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by Eoghan O Mahony

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"Comparison of Different Warm Up Strategies for Acute Hamstring Injury Prevention"

Eoghan O'Mahony

A dissertation submitted in part fulfilment of the requirement for the B.A. (Hons) Degree in Exercise and Health Studies

21/04/2016

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Abstract

Overview: The purpose of this study was to establish if foam rolling, static stretching and dynamic stretching were effective in increasing hamstring range of motion for the prevention of injury in sport. Further to this, the study sought to establish which of the three methods increases hamstring range of motion the most. Contrasting beliefs exist as to which of these methods is most beneficial for athletes to use as part of their warm up. This study aimed to answer the following *Research Questions:*

1) Does foam rolling increase hamstring range of motion for acute injury prevention?
2) Does static stretching increase hamstring range of motion for acute injury prevention?
3) Does dynamic stretching increase hamstring range of motion for acute injury prevention?
4) Is foam rolling, static stretching, or dynamic stretching most effective in increasing hamstring range of motion for acute injury prevention?

Methods: Fourteen healthy male college students from WIT were recruited for the study. They were gathered on three testing days, with an interval of one week between each testing day. On each testing day, one of the three stretching protocols was tested. Hamstring range of motion was measured using a goniometer at baseline level on each day and directly after each testing protocol was completed. Data was collected by the researcher.

Results: Al three of the protocols provided an increase in hamstring range of motion. Foam rolling produced a mean increase of 7.028% ($P<.001$), static stretching produced a mean increase of 7.144% ($P<.001$), and dynamic stretching produced a mean increase of 6.763% ($P<.001$). There was no significant difference in mean percentage increase achieved between the three protocols which were tested ($P>.05$).

Conclusions: Static stretching produced a marginally larger increase in hamstring range of motion than the other two protocols which were tested. Further research is required on each of the tested methods, to establish optimum technique for increased muscle range of motion so that the best practice of each technique can be measured and then tested against each other.

Literature Review

Introduction

Muscle strain injuries, especially hamstring injuries are a common problem in sports of all categories. They are especially common in sports with high demands on speed and power (Askling et al, 2003). Such sports include hurling, Gaelic football, and soccer. Much research exists which supports the theory that increased muscle range of motion i.e. increased flexibility is related to reduced risk of muscle injury (Witvrouw, 2003). There are many different methods which are used by athletes to increase their muscle range of motion in order to reduce their likelihood of picking up an injury during exercise. Foam rolling, static stretching and dynamic stretching are examples of such methods. This paper will examine the current literature on hamstring injuries in sport and the above three methods of increasing muscle range of motion to ultimately aid in the prevention of injury.

Incidence of Hamstring Injury in Sport

Eighty percent of injuries picked up by soccer players are in the lower extremities and 47% of those injuries are hamstring related (Ekstrand et al, 1983). It is also estimated that 10% of all major league soccer players will strain or injure their hamstring at some point during a season (Morgan and Oberlander, 2001). Murphy (2010) stated that hamstring injuries are the most common injury picked up by inter-county level Gaa players. Hamstring injuries are notoriously painful and slow to heal, with up to one third of hamstring injuries reoccurring in the first year after injury. The reoccurring injury is also often more severe than the first, leading to an extended recovery period (Heiderscheit et al, 2010). This shows just how common and serious an issue that hamstring injuries are in a variety of different sports.

Range of Motion and Injury

Increased range of motion in the muscle means that the likelihood of over stretching or straining the muscle during exercise is reduced, leading to reduced injury risk (Gossman, 1982). The aim of stretching and warming up muscles before exercise is to increase blood flow to the muscles, increase the temperature of the muscles, and to increase the muscles elasticity in preparation for exercise (van Mechelen et al, 1993). The idea behind this is to increase the range of motion in the muscle.

In an effort to combat hamstring injuries, there are many different techniques used to warm up the muscle prior to exercise. Static stretching, dynamic stretching, and foam rolling are examples of techniques used by athletes and their coaches to reduce the risk of hamstring injuries. The aim of the three techniques listed above is to reduce the likelihood of straining the hamstring muscle by increasing its range of motion. There are contrasting beliefs as to which of the techniques works best, leading to sports teams around the world using different styles of warm ups. This means that if the best technique is not used in warm ups, athletes can be put at a higher risk of injuring their hamstrings, as well as wasting time with a warm up which is not the most sufficient in protecting them against injury.

Research exists which supports the theory that increased muscle range of motion i.e. increased flexibility is related to reduced risk of muscle injury (Witvrouw, 2003). Bradley and Portas (2007) conducted a study to test elite soccer players in the English Premier League in connection with their flexibility in six different leg muscles and their likelihood of injury. The study concluded that of those who were tested, the players who had higher levels of flexibility in their muscles were significantly less likely to experoence any injury to these muscles throughout the season. Hamstring muscles were one of the muscles tested in the study which stated that a larger range of motion in the muscle leads to reduced injury risk. Witvrouw et al (2003) conducted a similar study on Belgian league footballers. This study showed similar results for hamstring and quadriceps muscles, stating that the players with most flexibility reported the lowest number of injuries over the duration of a competitive season. Woods et al (2007) also support the idea of warming up muscles before exercise in order to reduce occurrence of injury. They stated that warm ups should be

completed in the fifteen minutes immediately prior to physical activity, and should include stretches to increase the range of motion of the working muscles to receive the most benefit. Safran et al (1988) was also interested in studying the effects of muscle flexibility on likelihood of injury. In this study, tears in muscles which occurred with no warm up completed were compared to tears which occurred in warmed up muscles. The results showed that the warmed up muscles had a higher range of motion and had to be stretched a greater distance for a tear to occur. The muscles which were not warmed up, tore under less pressure while being stretched to a shorter distance. These studies show the importance of warming up muscles to increase their range of motion as it reduces the likelihood of injury occurring to the muscle during exercise.

Methods of Increasing Range of Motion

Many methods exist and are commonly used by athletes to increase the range of motion of their muscles before exercise to reduce their risk of injury. There are contrasting beliefs towards which technique is best, which is why so many athletes have varied warm ups. Three of the most commonly used methods are foam rolling, static stretching and dynamic stretching. The current state of research which exists on these three methods is discussed in this chapter.

Foam rolling

Foam rolling is a form of self-myofascial release which involves applying pressure to muscles with the use of a foam roller device. Myofascial release is a form of stretching which utilizes the concept of autogenic inhibition to improve soft tissue extensibility, thus relaxing the muscle and allowing the activation of the antagonist muscle (Gossman et al, 1982). The concept of massaging muscles before exercise is quite old but the idea of massaging oneself with the use of a foam roller is a new concept, with the first commercial foam roller only being released in 2005. There are many variations of the foam roller which are available in the market today. The majority of the products are smooth foam cylinders, whereas others have deep grooves and bumps designed for a deeper tissue massage. All of the studies referenced in this paper used the traditional smooth cylindrical foam rollers.

There are contrasting beliefs on the usefulness of foam rolling for increasing muscle range of motion. Some studies claim that self-myofascial release provides no increase in muscle range of motion (Miller et al, 2007) whereas others report that it does (McDonald et al, 2013). Much of the literature has utilized different methods of testing which may be why there have been conflicting results. Miller et al (2007) wanted to test if foam rolling increased range of motion of the hamstring over a duration of eight weeks. A population of twenty three healthy male and female college students took part in the eight week intervention and were split into a control group and a foam rolling group. The foam rolling group performed self-myofascial release on their hamstrings three times per week. They foam rolled for three minutes on each hamstring with a break of one minute between each minute of massage. After the eight weeks there was no evidence to show that the foam rolling group's hamstrings had improved in comparison with the control group who had been using no foam rollers. This study then concluded that foam rolling was of no use in increasing hamstring range of motion over a duration of eight weeks. In contrast, McDonald et al (2013) reported that foam rolling had an acute positive effect on the range of motion of the quadriceps muscle. Eleven healthy males were recruited for the study in which the quadriceps muscle was the main concentration, and knee extension distance was the measurement taken. Two bouts of self-myofascial release were completed by the intervention group, with one minute of massage completed in each bout. Knee extension angle was then measured at two minutes

and ten minutes after the foam rolling had finished and the results were compared to baseline measurements which were taken before any foam rolling took place. The results showed that the control group showed no improvements, but the intervention group increased the angle at the knee by 10% after two minutes, and 8% after ten minutes. The study concluded that foam rolling had an acute positive effect on the range of motion of the quadriceps muscle.

Similar to McDonald et al. (2013), Sullivan et al (2013) also used foam rollers, but on the hamstring muscle rather than the quadriceps muscle. In this study there were seven female and ten male participants in the intervention group, and a further three males and six females formed a control group. The intervention group completed bouts of foam rolling consisting of different durations, from five seconds up to ten seconds, on four different occasions. The results showed that foam rolling did in fact increase the range of motion of the hamstring muscles. The sit and reach test was used to determine if the hamstrings had increased in length. Hamstring length was measured three minutes after the foam rolling had finished. The results claimed that hamstring length was increased by foam rolling, and further increases could be achieved by foam rolling the muscle for a longer duration. Bouts of foam rolling the hamstring for ten seconds managed to increase hamstring range of motion by 4.3%. These studies showed contrasting results. This may be down to the different testing protocols used and the fact that different muscles of the body were used.

Mohr et al (2014) also sought to find out the effect foam rolling would have on hamstring flexibility when compared to static stretching, and a combination of static stretching and foam rolling. This was an interesting study as it combined two methods of increasing muscle range of motion and also tested the methods separately, by comparing which method provided the greatest increase in hamstring range of motion. Again, there was an increase in range of motion present for the group who used foam rolling alone. Interestingly the main finding of this study was that a combination of foam rolling and static stretching provided the largest increase in range of motion. This study again though was conducted over six separate sessions and measurements were taken at the beginning and end, providing little information about the acute effects of the conditions which were tested. Of the above studies, all bar one (Miller et al, 2007) are in support of the theory that foam rolling can positively increase the range of motion of the muscle in question. All sample

sizes were small and testing methods differed in many ways leading to conflicting evidence.

Static Stretching

Static stretching is another technique used by athletes to warm up their muscles in anticipation of exercise. The goal with static stretching is to bring the muscle to a point of tension and hold it there for a period of time, which will in turn increase the range of motion of the muscle (Woods et al, 2007). Various techniques of static stretching exist with some techniques holding the stretch for a few seconds (Young et al, 2006) and other techniques concentrating on holding the stretch for a number of minutes (Bandy & Irion, 1994). Most common practice involves holding the stretch for between thirty and sixty seconds. Much of the literature which exists on the topic of static stretching concentrates on the duration of stretches and which duration provides the most benefit in relation to increasing range of motion for the muscle being stretched (Bandy, 1997).

Bandy et al (1997) investigated how long a hamstring stretch should be held and how frequently it should be performed in order to achieve maximum increases in the muscles range of motion. The study recruited sixty-one males and thirty-two females for testing and split them randomly into five groups. Each group stretched their hamstrings at a different frequency and for a different amount of time to the other groups, with maximal range of motion tests being performed before and after the intervention. The results showed that the group who stretched their hamstrings for thirty seconds on five days of the week had the greatest increase in range of motion. This suggests that static stretching had a positive increase on hamstring range of motion over the duration of the six week intervention. Feland et al (2001) conducted a similar study but found different results. This study included sixty-two participants who were randomly split into three groups. One group held static hamstring stretches every day for fifteen seconds, the second group performed static hamstring stretches every day for thirty seconds, and the third group held the same static hamstring stretches for sixty seconds. A goniometer was used to measure the range of motion. The results showed that the group who held the stretches for the longest duration (sixty seconds), showed the largest increase in hamstring range of motion. They

achieved an increase of 2.4° in their hamstring flexibility per week, compared to the 0.6° achieved by the group who held their stretches for fifteen seconds. The above two studies were testing the same thing but reported different results. This may be down to the fact that the second study was based on older adults and the first involved relatively healthy and active younger participants. Although the results differed, they both still came to the conclusion that static stretching did actually increase the range of motion of the hamstring muscles.

Young et al (2006) wanted to study the effect of static stretching on power output and range of motion of the plantar flexors. The study involved twenty subjects completing five different warm ups consisting of a five minute treadmill run followed by different static stretching protocols, all lasting for thirty seconds. Following the warm up the participants were split into five groups and all completed static stretches for different durations. The results showed that the longer a static stretch was held, the less power the muscle could produce immediately afterwards. In terms of range of motion though, there were no significant differences in ankle range of motion for any of the different durations of static stretches which were tested. The study stated that this was probably due to the run which was completed in the warm up, but reported no acute increase in range of motion was found in the plantar flexors due to static stretching. In contrast to this, many more studies have found very positive results for static stretching in increasing muscle range of motion. Nordez et al (2006) conducted a study in order to measure any changes in range of motion or stiffness in hamstring muscles directly after the completion of static stretches. The participants completed five hamstring stretches and held each stretch for thirty seconds. These were standardised static stretches which are commonly used by athletes. The results showed that there was a significant acute reduction in stiffness in the hamstring muscles after the completion of the static stretches, which lead to an increase in the hamstring's range of motion. Magnusson et al (1998) also found positive results for static stretching on hamstring range of motion. This study had twelve recreational athletes who had their hamstring range of motion measured before and after a series of common static hamstring stretches. The results stated that static stretching, as it is commonly performed by athletes, increases joint range of motion by increasing stretch tolerance while the viscoelastic characteristics of the muscle remain

unaltered. This is further evidence that static stretching can have a positive effect on muscle range of motion.

Dynamic Stretching

Dynamic stretching basically means stretching while moving. In contrast to static stretching where one holds a stretch at a certain point, dynamic stretching occurs during movement. This acts to elevate core body temperature, enhance motor unit excitability, improve kinaesthetic awareness, and maximize active range of motion (Fowler et al, 2000).

This type of stretching often involves sport specific movements such as leg swinging for footballers or running athletes. Dynamic stretching incorporates whole body movements and involves actively and rhythmically contracting a muscle group through part of its functional range of motion (Curry et al, 2009). One of the advantages of dynamic stretching is that it involves more movement which will bring the body temperature up in preparation for exercise more than static stretching does (Mann et al, 1999). Dynamic flexibility programmes are designed from analysing the movements associated with a particular sport activity and developing stretches to enhance flexibility and balance necessary for that activity (Mann et al, 1999).

Curry et al (2009) conducted a study to examine the effect of dynamic stretching on muscular performance in women. There were twenty-four healthy women involved in the study. The results showed that dynamic stretching improved the power output of muscle and also increased the muscle's range of motion. A limit to this study is that there were only women involved and specific details of improvements to range of motion were not given as the main aim of the study was to examine the effect of dynamic stretching on power output. Osman et al (2011) conducted a study on how dynamic stretching effects the range of motion in the muscles involved in kicking a football. The participants in this study were eighteen professional male soccer players. To examine the effects, a control group and a dynamic stretching group were formed. The results showed that after a series of dynamic stretches, the professional soccer player's range of motion in the kicking muscles was increased. The study concluded that this increase in range of motion would enhance the player's ability to score and reduce the likelihood of injury. The above literature is in agreement that dynamic stretching as part of a warm up increases the range of

motion in muscles, but not all of the literature agrees with this. O'Sullivan et al (2009) compared the effect of static stretching and dynamic stretching on muscle range of motion in individuals with a history of injured hamstrings. Interestingly, this study found that there was no increase in hamstring range of motion after completing a series of dynamic stretches. This shows that there is still uncertainty amongst the research of the reliability of dynamic stretching for improving muscle range of motion.

Summary and Rationale

From the above research, it is clear that hamstring injuries are a very common and serious issue for athletes around the world. The research gives consistent evidence to support the notion that increasing the range of motion of muscles before the onset of exercise will reduce the risk of injury occurring (Gossman, 1982). Foam rolling, static stretching and dynamic stretching have demonstrated contrasting results based on varying methodologies, but commonly a positive effect on muscle range of motion was found. All three of the listed methods have been proven effective in certain studies, but have never been tested against each other in order to distinguish which is the most effective. The proposed study would aim to independently analyse each of the three methods to measure the percentage change from a baseline measurement taken before the condition, to a post condition measurement. The results from this study would give more concrete information as to whether they are in fact effective in increasing muscle range of motion, and which method increases range of motion the most, leading to maximum prevention of injury. This information would be of use to athletes worldwide as it could reduce the overall incidence of hamstring injuries by providing knowledge on the most effective and worthwhile method of warming up before exercise.

Research Questions

1. Does foam rolling increase hamstring range of motion for acute injury prevention?
2. Does static stretching increase hamstring range of motion for acute injury prevention?
3. Does dynamic stretching increase hamstring range of motion for acute injury prevention?
4. Is foam rolling, static stretching, or dynamic stretching most effective in increasing hamstring range of motion for acute injury prevention?

Methodology

Research Design

This study was a repeated measures design as outlined in Figure 1. Convenience sampling was used in order to recruit participants for the study. Once identified and cleared to take part in the study, participants were examined under three conditions; foam rolling (Trial 1), static stretching (Trial 2), and dynamic stretching (Trial 3). Testing of all conditions took place on three occasions. The participants completed a short warm up on all three occasions before any measurements were taken. After the warm up, baseline hamstring flexibility measurements were measured using a goniometer. After these measurements had been recorded, the participants began foam rolling. Immediately after completing the foam rolling protocols the group then had the range of motion of their hamstrings measured again. These results were taken by the researcher. A week later, the groups were then gathered again. On this occasion, the groups completed the same warm up, and then had their baseline hamstring range of motion tested again. They then completed the static stretching protocol and had their hamstring range of motion tested immediately after. Participants were tested in the exact same fashion as the third day, the only difference being that this time they were completing the dynamic stretching protocol. Percentage change for each trial was calculated and entered into the computer program SPSS for statistical analysis. Repeated measures ANOVA tests were completed using SPSS to compare the differences in the three methods. This aimed to show which method provided the greater percentage increase in hamstring flexibility from baseline to post condition measurements. Microsoft Excel and Word were used to illustrate the findings of the study.

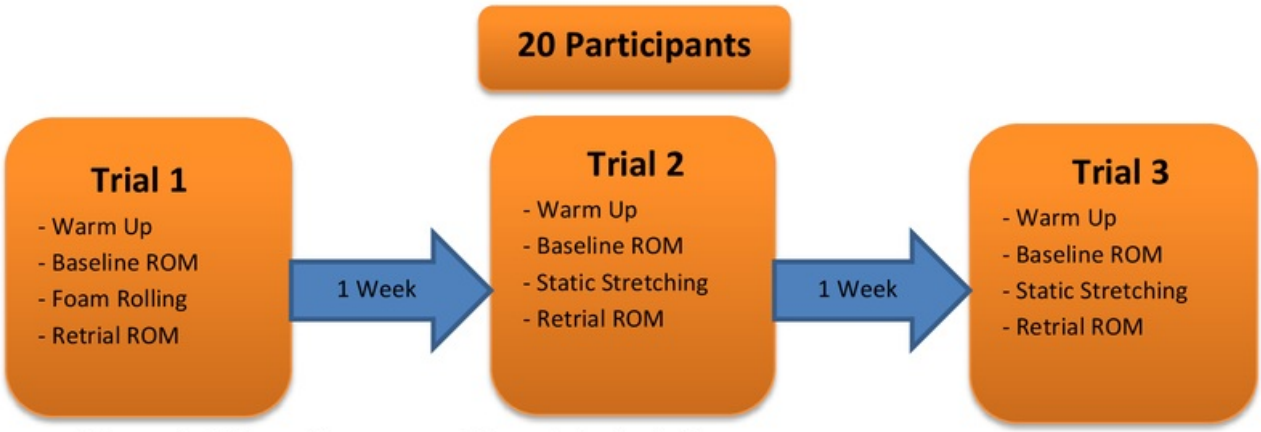

Figure 1: Schematic representation of study design

Study Population and Sampling

The study population for this study was WIT students who are physically active and not currently undergoing any flexibility program. Convenience sampling was used to recruit participants. Posters detailing the study were placed around the college with contact details for the researcher. Interested students were asked to contact the researcher who then gave further information and informed consent forms prior to the participation in the study.

All participants were given detailed information on what would be required of them to participate in the study. They were asked to read and sign an informed consent form (Appendix A) detailing the procedures of the different tests and protocols that would be used. They were also notified that the study would be kept fully confidential. The participants also reserved the right to drop out of the study at any time if they wished to do so.

Procedures

Participants attended 3 trials with a one week interval between each testing session. All three trials took place at the same time of day, and participants were asked to arrive in a similar state on all of the days to ensure tests would be comparable. This involved them eating the same breakfast on each trial morning, and travelling to the study location in the same way on each trial day. Participants were also required to refrain from completing any heavy training session the night before or morning of each of the three trials.

Standardised Warm Up

20m Jog
20m Side Step
20m Heel Flicks
20m High knees
} x3

20m Skipping

Participants walked back to their starting point after each exercise, then proceeded to the next exercise.

Participants were required to complete the above warm up. Each exercise was completed once, followed by the next, and the cycle was then repeated three times. This warm up is based on warm ups used in previous studies and is accredited by the ACSM (2010). The warm up was supervised by the researcher in order to standardise the warm up.

Assessment of Range of Motion

Hamstring flexibility was measured using the goniometer. The goniometer is a commonly used tool for the assessment of hamstring flexibility and has been approved as a valid measurement tool by Gajdosik et al (1987). The participants were asked to lie flat on the ground. One leg while being kept straight was then lifted upwards as far as the hamstring would allow. Range of motion was then measured at this point using the goniometer, as seen in Figure 2.. An average score for each participant was taken (to the nearest degree) from three measurements.

Figure 2: Goniometer measurement of Hamstring Range of Motion

Foam Rolling

Participants were asked to put their body weight on their hamstring, resting on the foam roller on the ground. They used their hands to support them. They then rolled themselves back and forth over the foam roller along the length of their hamstring. The weight was kept constant for the duration of the bout of foam rolling. If/when there was a certain point of tension or pain felt along their hamstring, they then concentrated on this area as it is the area of the muscle which is tightest. The participant then continued to foam roll on this area of their hamstring for a bout of sixty seconds (McDonald et al, 2013). An example of the foam rolling technique can be seen in Figure 3..

Figure 3: Foam Rolling Technique

Static Stretc

The static hamstring stretch that was used in this study was the seated hamstring stretch (Figure 4). Participants were asked to sit on the floor with one leg straight out in front of them. The sole of the other foot was then planted against the inner thigh of the outstretched leg. The participant then reached out towards the toes of the outstretched leg without any jerky movements. The participant was instructed to maintain good pelvic alignment and keep their chest upwards while completing this stretch, and reminded to breathe normally throughout. When they reached a point where considerable yet manageable tension could be felt, they then held this position for thirty seconds (Bandy & Irion, 1994). The participants stretched their hamstring muscle twice before having their range of motion tested again.

Figure 4: Seated Hamstring Stretch

Dynamic Stretch

Participants stood in an upright position with a stable support available to aid them with balance throughout the stretch. The balance support was at shoulder height. Keeping the leg straight during the forward movement, and slightly flexed during the backward movement, participants swung one leg back and forth at their full range of motion without feeling pain. Continuous swinging was completed for fifteen seconds, twice. Participants were told to concentrate on standing up straight and keeping the rest of their body still throughout the movement. An illustration of this movement can be seen in Figure 5.

Figure 5: Dynamic Hamstring Stretch

Data Analysis

The data was collected by the researcher on each occasion that the participants met up to complete tests. Once all tests were completed and results had been gathered, percentage (%) change in range of motion in each Trial was calculated as follows:

((Retrial ROM – Baseline ROM)/Baseline ROM)*100

The results were entered into the computer programme SPSS for analysis. Descriptive statistics were expressed as mean ± standard deviation. A repeated measures ANOVA test was used to determine the difference in range of motion between the three different methods used. Post hoc tests were used identify the location of any differences. The computer programmes Microsoft Excel and Word were used to illustrate the findings.

Results

Participant Information

Fourteen male participants were recruited to take part in the tests. They were all physically active males who were currently not involved in any flexibility programmes. Table 1 gives details of the average age, height and weight of the subjects who took part in the study.

Table 1: Participant Characteristics

Characteristic	Mean ± SD	Standard Deviation
Age (years)	20.9	2.76
Height (cm)	176	7.00
Weight (kg)	77.8	5.28

Effects of Foam Rolling on ROM

A paired sample t-test was used to determine the difference in range of motion before and after the foam rolling condition. The results showed that there was a mean increase of 7.02 ± 4.61% in range of motion for participants after the bout of foam rolling. A significant difference was found between pre and post condition scores, P<.001. Figure 6 illustrates the results from the foam rolling condition. "FR Pre" refers to the participants' baseline scores, and "FR Post" refers to their post foam rolling score. Significant difference is denoted by "*".

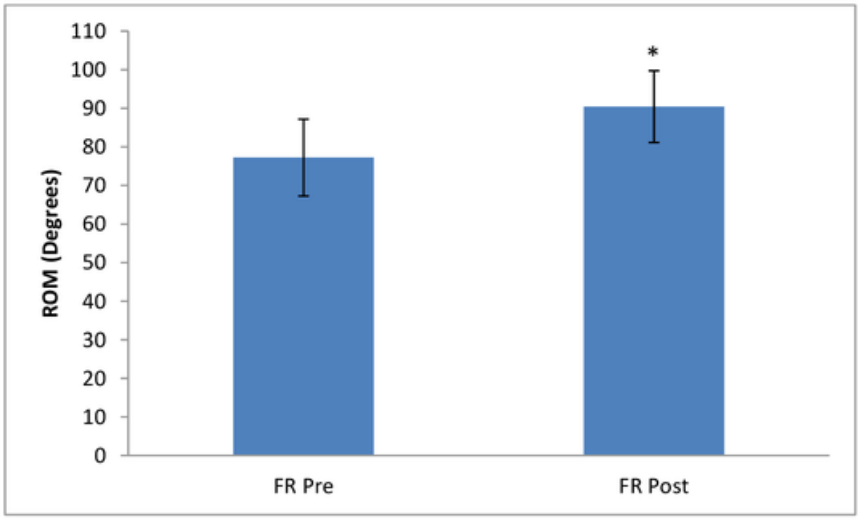

Figure 6: Effects of foam rolling

The Effect of Static Stretching

A paired sample t-test was used to determine the difference in range of motion before and after the static stretching condition. The results showed that there was a mean increase of 7.14% ± 4.03 in ROM for participants after the bout of static stretching. A significant difference was found between pre and post condition scores, P<.001. Figure 7 illustrates the results found for the static stretching condition. "SS Pre" refers to participants' baseline scores, and "SS Post" refers to their post static stretching scores. Significant difference is denoted by "*".

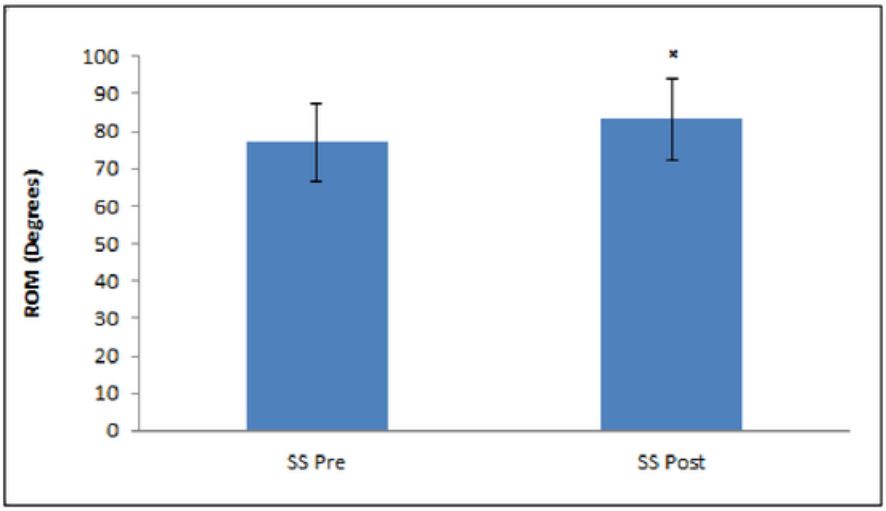

Figure 7: Effects of static stretching

The Effects of Dynamic Stretching

A paired sample t-test was used to determine the difference in range of motion before and after the dynamic stretching condition. The results showed that there was a mean increase of 6.76% ± 2.33 for participants after the bout of static stretching. A significant difference was found between pre and post condition scores, P<.001. Figure 8 illustrates the results found for the dynamic stretching condition. "Dynamic Pre" refers to the participants' baseline score, and "Dynamic Post" refers to their post dynamic stretching scores. Significant difference is denoted by "*".

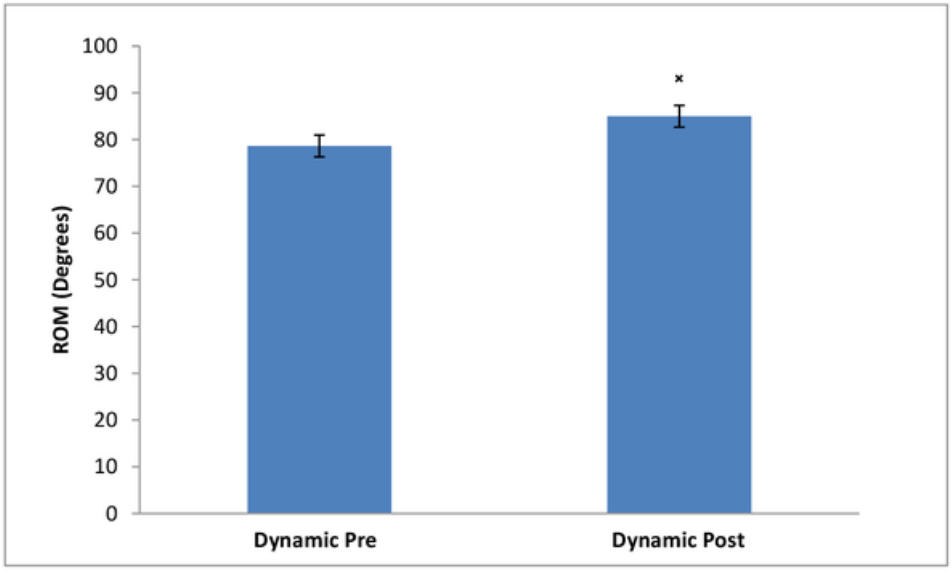

Figure 8: Effects of dynamic stretching

Comparison of Results for Foam Rolling, Static Stretching and Dynamic Stretching

A repeated measures ANOVA test was carried out to compare the range of motion percentage increase of all three conditions. The results show the mean score of differences, and that no significant differences were found - P>.05. Figure 9 illustrates the results.

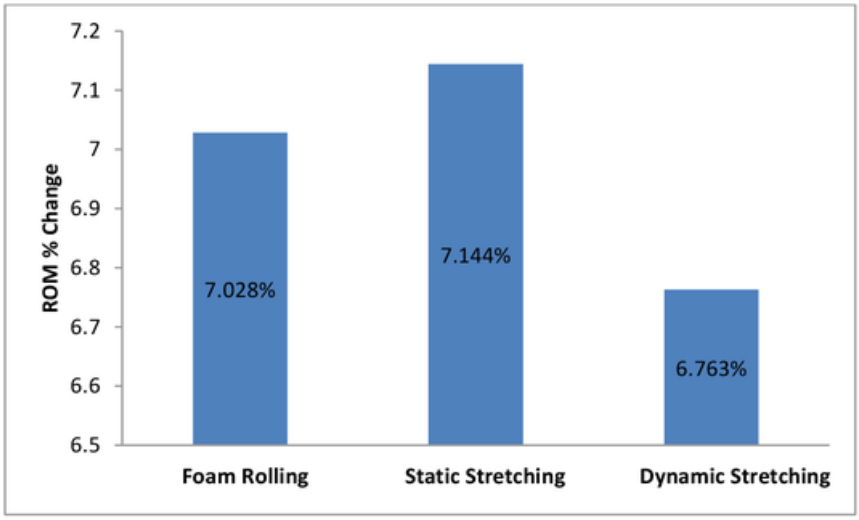

Figure 9: Mean Percentage Increase of 3 testing methods

Discussion

Introduction

The purpose of this study was to determine whether foam rolling, static stretching and dynamic stretching would increase the range of motion in the hamstring muscle in order to reduce the chances of injury during exercise. Once these questions were answered, the study then sought to distinguish which of the three listed methods provided the greatest increase in hamstring range of motion. The primary function of this section is to analyse the results from the three tests, and discuss these results in relation to previous literature in the area. Contrasting research exists which is why there are varied opinions on which of the three methods can be most beneficial for athletes to use in order to protect themselves from injury during exercise or participation in sports.

Main Findings

The results showed that foam rolling, static stretching, and dynamic stretching all increased hamstring range of motion. Although there was an increase in hamstring range of motion for all three conditions, there was no significant difference in the mean percentage of increase for either of the tests. Static stretching produced the largest increase in range of motion, followed by foam rolling, which was followed by dynamic stretching. The final results showed that there was only 0.377% of a difference between the static stretching post test score, which was the highest of the three, and the dynamic stretching post test score, which was the lowest. The research questions regarding each of the three protocols have been answered positively as they all showed an increase in hamstring flexibility. Statistically speaking, the answer to research question four is that static stretching was most effective in increasing hamstring range of motion, but not significantly so.

The Effect of Foam Rolling

The first research question in this study asked whether foam rolling could increase hamstring range of motion for acute injury prevention. The results have shown that a bout of foam rolling lasting sixty seconds was effective in increasing the hamstring's range of motion. All fourteen of the participants displayed positive results for the foam rolling protocol. The average increase for the fourteen participants was 13.1˚. The mean percentage increase achieved by the fourteen participants was 7.02%, which is a similar increase to that which was found in Sullivan et al (2013)'s study on the effects of foam rolling on hamstring range of motion. The average percentage increase found in Sullivan et al (2013)'s study was 4.3%. Both studies used similar sample sizes and foam rolling equipment. In the Sullivan et al study, bouts of foam rolling consisting of different time durations were tested. The study concluded that the longer the duration of the bout of foam rolling, the larger the increase in hamstring flexibility was likely to be. The 4.3% increase in range of motion was achieved by bouts of foam rolling which lasted ten seconds. Ten seconds was the longest duration tested in this study. The results found by Sullivan et al (2013) are consistent with those found in this study, as longer bouts of foam rolling were utilized. This study used sixty second bouts, and showed a larger increase in range of motion as a result of this.

Mohr et al (2004) also found positive results for increasing hamstring range of motion through the use of foam rolling. Mohr et al' (2004)s study was completed over six days, with a foam rolling group undergoing three bouts of foam rolling at a duration of one minute per bout, on each of the six days. Results were gathered directly after the bouts of foam rolling were completed. After the six days of testing had been completed, the results showed that there was an average increase of 8.06% in hamstring flexibility for the foam rolling group. Again, these results are similar to those achieved by my study. The methods used in Mohr et al (2004)'s study were similar to those used in mine, bar that they used three one minute bouts in comparison to one, one minute bout in my tests. The mean increase in range of motion of 8.06% achieved by three, one minute bouts is slightly higher than the 7.02% achieved with my singular one minute bout. This increase is also consistent with the conclusions of Sullivan et al (2014)'s study which stated that longer

durations of foam rolling provide greater increases in range of motion. Miller et al (2007) conducted a study which sought to find out if foam rolling regularly with three minute bouts would increase hamstring range of motion permanently. Although they used similar bout times to the studies mentioned above, their results showed no increase in hamstring range of motion after foam rolling for three minutes, three times a week, for eight weeks. The results in Miller et al (2007)'s study were collected in a different manner to the other mentioned studies. All of the other studies took hamstring measurements as soon as the bouts of foam rolling were completed, whereas Miller et al (2007) only took baseline measurements on day one, and the final measurements on the last intervention day of week eight. Taking this into consideration, it can be concluded that foam rolling is not effective in increasing hamstring range of motion chronically, yet it can be successful in increasing muscle range of motion acutely if performed as part of a warm up prior to the onset of exercise. There are many other variables to consider when it comes to foam rolling, other than duration and number of bouts completed. The type of foam roller used in these bouts may also have an effect on the increase in range of motion achieved. All of the studies discussed thus far have used smooth cylindrical foam rollers. Deep tissue massage foam rollers are also widely available and are designed with deep grooves and bumps along the surface of the foam roller. These bumps and grooves are designed to penetrate the muscle deeper than the average smooth foam roller. Behara and Jacobson (2015) utilized such deep tissue foam rollers in a study to determine the effects these devices would have on the range of motion and power output of the hamstring muscles. One minute bouts of foam rolling were completed on the hamstring muscles and measurements were taken at baseline and directly after these bouts were completed. Interestingly, the results showed that a singular one minute bout of foam rolling using a deep tissue massage foam roller provided a 15.6% increase in hamstring range of motion. This data shows that deep tissue massage foam rollers can have a far superior increase on muscle range of motion than traditional smooth foam rollers.

The Effect of Static Stretching

The second research question in this study aimed to determine whether or not static stretches could increase the range of motion of the hamstring muscle for acute injury prevention. The results have shown that the use of the commonly used seated hamstring stretch was effective in increasing hamstring range of motion when held for a duration of thirty seconds. All fourteen of the participants displayed positive increases in their hamstring range of motion after completing the static stretch protocol. The average increase in range of motion among the fourteen participants was 6.21°. The mean percentage increase in hamstring range of motion achieved by the participants was 7.144%. This was the largest increase in hamstring range of motion recorded in this study from all three conditions. These results are compliant with many previous studies conducted in the area of static stretching. Bandy et al (1997) found that hamstring range of motion was increased significantly when thirty second bouts of static stretches were completed on five days of the week. Bandy et al (1997) also tested different durations of static stretches but found that the thirty second version of the seated hamstring stretch provided the largest increase in range of motion. Nordez et al (2006) also found thirty second bouts of static stretches to increase hamstring range of motion. In this study there were a series of different methods used to perform the static stretches. These included the seated hamstring stretch, as well as assisted stretches and standing hamstring stretches. No indication was given in the results as to which of the five static stretches which were used provided the largest increase in range of motion, but the study concluded that each of the five static stretches provided positive increases in hamstring range of motion when held for thirty seconds. Research suggests that a combination of different static stretches completed after each other provide a greater increase in muscle range of motion than one singular static stretch. Nordez et al (2006) utilized five different static stretches before taking their final measurements and found an average range of motion increase of 11%. DePino et al (2000) also conducted a study which used multiple static stretches before assessing the increase in hamstring range of motion. In this study, they reported using four different static hamstring stretches, which achieved a mean increase in range of motion of 13%. In both of these studies, the static stretches were held for a duration of thirty seconds.

The results of all of the above studies suggest that thirty seconds is the optimal duration for holding a static stretch for increased range of motion in the hamstring muscles, and that the use of multiple static stretches performed simultaneously will provide further improvements in the range of motion of the muscle when compared to studies such as this one, which only utilized one static stretch.

The Effects of Dynamic Stretching

The third research question of the study sought to determine whether dynamic stretching could increase hamstring range of motion for acute injury prevention. The results of the tests showed that dynamic stretching did in fact increase muscle range of motion. All fourteen participants again displayed positive results and could stretch their hamstrings further after completing the dynamic stretch protocol. The average increase in range of motion achieved was 6.35°.The mean increase in hamstring range of motion among the fourteen participants was 6.763%. Dynamic stretching showed the lowest improvement in range of motion of the three protocols tested. Much research exists which supports the theory that dynamic stretching is an effective method of increasing muscle range of motion. This is expected because the muscle is brought through specific movements designed to elongate the muscle and allow it to expand further than it would without the dynamic stretch. Such increases were evident in this study. The results obtained through this study are consistent with those of Osman et al (2011) who also reported increases in hamstring flexibility when dynamic stretches were performed on the muscle. Osman et al (2011)'s study found greater increases than were found in this study though. This is most likely due to the fact that Osman et al (2011) incorporated an entire warm up of dynamic stretches concentrating on all the kicking muscles of the leg. In comparison, this study involved a general aerobic based warm up, followed by one singular dynamic stretch which focussed solely on the hamstring muscle. This concept of combining a light aerobic warm up with multiple dynamic stretches to obtain greater range of motion in the hamstring muscle is supported by another study conducted by Perrier et al (2011). In this study twenty one healthy male college students were split into a dynamic stretching group and a control group who completed no stretching protocol. The participants then completed a warm up which consisted of a five minute jog on a treadmill followed by eleven different dynamic hamstring stretches for those who were in the dynamic stretching group. The participant's hamstring range of motion was measured before and directly after their warm up was completed. A sit and reach test was used to measure their range of motion. The results showed that there were significant increases in range of motion for all participants in the dynamic stretching group when compared to those in the no stretching group. This further

supports the concept that multiple dynamic stretches on a particular muscle will provide greater gains in range of motion. The average time for completion of the series of dynamic stretches in Perrier et al (2011)'s study was 13.8 minutes. Ordinarily a warm up would last between five and fifteen minutes in duration, which should consist of aerobic exercises which warm up the entire body (ACSM, 2010). For this reason it is unrealistic to expect athletes to spend up to fourteen minutes concentrating on warming up one particular muscle. Research is needed in this area to determine the best way to get optimum results for increasing muscle range of motion in a manageable amount of time in a warm up.

Conclusion

After comprehensively testing all three methods of increasing muscle range of motion, the results showed that each of the three protocols were successful. Positive results were shown for foam rolling, static stretching, and dynamic stretching. It can so be concluded, that each of the three warm up techniques can be effective in reducing the acute risk of injury during sport. This is true because each of the three techniques increased the range of motion in the muscle, which reduces the likelihood of over stretching or straining the muscle during exercise (van Mechelen et al, 1993). Although the differences in mean range of motion increases were deemed not significant, the static stretching protocol provided the greatest increase overall.

Limitations

There were some aspects to this study which could have been improved on to secure more accurate tests and results. Firstly, the sample size was quite small. With a larger sample size, a more comprehensive result would have been achieved. Another limitation to the study was that participants were asked to arrive to each testing day well rested without having completed any vigorous physical activity in the last twenty-four hours. All participants did claim to stick to this condition yet there was no real way of telling whether or not this was in fact the truth without fulltime supervision of their activity levels. The fact that there were only three test days included in the study could be seen as another limitation. If there were perhaps two separate days of testing for each of the three protocols, more data could have been collected in order to give more accurate results. On occasion, during the test days, time management was an issue. Some participants arrived later than others, which meant they were scattered between warming up, undergoing the testing procedure, and getting their pre and post protocol measurements taken. This meant that the researcher had to acquire help on testing days and delegate jobs to other individuals, and thus could not supervise every part of the testing procedure.

Recommendations for future study

As warm ups are an area of extreme importance for both professional and amateur athletes, there are countless contrasting opinions as to what is best practice. The very nature of the topic area is so broad that it is clear that not one warm up will suit all athletes. Through studying the topic, many different issues were observed by the researcher which would be of great value to sports people worldwide if addressed. Firstly, there is contrasting evidence as to what duration and technique will increase range of motion the most for both static and dynamic stretching. There is little research that compares one method to the next, with virtually all existing evidence viewing static stretching and dynamic stretching as umbrella terms. It would be interesting to see a study establish best practice for increasing range of motion in one particular muscle, through testing different stretching protocols against each other. Additionally, there are multiple studies which have used a combination of different dynamic stretches. No existing study has determined how many dynamic stretches provide the greatest increase in range of motion, but many agree more than one solitary dynamic stretch is necessary. Similarly, it would be of interest to test the different types of foam roller that are available in today's market against each other. Deep tissue massage foam rollers did seem to provide larger increases in range of motion in particular studies which were researched in the duration of this dissertation, but there was little research which directly compared the two types of foam roller against each other. In addition to this, in many studies the duration of foam rolling bouts, and the techniques themselves differed hugely. It would be worthwhile to establish the optimum duration and technique for foam rolling for the benefit of future research and the benefit of athletes worldwide who use foam rollers frequently.

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Appendices

Appendix A : Informed Consent Form

Name:

You are invited to take part in a study comparing three common warm up practices in order to distinguish which provides the greatest increase in muscle range of motion for the reduction of injury during exercise. The three methods which will be compared are static stretching, dynamic stretching and foam rolling, and the muscle which will be tested will be the hamstring muscle. The study will take place over three weeks and will require your participation for fifteen minutes on three separate occasions. All test scores and personal details will be kept fully confidential. The completion of this study will pose no risk to your personal health or wellbeing. By signing below you, agree to participate in the study. You have the right to withdraw from the study at any time.

Signed _____

Date _____