Randomised observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility

BY

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Declaration

I, Madeline Vos, declare that this work presented within this document is my own, has been generated by myself and is the result of my own original research.

I confirm that:

- Where any part of this study has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where the works of others have been quoted, the source is always given. Apart from such quotations, this study is entirely my own work.
- I have acknowledged all main sources of help.

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Abstract

Introduction: Flexibility is an important component in everyday life, especially for athletes. Flexibility is related to improved quality of life, better performance and reduced risk of injuries, and better functionality are associated with improved ROM. Static stretching (SS) is one of the most frequently used mechanisms with self-myofascial release (SMR) being a newly implemented mechanism. Both these interventions are seen as an effective way of flexibility improvements, each with their own set of downfalls.

Objectives: The purpose of this study was to compare the effects of SS alone versus SMR + SS on hamstring flexibility. To assess the difference, SS alone and SMR + SS were evaluated over a 4-week period.

Methods: This was a randomized control study. Fifty-six (56) male high-performance athletes from the University of the Free State were recruited and were randomly assigned into the two intervention groups, 28 participants in group one who represented SS and 28 participants in group two who represented SMR + SS. Data collection took place over a period of one month, with three data collections taking place. Outcome measures for this study were hamstring flexibility, which was assessed with an active knee extension (AKE) test and a straight-leg raise test (SLR). The two groups received three sets of one-minute stretching and/or foam rolling with 30-second rests for at least 3 days out of a 7-day week.

Results: Both groups showed improvement in both AKE and SLR when comparing Week 0 to Week 4. However, the improvement seen when comparing SS alone versus SMR + SS was the same; the only exception was the pace at which improvement was seen at Week 2 and Week 4. Improvement at Week 2 was at a faster pace for both interventions than that of Week 4. When comparing the sport codes with one another, all showed improvements with both interventions; one intervention was not superior to another.

Conclusion: The results of this study show that the addition of SMR before SS does not show a significant improvement in hamstring flexibility than that of SS alone.

Actually, SMR + SS improved hamstring flexibility quicker than SS only when analysing Week 2 versus Week 4.

Keywords: Static stretching, Self-myofascial release, Hamstring flexibility, Range of motion, Active knee extension, Straight leg raise, High-Performance.

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List of Abbreviations

ACSM	American College of Sport Medicine
AKE	Active knee extension
cm	Centimetres
g	Gram
GTO	Golgi tendon organ
kg	Kilogram
m	Meter
max	Maximum
min	Minimum
ROM	Range of motion
sec	Second
SMR	Self-myofascial release
SLR	Straight leg raise
SS	Static stretching
SD	Standard deviation
UFS	University of the Free State

Definitions of terms

- Biokineticist: Exercise therapist/specialist (Lloyd, 2021)
- Conditioning: The process of training to become physically fit by a regimen of exercise (Voight, 2012).
- Eccentric: The lengthening of an active muscle under resistance (Kent, 2004).
- Flexibility: Ability to move a joint through its full range of motion (ACSM, 2018)
- Full ROM: The distance or direction a joint can move to in its full potential without being restricted (Prentice, 2013).
- Goniometer: an instrument for the precise measurement of angles (Svensson, Lind & Harringe, 2017).
- High-Performance: A sport at the highest level of competition (Goldsmith, 2009).
- Isometric: A contraction that increases the tension in a muscle while the muscle length remains the same (Kent, 2004).
- Kinetic Chain: Joints and segments have an effect on one another during movement (McMullen & Uhl, 2000).
- Mobility: the ability to move freely (Kent, 2004).
- Musculoskeletal: Denoting the muscles and skeletal together (Brukner & Khan, 2017).
- Static stretching: Stretch that follows a constant amount of stretch over a period of time, over a certain muscle when it takes the muscle to its end range and maintains this position (Davis et al., 2005b; Abdel-Aziem, Diaz & Mosaad, 2018).
- Self-myofascial release: A massage technique, done by the individual using their own body weight to create a pressure between them and the foam roller (Keys, 2014).
- Static: No movement (Kent, 2004).

CHAPTER 1: Introduction

1.1 Introduction

It is well documented that stretching exercises that increase the flexibility of muscles have been used by medical professionals and sports coaches for improving performance, as well as part of rehabilitation programmes (Prentice, 2013; Apostolopoutos et al., 2015). The current generation (18 years of age and older) struggles with a reduced hamstring flexibility due to the sedentary lifestyle they follow (Kim & Lee, 2020). Over the past decade, flexibility has become an expanding and growing component in the field of sport medicine rehabilitation. Flexibility is defined as the range of motion (ROM) around a joint, single joint or multiple joints (Prentice, 2013). However, the capability of connective and muscular tissues to adapt their architecture in response to different types of stretching is imperative for their proper function, repair and performance, as well as improved energy absorption during the lengthening phase to prevent risk of strain injuries (Apostolopoutos et al., 2015; Folli et al., 2020).

From previous findings, flexibility has been recommended as a concept which can be achieved through various interventions such as static stretching, dynamic stretching, proprioceptive neuromuscular facilitation, ballistic stretching, massage, myofascial release done by health professions, self-myofascial release, post-isometric relaxation and post-facilitation stretch (Davis et al., 2005; Miller & Rockey, 2006; Kokkenen et al., 2007; Ayala et al., 2013; Prentice, 2013).

A list of definitions on the recommended concepts to achieve flexibility improvements are briefly explained below:

- Static stretching (SS) involves stretching a limb to its full ROM and keeping it in that position for a set duration until muscle release is felt (Schneider, Frčová & Gurín, 2020).
- Dynamic stretching includes moving a muscle through its full ROM and back to the end range. This type of stretching is more sport-specific in manner (Page, 2012).

- Proprioceptive neuromuscular facilitation involves a contraction of the agonist or antagonist muscle while it is being stretched (Page, 2012). This stretch increases active and passive ROM as well as aids with muscular strength and peak torque (Pok-Him Tam, 2019).
- Ballistic stretching includes rapid and alternating movements that may occur as a bouncing technique at the end ROM (Page, 2012).
- Myofascial release involves therapists placing manual pressure over tissue with a collection of techniques, including that of osteopathic soft-tissue manipulation, structural integration, massage and muscle energy techniques (Couture et al., 2015).
- Massage involves the manipulation of soft tissue to reduce pain, spasms and to improve wellness and health (Bagher et al., 2020). It involves the rubbing or kneading of soft tissue structures (Bagher et al., 2020).
- Self-myofascial release (SMR) is a technique done by the individual using their own body weight to create pressure between them and the foam roller that is used to relieve tight fascia by means of a foam roller, where the individual places pressure on the source of pain or the trigger point (Miller & Rockey 2006; Keys, 2014; Agre & Agrawal, 2019).
- Post-isometric relaxation involves placing a muscle in a stretched position and then doing an isometric contraction. This technique is applied to tight and tender muscles that are associated with musculoskeletal pain (Thiyagarajan, 2012).
- Post-isometric facilitation includes a muscle contraction during a muscle mid-range followed by a rapid movement to its maximal length that will be followed by a short SS session (Page, 2012).

For this study static stretching (SS) and static stretching with self-myofascial release (SMR + SS) were applied in order to determine the best intervention for improved hamstring flexibility. These techniques were used because of the lack of knowledge, popularism within areas and evolvement. Although flexibility is a recommended modality to use and it is well studied, controversy still exists around the concept's effectiveness and importance for athletic performance (Worrell, Smith & Winegardner, 1994; Page, 2012; Behm et al., 2016).

The body functions as a kinetic chain, thus saying that the body is a linked system of segments that works in sequence (McMullen & Uhl, 2000; Brukner et al., 2017). When a certain muscle is stiff, the joint which functions around it will be limited to movement. Therefore, secondary muscles that are dependent on the influenced joint will not be able to function as it should.

Static stretching is a common and known technique, mainly used by strength and conditioning specialists and athletes (Davis et al., 2005a). Keys (2014) explains that SS involves a slow and constant stretch, where it is recommended that this stretching modality reduces the stiffness placed on muscle-tendon units. Static stretching may be done actively or passively, dependant on the intervention type (Keys, 2014).

Self-myofascial release is a new and evolving technique that is performed when the individual places an amount of pressure on the involved muscle and fascia (Beardsley & Škarabot, 2015). This mechanism stimulates the Golgi-tendon unit to initialise a relaxation response (Junker & Stöggel, 2015).

1.2 Problem statement

Flexibility is identified as an important health-related physical fitness component, whether it is for sport performance, functionality, or simply to continue with activities of daily living without limitations or restrictions (Ingraham, 2007). Within the scope of biokinetics, flexibility and ROM is a key health-related component of physical fitness to address during rehabilitation (Prentice, 2013); therefore the interest thereof in this study. Flexibility can be addressed with various methods such as SS, dynamic stretching, ballistic stretching, proprioceptive neuromuscular facilitation stretches, SMR and eccentric strengthening (Davis *et al*., 2005b; Prentice, 2013; Junker & Stöggel, 2015). This study focused on the differences between static stretching and static stretching with self-myofascial release on hamstring flexibility. The use of a foam roller has been reported as an effective intervention through SMR on the hamstring muscle to improve hamstring flexibility over a four-week period (Junker & Stöggel, 2015). However, this technique is new and a developing method, with a number of outcomes still unknown.

Poor flexibility has been found to increase the risk of overuse injuries and meaningfully affect the individual's level of function and performance (Keys, 2014). Keys (2014) also states that although SMR relatively new modality clinically used to increase flexibility, only a few studies are published on the technique. Large populations of people do not spend enough time to improve their flexibility, not only because of their limited time, but also because of their limited knowledge about the correct protocols to use (Mohr, 2011).

1.3 Rationale of the study

The purpose of this study was to compare the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility. In a study done by Mohr (2011), the author investigated the effectiveness of SMR in combination with SS on hamstring flexibility with the use of specific protocols. His hypothesis indicates that although numerous researchers report that SS improve muscle flexibility, the addition of SMR might add benefits that SS alone would not produce. Mohr (2011) also indicates in his study that clinicians often use SMR as a therapeutic intervention and therefore he incorporates the SMR intervention as a warm-up prior to SS. Beardsley and Skarabot (2015) indicate that the SMR has a wide range of effect, including the acute and chronic increase in flexibility, as well as the reduced onset of delayed muscle soreness. Beardsley and Skarabot (2015), also conclude that SMR might add exerted effects to SS for short-time effect. Mohr (2011) concludes that the addition of SMR to SS induces the greatest gain of benefits to participants than any other intervention he studied. Mohr (2011) indicates that SS is still the most popular and used method for increasing flexibility.

To support Mohr's conclusion, another study done by Keys (2014) investigating the acute effect of hamstring SMR and SS on hamstring flexibility, found that acute SMR has a greater effect on hamstring ROM than SS. The study done by Jung et al. (2017) concludes that SMR has a significant improvement on hamstring flexibility. Morton et al. (2015) conclude that SS is an effective intervention to improve flexibility. Furthermore, Morton et al. (2015) also conclude that the combination of SMR + SS has no benefit when performed at high volumes.

In the study, “The effect of foam rolling duration on hamstring range of motion” done by Couture et al. (2015), the author concludes that for self-administered foam rolling a total duration of 2 minutes is not sufficient to induce the improvements in knee joint flexibility. In addition, Miller and Rockey (2006) conclude that no increase in flexibility is associated with foam rolling alone over a period of 8 weeks. The author also suggests that stretching the hamstrings using a foam roller may not be an effective intervention for increasing flexibility within the hamstring muscle group (Miller & Rockey, 2006).

Limited studies have combined the two methods, namely SS and SMR. For that reason this study focused on the difference between SS and SS with SMR on hamstring flexibility when a flexibility programme is followed, and not primarily executed as a warm-up or additional activity to strength training programmes, as pervious literature studies have recorded.

1.4 Aim of the study

The aim of this study was to compare the effects of SS alone versus SMR + SS on hamstring flexibility.

The study aimed to address specifically this through the following secondary objective:

- To compare the effect of SS alone versus SMR + SS over a 4-week period.
- To assess the effects of the interventions after 2 weeks of training.
- To compare the effect of that of the last 2 weeks of training in high performance male athletes.
- Determine the effect of each technique within the different sport codes.
    - Comparing demographic information of the different sport codes.

1.5 Significance of this study

This study provided valuable information to the multi-professional team regarding the specific nature of flexibility and the possible differences in SS versus SS with SMR interventions. The results also provided patients, athletes and physical trainers with information regarding what type of stretching modality or modalities to use for optimal performance.

1.6 Structure of the study

The study consists of several chapters as illustrated by Figure 1.

Chapter one:

- Introduction and problem statement: This chapter introduces the study and address the problem statement, aim and objectives of the study

Chaper two:

- Literature review: This chapter includes a review previous literature regarding hamstring flexibility which is relevant to the study aims stated in Chapter one, Section three.

Chapter three:

- Research methodology: This chapter presents the research design and methodology.

Chapter four:

- Results: This chapter presents and report on all results found during te intervention process

Chapter five:

- Discussion: This chapter consists of the discussion of the results concerning what is the difference on intervention type on hamstring flexibility

Chapter six:

- Conclusions, limitations and future research: This chapter elaborates on recommendations for future research in the same area and will provide the conclusion of the study.

Chapter seven :

- Reflexion on the study: Referencing is according to the Harvard method, which is provided in a list at the end of the study.

Figure 1: Flow of chapters within this study

CHAPTER 2: Literature review

2.1 Introduction

In previous studies, different methods for the improvement of flexibility have been examined, such as static vs. dynamic stretching (Samson et al., 2012), hold-relax proprioceptive neuromuscular facilitation vs. static stretching (Puentedura et al., 2001, in Landers & Fernandez-De-Las-Penas, 2011), self-stretching technique vs. static stretching vs. proprioceptive neuromuscular facilitation incorporating the theory of reciprocal inhibition (Davis et al., 2005b), and self-myofascial release vs. a roller massage (DeBruyne et al., 2017).

Limited studies are those combining the two methods of static stretching and self-myofascial release (Mohr, 2011; Keys, 2014; Agre & Agrawal, 2019). The literature review will include information related to these methods to increase flexibility. It will cite evidence related to flexibility and all relevant concepts such as skeletal muscle physiology, muscle movement, injury histology, mechanisms of flexibility, techniques of static stretching and self-myofascial release.

2.2 Flexibility

2.2.1 Definition of Flexibility

Flexibility is defined by the ACSM (2018:102) as the "ability to move a joint through its full ROM". This is important in the ability to carry out tasks of daily living as well as for athletic performance (Kluwer, 2018). Flexibility is also defined as:

> a person's ability to move their musculoskeletal system through space and through the joint's full range of motion without being restricted by either soft tissue structures, age, connective tissue, muscle bulking and guarding, skin and proprioceptors (Janse van Rensburg, 2009).

Flexibility depends on variables such as circadian rhythm, distensibility of the joint capsule, adequate warm-up, muscle viscosity, joint integrity and musculoskeletal length and pliability (Cech & Martin, 2002; Ingraham, 2007; Kluwer, 2018).

As flexibility is dependent on a muscle moving around a joint or a group of joints within its full ROM, structures such as muscles, ligaments, tendons, fascia and the joint itself affect flexibility (Mohr, 2011; Behm et al. 2016; Stecco, et al., 2020). Mohr (2011) further stipulates that the main goal of a muscle is producing motion through a joint with either accuracy, speed, power or consistency. When hamstring flexibility is reduced, posture adaptations such as posterior pelvic tilt or reduced lumbar lordosis is seen due to the coupling forces of gluteus maximus, rectus abdominis and external abdominal obliques (Kim & Lee, 2020).

To have an increase in flexibility there has to be mechanical changes, such as viscoelasticity, sarcomere length, neuromuscular relaxation and stretch tolerance (Mohr, 2011). Increase in flexibility should be interpreted and thought of very carefully, as mechanical extensibility is not likely to take place (Mohr, 2011; Nuhmani, 2020).

This chapter broadly explains what happens during a stretch “cycle” and how to interpret it.

2.2.2 Factors limiting flexibility

As stated above, flexibility is the ability to move a joint through its full ROM (ACSM, 2018), but this term is also subject to a joint’s degree of freedom (Pestana, 2001). Range of motion can only occur within a joint’s possible degrees of freedom within the anatomical plane of the joint; therefore, it will not be larger (Pestana, 2001). For the hamstring muscle the joints it moves around is the hip joint which is a ball and socket joint and the knee joint which is a modified hinge joint, but the hamstring muscle can only produce movement within the sagittal plane (Pestana, 2001). This means that the joint is uniaxial; it only moves around one axis, as indicated in Figure 2.

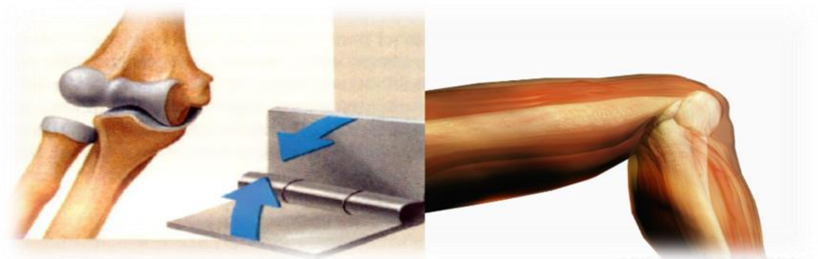


Figure 2: Synovial hinge joint (Marieb, Wilhelm & Mallat, 2014)

Another limitation to consider is age. Decrease in flexibility with age is partially due to physical inactivity and the replacement of degenerative muscle with fibrotic connective tissue (Pestana, 2001). Youdas et al. (2005) indicate that although age is associated with a reduction of ROM, there is not enough evidence to support the statistical and clinical significance of this statement.

Neuromuscular activation as a limitation of flexibility will be discussed in detail in the sub-section reflex physiology, page 17.

Connective tissue is referred to as the tissue that connects, binds, support, protects and separates different tissues or organs (Kent, 2004). Within this paragraph the limitations of connective tissue will be referred to as passive resistance of ROM, as there are three known mechanical components: parallel elastic component, series elastic component, and contractile component (Pestana, 2001; Purslow, 2020; Herzog, 2019). Parallel elastic components coexist parallel with the muscle's contractile elements; therefore working with the actin and myosin filaments (Pestana, 2001; Herzog, 2019). The parallel elastic component defined by Kent (2007), "enables muscles to stretch and recoil in a time-dependant fashion". This produces passive and resting tension in muscles (Pestana, 2001; Herzog, 2019). Series elastic component lies in series with muscle fibres and work in the muscle contractile element that stores energy, such as tendons (Pestana, 2001; Kent, 2007; Herzog,2019). The contractile component as defined by Kent (2007) is "a part of a muscle that is able to develop tension". This component works within the actin and myosin crossbridge, also known as the sarcomere (Pestana, 2001, Purslow, 2020; Kent, 2007; Herzog, 2019). All these components work in on the viscoelastic behaviour of a muscle, indicating lengthening within a musculotendinous unit under a stretch, decrease in resistance during a stretch in the musculotendinous unit and lastly the behavioural changes during loading and unloading of musculotendinous unit (Pestana, 2001; Purslow, 2020).

2.3 Static stretching

Mohr (2011) indicates that SS is the most popular and used method for increasing flexibility, not only used by health professions or coaches, but the general population as well. This type of stretching places a constant amount of stretch over a period of time over a certain muscle when it takes the muscle to its maximal range and maintains this position (Davis et al., 2005b; Abdel-Aziem et al., 2018). Static stretching facilitates a Golgi tendon organ (GTO) activation; therefore it is believed that this is effective in increasing hamstring flexibility (Davis et al., 2005b).

Static stretching is classified within three different categories, namely active, passive and active assisted (Mohr, 2011). Each of these categories involves moving a muscle to a point of tightness, holding that position for a period of time and repeating it for a set amount of time (Mohr, 2011). In the study done by Pestana (2001) it is recommended that the muscle be stretched slowly with a low force. When the force applied is from an external source such as a partner, the stretch is called a passive static stretch. When the force is produced by an antagonist muscle, the stretch is called an active static stretch (Pestana, 2001). Static stretching can be done pre- or post-activity for injury reduction and as prevention of post-exercise soreness (Mohr, 2011).

Controversy exists about the optimal duration, intensity and frequency of SS as seen in Table 1 below.

Table 1: Summary of static stretching and flexibility involving various interventions (Mohr, 2011; De Baranda & Ayala, 2010; Mohr, Long & Goad, 2014;Keys, 2014; Abdel-Aziem, Diaz, Mosaad, 2018; Nuhmani, 2020; Penichet-Tomas, Pueo, Abad-Lopez & Jimenez-Olmedo, 2021).

Author/year	**Duration**	**Frequency**	**Subjects**	**Results**
(Ross, 2007)	5 reps of 30 sec	15 days, once daily	13	Increase hamstring flexibility and single hop test
(Davis *et al*., 2005b)	1 rep of 30 sec	12 days, 3 days per week	19	Improved flexibility
(O'Sullivan, Murray & Sainsbury, (2009)	3 reps of 30 sec	2 sessions	36	Five-min warm-up increase the flexibility, SS increase flexibility further. Although flexibility decreases after 15 minutes.
(De Weijer, Gorniak & Sharmus, 2003)	3 reps of 30 sec	1 session	56	One session with or without a warm-up increases flexibility which was maintained over 24 hours.

(DePino, Webright & Arnold, 2000)	4 reps of 30 sec	1 session	30	Six active knee extensions prior to stretching increased the knee joint ROM, SS increased hip ROM for only 3 min where ROM returns to baseline by minute 6.
(Funk et al., 2003)	15 sec with 5 min in total	1 session	40	Claims it is more effective after exercise as muscles are less stiff.
(Kanazawa, Urabe, Shirakawa, 2010)	10 min	1 session	20	More stretching took place at the aponeurosis that at the muscle tendon junction in injured subjects. Not true in healthy subjects.
(Yaktasir & Kaya, 2009)	4 reps of 30 sec	6 weeks for 4 days per week	28	Increase flexibility over 6 weeks, had no effect on performance. Suggested that stretching had no long-term effect on performance.
(De Baranda & Ayala, 2010)	15 sec, 30 sec and 45 sec	12 weeks for 3 days per week	173 /150	Increase in flexibility
(Ylinen, Kautiainen, Häkkinen, 2010)	6 reps of 30 sec	4 weeks for 7 days per week	12	Instrument method of testing hamstring flexibility was superior to active straight leg raise or manual straight leg raise.
(Russel, Decoster, Enea, 2010)	1 rep of 30 sec	4 weeks, 3 days per week	47	Improved active knee extension.
(Mohr, Long & Goad, 2014)	3 reps of 1-min stretch with 30-sec rest	6 consecutive days with 48-hour separation	40	Improved ROM, but not as significant as myofascial release with SS.
(Keys, 2014)	3 min	1 week, 3 days per week	20	Static stretching resulted in similar increase in ROM as to myofascial release.
(Decoster et al., 2004)	3 reps of 30 sec	3 weeks for 3 days per week	29	Standing and supine stretches showed same improvement in ROM. Supine

				stretch may be recommended at home because of easier positioning and less worrying about pelvic position.
(Abdel-Aziem, Diaz, Mosaad, 2018)	3 reps for 30 sec	5 times per week for 6 weeks	60	Static stretching increase flexibility but is time dependant. SS show better improvement when done in the afternoons and evenings.
(Nuhmani, 2020)	2 sets of 30 sec	3 days per week for 12 weeks.	78	Soft tissue mobilization before SS does not significantly improve hamstring flexibility.
(Penichet-Tomas, Pueo, Abad-Lopez & Jimenez-Olmedo, 2021)	3 sets of 30 sec	Once per week for 1 week.	8	Static stretching produces a significant increase of ROM directly after intervention.

2.4 Self-myofascial release

Self-myofascial release (SMR) is a massage technique done by the individual using his own body weight to create pressure between the body and the foam roller, the equipment used to apply SMR (Keys, 2014; Agre & Agrawal, 2019). This modality facilitates a reaction within the muscle spindle and the GTO (Keys, 2014), by focusing on muscle spasms and connective tissue/fascia (Mohr, 2011). As previously mentioned, connective tissue binds muscle together to ensure the correct alignment of nerves, blood vessels and fibres (Mohr, 2011) and is formed of multiple layers of collagen fibre bundles (Beardsley & Škarabot, 2015). Self-myofascial release can be categorised into two types, namely mechanical and neurophysiological. The systematic review of Beardsley and Škarabot (2015) states that this mechanical type is pressure outside the normal human physiological range and would require induced tissue deformation in most tissue. The neurophysiological type SMR includes the Golgi reflex arch and the muscle spindle. The pressure that is applied to the mechanoreceptors, namely the Ruffini and Pacinian receptors, might stimulate the nervous system leading to reduced muscle tension (Beardsley & Škarabot, 2015). Local adaptations of the neural responses include increased blood flow, improved vascular function and reduction in viscoelastic stiffness and viscosity leading to muscle relaxation (Fuli *et al*., 2020). Self-myofascial release increases ROM, improves muscle recovery and muscle performance prior to exercise and thereafter, as well as relieves pain after exercise through increased blood lactate clearance (Penichet-Tomas et al., 2021). Self-myofascial release improves muscle soreness and muscle function loss by means of increasing the anti-inflammatory proteins and reducing proteins that promote inflammation (Penichet-Tomas *et al*., 2021).

The technique required for SMR requires of the individual to locate an area of tenderness that may cause restrictions and then apply a force that is usually with a low load, but long duration (Mohr, 2011). This technique is continued until a release is felt within the fascia. This feeling is better described as a restoration of homeostasis when the spasm cycle is broken and adhesions are decreased (Mohr, 2011).

Self-myofascial release is performed using a foam roller that is cylinder like. This product varies in size, shape, density and material used to manufacture it. For the hamstring muscle the position and direction of rolling are within the alignment of the muscle, on the posterior surface and perpendicular to the length of the femur. Therefore, the individual will apply myofascial release from the ischial tuberosity in the direction of the posterior tibial epicondyle.

Controversy exists about the optimal duration and frequency of SMR as seen in Table 2 below.

Table 2: Summary of self-myofascial release and flexibility involving various interventions (Junker & Stöggel, 2015; Couture *et al*., 2015; Sullivan et al., 2013; Mohr *et al*., 2014; Keys, 2014; Monteiro & Neto, 2016; Kim & Lee, 2020; Penichet-Tomas *et al*., 2021).

Author/ year	Duration	Frequency	Subjects	Results
(Junker & Stöggel, 2015)	30–40 sec (10 times back and forth)	3 days for 4 weeks. 3 sets in 1 session	47	They found that myofascial release is an effective intervention to improve flexibility within 4 weeks.
(Couture *et al*., 2015)	One group: 2 sets of 10 sec.		33	Self-administrative myofascial release for a total of 2 min is not enough to

	Second group: 4 sets of 30 secs rolling back and forth			improve in knee joint flexibility.
(Sullivan et al., 2013)	1 set of 5 sec, 1 set of 10 sec, 2 sets of 5 sec and 2 sets of 10 sec	2 sets per session for 3 days.	17	Self-myofascial release has no significant effect on strength but does have great effect on ROM.
(Mohr *et al*., 2014)	3 sets of 1 min stretch with 30 sec rest	6 consecutive days with 48-hour separation	40	Improved ROM, but not as significant as myofascial release with SS.
(Keys, 2014)	3 min	1 week, 3 days per week	20	Static stretching resulted in similar increase in ROM as to myofascial release
(Monteiro & Neto, 2016)	8-12 reps	3–4 sessions per week	25	Greater volumes of intervention improve ROM.
(Kim & Lee, 2020)	30 sec active 30 sec rest	4 sets for 5 days	20	No significant changes between the 3 methods, but SMR shows immediate improvement.
(Penichet-Tomas *et al*., 2021).	3 sets of 2 sec repetitions with a total duration of 30 sec per set	Once per week for 1 week.	8	Significant increase in ROM.

2.5 Skeletal muscle physiology

Flexibility influences the muscle, joints, fascia, tendons and ligaments (Mohr, 2011). For this reason, muscle plays a significant role in flexibility; therefore, to understand flexibility, one must understand muscle physiology (Mohr, 2011).

Skeletal muscles are surrounded by several layers of connective tissues that support the muscle during contraction, namely epimysium, perimysium and endomysium. This is illustrated by Figure 3 (Van Putte et al., 2017). The epimysium forms a connective tissue layer that surrounds the muscle; it has a layer of dense irregular connective tissue whose protein fibre merges with the muscular fascia (Van Putte et al., 2017). This muscular fascia are the connective tissue layer between neighbouring muscles and the skin. It also keeps the muscles separate from surrounding tissues and organs such as nerves, blood vessels and muscle fibres (Van Putte et al., 2017; Kim & Lee, 2020). Furthermore, the muscular fascia are responsible for myofascial force transmission (Stecco et al., 2020). Fascia are continuous viscoelastic tissue made up by several layers of dense connective tissue and loose connective tissue (Stecco et al., 2020). Deep fascia can be distinguished into two groups, namely epimysial fascia and aponeurotic fasciae (Stecco et al., 2020). These fascia are able to glide with underlying muscles and present specific connections with underlying musculature, referred to as myofascial expansions (Stecco et al., 2020). When a muscle contracts and causes movement, there is a simultaneous stretch that is related to myofascial expansion, transmitting muscular force to the aponeurotic fascia (Stecco et al., 2020).

Each muscle cell is termed a muscle fibre, which is surrounded by a plasma membrane called the sarcolemma (Van Putte et al., 2017). The sarcolemma's role is to transmit electrical impulses to the interior muscle fibres (Van Putte et al., 2017).

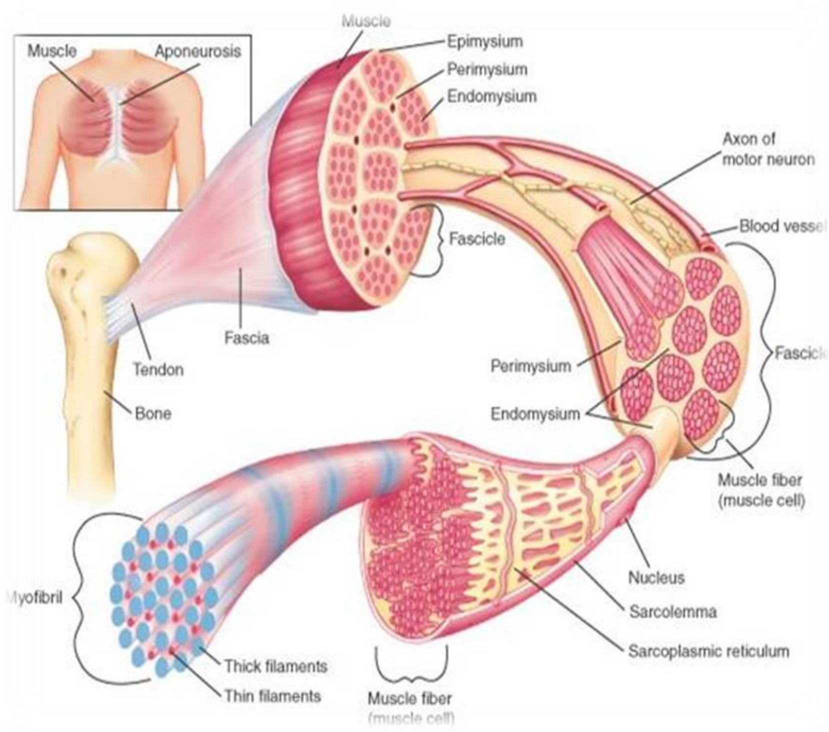


Figure 3: Structure of skeletal muscle (Juhee Kim , 2016)

Skeletal muscle cells' primary function is to generate force by using the sliding filament theory model (Van Putte et al., 2017). The sliding filament theory model as described in Seeley's *Anatomy and Physiology* (2017) describes what a muscle is made of and is a process by which a muscle receives a signal, contracts and relaxes.

The sarcoplasm is the cytoplasm of a muscle fibre that contains numerous myofibrils that are composed of actin and myosin, as illustrated in Figure 4 (Van Putte et al., 2017; Moo & Herzog, 2018). These myofibrils are the organelles responsible for muscle lengthening and shortening, also relaxation and contraction (Van Putte et al., 2017). From Figure 3 it is illustrated that these actin and myosin filaments work together as cross bridges within each muscle fibre to form a contraction (Van Putte et al., 2017). Due to the fact that the filaments slide across one another, they release and repeat the action until the desired muscle length is met, in which the muscle is stretched (Van Putte et al., 2017; Moo & Herzog, 2018). These structures are classified as extrafusal fibres, meaning they are involved with cross linking and muscle contractions (Van Putte et al., 2017).

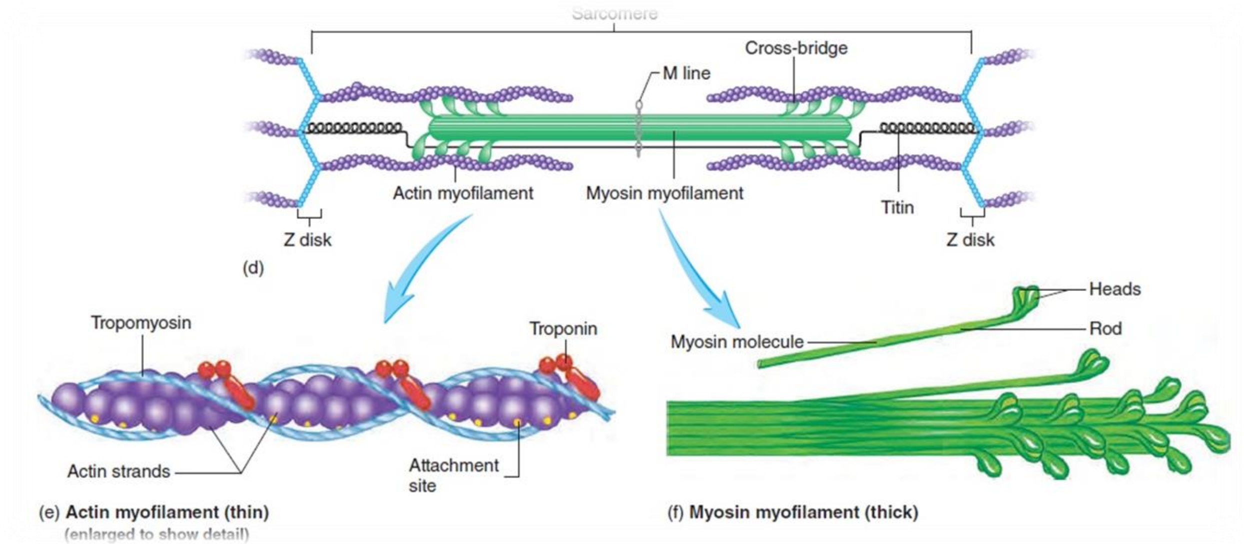


Figure 4: Organisation of sarcomeres (Van Putte et al.*, 2017)*

2.6 Reflex physiology

Van Putte et al. (2017) define a reflex as "an automatic response to a stimulus that is produced by a reflex arch". Defined in the study done by Costa et al. (2020), a reflex "can be defined as an involuntary, qualitatively invariable nervous stem response to a stimulus". The reflex arch is the basic structure of the nervous system that is skilled to receive a stimulus and produce a response (Van Putte et al., 2017). The reflex arch is also the fundamental part of physiology of posture and locomotion (Costa et al., 2020).

Reflexes have five basic components that are involved with physiological responses, namely receptors, sensory nerves, synapses, motor neurons and target organs (Costa et al., 2020). Neurons that integrate with the spinal cord, rather integrate with the brain via the spinal cord, therefore leading to a reaction in the effector organ stimulated by a stimuli in the sensory receptor (Van Putte et al., 2017). Some reflexes are integrated within the spinal cord, where others are integrated within the brain (Van Putte et al., 2017; Reschechto & Pruszynski, 2020).

A stretch reflex is a reflex contraction of a muscle in response to stretching of the same muscle; the sensory receptor that cause the reflex is the muscle spindle (Van Putte et al., 2017; Reschenhtko & Pruszynski, 2020). The stretch reflex is a monosynaptic reflex, due to the fact that it has no inter-neuron (Van Putte et al., 2014; Reschenhtko

& Pruszynski, 2020). When a muscle is put under tension the sensory units sense it as a stimulus; they are called intrafusal muscle fibres (Van Putte et al., 2017, Reschenhtko & Pruszynski, 2020). This mechanism is illustrated in Figure 5.

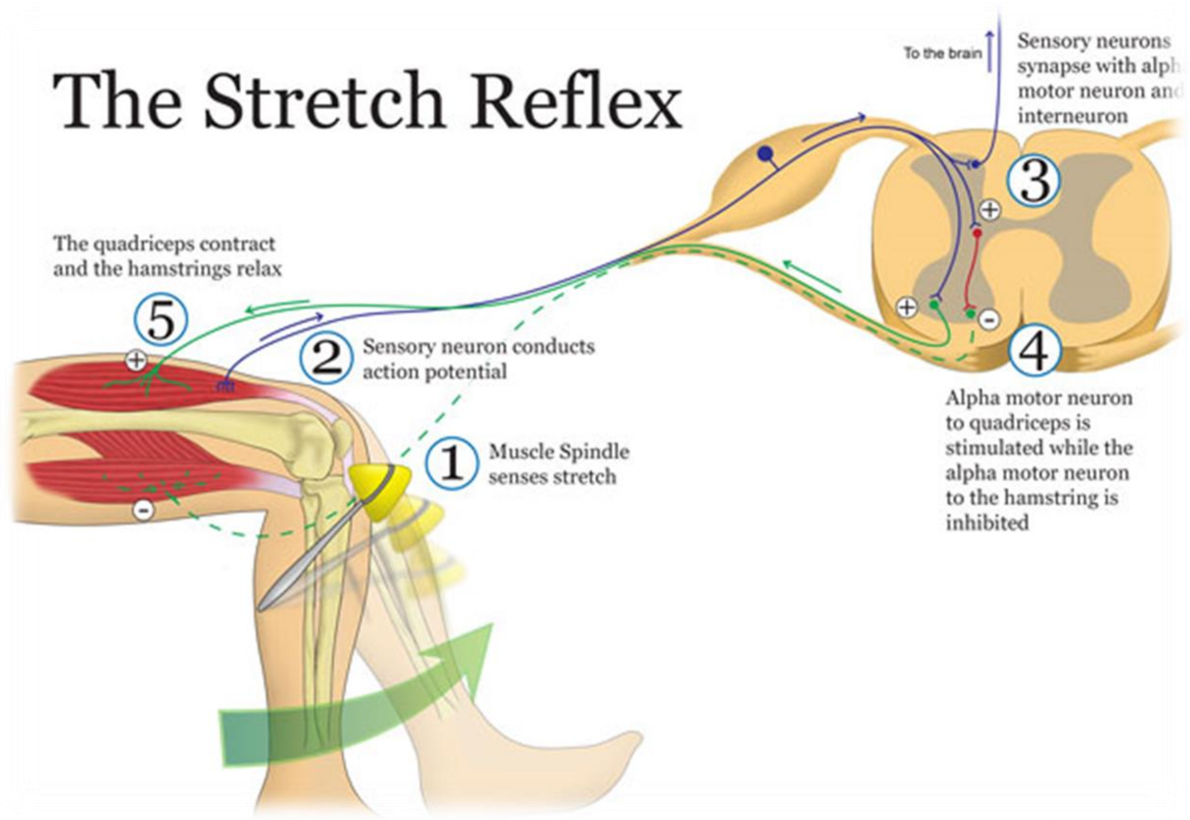


Figure 5: Muscle spindle reflex (Van Putte et al.*, 2017)*

The Golgi tendon reflex prevents a muscle contraction with the use of the GTO (Van Putte et al., 2017). The GTO is an encapsulated structure that is located near the muscle-tendon junction, where the collagen fibres of a tendon connect to the extrafusal muscle fibres (Van Putte et al., 2017; Costa et al., 2020). The stretch that occurs at the fibres also stretches the GTO. This compresses and stretches the nerve endings, causing their depolarization (Costa et al., 2020). The sensory organs stimulate an inhibitory response to the associated muscle and cause the muscle to relax (Van Putte et al., 2017). This stretch mechanism is illustrated in Figure 6.

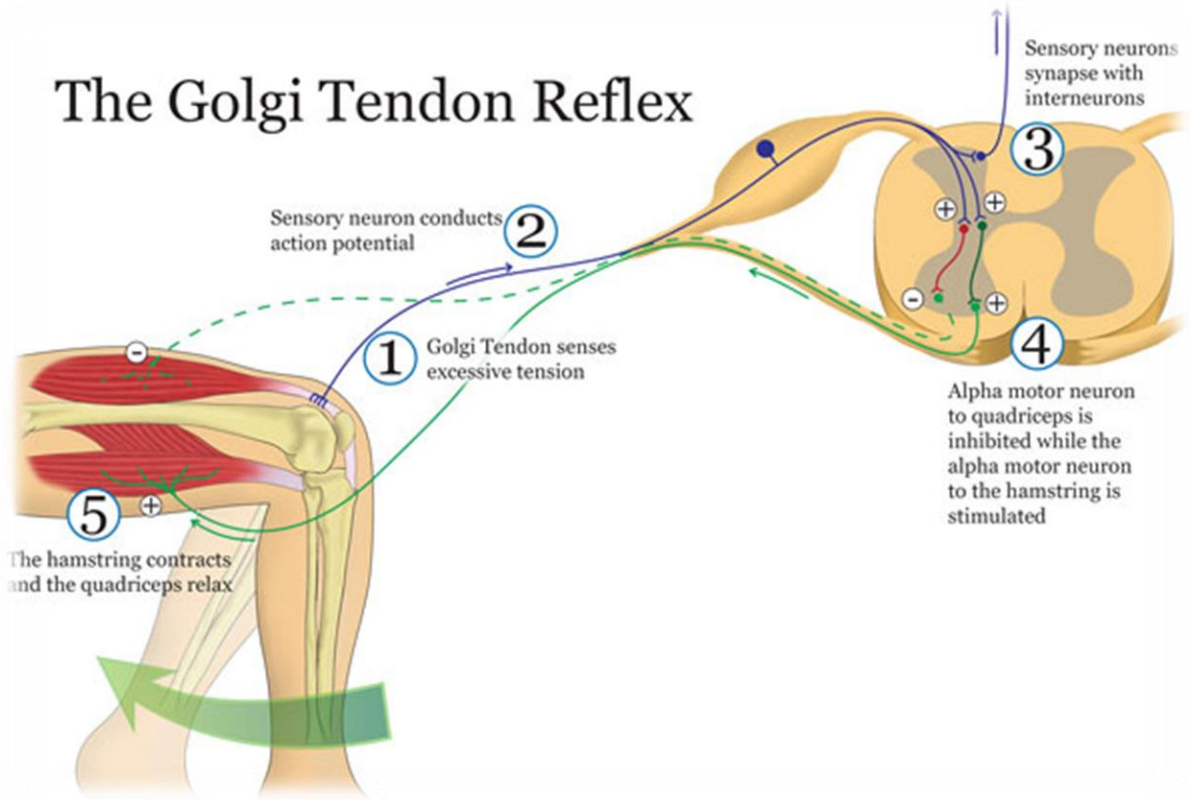


Figure 6: Golgi tendon (Van Putte et al.*, 2017)*

This reflex protects muscles and tendons from damage due to excessive tension (Van Putte et al., 2017). Golgi tendon organs are susceptible to changes in muscle tension, whereas muscle spindles are susceptible to a change in muscle length (Costa et al., 2020).

Muscle spindles are monosynaptic leading to a slow-adapting relaxation discharge to a muscle where length and velocity is applied in the form of a stretch (Van Putte et al., 2014). They are encapsulated and consist of specialized skeletal muscle fibres such as intrafusal muscle fibres ad extrafusal muscle fibres (Costa et al., 2020). Muscle spindles respond to a stretch and contribute to proprioception, because they have their own motor supply (Dimitriou, 2021). The intrafusal fibres can contract at their polar end; yet, at their apolar ends no contraction take place (Costa et al., 2020). The extrafusal muscle fibres can physically shorten a muscle and receive nerve supply in their motor neuron (Costa et al., 2020). This reflex helps to control posture, muscle tension and muscle length (Van Putte et al., 2014).

Active resistance, which is a neurological component, is also known to limit flexibility (Pestana, 2001). This component originates from muscle reflex activity, when elongation is resisted (Pestana, 2001). If one of the five fundamental components seizes to work, the expected reflex response would not occur (Costa et al., 2020).

2.7 Gender differences in musculotendinous structures

Bell et al. (2009) indicate that females have less stiffness than males for muscles surrounding and supporting the knees, including the hamstrings. Youdas et al. (2005) and Blackburn et al. (2009a), report that females have a larger ROM or flexibility than males. For this reason, Hoge et al. (2010) conclude that males may have to increase their stretch duration or intensity to achieve the same results in ROM as those of females. Due to this, only males were used in this study.

The effect of gender appear to be joint and motion specific (Youdas et al., 2005). The physiology of the connective tissue between males and female differ (Hoge et al., 2010). The potential physiological adaptations that allow for an increase in ROM include increased stretch tolerance and viscoelastic stress relaxation (Cipriani et al., 2012).

Females have hormonal fluctuations during the time of their menstrual cycle. These include oestrogen, progesterone and testosterone (Bell et al., 2009). Oestrogen receptors are present in the fibroblastic cells of tendons and ligaments, which affect tissue behaviour due to the influences on collagen synthesis (Hoge et al., 2010). During the menstrual cycle tissue adaptations may occur, as well as changes in tissue properties (Bell et al., 2009). During the ovulatory phase, oestrogen and progesterone levels are elevated, leading to greater hamstring extensibility than during the time of menstruation (Bell et al., 2009).

2.8 Hamstring muscle movement and injury

2.8.1 Muscle movement

Humans can perform a variety of smooth controlled movements of al joints, facet, costal and sacroiliac joints in the absence of ROM restrictions (Hanabusa et al., 2021). With ROM restrictions during training, stretching interventions are necessary (Hanabusa et al., 2021). Hamstring muscle tightness is due to the lack of ability to change in length from full contraction to full stretch (Agre & Agrawal, 2019).

The hamstring muscle group consists of three main muscles, as elaborated on in Table 3 below:

Table 3: Muscles of the Hamstring (Moore, Dalley & Agur, 2018)

Muscle	Proximal attachment	Distal attachment	Innervation	Main action
Bicep femoris	Long head – Ischial tuberosity Short head – linea aspera and lateral supracondylar line of femur	Lateral side of the head of fibula. Tendon split at this site by fibular collateral ligament of knee	Long head - Tibial division of sciatic nerve (L5, S1, S2). Short head- Common fibular division of sciatic nerve (L5, S1, S2)	Flexes leg and rotates it laterally when knee is flexed. When thigh and leg are flexed, these muscles can extend trunk.
Semi-tendinosus	Ischial tuberosity	Medial surface of superior part of tibia	Tibial division of sciatic nerve part of tibia (L5, S1, S2)	Extends thigh: flex leg and rotate it medially when knee is flexed; when thigh and leg are flexed.
Semi-membranosus	Ischial tuberosity	Posterior part of medial condyle of tibia. Reflected attachment forms oblique popliteal ligament.	Tibial division of sciatic nerve part of tibia (L5, S1, S2)	Extends thigh: flex leg and rotate it medially when knee is flexed. When thigh and leg are flexed.

These muscles named in the table above work actively to stabilize the knee joint and decelerate the knee by contracting eccentrically (Agre & Agrawal, 2019), flex the knee joint and extend the hip while assisting the stabilization of the knee (Mohr, 2011). During gait movements the quadricep femoris and the anterior cruciate ligament initiate the swing phase and support the lower leg for balance (Foli *et al*., 2020).

2.8.2 Flexibility-related Injuries

Previous literature suggest that flexibility might have a direct effect on hamstring muscle performance (Kokkekonen et al., 2007; Dorfman & Riebe, 2013; Haeley et al., 2013; Behm et al., 2016; Hatano et al., 2018). Hamstring flexibility as concluded by Hatano et al. (2018) is needed to limit the occurrence of injuries. Stretching exercises that are incorporated into flexibility programs have generally been accepted to decrease injuries, but previous research indicates that it may increase the prevalence of several overuse injuries (Witvrouw et al., 2004). Magnusson and Renström (2006) conclude that within the current available evidence there is no notion that injury risk can be influenced by stretching interventions. In a study done by Mohr (2011) it is stated that connective tissue trauma can be a cumulation in many overuse injuries for example sprains or contusions.

For injuries within connective tissue, the elastin, which is a major component for fascia, loses its pliability substance solidifiers and cross links (Mohr, 2011). When collagen within tissue is broken down, it makes the tissue more resistant to stretch, so when mobilization techniques is used, it keeps the cross-links from breaking down and keep stretch resistance to a minimum (Mohr, 2011).

Injuries can occur within all layers of tissue and structures of muscle, depending on a mechanism of injury and location of injury (Mohr, 2011).

Clark (2008) reports that for a sprint-related hamstring injury the flexibility of the hamstring muscles performs a major role in the prevention of these injuries. A sprint-related hamstring strain occurs in sports where rapid activation is required and the muscle needs to control the excessive strain within the eccentric deceleration phase (Liu et al., 2012; Brukner & Khan, 2017). Opposite to this is a stretch-related hamstring strain, where the mechanism for this injury is that the muscle is put under an excessive stretch in a hip flexion position (Brukner & Khan, 2017).

The hamstring injury recurrence rate, defined in a study done by Macaulay (2012), is double the chance of recurring than that of a first-time injury. Van Doormaal et al. (2016) state that hamstring muscle-limited ROM does not increase an individual's risk for developing an injury or re-injury. This study concludes that hamstring flexibility does not relate to the injury rate, but possible contributing risk factors include age and previous injuries (Van Doormaal et al., 2016). Clark (2008) and Brukner and Khan (2017) indicate that one of the primary predictors for hamstring re-injury is a previous hamstring strain injury.

Hamstring muscle injuries have a wide range of epidemiological spectrums, with the most common being strains, contusions, neurological referred pain and tears; with the least common injuries being a tendinopathy, bursitis, compartment syndrome, nerve entrapments, myositis ossificans, or an avulsion fracture (Brukner & Khan, 2017). Mechanisms of hamstring injuries include inconsistent quadriceps to hamstring ratio, direct trauma, dysfunctional muscle firing sequences, poor conditioning of the hamstring muscle with regard to strength, endurance or power, and that the muscle cannot keep up with the human growth rate (Mohr, 2011).

Although stretching the hamstring muscle group prior to exercise will reduce the chance of muscle injury occurrence, there is no conclusive evidence that stretching prevents injuries (Mohr, 2011). In a study done by Hanabusa et al. (2021) they describe an injury as a power that is applied to a surface that is returned by a stronger force that the body cannot absorb. The stress accumulates in weak or unstable parts of the body, leading to injuries or tissue damage. For this reason, flexibility is important in the absorption and dispersion of strong impacts and injury prevention (Hanabusa et al., 2021).

2.9 Conclusion

In conclusion, muscle anatomy and physiology remain a complex and intricate aspect with various influential factors. From previous research it is known that the effect that stretching interventions have on muscles is much deeper than we know to achieve optimal ROM. Additional factors to achieve flexibility include limitations, type of interventions, muscle movement and injury occurrence.

CHAPTER 3: Methodology

3.1 Introduction

This chapter elaborates on the study design and methodology used to answer the research question. The following sections will be discussed: (a) study design, (b) selection of participants, (c) screening procedure, (d) equipment, (e) data collection procedures, and (f) data analysis procedures.

3.2 Study design

This was a randomised control study to assess the differences between static stretching and static stretching with self-myofascial release on hamstring flexibility. Evaluation took place over a 4-week period with data being captured on Week 0, Week 2 and Week 4. A 4-week period was used, as most research found was done longer than a period of four weeks. Therefor this study focused on a shorter time span.

Participants were randomly assigned to one of the two groups. Group 1 was the static stretching group; these participants only participated in the static stretching protocol; Group 2 was the static stretching with self-myofascial release group. These participants participated in the static stretching and self-myofascial release protocols.

3.3 Study population

All high-performance athletes that represent the University of the Free State (UFS) in their particular sport type have access to the Sport Science Centre of the University of the Free State to complete their gym conditioning and/or rehabilitation, when required. From these high-performance athletes, male high-performance athletes between the ages of 18 and 24 years who volunteered and consented to participate in this study were recruited. The rugby, cricket and hockey high-performance teams were asked to join the study. There was approximately n=72 participants in total (12 cricket players, 20 hockey players and 40 rugby players) at the UFS that were asked to join, where after players were invited to the information session and screened. The participant recruitment process is illustrated in Figure 7.

3.3.1 Inclusion criteria

- Participants without knee, hip or spine injuries in the past year or in the present.
- Currently participating in high performance sporting activities and voluntarily consented to evaluation.
- Participant must be able to give consent on the consent form provided (hand-written or available electronic for computerised input).
- Only male participants (Bell et al., 2009).

3.3.2 Exclusion criteria

Participants needed to be free of any acute musculoskeletal, systemic, or metabolic disease that would prevent participation.

3.3.3 Withdrawal of study participants

Participation in this study was voluntary and participants could withdraw from the study at any time, without any penalties or consequences.

3.4 Screening Procedure

After ethics approval had been obtained, approval was obtained from the Director of Kovsie Sport with a request to receive a list of students involved in High-Performance Sport. Permission was also received from the Director of Kovsie Sport to contact these students via an electronic invitation. This invitation was e-mailed to each student's e-mail address, and an e-mail was sent to each sports code coach or manager for a request to distribute the formal invitations in order to ensure the invitation reaches students who have not consented to be contacted directly.

Participants were asked to report to the Sport Science Centre at the University of the Free State for an information session. It was verbally explained what was expected of them when participating, what to expect from the application of the protocols, and describe the timeline for participation in this study, from the first evaluation until the last data collection measurement. This process is discussed in Appendix C and was also communicated in a written information document. After explanation of the procedure and expectations, the participants were asked to sign an informed consent form (Appendix D).

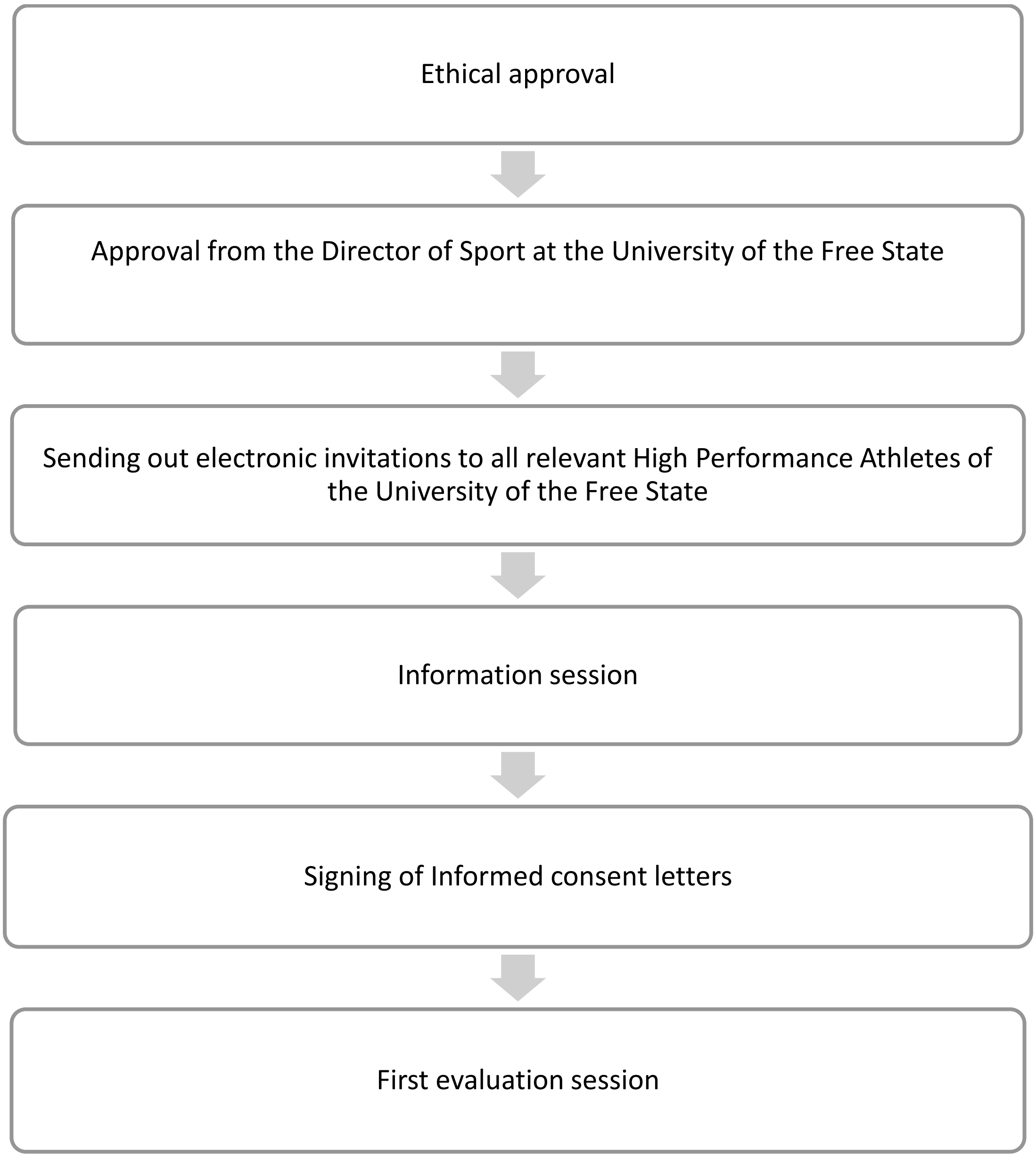


Figure 7: Flow chart of participant recruitment

3.5 Equipment

To measure hamstring flexibility, the use of a handheld digital goniometer with a display attached in the middle of the plastic ruler with a position sensor was used (Svensson et al., 2017).

Participants were measured in a supine position using a plinth. To limit and minimize accessory movement such as pelvic lifting of the table, pelvic rotation, hip flexion, the pelvic area and left leg were strapped down to the plinth with added straps to both sides of the table. The straps was 8 cm wide and 215-cm-long belts with Velcro sides to ensure stability. Static stretching protocols was done using a purple jump stretch band. Average bands are 1¾" wide and offer 65–85 lbs or 30–39 kilograms resistance per band. Self-myofascial release protocols were done using a foam roller with a 15 cm x 91 cm dimension.

Readings and recordings were captured first on the evaluation sheet which was then stored in a safe, then on an Asus laptop that is password protected. Microsoft Excel 2016 was used to collect each participant’s data on spreadsheets.

3.6 Data collection procedure

On arrival on the first day of the study, all participants received an information document (Appendix C) on how they were expected to participate with regard to the aim of this study, what to expect from the interventions, any benefits or risk that they should have been aware of and clothing, as they need to wear a T-shirt and shorts, and the familiarization session on the different protocols that were used in this study. In the familiarization session each participant had the chance to do each protocol once practically (Appendix F and Appendix G).

Figure 8: Static stretching demonstrated

Figure 9: Self-myofascial release demonstration

After this all participants underwent the screening session, which comprised an informed consent letter (Appendix D).

After participants had completed their informed consent, they were randomly assigned to one of the two groups using a statistical program. This was done by the statistician.

Evaluations took place at the University of the Free State's Exercise and Sport Science Centre by the researcher, in a private evaluation room. Three evaluation procedures took place over a 4-week period. All evaluations were done by the researcher. The first evaluation took place on week 0; this was done as an initial determination of all the subjects' hamstring flexibility. The second evaluation took place on Week 2 in the program. The last and final evaluation took place on Week 4 after the last program intervention. During the evaluation periods most of the time slots pr sport code was kept at the same time and the same location, thus limited external factors such as circadian cycle, sport or personal physical demands. This was also done to keep all athletes in their routine. For this reason, the reliability of each measurement was ensured. Although athletes still partook in comprehensive exercise sessions, the amount spend per athlete undergoing the evaluation was kept fairly the same (2-5min).

During the first evaluation opportunity, every participant's demographical information such as age, weight, height, dominant side (also described as the leg you would use to kick a ball) (van Melick, Meddler, Hoogeboom, Nijhuis-van der Sandem, van Cingel, 2017), intervention, sporting activity and anthropometry was collected. Two baseline tests were done to measure hamstring flexibility, active knee extension (AKE) test and straight leg raise (SLR) test. The test-retest reliability obtained in a study done by Neto et al. (2015), where that the intraclass correlation coefficient of the dominant legs for the AKE is 0.91 and 0.93 for the SLR (95% CI) and are therefore mentioned to have excellent intrarater reliability. The first of the baseline measurements is the AKE test. This measurement required of the participant to be positioned supine on a plinth, from where their left leg and their hips were secured using the straps. 1 strap was placed over the participant's left thigh just superior of the patella and the other strap was placed superior to the anterior superior iliac spine (ASIS). The participant was asked to place his hip joint at a 90-degree angle with knee flexion at 90 degrees as well. From this the digital goniometer was placed mid-thigh and the participant was instructed to straighten his leg till he experienced muscle stiffness. The digital goniometer was used to measure this value; the value was recorded and dotted down as the first of the baseline measurements. The norms for this test are 180 degrees (Stewart et al., 2011). The second of the baseline measurements was the SLR test. This measurement required of the participant to be positioned supine on a plinth, from where his left leg and hip were secured using the straps. One strap was placed over the participants' left thigh just superior of the patella and the other strap was placed superior to the anterior superior iliac spine (ASIS). From this position the digital goniometer was placed mid-thigh and the participant was instructed to lift his right leg, keeping it straight till he experienced muscle stiffness. The norms for this test are 90 degrees (Stewart *et al*., 2011).

After the first evaluation process had been completed, the intervention sessions took place under the careful supervision of the biokinetics students. During each protocol intervention all participants underwent a 5-minute warm-up on the Monark bike, where they cycled at target heart rate at low intensity (30-40% of their heart rate reserve, determined with the use of the Karvonen method).

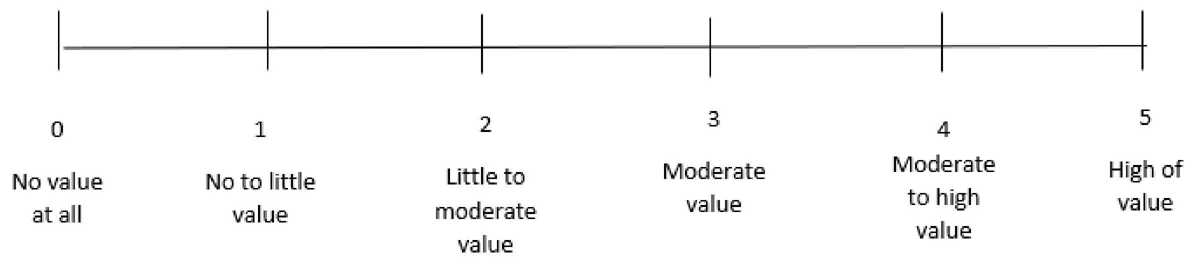
$$\text{THR} = ((\text{HRmax} - \text{HRrest}) \times \%\ \text{intensity}) + \text{HRrest}$$

Once the warm-up had been completed the participant continued with his flexibility sessions. Participants who received SS lay down in a supine position on a padded mat, where consecutive passive static stretches were performed with the help of a purple theraband while their relaxed leg and ASIS were placed flat on the mat (as seen in Figure 8). The protocol that was used followed the same intervention as that of Mohr, Long and Goad (2014); the stretch was held for one min with a 30-sec rest between sets. This was repeated for 3 sets.

Participants who received SS with SMR first used a foam roller that was placed underneath their right thigh (As seen in Figure 9). The participant was then passively rolling the roller from his ischial tuberosity to the popliteal area with his own body weight, while the leg is maintained in an extended position with the ankle relaxed and orientating it upwards. From this position the participant was instructed to maintain his body weight on his thigh with his arms extended to help maintain the pressure over the hamstring muscle. Subjects then actively moved their bodies over the foam roller. Protocol that was used followed the same intervention as that of Mohr et al. (2014), SMR was continued for one minute (rolling at a cadence of one second inferiorly and one second superiorly) with a 30-second rest between sets. This was repeated for 3 sets.

After the SMR protocol, the participants moved on to the SS where they followed the same protocol as those doing only SS.

After the second evaluation took place, the participants were asked to rate their perception of the interventions and the process, the rating score started at null and moved to five. Each with their own explanation. This data was only used as a method to investigate what intervention received a higher score than the other, if any.



All athletes who participated in the above-mentioned flexibility protocols performed these sessions during either the preparation or competition periodization phase for the particular sport, as it differed for each sport code's annual competitions or leagues, they participate in. Since the athletes performed the flexibility program it was not influenced by the season of the sporting code, nor did it have a negative impact on sport performance during the season. This program served as an additional training session to that which the coaching and conditioning staff performed during their own preparation and planning. The procedure of data collection is illustrated by the flowchart in Figure 10.

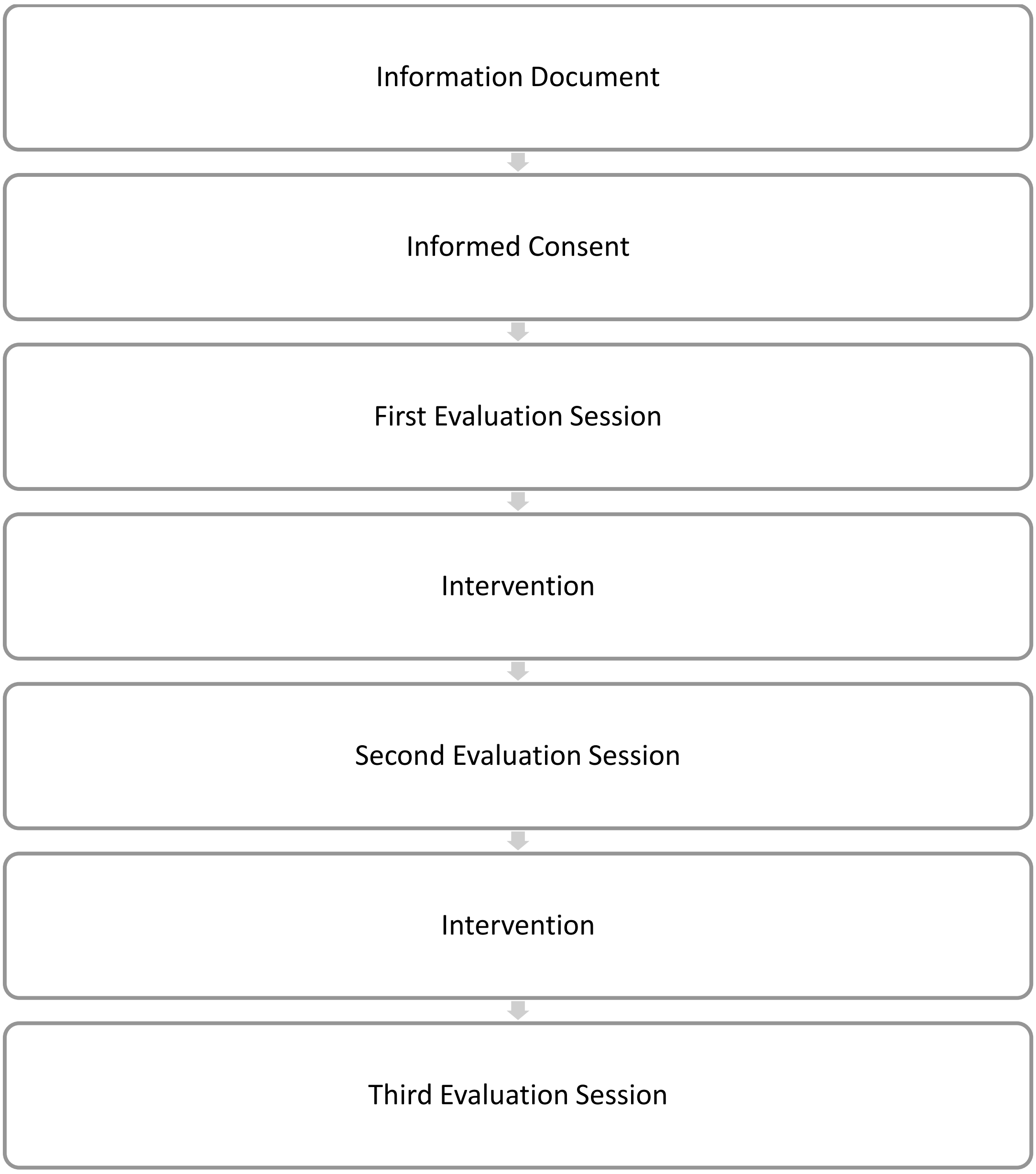


Figure 10: Flowcharts of data collection procedure

3.7 Methodological and instrument errors

Systematic methodological errors were minimized by using the same equipment and that all testing was performed by the same individual. All the equipment was standardised and calibrated to ensure the same equipment and procedure were used for all participants. Random methodological errors that may occur included time changes during the day when each participant did their interventions.

3.8 Randomisation and Statistical Methods

3.8.1 Randomization

The study participants were randomized to the two treatments SS and SMR + SS in a 1:1 ratio, using blocked stratified randomization, where the sport codes (rugby, hockey and cricket) formed the randomization strata. In order to achieve a balance between the two treatments, the randomization used a block size of four (Altman, 1991; section 5.7).

3.8.2 Data

Pre-intervention demographic data, and pre- and post-intervention data on AKE and SLR were available for 62 participants from three sports.

Data from the evaluation form were captured on the evaluation form by the researcher. At the end of the 4-week period all data were stored on a Microsoft Excel 2016 spreadsheet. Any further analysis was done by a statistician.

3.8.3 Statistical Analysis

3.8.3.1 Sample size calculation

Škarabot, Beardsley and Štirn (2015) report post-pre mean changes in passive ankle dorsiflexion of 0.9 cm for SS, and 1.3 cm for FR+SS (SD approximately 0.66). Given a standard deviation of the post-pre changes in ROM measurement of 0.66 and a two-sided significance level of 0.05, n=44 subjects would be needed per treatment group to detect a between-treatment difference of 0.4 with 80% power.

3.8.3.2 Demographic data

Demographic data such as anthropometric measurements were summarized descriptively, by sport and overall.

3.8.3.3 Descriptive statistics

For each measurement time (pre-intervention [Week 0]) and, where appropriate, post-intervention at Weeks 2 and 4) quantitative variables were summarized using descriptive statistics (mean, SD, minimum, median, maximum), generally by sport and overall. Categorical variables were summarized using frequencies and percentages.

3.8.3.4 Change in AKE and SLR from Week 0 to Weeks 2 and 4

The change in AKE and SLR from Week 0 to Weeks 2 and 4 was analysed descriptively.

3.8.3.5 Effect of intervention and AKE and SLR at Week 2 and 4

For the two post-intervention time points (Weeks 2 and 4) the effect of the intervention on AKE and SLR was analysed using analysis of covariance (ANCOVA) with the respective post-test value as dependent variable, treatment (SMR + SS [test] vs SS [control]) as independent variables, and the following covariates:

- the respective pre-test value of AKE or SLR
- Sport
- Height
- Weight
- Fat
- Dominant side

From these ANCOVA, least squares mean values of the dependent variables were calculated for each treatment (test and control), as well as the “test–control” difference in mean values and a 95% confidence interval (CI) for the difference. The associated F-test and P-value for the mean difference are also reported.

3.8.3.6 Comparison of sport codes with respect to AKE and SLR

To compare the sports with respect to AKE and SLR, AKE and SLR at Weeks 0, 2 and 4, were summarized descriptively by sport.

Furthermore, AKE and SLR at Week 0 were compared between sports using a one-way analysis of variance (ANOVA) with AKE and SLR, respectively, as dependent variables, and sport as categorical independent variable (cricket, hockey, rugby). From these ANOVA, the least squares mean values of the dependent variables were calculated for each sport, as well as the pairwise mean differences between sports and associated 95% confidence intervals (CIs) for these differences. The associated t-tests and P-values for the mean differences are also reported.

AKE and SLR at Weeks 2 and 4 were compared between sports using a two-way analysis of variance (ANOVA) with AKE and SLR, respectively, as dependent variables, and intervention (test and control) and sport as categorical independent variable (cricket, hockey, rugby). As before, from these ANOVA, the least squares mean values of the dependent variables were calculated for each sport, as well as the pairwise mean differences between sports and associated 95% confidence intervals (CIs) for these differences. The associated t-tests and P-values for the mean differences are also reported.

3.8.3.7 Correlation of fat percentage with AKE and SLR

To assess the potential correlation of body fat percentage with AKE and SLR, Pearson correlation coefficients and associated P-values were calculated between body fat percentage and AKE and SLR values at Weeks 0, 2 and 4.

Furthermore, to assess the potential correlation of body fat percentage with AKE and SLR after adjusting for the effect of intervention, the post-intervention measurements of AKE and SLR were analysed using analysis of covariance (ANCOVA) with the respective post-test value as dependent variable, and treatment (SMR + SS [test] vs SS [control]) and body fat percentage as independent variables. From these ANCOVA, least squares estimate of the regression slope for body fat, together with the associated standard error, t-test and P-value were calculated.

3.8.3.8 Correlation of height with AKE and SLR

The potential correlation of height with AKE and SLR was evaluated in the same manner as the correlation of fat with AKE and SLR, as described in section VII. Objectives: Comparison of sport codes with respect to AKE and SLR.

3.8.3.9 Effect of intervention on rating

The effect of the intervention on the rating was assessed by a Cochran-Mantel-Haenszel chi-square test (row mean score test). The chi-square statistic (one degree of freedom) and associated P-value are reported.

3.8.3.10 Comparison of sports with regards to rating

The differences of sports with regard to the rating, adjusted for the effect of intervention, were assessed by a stratified Cochran-Mantel-Haenszel chi-square test (row mean score test), where the stratification factor is intervention. The chi-square statistic (two degrees of freedom) and associated P-value are reported.

3.9 Pilot study

A pilot study with four subjects was conducted prior to the start of the intervention, once ethical approval had been obtained. The aim of the pilot study was to identify possible errors and to ensure that the evaluation procedure as well as flexibility interventions is effective, and data recording is sufficient. This process took place in the exact manner that the interventions and evaluation occurred. The results of the pilot study were included in the main study with no problems experienced with the interpretation and completion of the intervention and evaluation process.

3.10 Implementation of the findings

This study provided valuable information to the multi-professional team. The results provided information to athletes, coaches and all individuals who aim to improve their hamstring flexibility levels within a set time with the most efficient method.

3.11 Ethical aspects

Conducting research requires responsibility, honesty, and integrity to protect the right of participants. To render the study ethical, the rights to self-determination, anonymity, confidentiality and informed consent were obtained. The study was submitted to the Health sciences Research Ethics Committee (HSREC) of the University of the Free State.

Written permission to conduct the research study was obtained from the following professional bodies:

- Ethics committee of the Faculty of Health Sciences (HSREC)
- The Department of Exercise and Sport Sciences at the University of the Free State (UFS)
- UFS Gatekeepers approval
- Director of Kovsie Sport

All data collected for this study were kept confidential and were only used for the purpose of this study. The results of this study were presented through scientific forums and publications, and the participant information will not be revealed. Participation in this study was voluntary. Participants signed an information document long with the consent form that was signed as well as received a protocol page (Appendices C, D, E, F).

As mentioned above, participating in the study was absolutely voluntary and refusal to take part did not lead to any penalty or loss of benefits the player is entitled to. Each participant had the right to withdraw from the study at any time. Informed, written consent was also obtained from all study participants. Basic elements of Informed consent as defined by the Thomas, Nelson and Silverman (2015) are:

- Fair explanation of the procedure too be followed,
- A description of the attendant discomforts and risks,
- A description of the benefits to be expected,
- An offer to answer any inquiries concerning the procedure,
- Efforts will be made to keep all personal information confidential,
- For the chance the study is published, the participants will be informed beforehand
- Freedom of consent and instructions that the participants are free to withdraw consent and discontinue participation.

It was stated that participants will not receive any financial compensation for their contribution to this study. For the chance that this study is published the participants will be informed beforehand. Every effort will be made to keep personal information confidential.

CHAPTER 4: Results

4.1 Introduction

This chapter presents the results of the study. The primary objectives of this randomized controlled trial was to compare the effect of SMR + SS (test treatment) versus SS (control) on AKE and SLR over 4 weeks. Secondary objectives were to determine the effects of the interventions over a 4-week period and to assess the effects of the interventions after 2 weeks of training, as well as to compare the effect of that of the last 2 weeks of training in high performance male athletes.

The descriptive and inferential statistics are presented in this chapter. Anthropometric data (age, height, weight, and fat percentage) of 56 participants are reported.

Subjects were randomly assigned to two groups (static stretching and self-myofascial release with static stretching). Data collected were statistically analysed to evaluate the difference in hamstring flexibility measurements in degrees between the two intervention groups. The interpretation and the discussion of the findings will follow in the next chapter.

4.2 Descriptive Statistics

4.2.1 Demographic information of participants:

4.2.1.1 Number of participants:

Sixty-two (n=62) participants met the inclusion criteria (male participants between the ages of 18–25) and consented to the study. This is an 86% response rate to the study recruitment. All participants completed the first evaluation round. Due to COVID-19 and injuries, only fifty-six (n=56) participants completed the third evaluation. Participants in three sporting codes were enrolled at the first evaluation session, namely 8 cricket players; 17 hockey players and 37 rugby players, as illustrated in Table 4.

Table 4: Number of participants by sporting codes

Enrolled Participants			**Participants who completed the trial**		
Team	Frequency	Percentage	Team	Frequency	Percentage
Cricket	8	12.9 %	Cricket	8	14.3 %
Hockey	17	27.4 %	Hockey	15	26.8 %
Rugby	37	59.7 %	Rugby	33	58.9%
Total	62	100 %	Total	56	100%

4.2.1.2 Demographics by sport

Tables 5 to 7 provide the descriptive statistics (mean, standard deviation, minimum first inter quartile range, median, third inter-quartile range and maximum) for the demographic data of each group of the study participants, namely age, height, body weight and fat percentage.

Table 5: Physical characteristics of cricket participants: Descriptive statistics (n=8)

	Age (years)	**Height (m)**	**Body mass (kg)**	**Fat percentage (%)**
Mean	21.0	1.84	87.25	12.42
SD	2.62	0.03	13.72	2.35
Minimum	19	1.8	62	8.60
Q1	19	1.82	83.75	11.49
Median	21	1.84	85.5	12.42
Q3	11	1.85	92	13.77
Maximum	25	1.88	110	16.53

Table 6: Physical characteristics of hockey participants: Descriptive statistics (n=15)

	Age (years)	**Height (m)**	**Body mass (Kg)**	**Fat percentage (%)**
Mean	19.5	1.77	72.64	10.13
SD	1.69	0.07	8.90	3.24
Minimum	18	1.63	58.6	6.40
Q1	19	1.75	68	7.88
Median	19	1.76	73	9.76
Q3	20	1.83	76.5	10.77
Maximum	25	1.85	90	18.15

Table 7: Physical characteristics of rugby participants: Descriptive statistics (n=33)

	Age (years)	Height (m)	Body mass (kg)	Fat percentage (%)
Mean	19.46	1.82	91.07	13.32
SD	0.61	0.06	13.49	5.31
Minimum	18	1.75	69	5.72
Q1	19	1.78	80.33	9.35
Median	20	1.80	89.5	12.73
Q3	20	1.87	101.65	16.30
Maximum	20	1.96	117	27.56

As shown in the tables above, cricket and hockey had the eldest participants; and cricket and rugby had the tallest participants, with rugby being the tallest between the two sports. Rugby had the highest body weight and the highest fat percentage. These data are not specific to position and role of participation in a sport team.

Table 8 provides the descriptive statistics (mean, standard deviation, minimum first inter quartile range, median, third inter-quartile range and maximum) for the demographic data of all participants, namely age, height, body weight and fat percentage.

Table 8: Physical characteristics of all participants: Descriptive statistics (n=56)

	Age (years)	Height (m)	Body mass (kg)	Fat percentage (%)
Mean	19.73	1.81	86.2	12.40
SD	1.48	0.06	14.73	4.64
Minimum	18	1.63	58.6	5.72
Q1	19	1.77	76	8.85
Median	9.73	1.80	84.1	12.40
Q3	20	1.85	97.48	11.74
Maximum	26	1.96	117	27.56

4.2.1.3 Demographics by intervention

Table 9 provides the descriptive statistics (mean, standard deviation, minimum first inter-quartile range, median, third inter-quartile range and maximum) for the demographic data of the two intervention groups, namely age, height, body weight and fat percentage.

Table 9: Descriptive statistics for SMR + SS and SS participants

		Intervention	
		SMR + SS	**SS**
Age (years)	N	28	28
	Mean	20.14	19.36
	SD	1.99	0.78
	Min	18	18
	Median	20	19
	Max	26	21
Height (m)	N	28	28
	Mean	1.80	1.81
	SD	0.06	0.06
	Min	1.63	1.65
	Median	1.80	1.82
	Max	1.91	1.96
Body Weight (kg)	N	28	28
	Mean	85.27	85.95
	SD	13.66	16.02
	Min	60	58.60
	Median	84.60	83.10
	Max	117	115
Fat Percentage (%)	N	28	28
	Mean	12.30	12.34
	SD	4.62	4.75
	Min	6.40	5.72
	Median	11.39	11.63
	Max	27.56	25.86

As shown in Table 8, there are no notable differences between the two intervention groups regarding the demographic data.

4.3 Effect of intervention

4.3.1 Descriptive statistics for AKE and SLR from Week 0 to Weeks 2 and 4

Table 10 provides the descriptive statistics (mean, standard deviation, minimum first inter quartile range, median, third inter quartile range and maximum) for AKE and SLR for the two intervention groups for weeks 0, 2 and 4.

Table 10: Descriptive statistics for AKE from Week 0 to Weeks 2 and 4

		Week 0		Week 2		Week 4	
		Intervention		Intervention		Intervention	Intervention
		SMR + SS	SS	SMR + SS	SS	SMR + SS	SS
AKE	N	31	31	28	28	28	27
	Mean	119.81	113.48	156.71	150.21	159.36	157.44
	SD	12.55	11.94	12.54	18.29	8.96	11.05
	Minimum	100	99	126	106	141	137
	Median	116	113	160	156.50	160.50	160
	Maximum	162	151	173	178	179	178

As shown in Table 11, there was an increase in the mean values from week 0 to Week 2 in the mean data, but from week 2 to week 4 the improvement decreased.

Table 11: Descriptive statistics of SLR from Week 0 to Week2 2 and 4

		Week 0		Week 2		Week 4	
		Intervention		Intervention		Intervention	Intervention
		SMR + SS	SS	SMR + SS	SS	SMR + SS	SS
SLR	N	31	31	28	28	28	27
	Mean	77.42	77.39	82.64	78.04	79.64	78.33
	SD	12.56	12.21	8.75	10.77	10.58	9.82
	Minimum	49	49	60	60	53	60
	Median	81	78	83.50	77	80	79
	Maximum	102	99	98	98	104	96

As shown in Tables 10 and 11, mean values of AKE and SLR generally increased from Week 0 to Week 2, and thereafter showed a slight increase to Week 4, with the exception that the mean SLR in SMR + SS group decreased from week 2 to week 4.

4.3.2 Effect of intervention on AKE an SLR at Week 2 and Week 4

The following section summarizes the information regarding the effect the intervention on the average peak flexibility degree for SLR and AKE over 4 weeks by means of analysis of covariance.

Table 12: Effect of intervention on AKE and SLR (Analysis of covariance)

Variable	Week	Treatment Means[1]			Mean difference[1]: Test – Control		
		SMR + SS (Test)	SS (Control		Point Estimate	95% Confidence Interval	P-value[2]
AKE	2	154.92	147.58		7.3373	-1.3189 to 15.9935	0.0947
	4	158.90	156.54		2.3637	-1.7205 to 6.4480	0.2499
SLR	2	83.7850	78.7004		5.0845	1.5603 to 8.6087	0.0057
	4	81.6199	80.4337		1.1863	-2.2713 to 4.6438	0.4931

[1]Least squares means and point estimate and 95% confidence interval of for the mean difference “Test – Control” from an analysis of covariance of post-intervention values, fitting treatment (test vs control) as factor, and the corresponding pre-intervention values, sport, height, weight and fat percentage as covariates.

[2]P-value for t-test of the null-hypothesis that the mean difference is 0 (that is, null-hypothesis of no difference between experimental and control groups), from the analysis of covariance.

As shown in Table 12, the effect of SMR + SS on both AKE and SLR after 4 weeks is somewhat higher than the effect of SS alone, although the mean differences between treatments are not statistically significant. After 2 weeks, the difference between SS versus SMR + SS is larger than after 4 weeks. The improvement noticed at week 2 for SLR is statistically significant, whereas week 4 is not significant.

4.3.3 Comparison of sport codes with respect to AKE and SLR

To compare the sports with respect to AKE and SLR, AKE and SLR at Weeks 0, 2 and 4, were summarized descriptively by sport.

Table 13: Descriptive statistics for the differences between sports

		Sport								
		Cricket			Hockey			Rugby		
		Week			Week			Week		
		0	2	4	0	2	4	0	2	4
AKE	N	9	9	9	16	14	14	37	33	33
	Mean	129.44	141.89	147.56	110.38	152.57	157.64	116.24	157.00	161.81
	SD	15.01	11.98	9.94	7.52	15.80	7.79	11.62	15.66	8.75
	Minimum	106.00	124.00	137.00	99.00	130.00	144.00	100.00	106.00	139.00
	Median	132.00	145.00	143.00	110.50	155.50	159.00	116.00	160.00	162.00
	Maximum	151.00	158.00	170.00	125.00	178.00	171.00	162.00	175.00	179.00

AKE	N	9	9	9	16	14	14	37	33	33
	Mean	63.11	70.78	72.00	76.81	79.57	80.29	81.14	83.27	80.41
	SD	13.70	6.70	9.62	11.29	9.97	10.75	9.76	9.23	9.47
	Minimum	49.00	60.00	60.00	50.00	60.00	53.00	61.00	61.00	63.00
	Median	62.0	71.00	72.00	78.50	82.50	80.50	84.00	84.00	79.50
	Maximum	89.00	83.00	87.00	92.00	92.00	96.00	98.00	98.00	104.00

Furthermore, AKE and SLR at Week 0 were compared between sports using an one-way analysis of variance (ANOVA) with AKE and SLR, respectively, as dependent variables, and sport as categorical independent variable (cricket, hockey, rugby). From these ANOVA, the least squares mean values of the dependent variables were calculated for each sport, as well as the pairwise mean differences between sports and associated 95% confidence intervals (CIs) for these differences. The associated t-tests and P-values for the mean differences are also reported.

Active knee extension and SLR at weeks 2 and 4 were compared between sports using a two-way analysis of variance (ANOVA) with AKE and SLR, respectively, as dependent variables, and intervention (test and control) and sport as categorical independent variable (cricket, hockey, rugby). As before, from these ANOVA, the least squares mean values of the dependent variables were calculated for each sport, as well as the pairwise mean differences between sports and associated 95% confidence intervals (CIs) for these differences. The associated t-tests and P-values for the mean differences are also reported.

Table 14: Comparison of sports with respect to AKE and SLR (Analysis of covariance)

Variable	**Week**	**Treatment Means[1]**					**Mean difference[1]**		
		Cricket (C)	Hockey (H)	Rugby (R)		Comparison	Point Estimate	95% Confidence Interval	P-value[2]
AKE	2	141.63	152.21	156.90		C – H C – R H – R	17.48 12.88 -4.60	-23.7931 to 2.6209 -27.1656 to -3.3926 -14.0931 to 4.7072	0.1138 0.0128 0.3211
	4	148.12	156.72	161.76		C – H C – R H – R	-8.5952 -13.6373 -5.0420	-16.4733 to -0.7172 -20.7504 to -6.5241 -10.6804 to 0.5963	0.0331 0.0003 0.0785
SLR	2	64.8750	75.1765	81.1351		C – H C – R H – R	-10.3015 -16.2601 -5.9587	-19.8729 to -0.7300 -24.9645 to -7.5558 -12.4997 to 0.5824	0.0354 0.0004 0.0734
	4	71.1250	78.9485	83.2052		C – H C – R H – R	-7.8235 -12.0802 -4.2567	-15.7377 to 0.09071 -19.2031 to -4.9573 -9.8897 to 1.3763	0.0526 0.0013 0.1355

[1]Least squares means and point estimate and 95% confidence interval of for the mean difference from a two-way analysis of covariance of post-intervention values, fitting treatment (test vs control) and sport (cricket, hockey, rugby)

as factors.

[2]P-value for t-test of the null-hypothesis that the mean difference is 0 (that is, null-hypothesis of no difference between pairs of sport in question), from the analysis of covariance.

From Table 14 it is evident that AKE and SLR are more or less the same for week 2 and week 4. Data are statistically significant for all sports, except AKE at week 2 and SLR at week 4 for cricket versus hockey and hockey versus rugby.

4.4 Secondary Objectives

4.4.1 Correlation of fat percentage with AKE and SLR

In order to assess the potential correlation of body fat percentage with AKE and SLR, Pearson correlation coefficients and associated P-values were calculated between fat percentage and AKE and SLR values at weeks 0, 2 and 4.

Table 15: Pearson correlation coefficient (P-Value) of fat percentage with AKE and SLR

Week	Statistic	AKE	SLR
0	Correlation P-value	0.21446 0.0970	-0.19710 0.1279
2	Correlation P-value	0.04084 0.7672	-0.14754 0.2824
4	Correlation P-value	-0.03233 0.8148	-0.20235 0.1384

The size of the Pearson correlation coefficients interpreted using the following categories (Rebekic et al., 2015).

- 0.00 – 0.19 is very weak
- 0.20 – 0.39 is weak
- 0.40 – 0.59 is moderate
- 0.60 – 0.79 is strong
- 0.80-1.00 is very strong

As shown in Table15, the correlation of fat percentage with AKE and SLR was either very weak or weak in all cases, and none of the correlation coefficients were statistically significant. Furthermore, the post-intervention measurement of AKE and

SLR were analysed using analysis of covariance (ANCOVA) with the respective post-test value as dependent variable, and treatment (SMR + SS[Test] vs SS [Control]) and body fat percentage as dependent variables.

From these ANCOVA least square estimates of the regression slope for body fat, together with the associated standard error, t-test and P-value were calculated, the correlation of body fat percentage and AKE and SLR.

Table 16: Estimates for AKE Weeks 2 and 4

Week	Label	Estimate	Standard error	DF	T Value	Pr > [t]
2	Slope	0.1440	0.4646	52	0.31	0.7578
4	Slope	-0.06862	0.2970	52	-0.23	0.8182

Table 17: Estimates for SLR Weeks 2 and 4

Week	Label	Estimate	Standard error	DF	T Value	Pr > [t]
2	Slope	-0.3172	0.2879	52	-1.10	0.2757
4	Slope	-0.4414	0.2960	52	-1.49	0.1420

As shown in Tables 16 and 17, body fat percentage was not significantly associated with AKE and SLR. These data as seen in the tables above are a confirmation of Table 18; all the data are weak and have no significance; yet the slopes are negative for AKE at week 2 and SLR at weeks 2 and 4.

4.4.2 Correlation of height with AKE and SLR

In order to assess the potential correlation of body height with AKE and SLR, Pearson correlation coefficients and associated P-values were calculated between body height and AKE and SLR values at weeks 0, 2 and 4.

Table 18: Pearson Correlation Coefficient (P-value) of height with AKE and SLR

Week	Statistics	AKE	SLR
0	Correlation P-value	0.20415 0.1145	-0.17763 0.1708
2	Correlation P-value	-0.29700 0.0277	-0.26791 0.0482
4	Correlation P-value	-0.36425 0.0068	-0.33119 0.0144

The size of the Pearson correlation coefficient was used to interpret the value.

As shown in Table 18, the correlation of height with AKE and SLR was either very weak or weak in all cases, and none of the correlation coefficients were statically significant.

From these ANCOVA least square estimates the regression slope for body height, together with the associated standard error, t-test and P-value were calculated.

Table 19: Estimates for AKE Weeks 2 and 4

Week	Label	Estimate	Standard error	DF	T Value	Pr > [t]
2	Slope	-73.4010	33.9396	52	-2.16	0.0352
4	Slope	-58.5788	21.4447	52	-2.73	0.0086

Table 20: Estimates for SLR Weeks 2 and 4

Week	Label	Estimate	Standard error	DF	T Value	Pr > [t]
2	Slope	-40.1718	20.9851	52	-1.91	0.0611
4	Slope	-54.6137	22.1397	52	-2.47	0.0170

As shown in Table 19 and 20, height was not significantly associated with AKE and SLR. These data as seen in the tables above are a confirmation of Table 18; all the data are weak, but statistical significance is seen for both AKE an SLR at weeks 2 and 4, yet the slopes are negative for AKE and SLR at weeks 2 and 4.

4.4.3 Effect of intervention on rating:

The effect of the intervention on the rating of the trial and the intervention was assessed by a Cochran-Mantel-Haenszel chi-square test. The Chi-square statistics and associated P-values.

Table 21: Cochran-Mantel-Haenszel Statistics

Statistic	Alternative Hypothesis	DF	Value	Prob
2	Row Mean Scores Difer	1	0.7483	0.3870

As shown in Table 21, there is no statistically significant association between the intervention and the rating.

4.4.4 Comparisons of sports with regard to rating

The association of sports with regard to the rating of the trial and the intervention, adjusted for the effect of the intervention was assessed by a stratified Cochran-Mantel-Haenszel Chi-square test, where the stratification factor is intervention. The Chi-square static and associated P-value are reported.

Table 22: Cochran-Mantel-Haenszel Statistics

Statistic	Alternative Hypothesis	DF	Value	Prob
2	Row Mean Scores Difer	2	4.5080	0.1050

As shown in Table 22, there is no statistically significant association between the sport codes and the rating.

CHAPTER 5: Discussion

5.1 Introduction

This study was designed to determine the difference between the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility. The aim was to address the following objectives: to determine the effects of the interventions over a 4-week period and to assess the effects of the interventions after 2 weeks of training, and to compare the effect of that with the last 2 weeks of training.

5.2 Descriptive outcomes

5.2.1 Demographic information of participation

5.2.1.1 Number of participants

This study started with 62 participants; 6 participants withdrew from this study due to injuries, Covid-19 and exclusion from the sporting team. Subsequently, the study finished with 56 participants. When comparing to previous research, Keys (2014), investigated 10 male participants, Mohr (2011) investigated 14 male participants, and Neto et al. (2015) investigated 48 male participants. The highest reported age in previous research was done by Nuhmani (2020), who utilized 78 male subjects. This study utilized more than Keys (2014), Mohr (2011) and Neto *et al*. (2015), but fewer than Nuhmani (2020). This finding may be explained by the exclusion criteria, the timeframe of the investigation that was spread over 4 weeks, and the utilization of high-performance athletes.

5.2.1.2 Demographics by sport

As previously mentioned, research related to hamstring flexibility regarding SMR + SS and SS is scarce. However Mohr (2011), Keys (2014), Nuhmani (2020) and Neto et al. (2015) conducted similar studies related to this research. This study investigated and reported on the demographic information of 56 participants as indicated in Tables 5 to 8, such as age, height, body weight and fat percentage, as indicated in Tables 5, 6 and 7.

Age:

This current study reports a mean age of all the participants as 19,73 ±1,48 years. The study also reports a mean age for cricket as 21 ±2,62 years, for hockey as 19,5 ±1,69 years and for rugby as 19,46 ±0,61 years. The ages of these participants are slightly lower when compared to previous research. A possible reason is the universities authorizing that high performance athletes should be younger than or equal to 25 years of age. For this study the inclusion criteria were male athletes between the ages of 18 to 25 years; therefore this data are conformant with the inclusion criteria. The youngest age reported by research was that of Keys (2014), who conducted a study on college male participants with a mean age of 22 years ± 2 years. Mohr (2011) conducted a study on university students with a mean age of 21.29 years ± 2.58 years. The study done by Neto et al. (2015) was conducted on recreationally active participants and reported a mean age of 23.8 years ± 3.5 years. The highest reported age in previous research was done by Nuhmani (2020), who conducted a study on university students with a mean age of 24.50 years ± 2.38 years and 23.10 years ± 1.69 years.

Height:

This current study reports a mean height of all participants as 1.81 ±0.06 m. The study also reports a mean height for cricket as 1.84 ±0.03 m, for hockey as 1.77 ±0.07 m, and for rugby as 1.82 ± .06 m. The heights of the participants in this study is more than those of previous research. Mohr (2011) reports a mean height of 176.62 cm ± 5.28cm, Converted to metres, the range Mohr (2011) reports is between 1.71 m and 1.81 m. Keys (2014) reports a mean height of 172.7 cm ±4 cm, converted to metres. The range Keys (2014) reports is 1.69 m and 1.77 m. Neto et al. (2015) report a mean height of 1.67 m ±0.1 m and Nuhmani (2020) reports a mean height of 168.82 cm ±8.34 cm and 169.21 cm ± 5.51 cm. Converted to metres, Nuhmani (2020) reports a range between 1.65 m to 1.77 m. Conclusions for these findings might be due to different participating groups or the background of the different participants. When comparing the different sport codes with one another, cricket and rugby display the highest height ranges and hockey the shortest height ranges. This finding might be due to the nature hockey requires of athletes, being in a constant bent-over position.

Body weight:

This current study reports a mean body weight for all participants as 86.2 ±14.73 kg, this study also reports a mean body weight for cricket as 87.25 ±13.72 kg, for hockey as 72.64 ±8.90 kg and for rugby as 91.07 ±13.49 kg. The body weight is higher than that of previous research. Mohr (2011) reports a mean weight of 73.96 kg ± 16.9 kg and Keys (2014) reports a mean weight of 76.6 kg ±11.1 kg. The lowest mean body weight reported is from Neto et al. (2015) who report a mean weight of 67.9 kg ±13.3 kg, and Nuhmani (2020) who reports a mean weight of 69.32 kg ±17.32 kg and 70.21 kg ±16.53 kg. Due to the different demands each sport code has on the athletes, rugby athletes have the highest weight range and hockey the lowest. Rugby is classified into two main groups: forwards and backs, which is further classified upon position. Characteristics differ greatly between the two groups; both of these groups have the same sport demand, but has different characteristics. Forwards has a higher characteristic demand to be physical player; therefore they should have a higher weight than backs. Backs have a higher characteristic demand to be a running player, and will therefore have a lower weight. Hockey is classified into four main groups: forward, back, link and a goalie. Forwards is mainly the attackers, back the defenders along with the goalie, and links have to be good with attacking and defending. Although everyone in the team should maintain the same fitness level, it can be said that links has to be fitter because of their responsibilities, this said their weight will be lower than the rest of the team.

Fat percentage:

This current study reports a mean body fat percentage for all participants as 12.40 ±4.64%. This study also reports a mean body fat percentage for cricket as 12.42 ±2.35%, for hockey as 10.13 ±3.24% and for rugby as 13.32 ±5.31%. The studies that were compared do not provide any fat percentage values of their participants; however for the current study, fat percentage was calculated for comparative purposes. Fat percentage follows the same pattern as that of weight, with hockey having the lowest fat percentage and rugby the highest.

When comparing the different sport codes, hockey has the lowest fat percentage. This is due to the running nature of hockey; these athletes need to be fitter than the rest.

Although rugby has the highest fat percentage, the backs need to maintain a low fat percentage because of the running demands as described above. For the forwards to stay within the physical demand of the positions a higher fat percentage along with a higher body weight is required to protect against injuries.

5.2.1.3 Demographics by intervention

Participants were randomly distributed between the two interventions group (SS and SMR + SS). In Table 8 on can interpret that age, height, body weight and fat percentage is the same between the two groups. This is an important component to guarantee that all data are consistent and that any change in flexibility outcome is evenly spread. This is important because, no significant difference exists between groups because, one group wouldn't have more variables that may influence any outcome than the other.

5.3 Effect of intervention

5.3.1 Descriptive statistics for AKE and SLR from Week 0 to Week 2 and 4

Tables 9 and 10 illustrate the demographic information alternatively for AKE and SLR. Both AKE and SLR have their own scientific ranges, which are perceived to be normal, the closer an individual's degree is to this range (AKE the range is 180 degrees (°) and for SLR the range is 90 degrees (°) the more "normal" a ROM outcome is.

Hamstring flexibility measured by AKE for SS ranged from a mean 113.48 to 157.44 degrees and for SMR + SS from a mean 119.81 to 159.36 degrees. When measured by SLR, SS ranged from a mean 77.39 to 78.33 degrees and for SMR + SS ranged from a mean 77.42 to 79.64 degrees. For, AKE there is an improvement for both SMR + SS and SS alone from week 0 to week 2, with SMR + SS improving the most. From Week 2 to Week 4 both interventions increased but not as substantial as from Week 0 to Week 2; SS improved the most from Week 0 to Week 2. For, SLR there is an average improvement from week 0 to week 2 for both SMR + SS and SS alone, with SMR + SS improving the most. From week 2 to week 4, SS improved slightly but SMR + SS decreased.

By comparing week 2 versus week 4 measured by AKE, SS improved with 7.23 degrees and SMR + SS improved with 2.65 degrees. This suggests that the improvement seen from week 0 versus week 2, SMR + SS displayed the biggest improvement, but from week 2 to week 4 SS improved the most. When comparing the intervention outcomes, week 0 versus Week 2 measured by SLR, SS improvement with 0.65 degrees and SMR + SS improved with 5.22 degrees. When comparing Week 2 versus week 4 measured by AKE, SS improved with 0.29 degrees and SMR + SS decreased with 3 degrees. This suggests that in the improvement seen from Week 0 to Week 2, SMR + SS showed the biggest improvement, but from Week 2 to Week 4, SS improved when SMR + SS decreased.

An unexpected result of this objective was that the mean values showed a steep increase from Week 0 to Week 2, but showed a slower increase from Week 2 to Week 4. This might be because a sudden change in flexibility intervention caused a steep increase in muscle physiological adaptations and properties that led to an acute increase in ROM by means of flexibility training. However, from Week 2 to Week 4, the increase became flattened almost as if a plateau were happening due to flexibility restrictions being eliminated.

As Davis et al. (2005) theorize, a static stretch facilitates the GTO that stimulates muscle stretching, while Hudgson et al. (2017) theorize that SMR induces functional ROM that stimulates more than one sensory organ. Static stretching is a time-dependent task, as concluded by Abdel-Aziem et al. (2018). From this the conclusion can be drawn that SMR + SS might show a faster increase than SS only, as seen in this study. SMR results in an immediate improvement in ROM, as concluded by Cheatham and Stull (2018). This draws the conclusion that the addition of SMR to SS might lead to an acute increase.

The purpose of this study was to compare the effects of SS alone versus SMR + SS on hamstring flexibility, therefore further analysis was done by means of examining the effect of the intervention.

5.3.2 Effect of intervention on AKE an SLR at Week 2 and Week 4

Table 11 illustrates the effect the interventions had on alternatively AKE and SLR. This table compares the least square means with the interventions at Week 4 versus the pre-value as a covariant. This is a more efficient and powerful measurement of analysing the effect the interventions have on hamstring flexibility.

When comparing Table 12 with Table 10 and 11, there is a difference of the degrees that are reported at week 2 and week 4. This is because the values that is in, is adjusted to a 95% confidence interval.

By comparing AKE at week 2 and 4, the difference between the test (SMR + SS) and the control (SS alone) is that week 2 has a higher point estimate that that of Week 2. The effect of SMR + SS after 4 weeks is somewhat higher than the effect of SS alone, although the differences between treatments are not statistically significant. By comparing SLR at week 2 and Week 4, the difference between the test and the control is that Week 2 has a higher point estimate than that of week 4, although the same tendency can be seen with SLR than that of AKE. The effect of SMR+SS after 4 weeks is somewhat higher than that of the effect of SS alone. The difference at Week 4 is not statistically significant, but the difference at week 2 is significant. This suggests that although there is an improvement with ROM over 4 weeks with both interventions, the combined treatment (SMR + SS) will grasp hamstring flexibility quicker than SS alone.

Previous research reported confirmatory and contradictory findings. For instance, Nuhmani (2020) concludes that the addition of SMR prior to SS shows no better improvement than SS alone. Agre and Agrawal (2019) conclude that the combination of SMR + SS has greater effect on hamstring flexibility than SS alone. Keys (2014) concludes that SS and SMR + SS show similar increases in hamstring ROM. Mohr (2008) concludes that the addition of SMR to SS shows the greatest gain of ROM. Foli et al. (2020) conclude that SS improves ROM, but the addition of SMR makes the changes more noteworthy and may extend it over time.

This study succeeded in showing that there is no great difference between the improvement in hamstring ROM between SS alone and SMR + SS over a 4-week period. Therefore this study supports the findings of Nuhmani (2020) and Keys (2014).

5.3.3 Comparison of sport codes with respect to AKE and SLR

Table 13 illustrates the descriptive statistics for each sport code at Week 0, 2 and 4.

In a comparison of AKE, the sport code with the biggest improvement between Week 0 and Week 2 was hockey. The sport code with the biggest improvement from Week 2 to Week 4 was cricket. The sport code with the biggest improvement from Week 0 to Week 4 was hockey. In a comparison of SLR, the sport code with the biggest improvement between Week 0 to Week 2 was cricket. The sport code with the biggest improvement between Week 2 and Week 4 was cricket. The sport code with the biggest improvement from Week 0 to Week 4 was cricket.

To measure what sport code improved the most, a comparison of these sports was done with respect to AKE and SLR as variables over a 4-week period. These measurements were then also compared to one another as seen in Table 13. For AKE Week 2, the only statistical significance was determined between cricket and hockey. For AKE Week 4, statistical significance was evident for all three sport codes, with the greatest significance level between cricket and rugby. For SLR Week 2, statistical significance for all three sport codes was evident, with the greatest significance level between cricket and rugby. For SLR Week 4, statistical significance was evident between cricket and alternatively hockey and rugby, with the greatest significance level between cricket and rugby.

Based on these findings, it is suggested that a constant difference between cricket and rugby is evident. The results shows that the physical demand shown between these two sport codes is broad and that there is different expectations from these two sport codes. Yet there is a tendency that can be seen between cricket and hockey. A second reason for the findings can be interpreted as the phase of their season each sport code is with regards to the training session they had with their coaches. Cricket and hockey were in their pre-season phase while rugby was in its in-season phase.

Previous research reported confirmatory and contradictory findings, such as reported by Bakar et al. (2020), who conclude that no significant difference was seen in rugby players when evaluating SS and SMR on flexibility. Sarika, Balajirao and Shenoy

(2019) and Cejudo et al. (2020) conclude that cricket and hockey players benefit the most from combined stretching methods.

Despite inconsistent findings, from the results of this comparison it is evident that SMR + SS and SS on its own provoke hamstring flexibility improvements, regardless of the sport types.

5.4 Secondary objectives

5.4.1 Correlation of fat percentage with AKE and SLR

Table 15 illustrates the correlation of fat percentage with the test conducted. All correlations for this comparison ranged from *very weak* to *weak*, with al p-values having no statistical significance. Tables 15 and 16 compare the least square means of the regression slope for body fat percentage with the post-test value as a dependent variable and the treatment and body fat percentage as independent variables. This is a more efficient and powerful measurement of analysing the effect that body fat percentage might have on the test outcome.

A noticeable tendency is seen between Tables 15, 16 and 17. AKE at Week 4 has a negative slope indicating a negative correlation that is not statistically significant. SLR at Week 2 and Week 4 has a negative slope, indicating a negative correlation that is not statistically significant.

This study succeeded in showing that there is no correlation between body fat percentage with the AKE and SLR, whether the fat percentage is high or low (5.72%–27.56%) this will have no influence on the outcome of hamstring flexibility. Despite inconsistent findings, Sharma and Kailashiya (2017) are of the opinion that anthropometric variables, especially body composition show a significant correlation on flexibility. This study’s findings contradict that, as fat percentage is not an indicator that hamstring flexibility depends on it. This is rather an indication on the physical demands placed on an athlete leading to flexibility variables.

5.4.2 Correlation of height with AKE and SLR

Table 18 illustrates the correlation of height with the tests conducted. All correlations for this comparison ranged from *very weak* to *weak*, with only Week 0 for both AKE and SLR having low significance levels. Both AKE and SLR at Week 2 and Week 4 have high significance levels, with Week 4 having the highest significance within Table 17. Tables 18 and 19 compare the least square means of the regression slope for height, with the post-test value as a dependent variable and the treatment and height as independent variables. This is a more efficient and powerful measurement of analysing the effect that height might have on the test outcome.

Both Tables 18 and 19 illustrate a negative slope indicating a negative correlation that is statistically significance except for SLR at Week 2. Although limited studies could be found that have investigated the possible correlation height may have on hamstring flexibility, the results of this study suggest that there is no correlation between height and hamstring flexibility outcomes. Despite inconsistent findings this study is in contrast with Sharma and Kailashiya (2017), who conclude that anthropometric variables, especially height, show a significant correlation on flexibility. An athletes height is not a indication of hamstring tightness, these two variables are not dependant on one another but, rather dependant on external factors including but not limited to physical demands from sport.

5.4.3 Effect of intervention on rating

Table 21 illustrates that there is no significance associated between the intervention and the sport rating. Therefore, the intervention has no effect on the rating, nor does the rating has an effect on the intervention. These two factors are not related in any way.

The main finding of this objective was that there is no evidence that either SS on its own or SMR + SS produces a higher rating value on the rating scale. There is also no evidence supporting that either one of the rating values is associated with SS only or SMR + SS.

5.4.4 Comparisons of sports with regard to rating

Table 22 illustrates that there is no significance associated between the sport code and the rating. Therefore, the sport code has no effect on the rating, nor does the rating have any effect on the sport code. These two factors are not related in any way.

The main finding of this objective was that no evidence was found that either cricket, hockey or rugby produces a higher rating value on the rating scale. There is also no evidence supporting that either one rating value is associated with any one of the sport codes.

Chapter 6: Conclusion and future research

6.1 Introduction

The aim of this study was to compare the effects of SS only versus SMR + SS on hamstring flexibility. This was addressed by comparing the effect of SS only versus SMR + SS over a 4-week period. In order to reduce the risk of injury re-occurrence and to improve athletic performance, it is necessary for multi-disciplinary teams (especially biokineticists) to incorporate flexibility components into their programs. Chapter 2 elaborated on all research that had previously been investigated, including the types of stretching, and the physiology and anatomy of muscles. This study selected high-performance athletes within three sport codes (cricket, hockey and rugby). Given that this study is one of the first to examine the effect if SS alone and SMR + SS on hamstring flexibility within these sport codes, and to determine the effect of these interventions over 4 weeks and 2 weeks versus 4 weeks, sports medicine personnel can benefit from this by incorporating the findings in program prescription and periodization. This chapter will elaborate on the conclusion and limitations of this study and future research avenues

6.2 Conclusion

The current study imitated studies done by Nuhmani (2020), Agre and Agrawal (2019), Neto et al. (2015), Škarabot et al. (2015) and Keys (2014) by examining the effect of SS alone and SMR + SS on hamstring flexibility. The practical implication of this study is that demographic information will differ beyond the populations and this needs to be taken into consideration when interpreting further findings.

The main aim of was to compare the effects of SS only versus SMR + SS on hamstring flexibility, based on this study:

- It is evident that there is no great difference between SS alone and SMR + SS on hamstring flexibility. In this situation both SS alone and SMR + SS improved greatly until Week 2, but the improvement slowed down to Week 4.

- Based on these results and finding, it is evident that both interventions will improve hamstring ROM, but the combined intervention will reach the acute peak ROM quicker than the single intervention.

The secondary objectives included in this study:

- Comparison of sport codes with respect to AKE and SLR, indicated that upon the three sport codes neither one of them benefits more from one intervention versus the other. The most important benefit was the incorporation of a flexibility component within their training program.
- There were no correlation of fat percentage and height with AKE and SLR, the athletes' fat percentage and height did not correlate with hamstring flexibility outcome.
- The effect of the intervention on the rating as well as the comparison between sports and the rating, when evaluating the ratings against the intervention and sport codes, the findings suggest that no effect is shown on one another.

In conclusion, practitioners, including biokineticists, physiotherapists, sport scientists and conditioning coaches will benefit by including flexibility components in their programs for optimal performance. Consequently, it does not matter which intervention from this study they choose to use; the results will be the same.

6.3 Limitations and future research

A number of limitations occurred that could be beneficial to future research planning. This study was conducted on high-performance athletes from the University of the Free State only, which limited the number of participants included for screening. Thus, the researcher could not conclude that the results are applicable to female, high-performance athletes, nor on the general population. Future studies can compare the interventions on both males and females for high-performance or recreation athletes.

The current research worked with two intervention groups, SS and SMR + SS. Future research can standardize the data by incorporating one or two additional groups, such as a control group and an SMR-only intervention group.

The current study only provided data from participants' dominant side. Future research might want to focus on investigating the differences between participants' dominant and non-dominant side. This will provide evidence and a better understanding of side dominance and flexibility outcomes.

The timeline followed within this study was 4 weeks, with a midway evaluation scheduled at Week 2. For future research, the timeline can be stretched to evaluate over a longer period what the outcome of the interventions will be, as well as measure which intervention will provide results within the shortest period. This study also reported its data within the phase of the sport to ensure no external factors influence the evaluated data. All high-performance athletes should be in the same phase of their season.

CHAPTER 7: Reflection on the research process

7.1 Introduction

This chapter provides a visible journey of the research process. The research process gives the researcher the opportunity to provide and answer a question that holds value to the scholar but might also be relevant to the field. For practitioners, research provides a pathway to valuable knowledge, thinking processes, problem solving and ultimately provides the best service to patients and athletes.

7.2 Reflection on the research process

The research process can be described by a quote of Joel Osteen,

> God will never close doors without opening new doors, that no man can shut. He will connect you to the right people and thrust you years down the road.

This is so relevant to all aspects in our life; we often feel as if 'doors' are closed in our life and this leaves us devastated and demotivated to continue until a new 'door' opens with endless possibilities that take you further on your path to success. The fact is that things do not always go as planned; sometimes we need to make changes or adapt to changing environments to achieve success.

It is most appropriate to briefly describe the build-up and phases of this research process. The build-up started with me completing my Honours degree. I felt a huge sense of relief that my studies were finished and I could start my life as a working adult. However, after searching for internship vacancies the question surfaced about why some practitioners used SS and others SMR. After various conversations with colleagues and with my supervisors about the topic and the possibility of doing my Master's degree, I seriously began to anticipate the decision of starting with my Master's degree. Yet, the reality struck of enrolling for a Master's degree with the responsibility of fulltime employment.

Finding a research question that interested myself was the deciding factor. I decided to research this question, not only to answer this question to myself, but also to those wondering about the same thing. Once the gap of the literature was acknowledged, I decided to move forward with my supervisor and co-supervisors to conduct this study. During the first six to eight months, I realized that taking back a few steps and correcting faults would ensure one could take more steps forward in the right direction. The fact that we had classes to help with the first three chapters helped immensely, not only to move forward more quickly, but to also be constantly motivated to work. After receiving constructive criticism and feedback from the internal committee of the Department of Exercise and Sport Science, the quality of the research project improved. After the Evaluation Committee meeting, it was time for the submission to the HSREC. This provided difficulties, including constant improvement on different aspects with each submission, and with the confirmation that testing on human subjects is safe and effective.

The next phase of the research process included the data collection and this started off with doors closing one after the other. This was one of the most frustrating and difficult times in the process. After the initial planning for data collection I had to change co-supervisors. The COVID-19 pandemic struck and, I was forced to wait and sit to see how this pandemic would play out. In the light of this challenge, it gave me the opportunity to self-reflect and grow. After I had received the green light, data collection could start. After I had seen what happened all over the world with this pandemic, I was motivated to finish the data collection as fast and effectively as possible before the door might close on me again. I aimed to recruit 50 participants in the light of the pandemic. I achieved this and exceeded it, for which I am very thankful. Although 62 participants had initially been recruited, only 56 completed the full data collection process. This was due to injuries, withdrawing from high-performances sport groups and the COVID-19 isolation. I could not have done this without the help of the conditioning staff, coaches and athletes being mutually motivated to help me. These staff and athletes mentioned helped with the testing, planning and implementation of all the protocols. This would have not been such a success if there had not been two-way communication between the conditioning coaches of the teams and me.

The last phase of the research process consisted of writing up all data and finishing all chapters. This was also one of the hardest times during the entire process, because, during the COVID-19 pandemic, I had a lot of time in which I was unable to do anything. Therefore, until after data collection had taken place, it was “crunch” time. Time was limited to finish all writing and the corrections that were suggested before submitting for assessment. At this stage I was so tired of doors closing and struggling through this three-year process that was supposed to be two years, I just wanted to finish this and go on with my life. Having a change in co-supervisors, I had to find the groove with writing in a style that suits my supervisor and co-supervisor. I will definitely take responsibility for any additional or new “grey hair” my supervisors have. If it had not been the continuous feedback and communication, I would not have been able to finish this study in my set time frame.

The last phase includes the final editing and submission. This was the best time during the entire process. Seeing all the hard work, long hours, tears

and laughter was worth it.

7.3 Personal remark

Starting and finishing this study was a huge reward and blessing from above. Having the chance to answer the research question I had and the information gained in the research field was an invaluable experience. Although times were sometimes difficult, I can definitely say I came out stronger on the other side.

The most rewarding sense is being able to say that I am able to help fellow practitioners with my research study and being able to help practitioners deliver the best patient or athlete-focused service.

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APPENDICES

Appendix A: Cover letter

Knights Castle Nr 2
Mikro Street
Langenhoven Park
Bloemfontein 9301

THE CHAIR: ETHICS COMMITTEE
FACULTY OF HEALTH SCIENCES
UNIVERSITY OF THE FREE STATE

Dear Dr

PROJECT TITLE: Randomised observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility.

Enclosed please find the attached research protocol for your evaluation and approval.

Yours faithfully

MVos

....
SIGNATURE OF RESEARCHER

malinevos@gmail.com

071 896 0365

Appendix B: Summary of Research Protocol

Randomized observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility.

Principal investigator:

M. Vos

Where the study will be conducted?

Bloemfontein, Free State: at the Sport Science Centre of the University of the Free State.

What population will be included in the study?

Participants will be selected from the University of the Free State's High-Performance Athletes. All participants will be male athletes between the ages of 18 and 24, volunteering to take part in this study.

What method/s will be used?

The study will focus on assessing the effects of static stretching versus foam rolling with static stretching on hamstring flexibility.

Participants will be asked to come in for an information session where they will receive information regarding the process of evaluation and all intervention verbally as well as receive a letter stating all this information. Thereafter they will complete an informed consent letter. According to specific dates and times convenient to the athletes, their baseline values will be obtained, and all interventions will commence.

What treatment will be administered to participants?

Participants will participate in group sessions, where they will perform the assigned intervention program (either static stretching or foam rolling with static stretching) three times per week for period of four weeks.

Expected outcome of the research?

Determining the best intervention between static stretching and foam rolling with static stretching to improve hamstring flexibility.

The expectation is that foam rolling with static stretching will provide the best results based on the wide variety of physiological and neurophysiological adaptations that are mentioned in provided literature.

Description of ethical issues

Ethical issues include permission from the Ethics Committee of the Faculty of Health Sciences (HSREC) of the University of the Free State; The Department of Exercise and Sport Sciences at the University of the Free State; the Vice-Rector: Academic, Director of Kovsie Sport; and the Dean of Student Affairs.

The research proposal will be submitted to the Ethics Committee for approval, and once received, the testing will begin.

Appendix C: Information Document

Randomised observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility

You are invited to take part in a research study supervised within the Department of Exercise and Sport Sciences, at the University of the Free State. In this study we would like to investigate the effect of two different stretching interventions, in which static stretching or static stretching with foam rolling will compared to determine the different effects on hamstring muscle flexibility.

This is a flexibility program and it will not be influenced by the season of your sport, nor will it have a negative impact on your sport performance during the season. This program will serve as a training session additional to what the coaching and conditioning staff has planned.

If you agree to participate in this study, it will be required of you to participate in either static stretching sessions or static stretching with foam rolling sessions 3 times a week for a period of 4 weeks. You will be required to participate in the first session for all the necessary explanations, introductions, and health screening, as well as to complete three flexibility measurements so that we can determine your improvement or lack thereof during the timeline (4 weeks, as mentioned). Each stretching session will take approximately 30 minutes and will include a brief warm-up. The introductory session, as well as the three flexibility measure sessions, will take approximately 30–45 minutes per session. The dates on which this study data sampling will commence will be communicated to you once the logistical arrangements are in place.

All the necessary documentation, which includes a health history questionnaire, informed consent form, and waiver of liability and indemnity will be discussed and completed on a separate day than that of the first measurement, which will be scheduled on another available date.

The first measurement will then be taken and the 4-week period will begin. You will not receive any benefits for your participation in this study, and you will not be financially obligated to sustain any expenses related to these intervention programmes. Participants are not at risk while participating in this study, since the intervention programmes will be carried out by a biokinetics student, under the supervision of a registered biokineticist. All screening questionnaires and measurements will be completed in a private evaluation room, and all information will be kept confidential.

The information related to these measurements will only be shared among the research team, and participant's names will be replaced with a participant number to ensure anonymity is provided. By signing this form, you declare that you understand the requirements for participating in this research study, the process you are voluntarily complying to become involved with, and that all questions have been answered to your satisfaction. Should you have any questions in the future, it will also be addressed when raised. Participants are free to withdraw from this study at any time.

____________________________ ________________________________

Signature (Participants) Date

____

Madeline Vos (Researcher)

Appendix D: Informed Consent

Randomised observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility

The goal of this study is to determine which interventions promote hamstring flexibility the most, when comparing static stretching, and static stretching with foam rolling intervention programmes performed in four weeks.

The Master's degree study will be of no benefit to the participant, but will provide quality information to the Department of Exercise and Sport Sciences, biokineticists, physiotherapists, athletics trainers and athletes of various sport codes.

Participation in this study is voluntary and individuals who refuse to participate in the study will not be penalized in any way. The participants may also decide to discontinue their participation in the study at any time.

Measurements that will be completed during each scheduled evaluation (three separate sessions):

1. An active knee extension test will be performed to test the flexibility of the hamstring muscle group before the start of the interventions.
2. A straight-leg raise test will be performed to test the flexibility of the hamstring muscle group before the start of the intervention.
3. The same flexibility tests will be performed after 2 weeks of intervention and again after 4 weeks of intervention upon completing the interventions.

The participants will receive a flexibility program that consist of a warm-up and the stretching session. This program will be required to be completed 3 times per week under the guidance of a biokinetics student and will last approximately 30 minutes.

The results of the research study will be used for possible publications in health journals related to the research study.

I, the undersigned have read the information above. The nature, demands and benefits of the research study have been explained to me. I understand that I may withdraw my consent and discontinue my participation in this study. By signing this consent form, I am not waiving any legal claims, rights or remedies.

I, ____ (full name and surname), hereby provide my consent to participate, in this study, including completing the required health screening forms and allowing the above-mentioned measurements to be taken.

______________________________ ______________________________

Signature (Participant) Date

I hereby confirm that I have explained the nature, purpose, and potential benefits of participating in this study to the above-mentioned individual and that I have answered any questions that had been raised.

______________________________ ______________________________

Signature (Researcher) Date

UFS·UV

Appendix E: Evaluation form

Name and Surname: ______________________________

Age: _________

Weight: _________________

Height: _________________

Dominant side: ________________________

Intervention: ____

Sport: _______________________________

Anthropometry(R):

Tricep	
Sub-scapular	
Supra-iliac	
Abdominal	
Front thigh	
Medial Calf	

Evaluation values:

Week	Value: Active knee extension	Value: Straight leg raise
0		
2		
4		

How do you rate these sessions and interventions?

0	1	2	3	4	5
No value at all	No to little value	Little to moderate value	Moderate value	Moderate to high value	High of value

Appendix F: Static stretching protocol

Participants will start off with a 5-minute warm-up in the form of cycling on the Watt bike, at a light intensity, at 30–40% of their resting heart rate.

After the warm-up, participants will be going to an evaluation room where they will be supervised and escorted by a biokineticist. The equipment they will use is a black theraband.

Participants will be in a supine position, laying down on a padded table. Place the theraband over your right leg so that the band is on the plantaris muscle, keeping the other end of the band in your hand. Your will now be strapped down over your left leg and over their ASIS.

For the stretch keep your right leg straight, pulling your leg upward until a stretch can be felt in the hamstring muscle. It is important to keep your leg straight and the right foot should be relaxed. Once a stretch can be felt, keep it in that position for 1 minute. After the 1 minute, relax the leg for 30 seconds. This process will be repeated 3 times. This method is described by Mohr et al. (2014).

Once you are done with the 3 repetitions, the biokineticist will unstrap the belt from the assigned areas on your left leg and ASIS.

This protocol will be done 3 times a week for a total period of 4 weeks.

Appendix G: Self-myofascial Release Protocol

Participants will start off with a 5-minute warm-up in the form of cycling on the Watt bike, at a light intensity, 30–40% of their resting heart rate.

After the warm-up participants will go to an evaluation room where they will be supervised and escorted by a biokineticist. The equipment they will use is a foam roller.

Participants will place the foam roller under their right thigh, rolling it from their ischial tuberosity to the popliteal area, while the leg is maintained in an extended position, keeping their ankles relaxed and orientated upwards. From this position participants will be instructed to maintain their body weight on the thigh with their arms extended and help maintain the pressure over their hamstring muscle.

Subjects then actively move their body over the foam roller. Self-myofascial release will be continuing for 1 minute (rolling 10 seconds back and forth) with a 30-second rest between sets. This will be repeated for 3 sets.

This protocol will be done 3 times a week for a total period of 4 weeks.

Appendix H: Permission to Submit

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

School for Health and Rehabilitation Sciences (SHRS)
PO Box 339, Bloemfontein 9300, /Republic of South Africa

Prof. Derik Coetzee
Head of Department
Department of Exercise and Sports Sciences
University of the Free State
Tel: +27 (0)51 401 2944
Fax : +27 (0)51 401 9878
E-mail: coetzeef@ufs.ac.za
Web: www.ufs.ac.za/HMS

26 November 2021

TO WHOM IT MAY CONCERN

Masters (Madeline Vos 2014045088)

Herewith, the Study leader Prof FF Coetzee, confirms that the candidate has satisfactorily completed the requirements to submit her dissertation for submission to examiners for awarding the degree Magister Artium (Human Movement Science).

Prof FF Coetzee (DPhil, MPA)
Study Leader

Appendix I: Ethical approval

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

Health Sciences Research Ethics Committee

23-Aug-2021

Dear Miss Madeline Vos

Ethics Number: UFS-HSD2020/0101/2508-0001

Ethics Clearance: **Randomised observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring flexibility.**

Principal Investigator: Miss Madeline Vos

Department: Exercise and Sport Sciences Department (Bloemfontein Campus)

Submission Page

SUBSEQUENT SUBMISSION APPROVED

With reference to your recent submission for ethical clearance from the Health Sciences Research Ethics Committee. I am pleased to inform you on behalf of the HSREC that you have been granted ethical clearance for your request as stipulated below:

Continuation Report: The project's ethics clearance is extended until 22 AUgust 2022.

The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; International Council for Harmonisation (ICH) Harmonised Guideline, Integrated Addendum to ICH E6(R1), Guideline for Good Clinical Practice (GCP) E6(R2), 2016, SAHPRA Guidelines as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

For any questions or concerns, please feel free to contact HSREC Administration: 051-4017794/5 or email EthicsFHS@ufs.ac.za.

Thank you for submitting this request for ethical clearance and we wish you continued success with your research.

Yours Sincerely

Prof. A Sherriff
Chairperson : Health Sciences Research Ethics Committee

Health Sciences Research Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | E: ethicsfhs@ufs.ac.za
IRB 00011992; REC 230408-011; IORG 0010096; FWA 00027947
Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa
www.ufs.ac.za

Appendix J: Evaluation Committee Report

03 September 2019

Chair of the Research Committee
School for Allied Health Professions
Faculty of Health Sciences
University of the Free State

Dear Prof Walsh

Recommendation: Evaluation Committee:

Madeline Vos
Student nr: 2014045088
MA (Human Movement Science): Full Dissertation
Title:
Differences between static stretching and static stretching with self-myofascial release on hamstring range of motion.

Supervisor: Prof FF Coetzee
Co-supervisor: Me C Francisco (UFS)

It is hereby proposed that the following persons serve on the evaluation committee of the above candidate:

Chair:
Prof Corlia Janse van Vuuren (JanseVanVuurenEC@ufs.ac.za; x2837)
External expert: Department Physiotherapy:
Mrs. Cherezane Marais (MaraisC2@ufs.ac.za)
Internal Expert (Department Exercise and Sport Sciences):
Dr Marlene Opperman (Oppermm@ufs.ac.za; x 2289)
Biostatistitian:
Prof R Schall (SchallR@ufs.ac.za; 2945)
Representative from SA Defence Force: Masters : Topic on Flexibility: Exercise and Sport Science Centre
Me L Deacon (Lizl Deacon lizljvr1985@gmail.com : 3395)

Kind regards
Derik Coetzee

SCHOOL FOR ALLIED HEALTH PROFESSIONS

SKOOL VIR AANVULLENDE GESONDHEIDSBEROEPE

VERSLAG EVALUASIEKOMITEE

REPORT EVALUATION COMMITTEE - RESEARCH

DISSERTATION/VERHANDELING: **Master/Magister** X **Ph.D.**

CANDIDATE/KANDIDAAT: M Vos

DATUM/DATE: 22/11/2019

TITLE/TITEL: Differences between static stretching and static stretching with self-myofascial release on hamstring range of motion.

MEMBERS OF THE COMMITTEE/

LEDE VAN DIE KOMITEE

Chairman/Voorsitter: C Janse van Vuuren

Lid van die Dagbestuur:

Member of Executive Committee:

Expert/Kundige: C Marais (Physiotherapy)

Expert/Kundige: M Opperman (Exercise & Sport Sciences)

Expert/Kundige: L Deacon (SADF)

Biostatistician/Biostatistiek: R Schall

Studyleader/Studieleier: FF Coetzee

Co Study Leader/Mede-Studieleier: C Fransisco

PROCEDURE/PROSEDURE

1. Word of Welcome/Verwelkoming

All members welcomed, in particular the student and her supervisors.

2. Agreement on handling of session/

Ooreenkoms oor die hantering van die sessie

Committee agreed to first handle general comments (if any), then handle the protocol page-by-page for corrections/suggestions/questions and lastly, return to the title.

2.1 Candidate has been informed of the procedure/

Kandidaat is ingelig oor die prosedure

Yes

2.2 Committee Members has been informed of the procedure/

Komitee is ingelig oor die prosedure

Yes

3. Presentation – if applicable/

Voordrag – indien toepaslik

n/a

4. Summary of the most important recommendations on the protocol:/

Opsomming van die belangrikste aanbevelings ten opsigte van die protokol

4.1 Introduction

Only minor corrections suggested, including grammatical and/or technical editing.

4.2 Literature Review

Only minor corrections suggested, including grammatical and/or technical editing.

4.3 Problem Statement, Aim, Objectives

The problem statement, aims and objectives section has been reduced by the committee, with a number of paragraphs moved to either "concept clarification" or the "introduction".

The candidate was also requested to ensure that, when referring to other studies, she needs to be very clear in her descriptions of those studies … *For instance Mohr only used is as warm-up and not as part of his stretching protocol; Keys used it in isolation and not combined with SS; Couture also only used it in isolation; Miller & Rockey only used in isolation = so it has been indicated that it does not work in isolation, but the promising results Mohr found made you hypothesise that in combination with SS it could have a positive effect. He, however, did not test it in that specific scenario and that is why you want to do this study. You want to combine it with SS, because Mohr found that SS still remains the most commonly used method.*

Third research objective removed, as it was similar than the first objective.

4.5 Methodology/Metode

Inclusion criteria slightly adapted and the exclusion criteria removed, as all aspects will be addressed through the inclusion criteria.

Student requested to include much more detail on the study (data collection) procedure, e.g. *Will this be done daily for 4 weeks? Who will supervise? Who will measure? Will there current "normal" sporting activities be noted? Will it be on the same time of day with each intervention? Will it be before/after their "normal" exercise protocols?*

4.6 Pilotstudy/Loodstudie

No comments, clear.

4.7 Data collection and analysis/Data insameling en verwerking

See comments above under Methodology.

4.8 Reliability/Validity/ Betroubaarheid/Geldigheid

Not included, should be included with the assistance of the biostatistician.

4.9 Ethics/Etiek

No comments, clear.

4.10 Time Schedule/Tydskedule

Slight changes needed.

4.11 References/Verwysings

No comments, clear.

4.12 Budget/Begroting

Changes needed.

4.13 Appendixes/Bylaes

No comments, clear.

4.14 Language & technical editing/Taal & Tegniese versorging

Only minor language and technical editing suggested.

5. Discussion of the protocol with reference to:/

Bespreking van die protokol deur die komitee, ten opsigte van:

- **Feasibility of the study?/Uitvoerbaarheid van die studie?** ✓

- **Adhere the study to the level discriptors (NQF) of a Masters/Doctoral degree?** ✓

  Voldoen die studie aan die vlakvereistes (NKF) van die Magister of Ph.D van die graad?

- **Sal die kandidat opgewasse wees om die studie te voltooi?/ Will the candidate be able to complete the study?** ✓

  If not - reasons?/Indien nie - redes?

n/a

- **Is the title correct?/Is die titel korrek?** No
- **If no – recommend new title/ Indien nie – voorgestelde tiel**

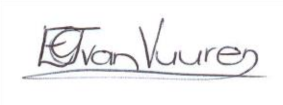
Randomised observer-blind controlled clinical trial of the effect of static stretching versus static stretching with self-myofascial release on hamstring range of motion.

6. RECOMMENDATIONS/AANBEVELINGS

Changes to be made in cooperation with the study leaders.

7. FINAL DECISION/ FINALE BESLUIT **DATE/DATUM:** 22/11/2019

Approved, with suggested changes to be made in cooperation with the study leaders.



CHAIRMAN/VOORSITTER

EVALUATION COMMITTEE/EVALUASIEKOMITEE

c:\evaluasiekommitee verslagvorm blanko.doc

Appendix K: Turn it in Report

MVos Dissertation

ORIGINALITY REPORT

18%	16%	4%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	thekeep.eiu.edu Internet Source	5%
2	scholar.ufs.ac.za Internet Source	3%
3	Submitted to University of the Free State Student Paper	1%
4	scholar.ufs.ac.za:8080 Internet Source	1%
5	shareok.org Internet Source	1%
6	Scholar.ufs.ac.za Internet Source	<1%
7	hdl.handle.net Internet Source	<1%
8	Submitted to University of Colorado, Denver Student Paper	<1%
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