Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

Empirical [1]

Student name:	Rory Ilott	***Student ID:***	ST10001855
Programme:	SCRAM		
Dissertation title:	The Effects of Combining Foam Rolling and PNF Stretching on Hamstring Flexibility in Gymnasts		
Supervisor:	Dr. Andy Miles		

Comments	Section
	Title and Abstract Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
	Methods and Research Design To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.
	Results and Analysis [2] To include: description and justification of data treatment/ data analysis procedures; appropriate presentation of analysed data within text and in tables or figures; description of critical findings.
	Discussion and Conclusions [2] To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.
	Presentation To include: academic writing style; depth, scope and accuracy of referencing in the text and final reference list; clarity in organisation, formatting and visual presentation

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CARDIFF SCHOOL OF SPORT
Prifysgol Fetropolitan Caerdydd

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT CONDITIONING REHABILITATION AND MASSAGE

TITLE
THE EFFECFTS OF COMBINING FOAM ROLLING AND PNF STRETCHING ON HAMSTRING FLEXIBILITY IN GYMNASTS

(Dissertation submitted under the discipline of SCRAM)

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REHABILITATION AND MASSAGE

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THE EFFECTS OF COMBINING FOAM ROLLING AND PNF STRETCHING ON HAMSTRING FLEXIBILITY IN GYMNASTS

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Notes:

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Acknowledgements

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Abstract

The purpose of this study was to explore the effects of combining foam rolling and PNF stretching on hamstring flexibility in gymnasts.

Previous research has stated that flexibility is a key fitness component in gymnastics and is often used in talent identification of certain skills. It has been suggested that the best way to improve flexibility in gymnasts is via stretching. Foam rolling is a therapeutic modality that has been suggested to aid muscle flexibility through various physiological effects when combined with a flexibility enhancing modality. This study focused on using a combination of PNF stretching and foam rolling as an intervention method and study its effects upon active and passive straight leg raise hamstring flexibility, comparing the results to a PNF stretching only intervention and used the findings to argue in favour of the use of foam rolling as an aid to enhance flexibility. This study met the research aims by conducting practical research. This was carried out using an active and passive straight leg raise test to assess hamstring flexibility in both legs and the use of foam rolling combined with PNF stretching as an intervention protocol. The active and passive straight leg raise test results were analysed using SPSS software to identify any significant differences between improvements across each intervention group. Analysis of the findings demonstrated that the combination intervention produced significant findings only in active left leg raise when comparing PNF/FR with PNF ($p = 0.046$) and PNF/FR with Control ($p = 0.028$), but significant findings were not present in the other three tests. The main conclusion drawn from the study was that the proposed physiological effects of combining foam rolling with PNF stretching in relation to increasing hamstring flexibility was not supported. By failing to support its use, this study has demonstrated that the use of a foam roller prior to stretching is not an effective way of increasing hamstring flexibility in gymnasts. Despite the lack of previous research into this topic area, this study argues that with improvements made to the methodology by minimising external variables and increasing intervention length, there could be significant differences found.

CHAPTER 1

INTRODUCTION

Introduction

Flexibility is an important fitness component in athletes as it allows many complex athletic movements to be completed, which in turn can increase the athletes performance through the increased range of motion about a joint (Baechle and Earle, 2000). Due to the nature of biomechanical movements required within Gymnastics, it is important for the gymnasts to maintain high levels of flexibility. This flexibility is needed to get into the positions for certain skills, such as splits, which requires hamstring flexibility and hip range of motion (ROM), and is often included in talent identification and screening programmes (Hancock, 1999; Kinser et al, 2008). Therefore, further research into modalities that could contribute to the increase in hamstring flexibility and the improvement of gymnastics performance needed to be developed.

Stretching is the most common method used to increase flexibility in sport, there are, typically, three separate methods used to enhance flexibility: Static stretching, Dynamic (Ballistic) stretching and Proprioceptive Neuromuscular Facilitation (PNF) stretching (Spernoga et al, 2001; Hartig and Henderson, 1999; Burke et al, 2001). It has been found that PNF stretching showed greater increases in flexibility compared to the other two methods (Burke et al, 2001).

Taylor et al (1990) stated that muscles and tendons have viscoelastic properties, and also have properties of a creep and stress relaxation. Improvements in flexibility can be seen as the proposed physiological effects of stretching on a muscle unit by the elongation of the muscle fibres and tendons, causing inhibition of the Golgi tendon organs located in the musculotendinous junctions (Knott and Voss, 1968).

Other modalities to improve ROM have been used such as foam rolling as a form of ‘self myofascial release’ (SMR), where their physiological properties, as described by Kaltenborn (2006). These are that foam rollers cause inhibition of the Golgi tendon organs, which allows the muscle to stretch further, which is similar to PNF without actually applying a stretch themselves. Limited research has been conducted into the area of foam rolling effects, one study by Miller and Rockey (2006) compared foam rolling to stretching and found that foam rollers made no improvement to flexibility. As a muscle needs to be stretched for there to be an improvement in flexibility, and as foam rollers do not apply a direct stretch, Kaltenborn (2006) describes them as being a compliment to other modalities such as stretching, therefore more research needed to be conducted within this area.

Given the theoretical potential for foam rolling to increase flexibility when combined with a stretching modality, this study was undertaken to determine the effectiveness of combining foam rolling with PNF stretching, and comparing it to just the use of PNF stretching to determine the effectiveness of improving hamstring flexibility in gymnasts. The aim of the study was to support the use of foam rolling when combined with a flexibility protocol and allow the development of implications made by Kaltenborn (2006). If the results of the study showed that combining foam rolling with stretching produced a greater increase than just stretching on gymnasts hamstring flexibility, it would help coaches to understand that there are other modalities available to be added to a stretching programme designed to improve a gymnast's performance.

Taking into account the previous research conducted into the fields of stretching, foam rolling and hamstring flexibility, the evidence lends weight to this study having a positive effect. Therefore, the study aimed to disprove the null hypothesis:

H0: It is hypothesised that combining foam rolling with PNF stretching, over a six week period, will show no significant improvement in straight leg raise flexibility of the hamstrings when compared to an intervention group only conducting PNF stretching, and a control group.

Hypothesis:

H1: It is hypothesised that combining foam rolling with PNF stretching, over a six week period, will show a significant improvement in straight leg raise flexibility of the hamstrings when compared to an intervention group only conducting PNF stretching, and a control group.

CHAPTER 2

REVIEW OF LITERATURE

2.0 Review of Literature

2.1 Introduction:

There is a wide range of literature looking at the effects of flexibility within sport and its importance in injury prevention and rehabilitation, but also in performance. In particular there is a selection of research that focuses on the hamstring muscle group, such as a review article by Decoster (2009), this looked at the effects of hamstring stretching on range of motion and found that stretching intervention groups always improved significantly in comparison to the control groups, that there were few significant differences between the methods of stretching used, and that the optimal amount of time to stretch was for 30 seconds. Research has also been done into ways of improving this flexibility for the purpose of rehabilitation and improving performance, whether it be stretching or using other modalities such as self-myofascial release techniques in the form of foam rollers. A review by D'Amico and Morin (2010) looked at the effects of myofascial release on human performance and found that as a method of improving flexibility, there was no significant difference in results between static stretching (SS) and self myofascial release (SMR), although it's recommended to complete static stretching as it is tried and tested. D'Amico and Morin (2010) also found that SMR showed an increase to static hamstring strength and jump height/distance when compared to a control group. This review of literature looks at and compares studies in the aforementioned fields of research in order to find a key area to study, taking positives and negatives from previous studies.

2.2 Hamstring Flexibility & Injury:

Flexibility can be described as the range of motion (ROM) about a joint in the body (Baechle and Earle, 2000). They further stated that flexibility within the muscles is an important component of many athletic movements and that optimal flexibility can increase an athlete's performance by improving a joint's ROM and possibly decreasing the chances of obtaining a musculoskeletal or soft tissue injury. Soft tissue injuries account for a significant percentage of athletic injuries (Curren et al, 2008). Funk et al., (2001) stated that inadequate flexibility is a contributing factor to musculoskeletal injury, especially in the hamstring muscle group where one of the most common musculoskeletal diagnoses in sport is a strain of the a hamstring muscle. This complements the study by Cross et al., (2010) who found that the prevalence of recurrence of this particular injury was as high as 34%. The properties of the hamstring muscle also add to the prevalence of injury, the muscle group causes extension of the hip during eccentric contraction meaning that it lengthens under load, where the injury is more commonly associated with length rather than tension of the muscle (Brukner and Kahn, 2001). This lengthening of a muscle under load can cause the muscle to over extend and tear if there is inadequate extensibility, a predisposing factor to hamstring muscle strains (Makaruk et al, 2010). Makaruk et al (2010) went on further to say that this injury is one of the most common seen within speed strength events, or events that involve sprinting and/or jumping, due to the explosive nature of these movements putting a large amount of stress upon the muscles. This puts athletes such as dedicated sprinters and jumpers at greatest risk, or sports that combine both such as gymnastics, but also games players such as football, hockey and basketball which all involve similar movements (Brukner and Kahn, 2001; Cross et al, 2010). Furthermore, hamstrings are part of the ‘tonic’ muscle group which when they grow and strengthen and increase in tone, lose flexibility, undermining their capacity (Makaruk et al, 2010). This adds further weight to the importance of enhancing flexibility within this muscle group.

2.3 Demands of Gymnastics:

Gymnastics is a very demanding sport; it requires suppleness, strength, form, agility and optimal weight for peak performance (Gabel, 1992). Gymnasts require a high power to weight ratio, this ratio is the gymnasts’ ability to efficiently move their body weight with a high degree of power and is better achieved with a strong athlete that has a lower mass to control. The need to move the body at speed with strength is important in almost every event (Goranson, 1981), such as in floor exercise where the ‘punch’ will get you into the air quickly and with height so there is enough time to complete the skill, therefore the gymnast has to have sufficient power in the upper and lower body. Tension strength, defined as being able to contract muscles and tense muscles to hold the body in a specific position (Goranson, 1981) is also required in the sport while taking off, completing or landing skills, this will stop the gymnast from losing the position mid skill or failing to stick the landing as their body wasn't tight enough in prepared for it (Goranson, 1981). During a gymnastics competition, especially the high standard ones where the gymnast is competing in the 'all round' category, it is required for males to compete on all 6 pieces (Floor, Vault, Rings, Parallel Bars, High Bar and Pommel) and women to compete on all 4 pieces (Floor, Vault, Balance Beam and A-symmetric Bars). The order in which the gymnast competes on these pieces differs between competitions, and as some events are more physically demanding than others, muscular endurance is a key characteristic required by gymnasts in order to be ready for the next event, and the most effective way described of building this routine endurance is by practising routines over and over (Goranson, 1981). And finally, flexibility plays a huge role in the physical demands of gymnastics due to the positions required.

2.4 Flexibility in Gymnastics:

As mentioned earlier, flexibility is important for performance in many sports so that the athletes can get into specific positions and move through specific movement patterns. In the sport of gymnastics, there is a fairly universal recognition that flexibility is a major fitness component (Hancock, 1999; Kinser et al, 2008), where the gymnasts have to achieve specific positions, where it is frequently included in talent identification and screening programmes. Due to the nature and judging of competitive gymnastics, achieving these positions is a crucial part of the sport where deductions will be made if a gymnast fails to meet these demands. Techniques such as the forward splits and split leaps are common skills within gymnastics and require a large range of movement around the hips from the hamstring and quadriceps muscle groups. Enhancing flexibility through this range of movement would prove advantageous to a gymnast's performance (Kinser, et al., 2008). Hancock (1999) further stated that to achieve these specific positions, training for the gymnasts has to be structured to improve flexibility in specific ranges of motion. However, there has been little research done into enhancing flexibility among elite performers. For some gymnasts, especially elite performers as described by Hancock (1999), it is difficult to improve performance in certain aspects of fitness, in this case flexibility, if the athlete has reached a plateau of performance, therefore they are unable to show consistent improvement on a large scale. This doesn't have to be applied to just elite performers, non-elite performers with a very high range of flexibility could also have trouble improving, what these athletes could find beneficial is maintenance of flexibility and strength within the muscles (Hancock, 1999) to prevent overload and over stretching of the muscles. As gymnastics is a high impact sport, injury rate can be high, although, a study by Kirby et al (1981) found that there was no clear link between flexibility and a gymnastics related injury. This study used 60 competitive female gymnasts aged 5-17, who were found to be more flexible than the control group through: Horizontal abduction of the shoulders, hip extension, toe touching ability and lumbar spine extension. However, the control group had greater flexibility through elbow supination, and no differences between the groups were found in elbow, lumbar spine or knee extension measurements. A minor drawback of the study was that the measurements were taken cold and statically rather than in a dynamic and loaded situation where injuries occur, it was also believed that a warm up would have enhanced the differences between the two groups. An unexpected result from the study also showed that gymnasts suffering from lower back injury symptoms had greater flexibility in toe touching ability.

2.5 Stretching to Improve Flexibility:

Traditionally the most common way of improving muscular flexibility is stretching, where it is frequently used as part of a warm up to increase pain free range of motion about a joint in an attempt to promote better performances (Marek et al, 2005). Taylor et al, (1990) described musculotendinous units functioning in a viscoelastic manner and therefore have the properties of creep and stress relaxation, the creep aspect being the lengthening of a muscle due to an applied fixed load, the decrease in force over time necessary to hold the muscle at a particular length is the stress relaxation aspect.

There are notably three forms of stretching: Static, holding a certain position with a muscle on stretch for a given period of time; Dynamic or Ballistic, repeatedly moving through a range of motion in a controlled manner to perform a stretch; and Proprioceptive Neuromuscular Facilitation (PNF), varying forms of resisted hold and relax stretches (Spernoga et al, 2001; Hartig and Henderson, 1999; Burke et al, 2001; Taylor et al, 1990). Research has shown that PNF stretching and its derivatives are the most effective techniques for increasing hamstring flexibility (Alter, 1988; Anderson and Burke, 1991; Greipp, 1985) similar findings were recorded by (Prentice, 1983; Sady, Wortman and Blanke, 1982; Wallin et al, 1985), where the benefits gained from this method of stretching are greater than those obtained through static and ballistic stretching methods(Burke et al, 2001; Schmitt, Pelham and Holt, 1998; Cornelius and Jackson, 1984; Etnyre and Abraham, 1986). This could be seen as the neural properties of PNF stretching increasing the range of movement from a process defined by Knott and Voss (1968) as the inhibition of the alpha motor neurons in the muscle by stimulation of the Golgi tendon organs. Due to these findings, a study was conducted by Spernoga et al (2001) to assess the claims. The purpose of the study was to measure the duration of maintained hamstring flexibility after a 1 time modified hold-relax stretching protocol (PNF). Results found that hamstring flexibility remained significantly improved for 6 min after the stretching protocol ended (5 modified hold-relax stretches). A similar study was conducted by Depino et al (2000) looked for the same effect caused by static stretching, and found that their static stretching protocol (one time session of 4 consecutive 30 second static stretches) was shown to increase hamstring flexibility for 3 minutes after the protocol. This study was what Spernoga et al (2001) based their research model on, and to their knowledge was the only study conducted within the field. Although the study in 2001 used a different statistical measuring system to the study conducted the previous year, and it was believed that if they had both used the same measuring system and continued for 6 minutes, there would be little to no difference in the results, therefore the findings may be down to how the results were handled, not the stretching technique. These results suggest that a single stretching session doesn't 'deform' tissues enough to produce a permanent change to muscle length. An earlier study by Tanigawa (1972) found that there was a significant increase in hamstring flexibility for both static and PNF protocols relative to the control group. However, there was a reported decrease in flexibility in both groups 2 days after the 4 week stretching protocol. In conclusion, Tanigawa (1972), states that the maintenance of increased flexibility requires a regular stretching routine.

One foreseen and tested problem is that PNF stretching could have a negative impact on power output post stretch due to the relaxation of the muscles. In 2005, Marek et al found that peak torque and electromyography measurements decreased post stretch, this could have impacts on performance of various rehabilitation and strengthening exercises. However, the results also showed that active and passive ranges of motion increase post stretch, this can increase performance in sports that require increased ranges of motion, such as gymnastics (Jeffreys, 2011). A recent study by Makaruk et al (2010) found that asymmetry of the hamstring muscles can be a predisposing factor to injury, and there can be bilateral asymmetry between dominant and non-dominant legs. They found that stretching reduces this asymmetry, therefore lowering the chance of hamstring injury. These findings can be backed up by an earlier study conducted by Hartig and Henderson (1999); their objective was to prove that increasing hamstring flexibility would reduce the number of lower extremity overuse injuries that occur in military basic trainees. They tested two companies over a 13 week period; one was used as a control and the other incorporated 3 extra hamstring static stretching sessions a day, on top of their routine. Results found that hamstring flexibility in the intervention group had increased significantly compared to the control group, and that over the 13 week period there were only 25 injuries compared to the control groups 43.

A common issue associated with stretching, especially PNF and its derivatives is that they can be seen as ‘invasive’, another issue being the temperature of the muscle being stretched, where it is commonly perceived that stretching a colder muscle is more likely to lead to injury than stretching a warm muscle due to their elastic properties. To test this, Burke et al (2001) tested the effects of PNF stretching with hamstring muscles at different temperatures, which were induced in two groups of participants standing submerged in either warm water or cold water up to their gluteal fold for 10 minutes, with a control group standing motionless outside a bath for the same period of time. This was a onetime protocol with measurements taken before submersion and after stretching, where all groups showed significant changes in hamstring length between pre and post testing. Although possibly the most influential finding from the study was that no significant differences in results could be found between the three groups, showing that for this test, the experimental temperatures used did not differ in their ability to influence flexibility change. This could be down to the temperatures used not being extreme enough to cause a difference, or the exposure to them not being long enough, but as shown by the results, muscle temperature may not play as big a role in flexibility training as previously thought. In conclusion, it can be seen that hamstring flexibility can be significantly increased by PNF stretching, and the temperature of the muscle does not adversely affect the results collated within this test.

2.6 Other Modalities of Improving Flexibility:

Besides stretching, there are other modalities that can be used to increase flexibility or aid in the increasing of flexibility. Funk et al (2001) described an attitudinal bias towards stretching over different modalities, particularly the application of a moist heat pack used within their study. It compared the effectiveness of 3 sets of 30 seconds static stretching against a 20 minute application of the moist heat pack on improving hamstring flexibility. The study split 30 participants into two groups, with a single session each week then swapping which treatment the group received during the second week. The results found that there was no difference to which treatment was completed first, but showed a significant increase in hamstring flexibility after the heat pack application compared to stretching. A problem with this was that the results are very acute, moist heat packs making the muscles more pliable for testing but could not possibly be used to solely increase flexibility as they are in no way forcing the muscle to make a great enough change to make a permanent, long term adaptation. So although the results show that as a one off, the moist heat packs showed greater flexibility than a stretching protocol, over time after continuous stretching, hamstring flexibility will become greater through this method. However, the results do imply that moist heat packs can be used in conjunction with stretching to improve flexibility. Similarly, a study by Miller and Rockey (2006) compared the effectiveness of the foam roller, a modality used for Self Myofascial Relief (SMR) to a control group instructed not to complete any further stretching outside of their usual training. With soft tissue injuries accounting for a large percentage of athletic injuries, the athletes can gain dysfunction of their soft tissue in either an acute or chronic manner (Curren et al, 2008). The study goes on further to state that layers of fascia are usually affected, with the injuries causing the development of inelastic fibrous adhesions that prevent normal muscle mechanisms and a decrease in soft tissue extensibility. Self myofascial release, produced by the foam rollers, is a technique used to treat myofascial restrictions and restore normal soft tissue extensibility. Earlier work by Kaltenborn (2006) states that foam rolling can be seen as a complement to traditional therapies, the work by Miller and Rockey (2006) used the foam roller as a form of stretching, which although it showed improved hamstring flexibility among participants in the study, did not produce significant results as foam rollers are not a form of stretching. Kaltenborn (2006) describes foam rollers as a complement to stretching by their ability to increase muscle extensibility prior to stretching.

The physiological changes induced by foam rolling is the autogenic inhibition of the Golgi tendon organs (GTO) of a muscle, these sense tension and rate of tension change within the musculotendinous junction. Extended stimulation of the GTO by pressure exerted from the foam roller causes muscle spindles to become inhibited, and fascial adhesions to become more elastic, increasing the extensibility of the muscle group, this occurs when the tension on the muscle from the foam roller is greater than the impulses causing muscle contraction. The mild increases in hamstring flexibility present in Miller and Rockey's study could be seen as the loosening of the fascia over the 8 week study period and a mild increase to hamstring extensibility, but when looking at the effects described by Kaltenborn (2006) it can be seen why there was no significant improvement. Perhaps having combined foam rolling with a form of stretching could have led to a more significant improvement, with the muscles having an increased extensibility, they would have been able to stretch through a greater range of motion applying more permanent changes.

Upon reviewing the literature, it can be said that there is a gap within the research in which foam rolling has yet to be used in conjunction with a flexibility protocol in order to see if there is a positive effect caused by the physiological properties of the roller. The results of Miller and Rockey's (2006) study show that foam rolling by itself has no significant impact on increasing muscular flexibility, this aspect of study does not need to be tested again. The literature also concludes that the most effective form of stretching is PNF and its derivatives; therefore the next logical step for further research to take would be to use foam rolling in conjunction with a PNF stretching protocol, and compare the effects to that of just PNF stretching.

CHAPTER 3

METHDOLOGY

3.0 Methodology

3.1 Participants:

13 Gymnasts, 3 males (Height = 175cm ± 1cm, Mass = 72kg ± 7kg, Age = 20.3yrs ± 0.6yrs) and 10 females (Height = 162.2cm ± 7.3cm, Mass = 58.2kg ± 6.8kg, Age = 18.9yrs ± 0.7yrs) participated in the study. All participants were a mixture of competitive and recreational university standard gymnasts, all with a background in the sport. This population was selected to study due to a sufficient amount of previous experience in the sport, regular training loads as well as ease of accessibility. The participants for the study completed an injury screening questionnaire (APPENDIX A) to check for previous and current injuries. If they were currently not carrying an injury to their hamstrings, or had not been recovering from an injury to their hamstrings in the 2 months prior to the study, they were allowed to participate. The participants were familiar with flexibility training, although the concepts of Proprioceptive Neuromuscular Facilitation (PNF) and foam rolling were new to a few of them. The protocols were explained to all the participants on a participant information sheet (APPENDIX B) and informed consent was gained from each individual prior to the testing stage (APPENDIX C), where it was also explained that their involvement in the study was voluntary, and they were free to withdraw at any stage.

3.2 Facility:

All testing procedures and the following protocol were conducted in the Gymnastics facility containing all the standard artistic gymnastics apparatus on the university campus. The programme was conducted at the start of the gymnasts' normal training sessions in the facility and specific times every week that the gym team had booked; this meant there were no interruptions. The session times were: Mondays - 6.30pm to 8.30pm, Wednesdays - 12.00 to 14.00pm and Fridays – 6.30pm to 8.30pm. Although these times and days were mainly used for logistical reasons, there is scientific evidence backing up the consistent use of flexibility training at the same times of day. A study by Guariglia et al (2011) suggested from their findings that flexibility performance is affected by the time of day, with higher performance in the evening (06:00pm onwards). Therefore, for consistent flexibility improvement, it was important to conduct the training at the same points in time during the week to remove the effects of inconsistent training times, which would affect the findings.

3.3 Instruments:

The hip angle was measured on an active and passive straight leg raise using a clinical goniometer placed on the subject's thigh, just above the patella. The readings were taken three times for the active straight leg raise on both legs and an average was worked out (Figure 1.0), and just once for the passive leg raise. The average was taken from the active leg raise to account for fatigue, as the participant would end up in similar positions multiple times during their routines in which fatigue would play a role, and the testing tried to replicate that situation. The passive raise was only conducted once as the leg was being taken into greater stretch compared to actively conducting the movement. This would then have had a knock on effect on following measurements as the leg would be able to stretch further for the second two readings due to the muscle having less tension due to the previous stretch, and not have given clear results of the participants' passive flexibility.

Figure 1.0: End position of the participant conducting an active straight leg raise while being measured.

The readings were taken by the same person each time, who had training in using the equipment, to minimise intrarater variability and remove reader bias that could occur if multiple testers had been used, making the results more reliable. The foam rollers used for the 6 weeks were standard bio-foam rollers due to the ease of accessibility from the university.

3.4 Testing Procedures:

Prior to the flexibility training, all the participants were tested for hamstring flexibility by conducting an active straight leg raise and hold for 3 seconds at maximum height, with the knee at full extension to achieve maximum active hip flexion. This was conducted 3 times on both legs using a clinical goniometer to measure hip angle. A single, passive leg raise was then conducted on either leg, for reasons explained in the resting section, with a supervisor lifting the subject’s leg into position, which was deemed to be at maximum flexibility when the subject felt a sensation of mild discomfort.

The starting position for the test had the subjects standing in a straight position with their back pressed against the wall. The subjects were instructed that during their leg raise their back has to remain against the wall and the knee has to remain straight. Once the back lost contact with the wall or their leg began to bend, they were deemed to be at their maximum hip flexion, the same rule applied during active and passive lifts. These rules were taken from a study by Burke et al., (2001) who stated that the participants will be judged to achieve their maximum active hip flexion once they can no longer keep their pelvis on the testing table, or their knee starts to bend. This previous study had subjects lying supine on a physio bed compared to standing against a wall; I changed this in my study as the participants had to combat gravity, making it more specific to gymnastics. This is due to them having to reach these shapes from a standing position within the sport, rather than lying down, and having the rest of their body replicating positions used within the sport.

It is important to remember that the inclinometer can be set to 0 degrees while they are in neutral (standing) position, therefore the further they could reach away from 0, producing a larger number, meant a better result and showed greater flexibility. The participants were then randomized and split between the two test groups and the control group, with each gender being evenly split across the three groups. Participants then attended three sessions a week over a 6 week period and post study results were collected at the end of this period using the same method and tester.

3.5 Flexibility Protocol:

During each session, the group using the foam rollers conducted the rolling prior to PNF stretching. The rolling consisted of three repetitions of 30 secs of continuous rolling on both hamstrings at the same time, from the Ischial Tuberosity to the posterior knee, using the arms as support. They then had 30 secs rest between repetitions; both rolling and stretching were timed with a stop watch, a slight modification to the study conducted by Miller and Rockey, (2006). The rolling was completed at a medium, flowing pace where the length of the hamstring was covered a minimum of four times (Ischial Tuberosity to knee equalled one covering, and vice versa).

They were then paired up with a member of the control group or the group only completing the PNF stretching, where the foam rolling group completed the stretching first so the effects of the rolling were still present. The participants were matched with someone of a similar height to make the stretching as easy for the supporter as possible. The following PNF protocol consisted of an assisted ‘hold and relax’ stretch, where the participant’s hamstrings were moved through the straight leg raise until a stretching sensation was felt, this was then held for 10 seconds, followed by a 10 second isometric contraction against their partner. The participant then relaxed for 5 seconds before they were assisted further through the straight leg raise until they felt a slight stretching sensation, where the process was carried out again, a slight moderation to the study carried out by Spernoga et al., (2001). This was completed on both legs, and once the participant being stretched had finished, they swapped with their partner who was either in the PNF stretching only group to do the stretching on them, or their partner in the control group, in which case no more stretching was performed.

Individuals were taught how to conduct the PNF protocol prior to the training period, and the teaching was structured so that it did not enhance the participant’s flexibility prior to the programme. Post intervention tests determined whether the suggested physiological properties of foam rolling had an effect on improving flexibility when combined with a stretching protocol.

3.6 Data Analysis:

Data for each variable was analysed using three different tests, a paired t-test was used to compare the inter group pre to post results to see if the improvement made was significant. This was followed by two different 1-way ANOVA's, the first compared the average starting value for each group in the individual testing procedures to see if there were any significant differences in starting values. The second 1-way ANOVA compared the improvements made by each group within the individual tests to see if there were any significant differences. This statistical analysing method was best suited to the study as there were 3 testing group variables (Foam Rolling and PNF, PNF, and Controlled).

CHAPTER 4

RESULTS

<u>4.0 Results</u>

This chapter presents the main study results obtained from a standing active straight leg raise tests and a standing passive leg raise tests, including descriptive results, statistically significant (*p*) differences and the mean (± SD) differences. The results had to be tested to determine whether they were statistically meaningful ($p < 0.05$) and were not a subject of chance ($p > 0.05$).

<u>Main Study Results</u>

4.1 Active Left Leg Raise:

These results had a number of tests conducted on them in order to determine their significance. First of all, a 1-way ANOVA was conducted on the results to determine whether there were any significant differences between each group's average baseline measures ($p < 0.05$). The Post Hoc Tests (APPENDIX D-1) revealed that there was no significant difference between PNF/FR and PNF ($p = 1.00$), but there were significant differences between PNF/FR and Cont ($p = 0.027$), and between PNF and Cont ($p = 0.016$).

Secondly, a paired t-test was conducted on each group to determine whether a significant improvement had been made between pre and post intervention testing ($p < 0.05$). PNF/FR= 0.003, PNF = 0.002 and Cont = 0.035, these results show that a significant improvement in flexibility was made within each test group (APPENDIX D-2).

Finally, a 1-way ANOVA was conducted to find whether the improvements made between each group were significant when compared to the each other ($p < 0.05$). The Post Hoc Tests (APENNDIX D-3) revealed that there were significant differences between the improvements made by PNF/FR and PNF ($p = 0.046$) and PNF/FR and Cont ($p = 0.028$). However, there was not a significant difference between PNF and Cont ($p = 1.00$).

The bar chart (Figure 1.1) shows the increase in mean scores for hip displacement between pre and post tests comparing each intervention group. It shows that the average increase for each group was: PNF/FR = 16.75^o, PNF = 8^o and Control =

7.8°. This was confirmed by the descriptive statistics (see APPENDIX D-4), where the mean score from each group for pre intervention tests (90.25°, 89° and 103.8°) were lower than that for the post intervention tests (107°, 97°, 111.6°) respectively.

In conclusion, combining PNF and foam rolling has a more significant effect on active left leg hamstring flexibility and just PNF stretching and normal gymnastics training, and also that there were no significant gains in flexibility when comparing PNF stretching to the control group.

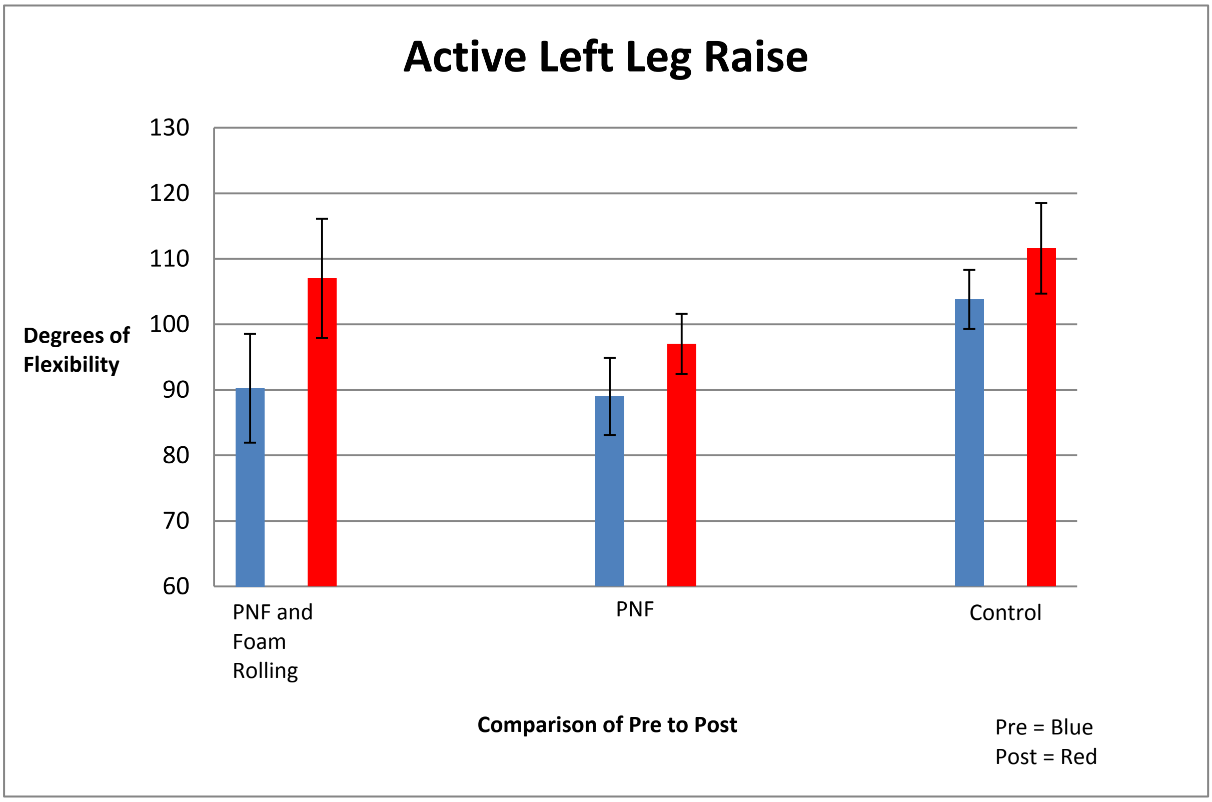

Figure 1.1: Graph showing the pre and post results of the active left leg raise test.

4.2 Active Right Leg Raise:

These results had a number of tests conducted on them in order to determine their significance. First of all, a 1-way ANOVA was conducted on the results to determine whether there were any significant differences between each group's average baseline measures ($p < 0.05$). The Post Hoc Tests (APPENDIX E-1) revealed that there were no significant differences between the groups with ($p = 1.00$) being the significance value for all comparisons.

Secondly, a paired t-test was conducted on each group to determine whether a significant improvement had been made between pre and post intervention testing ($p < 0.05$). PNF/FR = 0.081, PNF = 0.392 and Cont = 0.077, showing that there were no significant gains in flexibility in any of the groups (APPENDIX E-2).

Finally, a 1-way ANOVA was conducted to find whether the improvements made between each group were significant when compared to each other ($p < 0.05$). The Post Hoc Tests (APENNDIX E-3) revealed that there were no significant differences between any of the groups, with each comparison having a *p* value of 1.00.

The bar chart (Figure 1.2) shows the increase in mean scores for hip displacement between pre and post tests comparing the intervention groups. It shows the average for each group was: PNF/FR = 9.5^o, PNF = 5.25^o and Cont = 6.8^o. This was confirmed by the descriptive statistics (APPENDIX E-4) where the mean score of each pre intervention test were lower than the post intervention tests.

In conclusion it can be said that there were no significant differences in the starting values of each group, no significant improvements within groups, and that there were also no significant differences in improvements made when comparing each group.

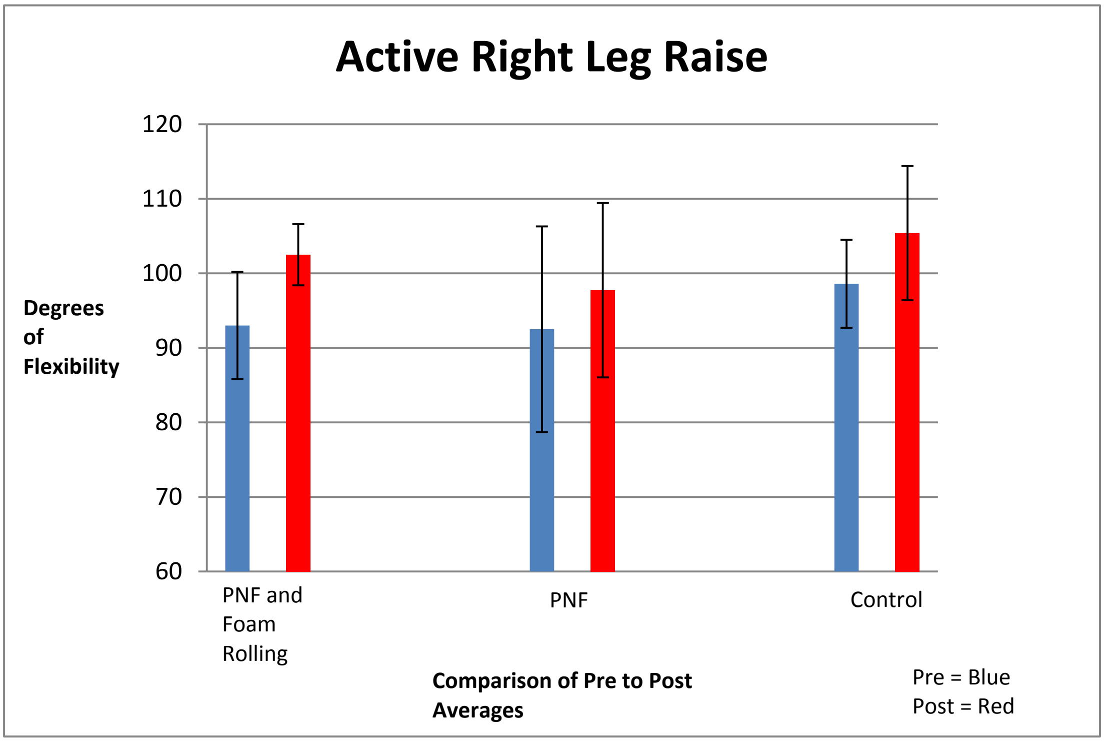

Figure 1.2: Graph showing the pre and post results of the active right leg raise test.

4.3 Passive Left Leg Raise:

These results had a number of tests conducted on them in order to determine their significance. First of all, a 1-way ANOVA was conducted on the results to determine whether there were any significant differences between each group's average baseline measures ($p < 0.05$). The Post Hoc Tests (APPENDIX F-1) revealed that there were no significant differences in the start values between each group.

Secondly, a paired t-test was conducted on each group to determine whether a significant improvement had been made between pre and post intervention testing ($p < 0.05$). PNF/FR = 0.070, PNF = 0.014 and Cont = 0.156, showing that there was a significant gain in flexibility within the PNF group, but not within the PNF + Foam Rolling or Control groups (APPENDIX F-2).

Finally, a 1-way ANOVA was conducted to find whether the improvements made between each group were significant when compared to each other ($p < 0.05$). The Post Hoc Tests (APENNDIX F-3) revealed that there were no significant differences in improvements made between each group,

The bar chart (Figure 1.3) shows the increase in mean scores for hip displacement between pre and post tests comparing each intervention group. It shows that the average increase for each group was: PNF/FR = 20.25^o, PNF = 15.75^o and Cont = 8^o. This was confirmed by the descriptive statistics (see APPENDIX F-4), where the mean score from each group for pre intervention tests (139.75, 147.75^o and 154.6^o) were lower than that for the post intervention tests (160^o, 163.5^o, 162.6^o) respectively.

In conclusion it can be said that there was a significant improvement within the PNF group, but as well as the Cont group, the improvement was not significant for PNF/FR. There were no significant differences in the groups starting values, and no significant differences between the improvements made by each group on passive left leg hamstring flexibility.

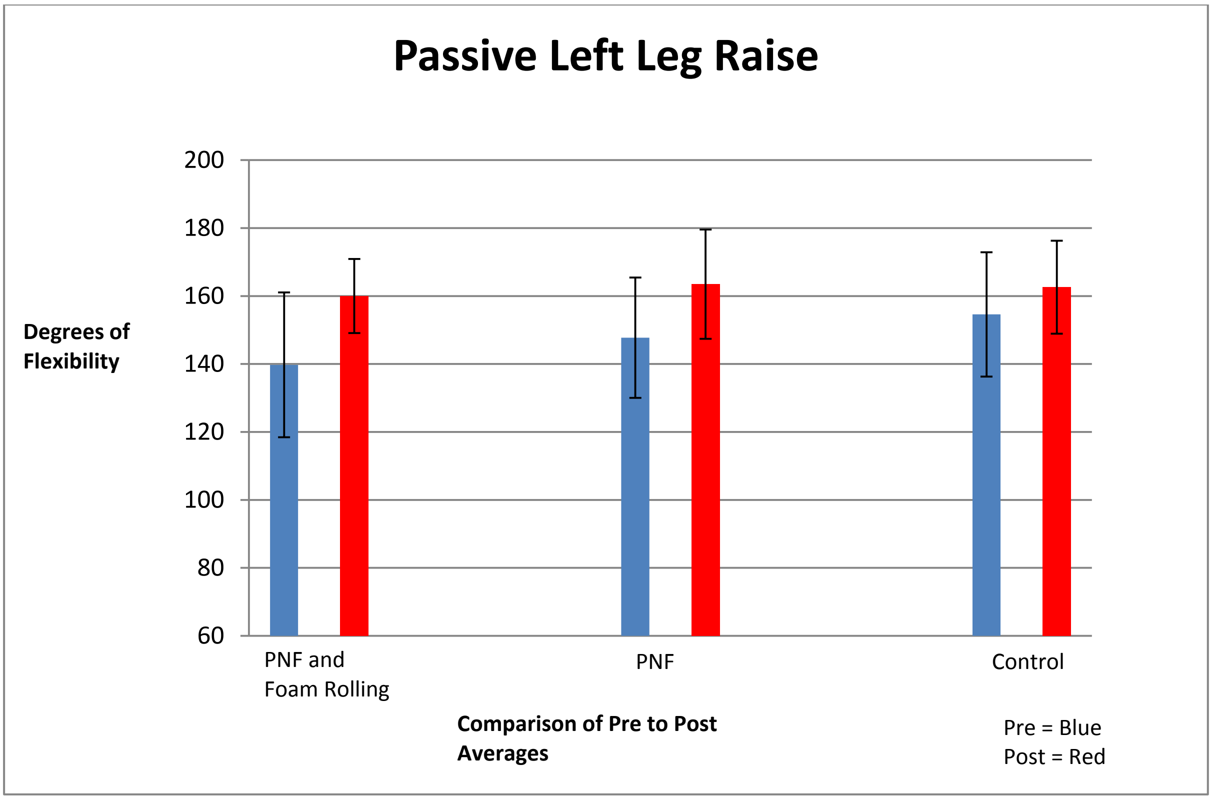

Figure 1.3: Graph showing the pre and post results of the passive left leg raise test.

4.4 Passive Right Leg Raise:

These results had a number of tests conducted on them in order to determine their significance. First of all, a 1-way ANOVA was conducted on the results to determine whether there were any significant differences between each group's average baseline measures ($p < 0.05$). The Post Hoc Tests (APPENDIX G-1) revealed that there were no significant differences between the start values, with $p = 1.00$ being the value for all comparisons.

Secondly, a paired t-test was conducted on each group to determine whether a significant improvement had been made between pre and post intervention testing ($p < 0.05$). PNF/FR = 0.353, PNF = 0.272 and Cont = 0.164, showing that there were no significant improvements made within each group (APPENDIX G-2).

Finally, a 1-way ANOVA was conducted to find whether the improvements made between each group were significant when compared to each other ($p < 0.05$). The Post Hoc Tests (APENNDIX G-3) revealed that there were no significant differences between the improvements made between each group, with $p = 1.00$ being the value shown for each comparison.

The bar chart (Figure 1.4) shows the increase in mean scores for hip displacement between pre and post tests comparing the intervention groups. It shows the average for each group was: PNF/FR = 4.5^o, PNF = 7.75^o and Cont = 6.8^o. This was confirmed by the descriptive statistics (APPENDIX G-4) where the mean score of each pre intervention test were lower than the post intervention tests.

In conclusion it can be said that no significant improvements were made within each group, and the starting values and average improvements compared by their 1-way ANOVA tests showed that there were no significant differences, and that neither intervention made a significant improvement on passive right hamstring flexibility.

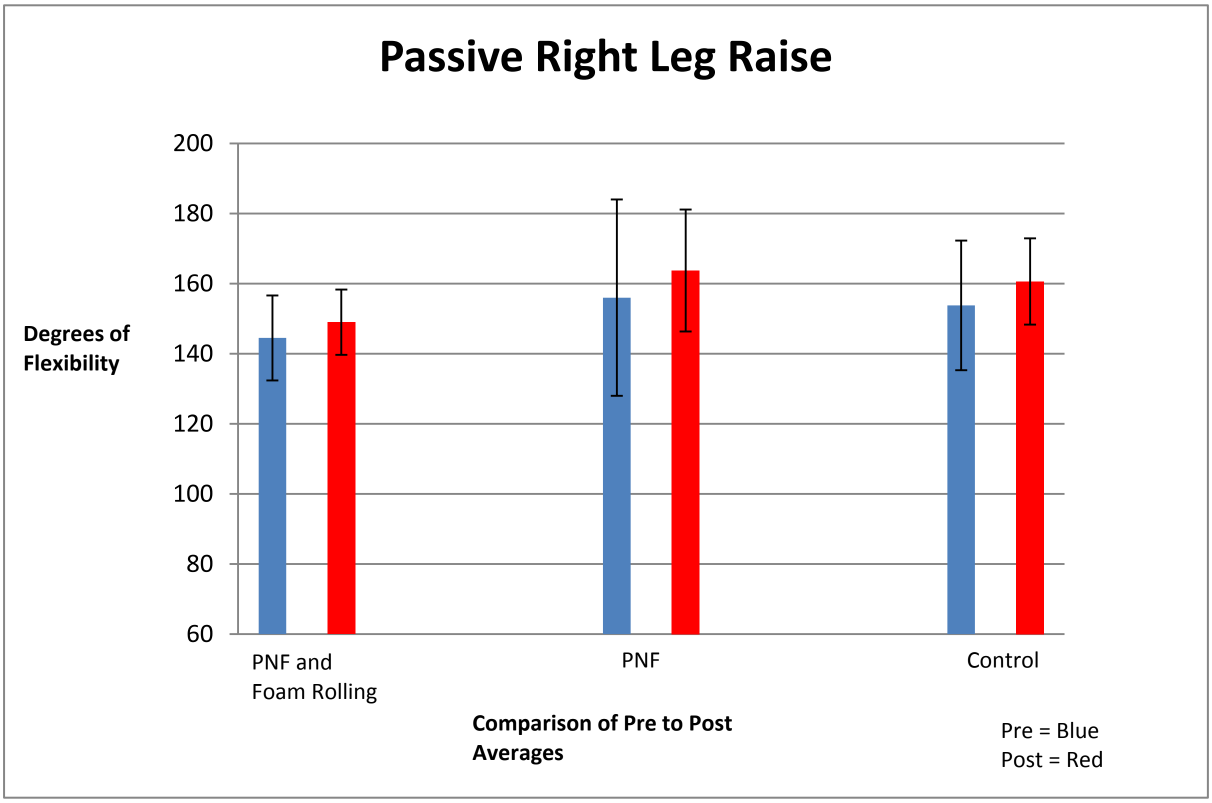

Figure 1.4: Graph showing the pre and post test results of the passive right leg raise test.

CHAPTER 5

DISCUSSION

5.0 Discussion

5.1 Interpretation of Findings:

This study of 13 gymnasts (10 female, 3 male) found significant improvements made between intervention groups in one test, the passive left leg raise. The combination of PNF and foam rolling during the active left leg increased hamstring flexibility by 16.75^{o} (18.56%) compared to an 8^{o} (8.99%) increase by PNF stretching and a 7.8^{o} (7.51%) increase by the control group. Passive left leg flexibility was the only test that produced significant differences between PNF/FR and the other intervention groups, the other three tests had no significant differences in improvements made.

Flexibility is a key fitness component of gymnastics (Hancock, 1999; Kinser et al, 2008) and therefore needs to be improved upon and maintained by gymnasts. One reason for the lack of significant differences could be due to the control group making improvements. Although the members of the control group did not take part in either of the external interventions of PNF/FR or PNF to improve their flexibility, they did partake in normal gymnastics training; therefore the improvements made within this group could be seen as a training effect just from taking part within the sport. As many of the gymnasts had recently started training again after the university summer holidays, their flexibility would have naturally improved due to the stretching they conducted. These stretches involved many dynamic movements as part of their warm up, as well as static holds in positions required by gymnastics such as splits, both forms of stretching have been found to make improvements in flexibility (Spernoga et al, 2001; Hartig and Henderson, 1999; Burke et al, 2001) due to the properties of muscles. Although these studies found that PNF stretching showed the greatest improvements, static and dynamic forms of stretching made improvements too. However, limiting or removing the improvements made by the control group was difficult due to ethical reasons, which would have stopped the participants from completing any form of training that would improve flexibility. This was difficult as the gymnasts could not be prevented from completing their normal training for such an extended period of time with flexibility being such an integral part of their sport, and competitions they had to prepare for. This was a limitation present in the study, and although it was not ideal, it did prove useful within the results as it allowed comparison of the two interventions (PNF/FR and PNF) to be compared with the improvements made by the training effect of gymnastics. An ethical way of avoiding this problem, which would have just isolated the improvements made by the interventions, would have been to conduct the study on a sporting population where flexibility, although an important aspect, was not integral and key to the athlete's success in the sport. This would have allowed the control to group to be withheld from any rigorous flexibility training such as the style present within gymnastics, and just complete normal warm up and mobility training that doesn't require extreme ranges of movement, without any ethical concern that the study would have reduced their ability to take part in their sport by creating a disadvantage. Another approach would have been to use the same group of participants, over a long period of time, and have them exposed to each intervention, including the control, in a randomised order. This would have increased the number of participants in each group, and used the participants as their own controls.

One disadvantage of this study was the small population size, which meant each intervention group only contained 4 or 5 people. Due to such low numbers within each intervention, one result could have a large influence on the average of the group causing it to spike higher or lower, depending on how their result compares to the rest of the group. During the passive right leg raise test, the PNF/FR group only had 3 participants due to one of the members suffering from a mild hamstring strain. While the individual was able to complete the active right leg raise test due to the hamstrings not reaching a painful range of movement, the passive right leg test was too painful for the individual and as a safety precaution, was not tested. This meant that there were less people within the group to influence the average result, which could be why there were no significant differences.

Prior to the study taking place, once the groups had been randomly selected, individuals were asked which was their dominant/most flexible leg, and there was an even split between left and right leg within each group. During the active left leg raise test, the four individuals in the PNF/FR group all showed improvements of: $13^{o,}$ 16^{o} and $16^{o,}$ but one individual showed a larger improvement of 22^{o}. With this result being higher than the rest, and only four of them being in the group, this increased the average. The results from this test added weight to the argument presented by

Kaltenborn (2006) that foam rollers are best used as a complement to a therapy such as stretching to get better results by reducing muscle tension prior to stretching. On the other hand, there was no clear indication as to why the individual increased by this much on one leg and not the other, one theory is that they described their left leg as their non-dominant/less flexible leg, meaning it was possible for them to show a greater improvement before reaching a performance plateau (Hancock, 1999). However, there was only a 3^{o} difference in the baseline measures of left and right legs on the active leg lifts. Therefore it is difficult to find a physiological explanation as to why the left leg flexibility of the individual increased by twice the amount of their right leg, and the differences could be down to the design and application of the study.

Considering the plateau of performance (Hancock, 1999), all the participants of the PNF/FR group managed greater gains in their active left leg than their active right leg flexibility, even if their left leg was considered more flexible to begin with and being closer to their physiological maximum. The plateau of performance principle should have meant there was less room for improvement, but that was not the case. The protocol was performed exactly the same on both legs, so the contents of the protocol itself shouldn't have been biased to one leg, the results just appear to be an unexplained reaction of the group, which was not present in any other test or intervention group, other than active left leg flexibility. If the significant differences noted in active left leg flexibility were a result of the intervention, they should have been mirrored in results of the active right leg flexibility.

During the active left leg raise, not only were there significant differences between improvements, but there were also significant differences between baseline measures within this test, which could explain why the differences were so significant. The control group's flexibility started much higher than the other two groups, meaning that theoretically, they were closer to their physiological maximum and therefore had less room to make improvements. However, this test is different from the other three, where it is the only test with significantly different baseline measures. Therefore the difference in baseline measures having an impact upon the results can be discarded as there were only differences present in one test, equivalent to 25% of the findings, meaning that 75% of the time they had no effect.

There are a number of reasons as to why the study showed so few significant improvements, one reason possible reason causing this could have been the length of the intervention. While, due to certain time frames that had to be met, this intervention was only 6 weeks long, which is shorter than the studies that the intervention was based on, Miller and Rockey (2006) was 8 weeks long, Hartig and Henderson (1999) was conducted over 13 weeks. This shortened time frame could have had an effect on the physiological adaptations of the muscle, where it could have taken the hamstring muscles longer to respond to the training stimuli, potentially showing lesser differences between results. With a longer time frame for the training to have an effect, if there were differences between the interventions, it would give them more time to emerge.

Another reason for there not being significant differences could be due to some of the participants not attending every training session due to a number of reasons. As stated by Baechle and Earle (2000), lack of training has a negative effect on performance, if physiological adaptations, be it in strength, flexibility or many others are not maintained or improved upon, then adaptations will be lost over time. This would be more serious if participants missed multiple sessions in a row, but the effects would still be present. This lack of intervention adherence suggests that the actual impact of the intervention could have been affected, leading to less reliable results.

Furthermore, it was found by Guariglia et al (2010) that stretching at different times of day has different effects on flexibility performances, where the greatest performances were found to be after 6pm. Throughout the study, the training session times did not alter each week in order to minimise the change in time of day effect, with two of the sessions being after 6pm. One session, although it was for logistical reasons, was before 6pm, where it was found that flexibility does not improve as much. Although the effect of this could be minimal, given the previous research, it still has to be taken into consideration when looking at why there were no significant improvements. It would also help coaches if they were informed of the time of day effect, and could possibly aid them in designing coaching programmes to develop athletes.

Improvements in flexibility were found across every test in each intervention, showing greater flexibility in the results following the 6 week protocol. During the active left leg raise test, all pre to post tests were found to be significant, no significant improvements were found in the active right leg raise, in the passive left leg raise test, the only significant improvement was found in the PNF group (p = 0.014), and there were no significant improvements in the passive right leg raise test. Although not all of the results were significant, it can still be said that stretching is a way of improving hamstring flexibility among gymnasts, be it from PNF, with or without foam rolling prior to stretching, and the stretching conducted within the normal gymnastics training. The combination of PNF and Foam rolling showed the greatest improvements across both active leg tests and the passive left leg test, but not the right leg, where the improvements were smaller than those of the PNF and control groups. Despite the findings not all being significant, it can still be said that improvements have been made and the combination of PNF and foam rolling can still be considered by coaches as a tool used to improve hamstring flexibility. Furthermore, the PNF stretching by itself still showed greater improvements across every test than the control groups, rendering it a valid stretching modality to be considered for use while training.

Although the study did not fully support the physiological effects that foam rolling prior to stretching produces, there was also a lack of research to support these findings. Kaltenborn (2006) favoured the view that foam rollers are now becoming more popular within athletes as a tool for self myofascial release, there was minimal evidence that this was beneficial. However, this can only be said from a prospective that flexibility was not affected, there could be other positive effects of self myofascial release that were not measured within the study. This led onto the fact that there was little to no research with scientific findings to support this statement, or method models to base this study on, meaning that the basis of the study was build on assumptions. Where Kaltenborn (2006) suggested that foam rollers relax muscles by stimulating the Golgi tendon organs, resulting in the muscle becoming more pliable, this was only a suggestion with no scientific evidence to back this up. Research by Miller and Rockey (2006) looked at the effects of foam rolling on hamstring flexibility compared to static stretching and found that foam rollers showed no increase in hamstring flexibility after an 8 week period, which led to their conclusion that foam rollers may not be an effective tool for increasing hamstring flexibility. This could be seen to support the suggestions made by Kaltenborn (2006) that foam rollers do not apply a stretch, but ready the muscles for stretching. This made the study by Miller and Rockey (2006) a standalone study, with a lack of research to support this study's findings. The lack of research in this area could be a positive of this study as it tried to fulfil the missing gap in this area of research. However, the limited research in this area also became a weakness of the study as there was very little to base the methodology model on with testing procedures and protocol directions, but there was also a lack of support to back up the findings.

In relation to the testing procedures in the methodology of this study, the active leg raise tests were conducted three times during the pre and post testing procedures to gain an average score for hip displacement on each subject. However, taking the average score could be viewed that there may be an element of fatigue of the agonist muscles involved. If this was the case, it may have contributed to the effects of the flexibility protocol and caused the reliability of the results to be adversely affected. Future improvements to the results would still be to conduct 3 tests, but take the highest score as that would should the participant's true maximum for active leg flexibility.

5.2 Directions for Future Research:

Hancock (1999) conducted a study on how to improve flexibility within gymnastics, and stated in elite gymnasts, it is difficult to generate consistent improvements in flexibility as they are at such a high level, there is very little room for improvements. Although the gymnasts used in the study were not at elite level, they still had a high range of flexibility in their baseline measures; therefore the lack of room for improvement may have been the cause for the lack of significant findings. Future research could be conducted into the effects of combining PNF stretching and foam rolling using a less flexible sporting population where they have a greater room for improvement, which could have the potential to show greater significance between the results. This would allow the findings to be more conclusive and recommendations of including foam rolling in training programmes could be made.

As previously mentioned, this study found that the control group also made improvements. This was due to the participants being allowed to continue with their normal gymnastics training, as preventing them to do so was un-ethical. This meant that there was a lack of constraint on the control group, which may mean that the results are unreliable; however, it did allow the study to compare the interventions to what could be seen as the normal training effect of gymnastics. For the study to have more constraint on the control group and minimise the deviation between pre and post test results, the study could have been conducted on a sporting population, that although requires flexibility, does not have it as such an integral part of their sport, and does not train it to produce performance enhancing gains. This would allow the control group to go about their normal training, without worrying that withholding the flexibility training from them would hinder their sporting performance.

Although previous research stated that PNF stretching was the most efficient form of stretching in improving hamstring flexibility (Alter, 1988; Anderson and Burke, 1991; Greipp, 1985), this study only combined PNF stretching with foam rolling. Although the findings of this study suggest that using the combination of foam rolling with PNF stretching shows no significant differences in improvements when compared to just PNF stretching, there may be other stretching techniques that had a greater significant effect. Therefore it would be useful for future research to compare a variety of stretching techniques to see when combined with foam rolling, which one produced a greater effect on increasing hamstring flexibility, making sure the athletes received the most beneficial modality.

When compared to other studies that involved a multiple week training programme, although it was for logistical reasons, this study was shorter than the studies it was based upon. Many other studies used ‘one time’ protocols (Spernoga et al, 2001; Burke et al, 2001), comparing pre and post results, but their methods were discarded for this study as the effects were not deemed to represent long term flexibility development, which this study aimed to achieve. The study only lasted 6 weeks, compared to studies it was based upon, with Miller and Rockey (2006) lasting 8 weeks, and Hartig and Henderson (1991) lasting 13 weeks. This time frame could have been too short for significant differences to develop, so future research into the area should address the issues of the length of time for a protocol.

Another point, that although may not have had an effect on the study, still needs to be considered, which is the time of day at which training is conducted, Guariglia et al (2010) found that flexibility improvements could differ, depending on what time of day the stretching was conducted, and that the best results were found to be after 6pm. Although two of the 3 weekly sessions for the study were conducted after 6pm, one session was conducted during the middle of the day for logistical reasons. To minimise the effects of this, future research should make sure that all flexibility training in their protocols are conducted at the same times of day on training days.

As previously discussed, there is very little research carried out in foam rolling, and many of the points made about the topic area were suggestive and only assumptions of the effects produced. Therefore, to understand the true effects of foam rolling, more scientific studies into the area are necessary to either prove, on contradict the effects assumed by this research, and be compared to the scientific research out there.

Finally, there are two points that would have a large impact on the findings. First of all, the number of participants within the study needs to be increased to the averages are not split between small groups of people and are not as easily influenced by one odd results. Secondly, the intervention needs to be conducted over a longer time period with stricter controls, this will allow a greater time for differences between groups using the interventions to develop.

5.3 Conclusion:

The null hypothesis stated the following:

H0: It is hypothesised that combining foam rolling with PNF stretching, over a six week period, will show no significant improvement in straight leg raise flexibility of the hamstrings when compared to an intervention group only conducting PNF stretching, and a control group.

From the analysis of results, it was shown that the null hypothesis was proved correct, due to only one of the flexibility tests showing significant differences between improvements gained between pre and post test scores, and not the other three tests. By disproving the hypothesis, it was concluded that the combination of PNF stretching and foam rolling was in agreement with the null hypothesis, and was not a more significantly effective method of increasing active and passive hamstring flexibility in gymnasts over a 6 week period, when compared to just PNF stretching, and a control group.

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APPENDICES

APPENDIX A

Project Health Screening Questionnaire

Are you currently carrying a form of hamstring injury?

If yes, how long ago did it happen? How long have you been carrying it? And is it stopping your involvement in sporting activities?

Have you been recovering from a hamstring injury in the past two months?

If yes, have you recovered? Are you able to participate in physical and stretching activity with no pain?

Have you had any lower limb surgery in the last 6 months? If yes, please give details.

Are you currently carrying any form of lower limb injury that limits your participation in activity and would be aggravated by the stretching protocol in this study? If yes, please give details of injured area and injury if it has been diagnosed.

Signature: Date:

APPENDIX B

Participant Information Sheet

Project Title: Foam rolling, a compliment to PNF stretching?

This document provides a run through of:

1) the background and aim of the research,
2) my role as the researcher,
3) your role as a participant,
4) benefits of taking part,
5) how data will be collected, and
6) how the data / research will be used.

The purpose of this document is to assist you in making an *informed* decision about whether you wish to be included in the project, and to promote transparency in the research process.

1) Background and aims of the research

Flexibility is considered a key fitness component in gymnastics; there are many methods and modalities available to improve flexibility. Foam rollers are regarded as an effective mechanism of self myofascial release, but not as effective at improving flexibility by itself, it is suggested that it would work better when coupled with a flexibility protocol. I intend to investigate whether using a foam roller in coupling with a PNF stretching protocol increases hamstring flexibility in comparison to stretching without the influence of a foam roller.

2) My role as the researcher:

The project involves me (Rory Ilott), the researcher, testing the level of your hamstring flexibility on both legs using an active straight leg raise test, measuring hip angle. Following the testing there will be an 8 week period of study where I will take PNF stretching sessions 3 times a week, giving clear instruction on how to complete the stretches. Following the 8 week period I will then conduct the same tests again to look at the differences in hamstring flexibility.

3) Your role as a participant:

Your role, depending on whether you are allocated to the control group, PNF group or PNF with foam rolling group will differ. The control group will only be required for testing before and after the 8 week period, the other participants will be required to complete the 3 PNF stretching sessions

4) Benefits of taking part:

If the hypothesis of the study is proved to be correct, participants will see an improvement in hamstring flexibility, improving gymnastics performance and decreasing injury risk. The control group will then be offered the treatment so long as it is proven to be beneficial. Participants will have access to their scores if they desire to see the differences the training has made.

5) How data will be collected:

Data will be collected prior to the study, participants will complete an active straight leg raise and have their hip angle measured using a device called a clinical goniometre. The data will be collected upon completion of the study through the same process to compare the results, it is important to remember that the smaller the angle, the better the flexibility. I will be collecting the data myself on both occasions.

6) How the data / research will be used:

In agreeing to become a ***voluntary*** participant, you will be allowing me to include your results within a larger data set that includes the data of other participants. Your personal data will be anonymous and will not be reported alone, but within the total sample of participants.

Your rights

Your right as a ***voluntary*** participant is that you are free to enter or withdraw from the study at any time. This simply means that you are in full control of the part you play in informing the research, and what ***anonymous*** information is used in its final reporting.

Protection to privacy

Concerted efforts will be made to hide your identity in any written transcripts, notes, and associated documentation that inform the research and its findings. Furthermore, any personal information about you will remain ***confidential*** according to the guidelines of the Data Protection Act (1998).

Contact

If you require any further details, or have any outstanding queries, feel free to contact me on the details printed below.

Rory Ilott

Cardiff School of Sport
Cardiff Metropolitan University
CF236XD, United Kingdom
Email: st10001855@outlook.uwic.ac.uk

APPENDIX C

CARDIFF METROPLOLITAN
INFORMED CONSENT FORM

CSS Reference No:
Title of Project: The Effects of Combining Foam Rolling and PNF Stretching on Hamstring Flexibility in Gymnasts
Name of Researcher: Rory Ilott

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet dated ………. For this evaluation study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that it is possible to stop taking part at any time, without giving a reason. ☐

3. I also understand that if this happens, our relationships with the

   Cardiff Metropolitan University, or our legal rights will not be affected ☐

4. I understand that information from the study may be used for reporting purposes, but I will not be identified. ☐

5. I agree to take part in this study on 'The effects of foam rolling when coupled with a PNF stretching protocol on hamstring flexibility in gymnasts' ☐

____
Name of Participant

___________________________ __________________
Signature of Participant Date

___________________________ __________________
Name of person taking consent Date

____
Signature of person taking consent

APPENDIX D

D-1, 1-way ANOVA Results of Groups Baseline Measures on Active Left leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: PreAcLeft

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	1.25000	4.42465	1.000	-11.4491	13.9491
		3.00	-13.55000*	4.19759	.027	-25.5974	-1.5026
	2.00	1.00	-1.25000	4.42465	1.000	-13.9491	11.4491
		3.00	-14.80000*	4.19759	.016	-26.8474	-2.7526
	3.00	1.00	13.55000*	4.19759	.027	1.5026	25.5974
		2.00	14.80000*	4.19759	.016	2.7526	26.8474
Games-Howell	1.00	2.00	1.25000	5.08879	.967	-14.8702	17.3702
		3.00	-13.55000	4.61185	.080	-29.3274	2.2274
	2.00	1.00	-1.25000	5.08879	.967	-17.3702	14.8702
		3.00	-14.80000*	3.56464	.017	-26.0019	-3.5981
	3.00	1.00	13.55000	4.61185	.080	-2.2274	29.3274
		2.00	14.80000*	3.56464	.017	3.5981	26.0019

D-2, T-Test Results of Pre to Post Scores within Subject Groups on Active Left leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PreAcLeft1 - PostAcLeft1	-16.75000	3.77492	1.88746	-22.75674	-10.74326	-8.874	3	.003
Pair 2	PreAcLeft2 - PostAcLeft2	-8.00000	1.63299	.81650	-10.59846	-5.40154	-9.798	3	.002
Pair 3	PreAcLeft3 - PostAcLeft3	-7.80000	5.54076	2.47790	-14.67976	-.92024	-3.148	4	.035

D-3, 1-way ANOVA Results of Groups Improvement Differences on Active Left leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: AvAcLeft

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	8.75000*	2.94576	.042	.2955	17.2045
		3.00	8.95000*	2.79459	.028	.9293	16.9707
	2.00	1.00	-8.75000*	2.94576	.042	-17.2045	-.2955
		3.00	.20000	2.79459	1.000	-7.8207	8.2207
	3.00	1.00	-8.95000*	2.79459	.028	-16.9707	-.9293
		2.00	-.20000	2.79459	1.000	-8.2207	7.8207
Games-Howell	1.00	2.00	8.75000*	2.05649	.027	1.4908	16.0092
		3.00	8.95000	3.11488	.056	-.2580	18.1580
	2.00	1.00	-8.75000*	2.05649	.027	-16.0092	-1.4908
		3.00	.20000	2.60896	.997	-8.3906	8.7906
	3.00	1.00	-8.95000	3.11488	.056	-18.1580	.2580
		2.00	-.20000	2.60896	.997	-8.7906	8.3906

D-4, Descriptive Statistics of Active Left leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreAcLeft1	90.2500	4	8.30161	4.15080
	PostAcLeft1	107.0000	4	9.09212	4.54606
Pair 2	PreAcLeft2	89.0000	4	5.88784	2.94392
	PostAcLeft2	97.0000	4	4.61880	2.30940
Pair 3	PreAcLeft3	103.8000	5	4.49444	2.00998
	PostAcLeft3	111.6000	5	6.91375	3.09192

APPENDIX E

E-1, 1-way ANOVA Results of Groups Baseline Measures on Active Right leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: PreAcRight

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	.50000	6.58103	1.000	-18.3880	19.3880
		3.00	-5.60000	6.24332	1.000	-23.5188	12.3188
	2.00	1.00	-.50000	6.58103	1.000	-19.3880	18.3880
		3.00	-6.10000	6.24332	1.000	-24.0188	11.8188
	3.00	1.00	5.60000	6.24332	1.000	-12.3188	23.5188
		2.00	6.10000	6.24332	1.000	-11.8188	24.0188
Games-Howell	1.00	2.00	.50000	7.77282	.998	-25.8050	26.8050
		3.00	-5.60000	4.46019	.468	-19.3697	8.1697
	2.00	1.00	-.50000	7.77282	.998	-26.8050	25.8050
		3.00	-6.10000	7.39211	.710	-32.7874	20.5874
	3.00	1.00	5.60000	4.46019	.468	-8.1697	19.3697
		2.00	6.10000	7.39211	.710	-20.5874	32.7874

E-2, T-Test Results of Pre to Post Scores within Subject Groups on Active Right leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PreAcRight1 - PostAcRight1	-9.50000	7.32575	3.66288	-21.15691	2.15691	-2.594	3	.081
Pair 2	PreAcRight2 - PostAcRight2	-5.25000	10.53170	5.26585	-22.00828	11.50828	-.997	3	.392
Pair 3	PreAcRight3 - PostAcRight3	-6.80000	6.41872	2.87054	-14.76990	1.16990	-2.369	4	.077

E-3, 1-way ANOVA Results of Groups Improvement Differences on Active Right leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: AvAcRight

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	4.25000	5.73825	1.000	-12.2192	20.7192
		3.00	2.70000	5.44378	1.000	-12.9240	18.3240
	2.00	1.00	-4.25000	5.73825	1.000	-20.7192	12.2192
		3.00	-1.55000	5.44378	1.000	-17.1740	14.0740
	3.00	1.00	-2.70000	5.44378	1.000	-18.3240	12.9240
		2.00	1.55000	5.44378	1.000	-14.0740	17.1740
Games-Howell	1.00	2.00	4.25000	6.41450	.793	-16.1396	24.6396
		3.00	2.70000	4.65367	.835	-11.5159	16.9159
	2.00	1.00	-4.25000	6.41450	.793	-24.6396	16.1396
		3.00	-1.55000	5.99743	.964	-21.4619	18.3619
	3.00	1.00	-2.70000	4.65367	.835	-16.9159	11.5159
		2.00	1.55000	5.99743	.964	-18.3619	21.4619

E-4, Descriptive Statistics of Active Right leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PreAcRight1	93.0000	4	7.16473	3.58236
	PostAcRight1	102.5000	4	4.12311	2.06155
Pair 2	PreAcRight2	92.5000	4	13.79613	6.89807
	PostAcRight2	97.7500	4	11.70114	5.85057
Pair 3	PreAcRight3	98.6000	5	5.94138	2.65707
	PostAcRight3	105.4000	5	9.01665	4.03237

APPENDIX F

F-1, 1-way ANOVA Results of Groups Baseline Measures on Passive Left leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: PrePasLeft

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	-8.00000	13.50685	1.000	-46.7656	30.7656
		3.00	-14.85000	12.81372	.820	-51.6263	21.9263
	2.00	1.00	8.00000	13.50685	1.000	-30.7656	46.7656
		3.00	-6.85000	12.81372	1.000	-43.6263	29.9263
	3.00	1.00	14.85000	12.81372	.820	-21.9263	51.6263
		2.00	6.85000	12.81372	1.000	-29.9263	43.6263
Games-Howell	1.00	2.00	-8.00000	13.87294	.837	-50.9768	34.9768
		3.00	-14.85000	13.44207	.546	-56.0740	26.3740
	2.00	1.00	8.00000	13.87294	.837	-34.9768	50.9768
		3.00	-6.85000	12.07018	.841	-42.8434	29.1434
	3.00	1.00	14.85000	13.44207	.546	-26.3740	56.0740
		2.00	6.85000	12.07018	.841	-29.1434	42.8434

F--2, T-Test Results of Pre to Post Scores within Subject Groups on Passive Left leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PrePasLeft1 - PostPasLeft1	-20.25000	14.63728	7.31864	-43.54118	3.04118	-2.767	3	.070
Pair 2	PrePasLeft2 - PostPasLeft2	-15.75000	6.13052	3.06526	-25.50503	-5.99497	-5.138	3	.014
Pair 3	PrePasLeft3 - PostPasLeft3	-8.00000	10.24695	4.58258	-20.72327	4.72327	-1.746	4	.156

F-3, 1-way ANOVA Results of Groups Improvement Differences on Passive Left leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: AvPassLeft

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	4.50000	7.66649	1.000	-17.5034	26.5034
		3.00	12.25000	7.27307	.369	-8.6242	33.1242
	2.00	1.00	-4.50000	7.66649	1.000	-26.5034	17.5034
		3.00	7.75000	7.27307	.935	-13.1242	28.6242
	3.00	1.00	-12.25000	7.27307	.369	-33.1242	8.6242
		2.00	-7.75000	7.27307	.935	-28.6242	13.1242
Games-Howell	1.00	2.00	4.50000	7.93463	.844	-23.7103	32.7103
		3.00	12.25000	8.63496	.398	-15.4424	39.9424
	2.00	1.00	-4.50000	7.93463	.844	-32.7103	23.7103
		3.00	7.75000	5.51324	.391	-8.7196	24.2196
	3.00	1.00	-12.25000	8.63496	.398	-39.9424	15.4424
		2.00	-7.75000	5.51324	.391	-24.2196	8.7196

F-4, Descriptive Statistics of Passive Left leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PrePasLeft1	139.7500	4	21.32878	10.66439
	PostPasLeft1	160.0000	4	10.89342	5.44671
Pair 2	PrePasLeft2	147.7500	4	17.74589	8.87295
	PostPasLeft2	163.5000	4	16.09348	8.04674
Pair 3	PrePasLeft3	154.6000	5	18.29754	8.18291
	PostPasLeft3	162.6000	5	13.72224	6.13677

APPENDIX G

G-1, 1-way ANOVA Results of Groups Baseline Measures on Passive Right leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: PrePasRight

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	-11.50000	14.43918	1.000	-52.9415	29.9415
		3.00	-9.30000	13.69821	1.000	-48.6149	30.0149
	2.00	1.00	11.50000	14.43918	1.000	-29.9415	52.9415
		3.00	2.20000	13.69821	1.000	-37.1149	41.5149
	3.00	1.00	9.30000	13.69821	1.000	-30.0149	48.6149
		2.00	-2.20000	13.69821	1.000	-41.5149	37.1149
Games-Howell	1.00	2.00	-11.50000	15.27798	.748	-65.4386	42.4386
		3.00	-9.30000	10.25622	.654	-39.6944	21.0944
	2.00	1.00	11.50000	15.27798	.748	-42.4386	65.4386
		3.00	2.20000	16.28210	.990	-50.7903	55.1903
	3.00	1.00	9.30000	10.25622	.654	-21.0944	39.6944
		2.00	-2.20000	16.28210	.990	-55.1903	50.7903

G-2, T-Test Results of Pre to Post Scores within Subject Groups on Passive Right leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PrePasRight1 - PostPasRight1	-11.00000	15.87451	9.16515	-50.43446	28.43446	-1.200	2	.353
Pair 2	PrePasRight2 - PostPasRight2	-7.75000	11.55783	5.77891	-26.14108	10.64108	-1.341	3	.272
Pair 3	PrePasRight3 - PostPasRight3	-6.80000	8.92749	3.99249	-17.88494	4.28494	-1.703	4	.164

G-3, 1-way ANOVA Results of Groups Improvement Differences on Passive Right leg Raise:

Group 1.00 = PNF/FR, Group 2.00 = PNF, Group 3.00 = Control

Multiple Comparisons

Dependent Variable: AvPassRight

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Bonferroni	1.00	2.00	3.25000	8.90529	1.000	-22.8721	29.3721
		3.00	4.20000	8.51508	1.000	-20.7775	29.1775
	2.00	1.00	-3.25000	8.90529	1.000	-29.3721	22.8721
		3.00	.95000	7.82160	1.000	-21.9933	23.8933
	3.00	1.00	-4.20000	8.51508	1.000	-29.1775	20.7775
		2.00	-.95000	7.82160	1.000	-23.8933	21.9933
Games-Howell	1.00	2.00	3.25000	10.83494	.952	-37.8300	44.3300
		3.00	4.20000	9.99700	.910	-39.8022	48.2022
	2.00	1.00	-3.25000	10.83494	.952	-44.3300	37.8300
		3.00	.95000	7.02395	.990	-21.0644	22.9644
	3.00	1.00	-4.20000	9.99700	.910	-48.2022	39.8022
		2.00	-.95000	7.02395	.990	-22.9644	21.0644

G-4, Descriptive Statistics of Passive Right leg Raise:

Pair 1 = PNF/FR, Pair 2 = PNF, Pair 3 = Control

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PrePasRight1	141.0000	3	12.12436	7.00000
	PostPasRight1	152.0000	3	8.66025	5.00000
Pair 2	PrePasRight2	156.0000	4	28.04758	14.02379
	PostPasRight2	163.7500	4	17.36615	8.68308
Pair 3	PrePasRight3	153.8000	5	18.49865	8.27285
	PostPasRight3	160.6000	5	12.34099	5.51906