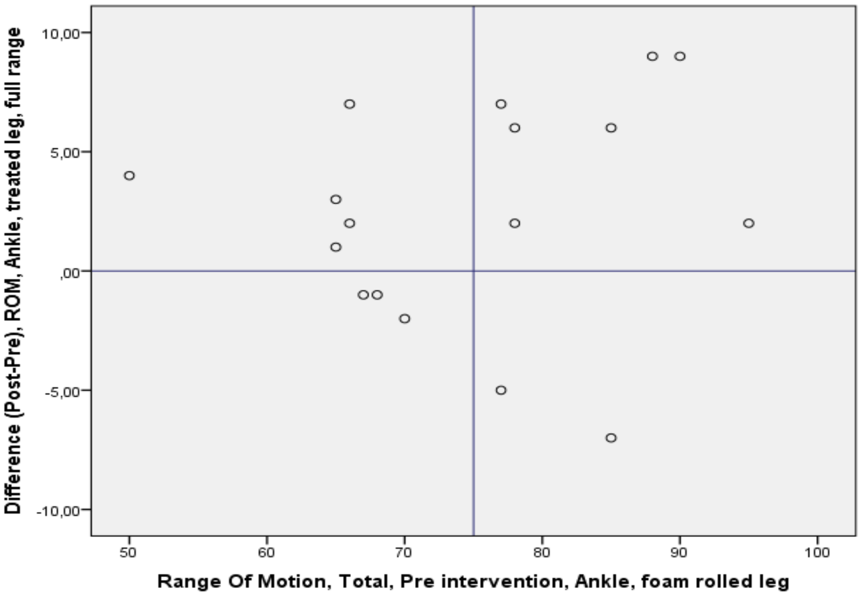

Figure 14. Illustrating the responses within the intervention group for ankle joint range of motion. Y-axis shows the differences post-intervention (Post-Pre). The X-axis shows the range of motion pre-intervention. The vertical line is drawn at the recommended range of motion.

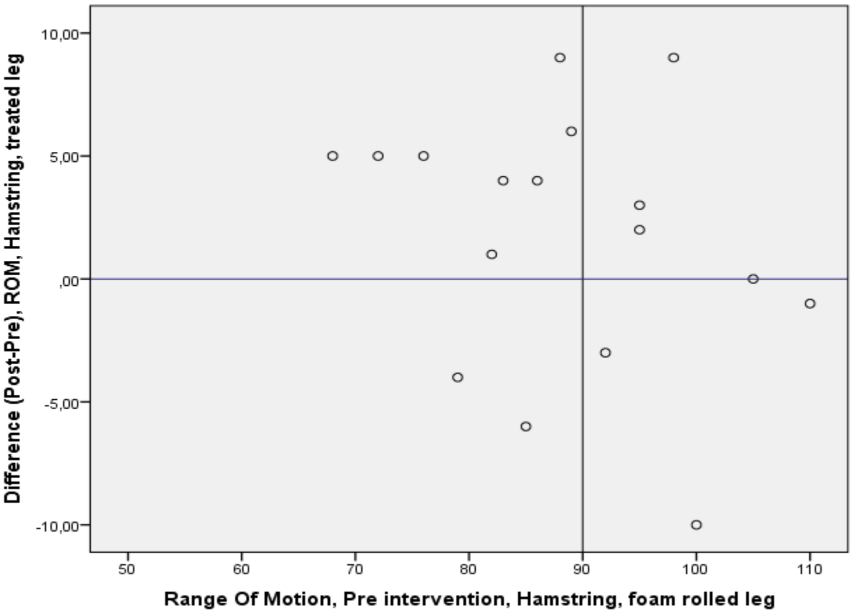

Figure 15. Illustrating the responses within the intervention group for hip joint range of motion. Y-axis shows the differences post-intervention (Post-Pre). The X-axis shows the range of motion pre-intervention. The vertical line is drawn at the recommended range of motion.

Research question 2

Descriptive statistic is used to illustrate how gender (figure 16 & 17), hours of activity per week (figure 18 & 19) and type of recreational activity (figure 20 & 21) affect the results of the intervention. Figure 22 & 23 describe the influence of force used on ankle joint range of motion. Figure 24 & 25 describes the influence of force used on hip joint range of motion.

Gender

Determined by descriptive statistics, figure 16 & 17 are used to illustrate the gender responses after foam rolling. The graphs show a relatively even distribution of females and males after foam rolling.

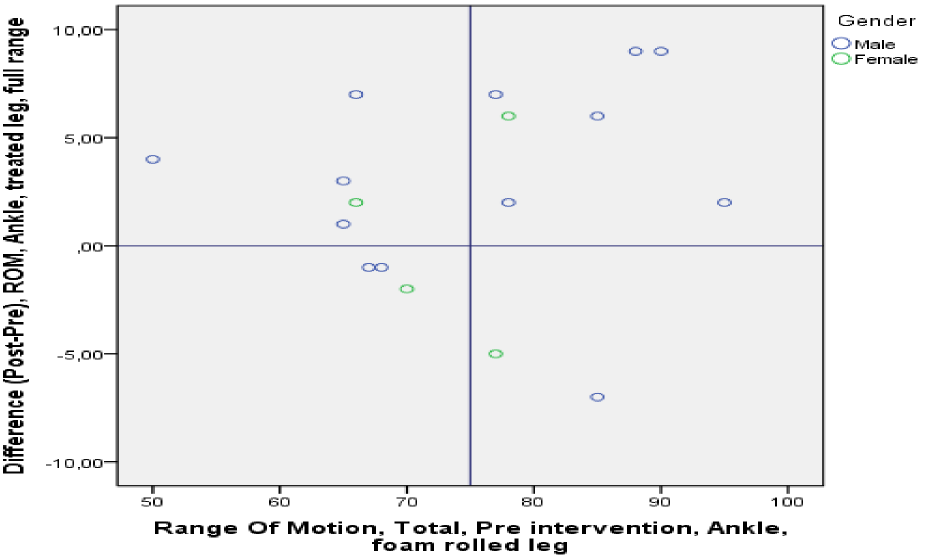

Figure 16. Illustrating the gender responses post-intervention. Y-axis shows the difference in range of motion post-intervention. X-axis is the range of motion pre-intervention. The vertical line is drawn at the recommended range of motion.

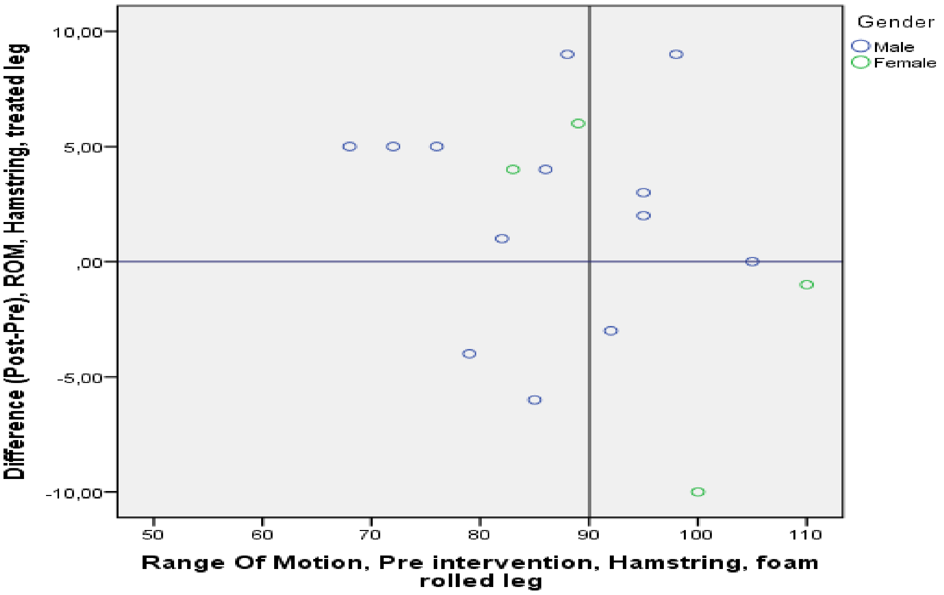

Figure 17. Illustrating the gender responses post-intervention. Y-axis shows the difference in range of motion post-intervention. X-axis is the range of motion pre-intervention. The vertical line pre-intervention at the recommended range of motion.

Hours of activity/week

Determines by descriptive statistic and reworked in excel, figure 18 & 19 are used to illustrate how activity level is influencing the results, the gender is also added in form of coloring. While most of the above average active individuals (straight lines) show an improvement in post-ROM, about half of the less than average active individuals (dotted lines) are also showing an improvement.

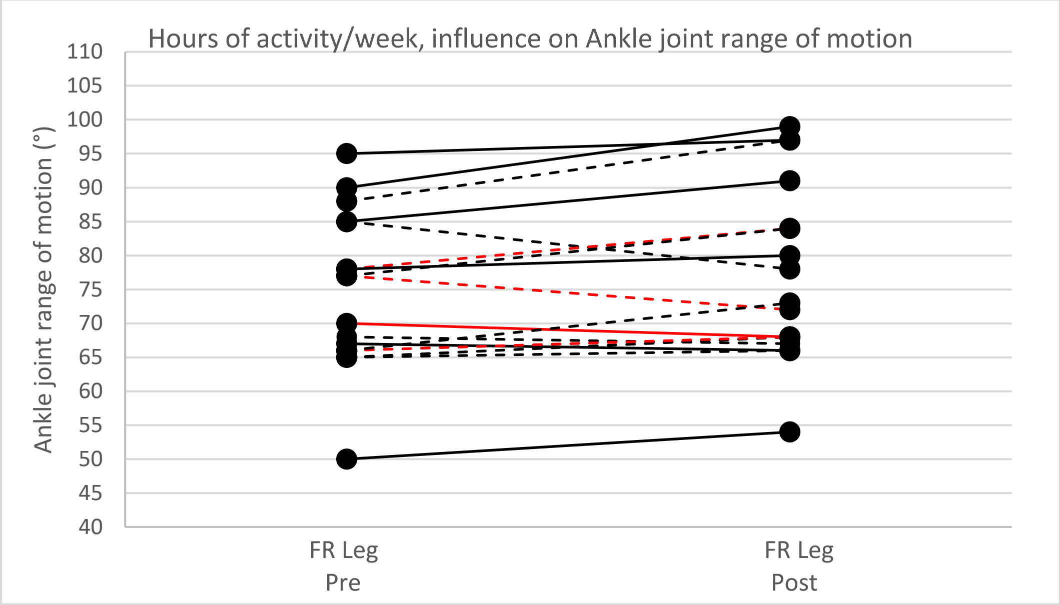

Figure 18. Illustrating the effect of activity on the differences in ankle joint range of motion. Based on the mean value of activity/week, straight lines are above mean, while dotted are below mean. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

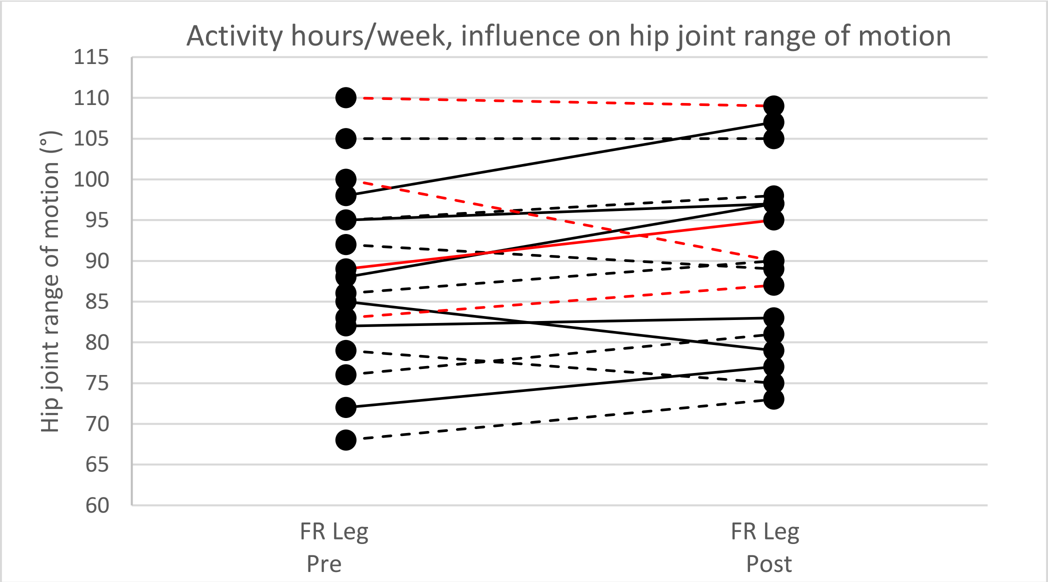

Figure 19. Illustrating the effect of activity on the differences in hip joint range of motion. Based on the mean value of activity/week, straight lines are above mean, while dotted are below mean. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

Type of activity

Determines by descriptive statistic and reworked in excel, figure 20 & 21 are used to illustrate how the type of recreational activity is influencing the results, the gender is also added in form of coloring. There is a skewed distribution with a majority of combination activity, who responded in both ways. The aerobic group all increased in ROM post-intervention while the resistance training group decreased.

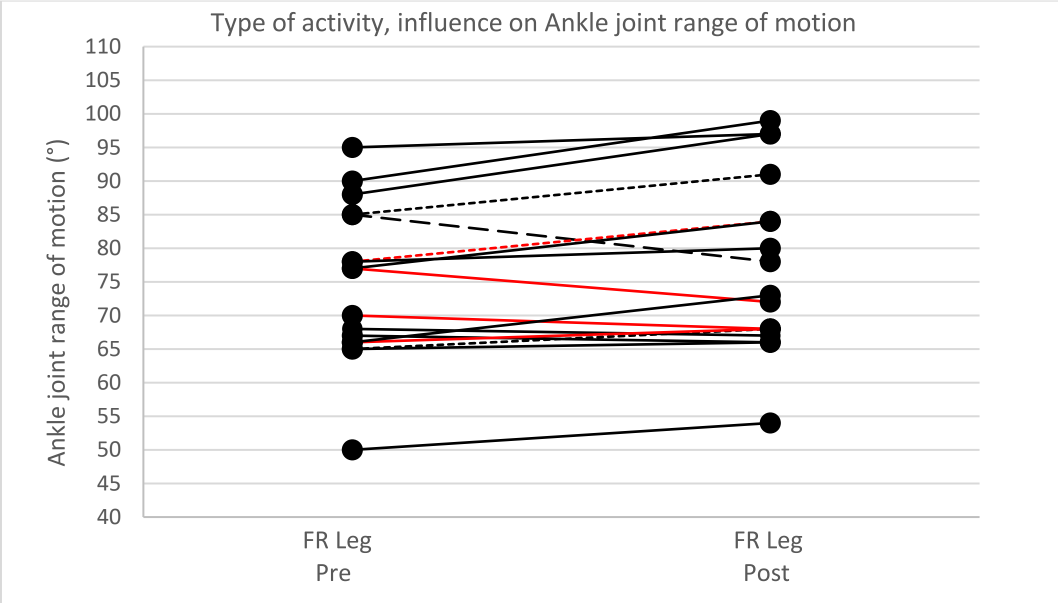

Figure 20. Illustrating the effects of the type of recreational activity on the differences in ankle joint range of motion. Based on the categorical ordering of activities. Straight lines represent the combination of aerobic and anaerobic activity, small dotted lines represent aerobic activity and large dotted lines represent resistance training. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

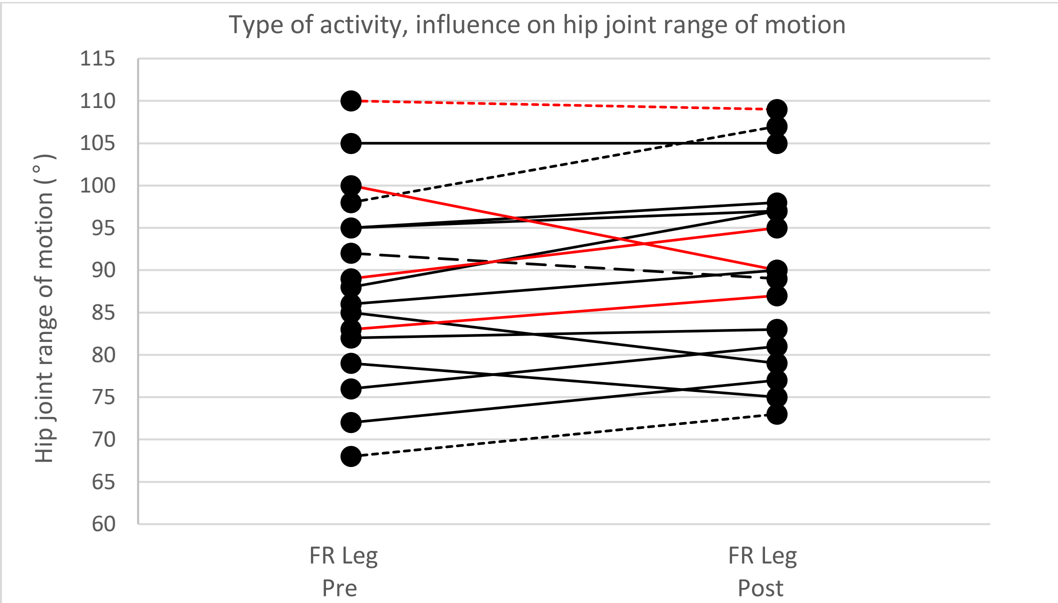

Figure 21. Illustrating the effects of the type of recreational activity on the differences in ankle joint range of motion. Based on the categorical ordering of activities. Straight lines represent the combination of aerobic and anaerobic activity, small dotted lines represent aerobic activity and large dotted lines represent resistance training. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

Force used when foam rolling

Determines by descriptive statistic and reworked in excel, the force is calculated as % of body weight and then divided into two groups, above and below the mean value. Figure 22 & 23 illustrate the influence of force applied on ankle joint range of motion, rolling the plantar fascia and the calf muscle respectively. There is no apparent pattern from the force applied on either the plantar fascia or the calf muscle.

Figure 24 & 25 illustrates the influence of force applied on hip joint range of motion when rolling the calf muscle and the hamstring muscles respectively. In both figure 24 & 25, the individuals with lower than average force applied (dotted lines) increased in ROM most of the time. The Higher than average force applied group did not show any patterns.

Pearson's correlation coefficient revealed no significant ($p<0.05$) correlations between force used and difference in range of motion post-intervention. These results were consistent with both raw average force and when excluding the weight variable by applying % of body weight. This is further illustrated in figure 22 and 23 for the ankle joint and 24 and 25 for the hip joint.

Checking for correlations between force applied when rolling and body weight only one significant ($p<0.05$) correlation where found, it was between body weight and force applied when foam rolling the hamstrings.

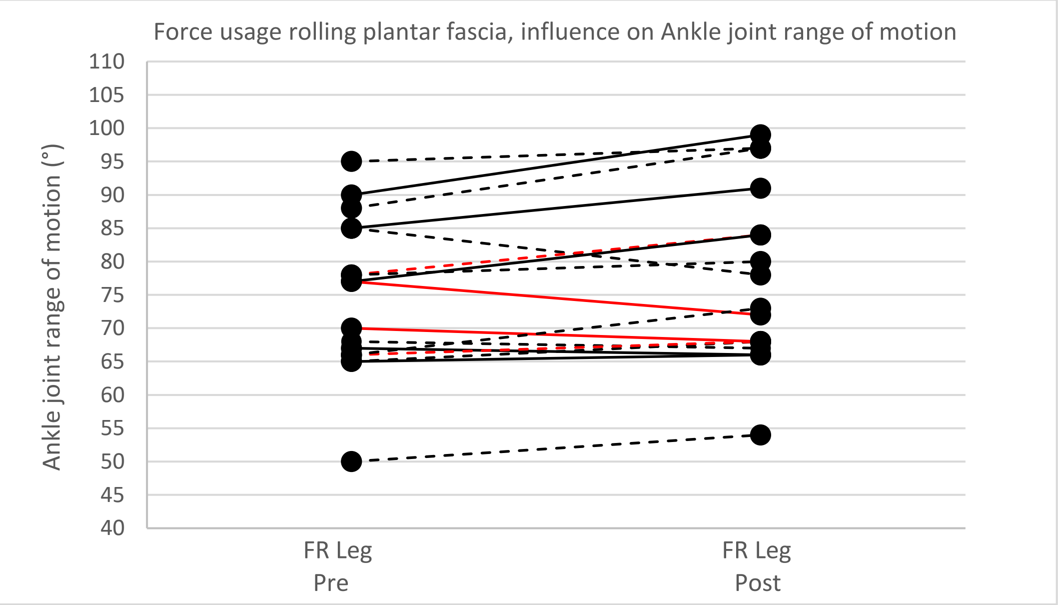

Figure 22. Illustrates the effect of force usage when foam rolling the plantar fascia, on ankle joint range of motion. The lines are based on mean values from force exerted when rolling, based on % of body weight. Straight lines represent above mean force, dotted lines represent below mean force. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

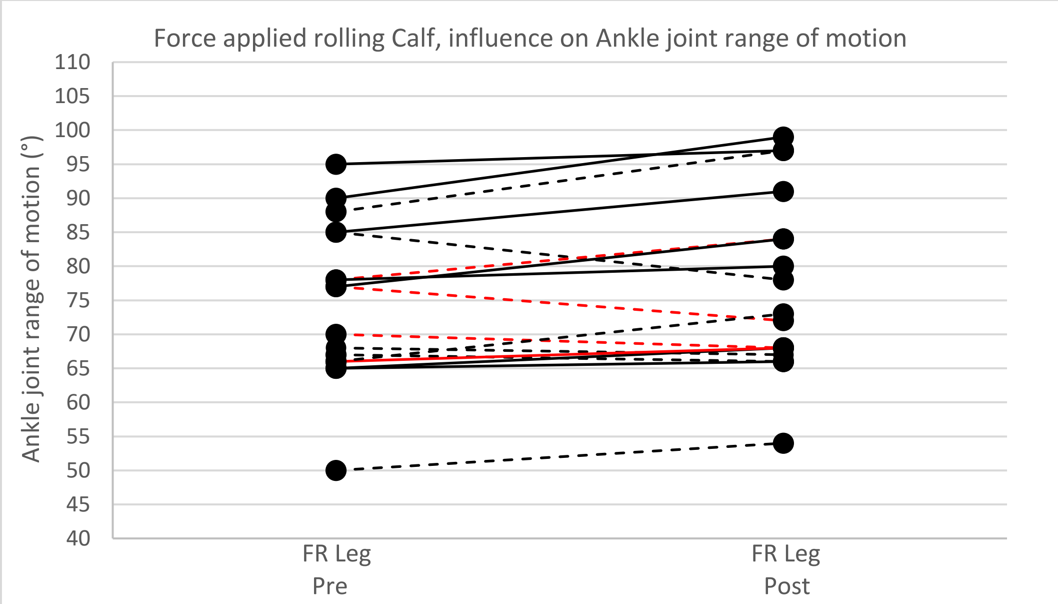

Figure 23. Illustrates the effect of force usage when foam rolling the calf muscles, on ankle joint range of motion. The lines are based on mean values from force exerted when rolling, based on % of body weight. Straight lines represent above mean force, dotted lines represent below mean force. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

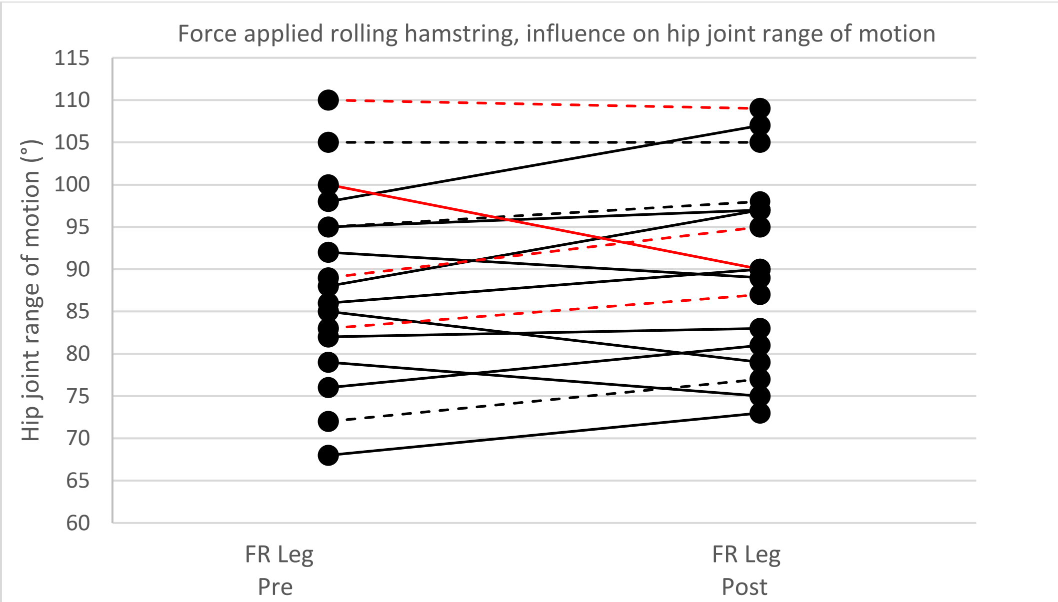

Figure 24. Illustrates the effect of force usage when foam rolling the hamstring muscles, on hip joint range of motion. The lines are based on mean values from force exerted when rolling, based on % of body weight. Straight lines represent above mean force, dotted lines represent below mean force. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

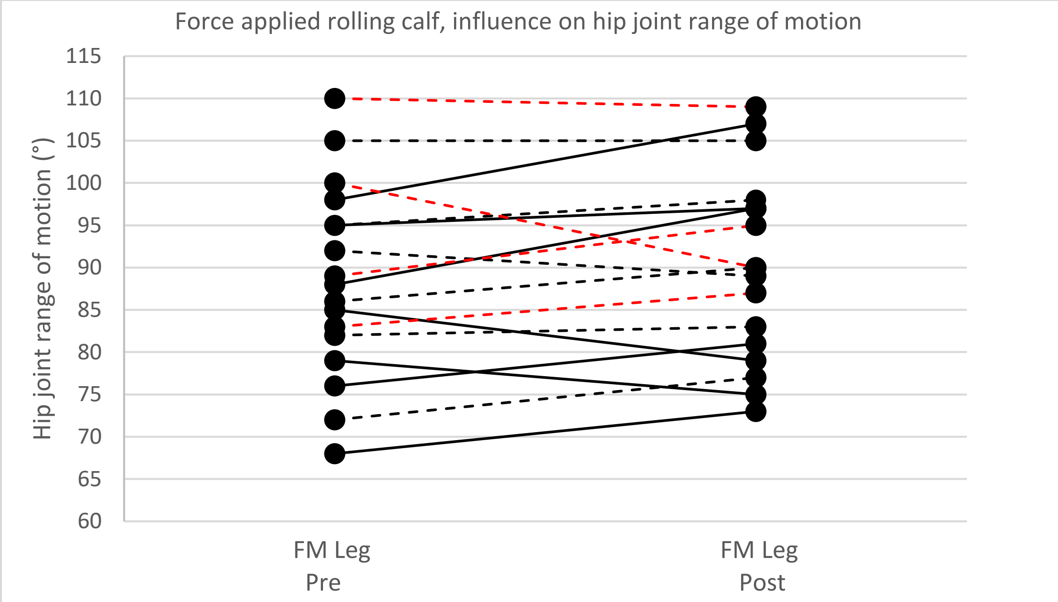

Figure 25. Illustrates the effect of force usage when foam rolling the calf muscles, on hip joint range of motion. The lines than on mean values from force exerted when rolling, based on % of body weight. Straight lines represent above mean force, dotted lines represent below mean force. Lines colored red represent the females. Y-axis is the range of motion. X-axis is used to illustrate the difference between pre- and post-intervention.

Discussion

Method discussion

There are several limitations due to the current body of research. To our knowledge, there are no standardized methods to foam roll and no knowledge of factors that might influence the foam rolling. Foam rolling is usually done 30-60 sec and in sets, the duration is usually motivated by a reference to the myofascial release technique (Barnes, 1997). To our knowledge, there is no research suggesting the effects of foam rolling and myofascial release are the same and that they work in the same way. Foam rolling covers a whole muscle and might stimulate the muscle in a different way, it is also harder to account for the force used, making it hard to adjust for how much force should be used. Couture et al (2015) did look at different timings when foam rolling, there were no significant differences between two sets of 10s or four sets of 30 sec rolling.

Other influencing limitations could be the amount of rolled muscle groups, rolling speed and the order of rolling during the intervention. The choice of only rolling three different muscle groups instead of full lower extremity were made since the impact of foam rolling on muscle groups in direct connection on the measured joints. Rolling too many muscle groups could impact the result in a way that no conclusion should be able to be made. The rolling speed was instructed before the intervention to have an even pace. But it was not controlled with and external tool to keep track during the foam rolling. Some of the subjects were told to higher or lower their speed but an exact pace was not controlled. The rolling order was chosen from directive by an experienced foam roller at the CHP at the University of Gothenburg. A greater impact would rather be the amount of pressure that was used during the rolling.

Some studies controlled for force, however, the only guideline is that no pain should be experienced, this could be due to research suggesting pain leads to the muscle stiffening, on the contrary the rolling aims to reduce stiffness. We experienced that inexperienced foam rollers are struggling with how much force they should apply, leading to a lot of subject's experience pain or discomfort despite clear instructions and a visual demonstration. There is a possibility the result might differ if experienced foam rollers were used in the study. There is a belief that more pressure on the fascia will yield better result, this has not been proven to our knowledge. There has however been research on different type of rollers. Curran, Fiore & Crisco (2008) found that a denser roller puts significantly more pressure on the tissue and on a smaller contact area. There is a concern that it is unrealistic to influence the deeper fascia as it would take significantly more force then one individual could handle, thus being too painful (Schleip, 2003a).

The final point of standardization we struggled with was the warm-up. The only motivation we could find in the current body of research is that it simulates how the situation would look in real life. While this is correct it does not suffice to cover what effect a warm-up might have on the intervention. Question marks surrounds how the pre- intervention mobee measurement and the intervention itself helps a subject's flexibility for the post mobee measurement, flexibility might increase due to stretching not achieved by the foam roller itself.

While the results from foam rolling literature differ, the means to analyze the results are mainly done through comparing mean values, this does not address the problem of different responders. The studies that do show a calculation for the difference between pre- and post-intervention the standard deviation is rather high. We call for different methods to analyze the results and to address the issue of who responds well to foam rolling to find for who and what it is useful.

Apart from previous mentioned issues, the usage of the Mobee device is clearly a measurement tool that needs to be discussed. The mobility and easy usage of the Mobee device and software is also one of its disadvantages since the placement of the Mobee device is placed manually. Since every subject don't look the same there will always be problems to find the identical position for all subjects. Another issue with the usage of testing ROM and flexibility were that the subjects were instructed to tell when they perceived pain. This could be a problem since the amount of perceived pain is highly individualistic. Using another tool which removes the influence of the subject's perception would be an alternative.

Result discussion

Effects of foam rolling

Although we did not look at what effect foam rolling have on the muscle or fascia in this section of our study, we think it is important to look at the current body of research to find answers to the common assumption.

When looking at research about these physiological mechanisms the conclusive proofs were scarce. The Piezoelectricity theory states that the fibroblasts are supposedly stimulated through an electric charge when pressure is applied to the tissue. Schleip (2003a) states that while the process could occur it is very slow. The change was seen in myofascial release and thus self-myofascial release are immediate and cannot be explained by the slow process of piezoelectricity.

Thixotropic is another recurring effect that supposedly explains the process which the connective tissue becomes more fluid like. Dense connective tissue requires a long amount of time or large amount of pressure, yet this effect is supposed to work within the short amount of time and relatively low amount of pressure used by the foam roller in SMFR or hands in MFR. A reversibility effect might also take place since the effect will only be present when the heat or pressure is applied, meaning the changes will revert once the pressure or heat is gone (Schleip, 2003a, 2003b). In addition, it was found that foam rolling does not increase the acute temperature within the tissue (Murray, Jones, Horobeanu, Turner, & Sproule, 2016). Schleip (2003a) also questions the Golgi reflex arc theory, while it is true that stimulation of the Golgi receptors could lead to lowered firing rates the stimulation only occurs when muscles actively contract. Meaning that stretching or stimulating the muscle in other ways does not stimulate the Golgi receptors.

In the end, many of the changes seen after myofascial release and self-myofascial release might be because of responses in the autonomic nervous system and not because of the mechanical effects. Schleip (2003b) states that the stimulation of the fascia and in turn the mechanoreceptors could also be responsible for triggering the autonomic nervous system to contract the fascia through smooth muscle cells. These contractions can explain the relaxation effect and the increase in blood flow and change in viscosity, in turn helping the connective tissue and as a result reducing DOMS and increasing ROM (Schleip, 2005, 2006).

Research question 1

Ankle joint

In our study, we did get one significant value when comparing the means of the pre- versus post-intervention ankle joint range of motion within the intervention group. However, this is somewhat misinformative since the changes are not significant when looking from a practical point of view. The mean increase in the ankle joint range of motion was 2.4 degrees, this is not enough to impact any sort of athletic performance. Meanwhile the standard deviation is at 4.6 degrees, this point towards a big difference in responses, thus making it hard to generalize the results. Considering this we feel it is crucial to complement the results with additional forms of analyzing methods.

When looking at figure 23 and 24 we can compare the results within the intervention group for both the ankle and hip joint. Here we can clearly see that the results look similar despite the results in hip joint range of motion are non-significant, the spread is a little bigger with more outliers for the hip joint but they both show the same pattern.

The statistical significance disappeared when compared to the control group, the small increase in range of motion in the control group likely contributed enough to make it non-significant. This likely signal that something else then the foam rolling itself influences the range of motion. There are any number of factors besides the foam rolling that could influence the result, the first mobee test stretches the muscles and the intervention itself works as sort of a warm up, both factors could lead to an improved range of motion. As we did not use a control group consisting of other subjects there is no way of knowing if other factors influence the results.

Hip joint

None of the results proved significant for the hip joint range of motion. The same patterns of high standard deviation persisted in both groups. Interestingly the control group gained more range of motion then the intervention group. This could be contributed to a crossover effect, but since the change is so small it is difficult to predict if it's a crossover effect or due to other factors. Additionally, the hip joint has more muscle groups contributing to its range of motion then the ankle joint. This could mean that too few muscle groups were treated to provide an increase in range of motion.

Research question 2

The illustration of different responders is shown in figure 10-13, the reasoning for this is to illustrate how different the individual responses to foam rolling seem to be. We feel it is important to find out why individual responses differ, because this is in line with previous research, even if a significant result is found the responses differ. To determine who will benefit from foam rolling we first must find the reasoning for why some individuals responds well and why some do not, or even responds negatively.

We are unable to draw a clear conclusion from the charts if gender, activity type or time spent exercising influence the rolling. For our subjects there does not seem to be any patterns, but there are a number of limitation within our pool of subjects.
There are too few females in order to clearly determine a pattern if the gender influences the results. The type of activity also suffers from the low number of subjects, it is also difficult to draw a conclusion since these where all recreational activities. There is no telling of how experienced or how serious the recreational activity was. The amount of exercising done per week was very subjective and it might not be correct to compare these without any knowledge on what type of activity it was since it was total amount of hours, not hours of the recreational activity. The intensity of the activity is also not considered.

The correlation revealed that the assumption of more pressure equals better results to be false, at least for our subjects. This could also be contributed to some individuals rolling with too much pressure because of inexperience, leading to it negatively affecting the muscle. Surprisingly there was no correlation for the plantar fascia or calf muscle when checking how pressure exerted correlated with body weight. This would imply that there is a technique to rolling these areas and the pressure is regulated by the individual.

Going forward it seems that research needs to consider either categorizing individual responses and research the different groups to move forward with the issue, or researcher needs better tools or different methods to evaluate why individual responds differently. Not only do we lack the knowledge of knowing who responds, but we also do not know the implications of foam rolling for a non/negative-responder.

Conclusions and implications

We are unable after this study to conclude the reason behind why foam rolling works. The number of subjects and the standardized methods in our study might not be excellent, the results, however, indicate that the factors we studied do not influence the rolling, at least not directly. The only significant result fails to achieve any practical relevance and follows the same pattern as previous research along with our other results. There are still many unanswered questions to what foam rolling does to affect the muscle and surrounding tissue. As previously listed there are many theories for why foam rolling should work, however many of these lacks substantial research to back them up.

Future research has a couple of angles they can focus on. One suggestion is looking at what impact foam rolling have on the muscle and surrounding tissue, preferably also comparing inexperienced and experienced subjects with foam rolling. This way we might get a better understanding of different responses in the muscle and how it affects the results of foam rolling. Another angle is the methods used to research foam rolling, both to standardize the research and to find the best methods to use. Reliability studies to find the best method and testing what effect variables such as warm up and foam roll protocol (timing, duration, and repetitions) have on the results.

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Appendix

Appendix 1 – Information

Hej kära testperson

Var god LÄS IGENOM FÖLJANDE INFORMATION inför testet och återkom med frågor eller synpunkter så snart några dyker upp. Längst ner finns information inför testet.

Innehåller

- Allmän information om studien
- Hur du skall förbereda dig?
- Att ta med till testet
- Karta

Information om studien

I denna studie kommer vi mäta muskelvävnaden på vadmuskeln genom ultraljud. sedan kommer vi att mäta flexibiliteten av hälsenan och höften genom en range of motion mätning. Därefter följer en foam rolling session där testpersonen rullar 3 muskler, 60s vardera. Vi kommer sedan utföra ännu en range of motion mätning av hälsena samt höft, följt av en ultraljudsmätning. Utförandet av testerna kan vara delvis fysiskt krävande och en viss smärta i samband med utförandet av foam rolling kan uppkomma. Testerna avser att hålla på upp till 90 minuter.

Du håller på så länge du orkar och är fri att sluta när du inte orkar längre eller känner obehag.

Förberedelse inför test:

- Du skall känna dig frisk.
- Ingen hård träning 48h innan test.
- Endast lätt träning dagen innan
- Ingen träning samma dag som testet.

Ta med:

- Träningsshorts eller tights som slutar ovanför knäna.

Tänk på att du är fri och när som helst avbryta testet om du känner obehag eller liknande.

Förhinder

Du skall inte genomföra test om du känner dig sjuk, skadad eller motsvarande som kan påverka din rörelseförmåga i nedre i extremitet. Kontakta oss snarast så vi kan boka en ny tid.

På plats

Du måste komma i tid till testerna i KHP (Skånegatan 14b). (Se bifogad vägledning). Där har du möjlighet och byta om. Efter ombyte kommer du fylla i hälsodeklaration och friskrivningsblankett samt mäta längd och vikt. Därefter påbörjas testet.

Vid frågor eller synpunkter hör av dig snarast.
Lägg in mitt mobilnummer i din telefon om du snabbt behöver ta kontakt med mig.

Mvh
Oskar Brengesjö, Jonathan Lohaller & Florian Birk

Idrottshögskolan sedd från Skånegatan

Detaljkarta över det närliggande området

Kontakt:

Oskar Brengesjö
oskarbr@gmail.com
0703-65 89 15

Hälsoenkät och medgivande inför test av rörelseförmåga i hamstring och dorsal och plantar flexion

För deltagande i studien så behöver vissa uppgifter uppges. Vi kommer att behandla uppgifter om dig för att säkerställa att du är fullt frisk för att utföra ett fysiologiskt och biomekaniskt test, är medveten om riskerna samt att du genomför detta forskningsinriktade test på egen risk. De uppgifter vi avser att samla in är de som återges i formuläret nedan. Du avgör själv om du vill lämna några uppgifter till oss. Uppgifterna kommer endast att behandlas av oss i denna studie. Genom att signera detta medgivande samtycker du till att vi behandlar uppgifter om dig. Studiens behov av data är enbart i forskningssyfte och dina uppgifter är sekretesskyddade och ingen obehörig har tillgång till uppgifterna. Studieresultat som kommer att presenteras kommer inte att röja enskild individ.

Namn: ____ Datum: _____________

Kön: __________________ Ålder: ________________

Mobnr: ____________________ Email: ____

Idrott/disciplin: _______________________ Träningstimmar/vecka: __________________________

Ifylles av ansvarig testledare för studien:

Vikt (kg): Längd (cm): Deltagarnr:

Har du avbrutit träning/tävling de senaste två-tre veckorna? **JA** **NEJ**

Om JA, varför: ____

Har du eller har du haft någon skada som du upplever kan påverka din rörelseförmåga idag? **JA** **NEJ**

Om JA, varför: ____

Känner du dig fullt frisk idag, för ett fysiologiskt och biomekaniskt test? **JA** **NEJ**

Om NEJ, varför inte: ____

Är det något annat testledaren bör känna till angående din hälsa? ________________________________

- **Jag genomför dagens forskningsinriktade test på egen risk.**
- **Jag har läst/tagit del av/blivit informerad om förberedelserna inför testerna på förhand.**
- **Jag har blivit muntligt eller skriftligt informerad kring riskerna med testerna.**
- **Jag genomför dagens test av egen FRI VILJA och är informerad om att jag är fri att avbryta testet när som helst utan att jag behöver ange orsak.**

___________ ______________________________ ____________________________________

Datum Underskrift Testledare