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THE EFFECTS OF STATIC STRETCHING OF THE HAMSTRING  
MUSCLES IN A WARM-UP ON PERFORMANCE AMONG  
FOOTBALL PLAYERS: A SYSTEMATIC LIVERATURE REVIEW

Degree Programme in Physiotherapy

2016

# THE EFFECTS OF STATIC STRETCHING OF THE HAMSTRING MUSCLES IN A WARM-UP ON PERFORMANCE AMONG FOOTBALL PLAYERS: A SYSTEMATIC LIVERATURE REVIEW

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March 2016  
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Number of pages: 40  
Appendices: 1

Keywords: STATIC STRETCHING, HAMSTRINGS, WARM-UP, FOOTBALL, PERFORMANCE.

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The purpose of this thesis was to research the most recent evidence surrounding the effects of static stretching among football players on the hamstring muscles, and how it affects their performance. The research for this thesis was carried out in the form of a systematic literature review. The content of the thesis looks at the importance of a warm-up including the different types, the demands of football, the anatomy of the hamstring muscles, and the differing types of stretching.

The search for free full access articles was made using three different online databases; Science Direct, EBSCO, and PubMed, and aimed to find the most recent articles since 2010. Five relevant studies were found and approved using the PEDro scale.

Static stretching was found not to impair performance, although dynamic stretching showed significantly better results in explosive performance activities which included counter movement jump performance (CMJ), sprinting, and standing long-jump. It should be recognised that only five studies made this review, and further study is required to determine the impact static stretching has on the performance of footballers. Duration of static stretching should also be recognised, as only one of the five studies included a protocol where static stretching was held for a period of 30 seconds in comparison to the other protocol times of 20 seconds and 10 seconds.

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## 1 INTRODUCTION

Warming-up for a sport or activity is a universally accepted method. There are many reasons as to why a warm-up should be performed, as it helps the athlete prepare for their sport both mentally and physically. (Young and Behm, 2002).

Within football (soccer), it is important to warm-up the muscles that are to be used before a match or training session. Football is a demanding and high intensity sport and therefore there is a substantial risk of injury. A thorough warm-up should include exercises not only to optimise performance, but also prevent injury. (Website of Sports Scientists, 2010).

The precise protocol for a warm-up varies through different authors and is difficult to clarify. It is widely accepted that a warm-up should include movements that are sport specific to prepare the body for the tasks required in the following activity, as well as stretching (Website of PhysioAdvisor, 2016) of which there are various types such as proprioceptive neuromuscular function (PNF), dynamic and static (Young and Behm, 2002). The aims of stretching are usually to increase joint mobility, muscle length and flexibility, and to also try and relax muscles (Ylinen, 2008, 3).

The use of passive, or static stretching remains popular within a warm-up routine. Although passive stretching of the muscles has been found to have an acute increase in range of motion, research suggests this type of stretching reduces performance where power is required. (Young & Behm, 2002). Based on this perception, it is difficult to clarify the requirement of static stretching in football, as the requirements demand the physical attributes of a marathon runner and sprinter (Hawkins, 2004, 33).

## 2 FOOTBALL AS A SPORT

Football is the most popular sport in the world (Website of Biggest Global Sports, 2015). With an estimated population of 54.3 million people in England (Office for National Statistics: Overview of the UK Population, 2015), football is part of the weekly routine for over 1.9 million people (Website of Sport England: Who Plays Sport, By Sport, 2015).

As a sport, football has high levels of physical demand which comprises of multiple sprints, changes in direction, jumping, and interactions with the ball. The average distance covered can range from 10-15km per match (Website of Sports Scientists, 2010). According to Hawkins (2004, 33) the physiological demands of football are different to many other sports as players need the attributes of both a sprinter and marathon runner. Bangsbo (2003, 58) found from a study of a Danish professional footballer during a match, that they covered 12.1km, 11km of which was walking to moderate intensity running and the remaining 1.1km accounted for high intensity running and sprinting.

It should be noted that due to high complexity of demands in football, it is more difficult in the design of training programmes. The coaches must therefore have a thorough understanding of how to make the training most efficient for the players, incorporating the different demands into the training programme (Reilly, 2007, xi).

## 3 HAMSTRINGS

### 3.1 Anatomy of the hamstrings

The hamstrings are made up of three muscles, biceps femoris (long and short head), semitendinosus and semimembranosus, and are located at the posterior region of the thigh as seen in Figure 1. They are the main muscles responsible for hip extension and

knee flexion, which are essential movements required for daily life. (Tortora, 2009, 399).

The sciatic nerve originates in the sacral plexus (L4-S3) and runs through the hamstrings to the popliteal fossa, at the back of the knee joint, where it splits into the tibial nerve and fibular nerve. (Grant 2013, 363).



Figure 1. Hamstring Muscle Anatomy

(Website of the American Academy of Orthopaedic Surgeons, 2009)

Figure 1 shows the biceps femoris' long head originating from the ischial tuberosity and inserting into the head of the fibula and lateral condyle of the tibia. Both the semitendinosus and semimembranosus originate from the ischial tuberosity and attach to the medial side of the tibia. The biceps femoris short head which is not shown, originates from the roughened surface on the posterior part of the femur known as the linea aspera, and attaches to the head of the fibula and lateral condyle of the tibia. (Grant 2013, 395).

The hamstrings span across two joints, the hip and the knee, and are responsible for extending the hip and flexing the knee. The hip joint is a ball and socket joint. The head of the femur being the ball, and the acetabulum (the concave surface of the pelvis) being the socket. The hip joint allows various movements including flexion, extension,

abduction, adduction, circumduction, internal rotation and external rotation. (Tortora 2009, 288).

Tortora (2009, 290) states that the knee is the largest and most complex joint in the body. It is a hinge joint, made up of three joints in a single cavity; the medial tibiofemoral joint, lateral tibiofemoral joint, and patellofemoral joint. Movements allowed at the knee joint include flexion and extension, as well as slight internal and external rotations when the knee is in the flexed position. The femur and tibia meet to form the knee joint. Where they meet, their ends are covered in cartilage which allows them to move freely and without friction. (Website of Central and North West London NHS, 2011).

### 3.2 Muscle Composition

There are three types of muscle tissue; skeletal, smooth, and cardiac. Skeletal muscle is so called as it moves the bones of the skeleton. It is this muscle type which provides voluntary movement. (Tortora & Grabowski, 2000, p.302). The primary function of skeletal muscle is producing movement through contraction and relaxation in a coordinated manner (Jarmey, 2008).

Muscles vary both in size and shape, although they all share the same basic structure. At the highest level, muscle is composed of many strands of tissue called fascicles. Each fascicle is composed of fasciculi (bundles of intrafusal and extrafusal muscle fibers). These muscle fibers are composed of tens of thousands of myofibrils. The myofibrils are responsible for the muscle being able to contract, relax, and elongate as they contain millions of sarcomeres. Each sarcomere is made of overlapping thick and thin filaments called myofilaments. (Website of Bath University, 1994). These thick and thin myofilaments are composed of the proteins actin and myosin as seen in Figure 2 (Website of Yoga Evolution, 2014).

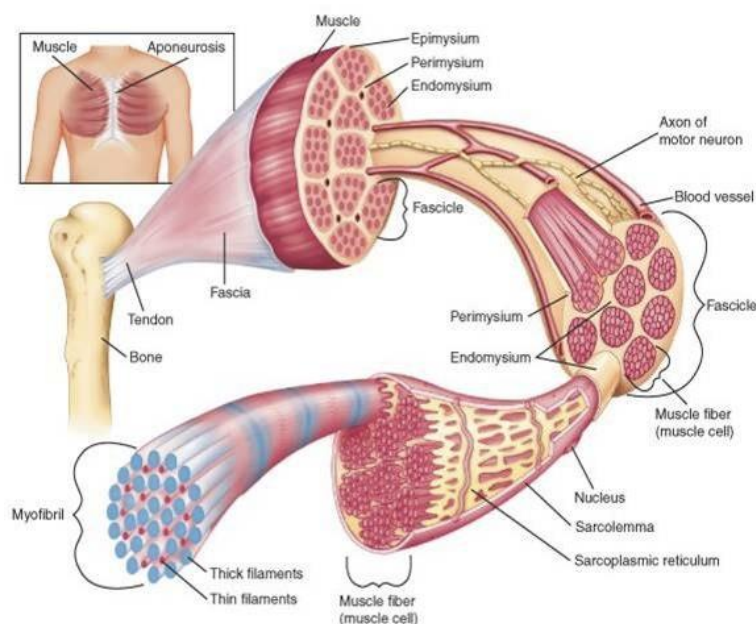


Figure 2. “What happens when we stretch?”

(Website of Yoga Evolution, 2014)

As seen in Figure 2, a skeletal muscle is covered by fascia. Fascia is a broad sheet of irregular connective tissue which lines the body wall and supports and surrounds the muscles and organs. Fascia allows the free movement of muscles, whilst also carrying nerves, blood vessels and lymphatic vessels. Fascia also fills spaces in between different muscles. There are three layers of connective tissue that extend from the fascia in helping protect and strengthen skeletal muscle. The outermost layer is the epimysium, which covers the entire muscle. The next layer from the epimysium is the perimysium which surrounds bundles of muscle fibers. The innermost layer is the endomysium. The endomysium separates individual muscle fibers from one another. All three layers are continuous with the connective tissue that attaches the skeletal muscle to different structures (Tortora, 2009, 303).

### 3.3 Hamstring function in football

As previously mentioned, the hamstrings are required for both knee flexion and hip extension which are vital movements in football. The hamstrings are required to endure these movements at high speeds and forces, and at extreme ranges of motion. It

should be noted that lengthening the hamstrings through stretching, without having the strength, increases the risk of injury. (Jarvis, 2015, p.67.)

### 3.4 Hamstring Injury

According to a study by Woods et al (2004) which surveyed two competitive seasons of 91 professional English football clubs, 12% of all injuries were hamstring related. 94% of these hamstring injuries were hamstring strains. The study also found that the hamstrings are 2.5 times more likely to be injured compared to the quadriceps.

Figure 5 shows the reason for injury. It can be seen that almost 20% of non-contact injuries to the hamstrings are caused by stretching. This study does not determine the type of stretching that caused injury, however it does show that if stretching is not performed correctly, it causes almost 1 out of 5 hamstring injuries.

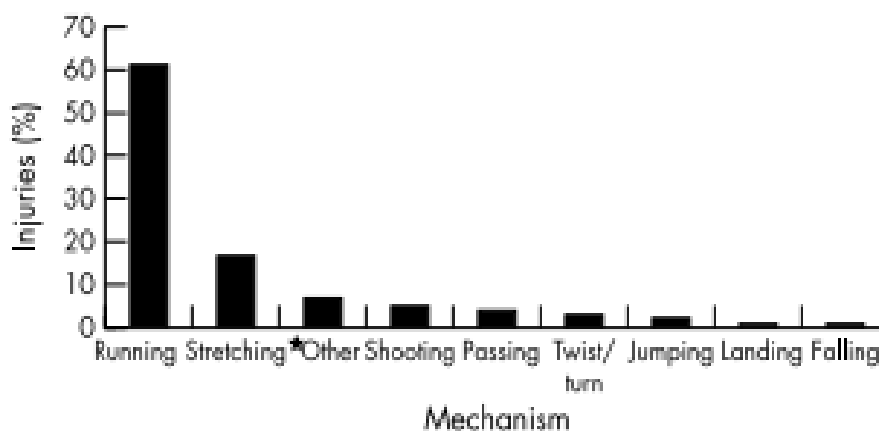


Figure 5. Mechanism of non-contact hamstring strains.

(Journal of Sports Medicine Online, 2004)

## 4 STRETCHING

### 4.1 Definition of stretching

Stretching can be simply defined as the action of elongating or dilating something, specifically a muscle (Morán and Arechabala, 2012, 11). The human body contains about 700 individual muscles, most of which are made up of both skeletal muscle tissue and connective tissue (Tortora, 2013, 337). These muscles are designed to create movement within the joints (Berg, 2011, 2). The agonist muscle is the prime mover, and the antagonist is the opposing muscle that is stretched, resisting the movement. An example of this is flexing the knee. In this particular movement the hamstrings are the primary flexors of the knee and they contract and shorten as the knee is flexed as the agonist, whilst the quadriceps are stretched and elongate, resisting the pull of the hamstrings and work as the antagonist (Figure 6).

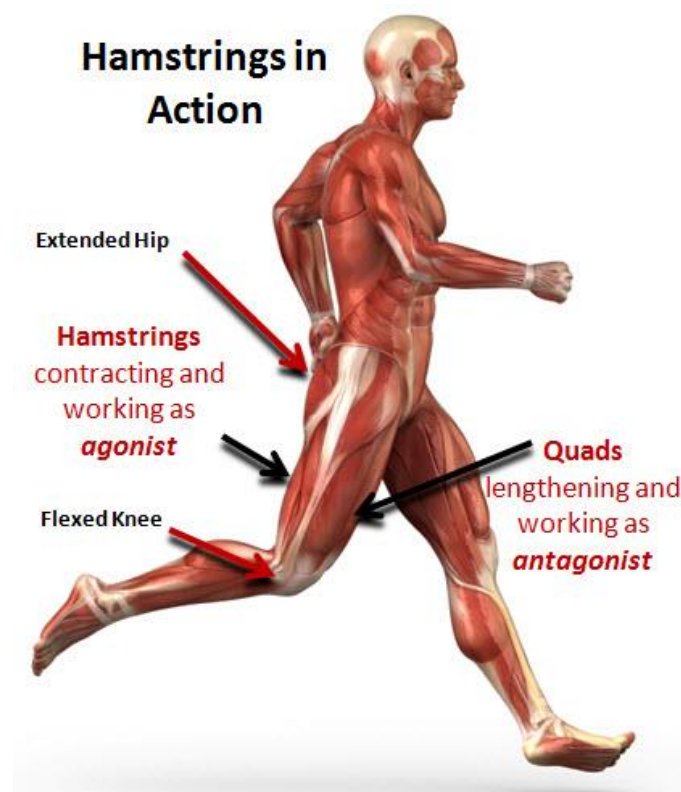


Figure 6. Hamstrings in Action  
(Website of Core Walking, 2013)

Skeletal muscle contains two types of sensory units known as muscle spindles (intra-fusal muscle fibers) and Golgi tendon organs that are sensitive in the detection and response of when a muscle is stretched (Gibbons 2013, 23). Stretching starts with the sarcomere elongating and therefore reducing the overlap of thick and thin myofilaments which allows the muscle fiber to fully lengthen. Once all the muscle fibers are fully lengthened, additional stretching takes place within the connective tissue as the collagen fibers align themselves in the same direction as the tension direction of the stretch. (Website of Bath University, 1994).

Stretching is commonly used in sport as a method of preparing the specific muscles to be used during the activity, as well as relaxing the muscles following exercise (Anderson and Anderson, 2010)

People stretch for various reasons. The most common aims of stretching are to increase range of motion and to minimise muscle soreness following exercise (Walker, 2011). According to Craig Smith (2015), who works as a physiotherapist at Nottinghamshire County Cricket Club, stretching should be an essential part of everyone's training regime as it helps make an athlete more supple and flexible, whilst it also increases blood flow to the muscles and helps to prevent injury (BBC Sport Website, The Secrets of Stretching, 2015).

Berg (2011, 9) identifies four main principles on stretching safely and effectively, which are; to avoid pain, to stretch slowly, to ensure the correct muscle is being stretched, and to avoid affecting other muscles and joints whilst stretching.

#### 4.2 The stretch reflex

The stretch reflex is also known as the myotatic reflex and occurs in a muscle due to an unexpected increase of that muscle's length. When a certain muscle is stretched, the sensory receptors in the muscle known as muscle spindles notice the change in length. The spindles generate a sensory nerve impulse which is sent into the spinal cord where it activates a motor neuron. The motor neuron is sent back to the muscle which is being stretched, and contracts the muscle, which in turn relieves the stretch

and tries to minimise the increase in its length (Tortora and Grabowski 2000, p.420-421).<sup>7</sup>

Alter (1998) explains that a classic example of the stretch reflex is the patella reflex. When the patella tendon is tapped, the muscle spindles are stretched and change their shape, which causes them to react and send a message to the spinal cord. The spinal cord sends an impulse to the quadriceps which makes them contract. When the quadriceps contract, they shorten, and this takes the tension of the muscle spindles.

In static stretching, the muscles are stretched slowly. This means the stretch reflex is smaller (McGinnis, 2013, 305) and sometimes not even stimulated (Baechle & Earle, 2008, 300). In comparison, during ballistic stretching - which involves a bouncing motion at the end of the stretch, the stretch reflex is larger, and therefore the risk of injury is greater as it does not allow the muscle to relax. (Baechle & Earle, 2008, 300).

#### 4.3 Golgi Tendon Organ

Skeletal muscle contains sensory units called muscle spindles and Golgi tendon organs which respond to the change of a muscles length. The Golgi tendon organs are located in the muscle-tendon junctions in the body, which are activated when a muscle contracts, and can respond to the contraction of just a single muscle fiber. Their function is to prevent injury by inhibiting the contracting muscle, and exciting the antagonist. (Gibbons, 2013, 23).

In passive and static stretching, Golgi tendon organs are only slightly affected, and primarily sense muscle tension during active contraction. Golgi tendon organs have a high level of tolerance to being irritated which is why they primarily sense tension within the muscle during active contraction. (Ylinen, 2008, 40)

#### 4.4 Types of stretching

There are many different types of stretching, some of which are arguably similar. Although there is no official list of classified stretches, it is generally accepted that the

most common types are; dynamic, static, proprioceptive neuromuscular function (PNF), and ballistic (Ylinen, 2008, 46-48 & Morán and Arechabala, 2012, 13-14).

Norris (2007, 57) claims the three main categories in which these stretching types fall under, are; static, dynamic, and PNF. These three types of stretching can be further categorised as seen in Figure 7.

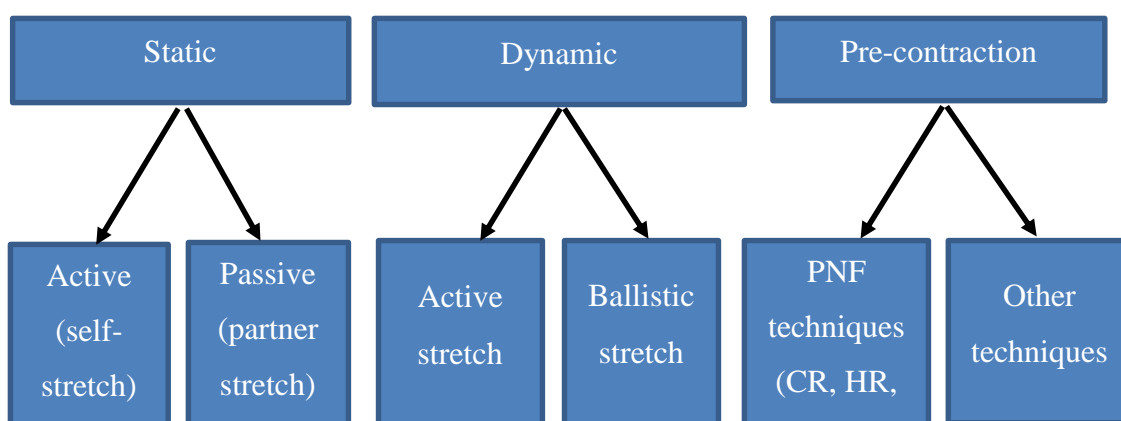


Figure 7. Techniques of Muscle Stretching

(International Journal of Sports Physical Therapy, 2012)

#### 4.4.1 Static stretching

A static stretch is, as it sounds, moving a joint to its maximum position with the tension of the surrounding muscles resisting. Static stretches are where a joint is moved to a position in which there is considerable resistance. This position is held for a range of seconds until the feeling of tension fades, and it is then released from the stretching position. (Ylinen, 2008, 48).

It is argued that static stretching can also be referred to as passive stretching (Moran and Arechabala, 2012, 13). However, Ylinen (2008, 48) states that a passive stretch is one type of static stretching that requires an external force to be applied, whether it be from a person or machine.

There are varying arguments into how long a static stretch should be held for, as well as how many times it should be repeated, with Moran & Arechabala (2012, 13) advising that a static stretch should be held in position for approximately 20 seconds, whereas Norris (2007, 57) recommends anything up to 30 seconds. Depending on when the stretch is performed, this can have an implication on how long to hold the stretch. If it is part of the cool-down, it is argued that after running, a static stretch should be held for 8-12 seconds to allow the muscle fibres to realign, in comparison to 30 seconds if it is part of a flexibility programme (Run Britain Website, 2014). Whereas in a warm-up, a static stretch could be held for 20 seconds (FourFourTwo Performance Website, 2015).

#### 4.4.2 Dynamic stretching

Dynamic stretching involves moving a muscle in a controlled motion to its maximum point (Moran and Arechabala, 2012, 14). It is quite literally, stretching with movement (Norris, 2007, 58). Dynamic stretching is considered to be an important part of a sport-specific warm-up. Baechle & Earle (2008) argue that an 8-12 minute period of the warm-up should be spent performing dynamic stretches which are focused on movements that work through the range of motion applicable to the sport.

Although ballistic stretching is categorised as a form of dynamic stretch in Figure 7, it is a type of stretching that is usually seen as causing greater trauma to the tissues as they stretch, as well as greater residual muscle soreness due to the high-speed and intensity they are performed at. (Kisner and Colby, 2012, 89). Madden et al (2010, 135) states how the sports medicine community generally share the opinion that ballistic stretching is dangerous. Blahnik (2011, 4) explains how dynamic stretching involves controlled and smooth movements, whereas ballistic stretching is uncontrolled and erratic, and therefore should not be confused with each other.

Both static and dynamic movements are commonly used in football, and Norris (2013) highlights the differences between these movements in Table 1.

Table 1. Differences between static and dynamic stretching (Norris, 2013).

<b>Static</b>	<b>Dynamic</b>
- Isolates body part	- Uses several body parts simultaneously
- Able to focus on single structure	- Can be used to match functional movement
- Slow and controlled	- Faster action
- Uses single fitness component	- Uses several fitness components
- Starting position usually fully supported	- Movement rehearsal
- Little skill required	- Skill and timing used

#### 4.4.3 Pre-contraction stretching

Page (2012) states that pre-contraction stretching involves contracting the muscle that is being stretched. The most common type of pre-contraction stretching is proprioceptive neuromuscular facilitation stretching (PNF) of which there are several types. Kisner and Colby (2012, 93) state that PNF stretching involves both passive and active movements and can be divided into three main different types; hold-relax (HR), agonist contraction (AC), and hold-relax with agonist contraction (HR-AC). The resistance that is applied in the PNF techniques can be provided either by another person or then with a band or strap (Page, 2012). Numerous studies have shown that PNF techniques improve both range of motion and flexibility (Kisner and Colby, 2012, 93).

## 5 WARM-UP

### 5.1 Definition of a warm-up

A warm-up is usually designed to be specific to the activity that follows. An ideal warm-up should incorporate the muscle groups and movements that are required during the following activity (Australian Sports Commission, 2010).

According to the Australian Sports Commission (2010), a warm-up should aim to prepare the body and mind for the activity, increase the core temperature of the body, as well as increase the heart and breathing rate. They also recommend that 5-10 minutes is enough.

In elite level sport, a warm-up must be thorough, ensuring the athlete is fully prepared for the activity to follow. Dr Richard Hawkins (2004, 102-103) states that the recommended time for a warm-up is between 15-20 minutes, although at elite level a warm-up usually lasts longer and involves running, sprints, ball work, and stretching (Reilly, 2006).

It is important to recognise that a warm-up does not only prepare the body for the following activity, but it also aims to increase the blood flow to the muscles and other soft tissues. This is noted to be an important factor in preventing injury to the ligaments, tendons, joints, and muscles (CSP Webpage, 2012).

In the UK, the Active Age 2012 survey found that from those who regularly exercise, only 1 in 5 people consistently warm up. Professor Greg Whyte, a former Olympic modern pent-athlete is concerned by this and states that warming-up properly reduces the stress placed on the joints and muscles, as well as reducing the risk of injury (CSP Webpage, 2012).

In football, knee injuries are one of the most common types of injury. Therefore it is recommended that the joints and the muscles surrounding these joints are thoroughly warmed-up before the main activity. The main muscles of the lower limb involved in

hip flexion and extension and knee flexion and extension are the hamstrings and the quadriceps, although the main hip flexors also include the iliopsoas and sartorius. It is vitally important that these muscles are warmed up in preparation for the activity of football where flexion and extension of the hip and knee are required for running, jumping, tackling, and kicking the ball. (CSP Webpage, 2012).

## 5.2 Types of warm-up

There are various types of warm-up to consider. Figure 8 categorises the types of warm-up whilst also explaining the differences. A warm-up can either be passive, where the body is heated from the outside, or active, which uses exercise to create heat internally. An example of a passive warm-up would be a sauna, or a hot shower. This is commonly used to help the muscles relax and to reduce pain, whilst helping injured tissues to recover without having to move the affected area. (Norris, 2007, 46).

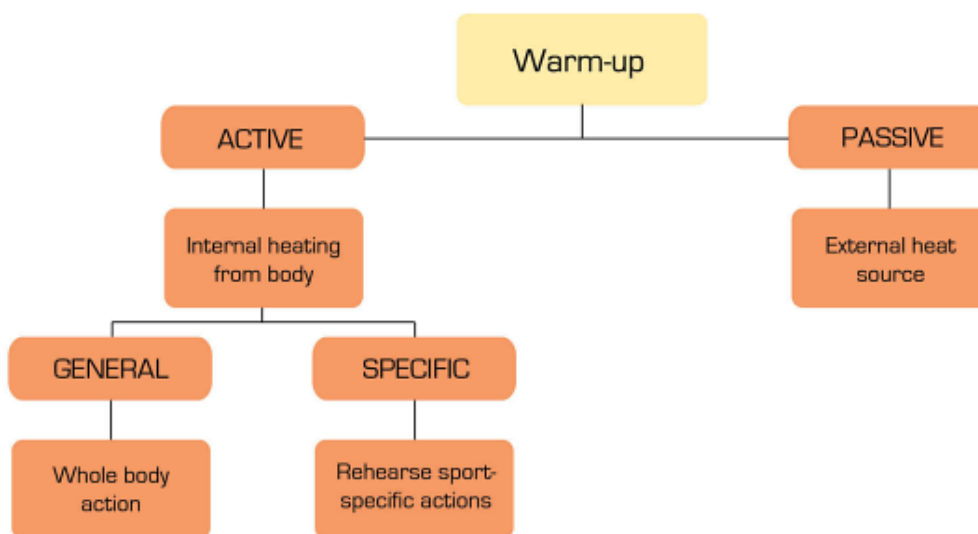


Figure 8. Types of Warm-up (Norris, 2007, 46)

An active warm-up is the most common type of warm-up, and includes general movements, as well as more specific movements that are related to the sport. A passive warm-up increases the tissue temperature, but is not a very practical method, and is therefore quite uncommon (Roetert et al, 2007, 43-44).

## 6 PURPOSE AND AIMS OF THE THESIS

The purpose of this thesis is to gain an understanding of the effects of static stretching the hamstring muscles in a warm-up among football players, and its effect on performance. The thesis will review and analyse previous studies to determine if static stretching in the warm-up prior to exercise is beneficial, or whether it has negative implications on performance.

There are various arguments about what stretching is, and what it aims to do. It is commonly accepted that stretching is an accepted and beneficial part of physical activity. There is a long history into the research of stretching and its implications on the human body, yet it continues to provide new developments whilst also causing arguments among scientists. The research questions of this systematic review are as follows:

1. How does static stretching of the hamstring muscles in a warm-up affect performance among football players?
2. Which type of stretching should be performed in a warm-up prior to performance?

## 7 SYSTEMATIC LITERATURE REVIEW

A systematic literature review is conducted by the researcher who systematically approves or rejects certain studies when writing their review. Khan et al (2003. 118-121) states that for a literature review to earn the systematic title, it must first of all be based on a clearly formulated question, then identify relevant studies, and appraise the quality of these studies.

To form a systematic literature review, it is best advised to follow these 5 steps.

The first step is to formulate the research questions that you are aiming to address. This is commonly done with the researcher identifying the key words connected to their topic, and linking the terms in different ways to form a search strategy.

In creating the research questions, it is best advised that the researcher follows the PICO framework (Sayers, 2008, 136).

P = Population. The specific population we are focusing on, such as soccer players.

I = Intervention. An intervention, such as static stretching in a warm-up.

C = Comparison. A comparison such as a randomised controlled trial (RCT)

O = Outcome. The outcome we are concerned with.

(da Costa Santos et al, 2007, 508-511)

The PICO framework allows the researcher to formulate the study questions. The researcher can search each term under a similar heading. For example;

P would be FOOTBALLERS – soccer players,

I would be STATIC STRETCHING – passive stretching.

C would be DYNAMIC STRETCHING – active stretching, ballistic stretching,

O would be PERFORMANCE – effort, achievement, failure, success.

This helps provide articles directly related to the research area.

By using different words from each category and building a search strategy, it enables the researcher to retrieve studies relevant to their research question. For instance, soccer players AND static stretching AND dynamic stretching AND performance.

Once the search strategy has been completed, the next step is to identify the relevant publications, which ones are to be included, and which ones excluded. In the next step the researcher is required to assess the quality of the included studies. In this case, PEDro (Physiotherapy Evidence Database) is a useful tool to assist the researcher performing a quality check on the collected articles.

The researcher can then summarise the evidence collected, and compare the initial findings. The final step is to interpret these findings, and provide conclusions from the results. This last step can be limited, depending on the quality of the studies that have been included and reviewed (Khan et al, 2003, 118-121.).

## 8 RESULTS

### 8.1 Search Strategy

The database search was conducted on 13.7.2015 and 14.7.2015. The search was undertaken with static stretching as the main heading along with one of the following terms: AND football, AND soccer, AND warm up, AND performance, AND exercise, AND effect, AND muscle, AND soccer player, AND leg muscles, AND hamstrings, AND dynamic stretching, AND soccer warm up, AND football warm up. PubMed, EBSCO, and Science Direct were the selected databases to perform the search, with the results show in Table 2.

Table 2. Database search

Entry Terms		EBSCO	PubMed	ScienceDirect (journals)
Static Stretching	AND "Football"	1	2	4
	AND "Soccer"	3	4	6
	AND "Warm up"	12	17	13
	AND "Performance"	16	26	18
	AND "Exercise"	27	21	19
	AND "Effect"	21	26	25
	AND "Muscle"	17	26	23
	AND "Soccer player"	2	0	5
	AND "Leg muscles"	0	0	3
	AND "Hamstrings"	5	3	10
	AND "Dynamic stretching"	20	8	4
	AND "Soccer warm-up"	0	1	0
	AND "Football warm-up"	0	0	0
<b>Total Hits</b>		<b>124</b>	<b>134</b>	<b>130</b>

## 8.2 Study Selection

Figure 9 displays the study selection process and the reasons as to why some studies were excluded at different stages. There were a total of 388 studies which met the criteria of being published from 1<sup>st</sup> January 2010, which were peer reviewed, and were available as a free full text.

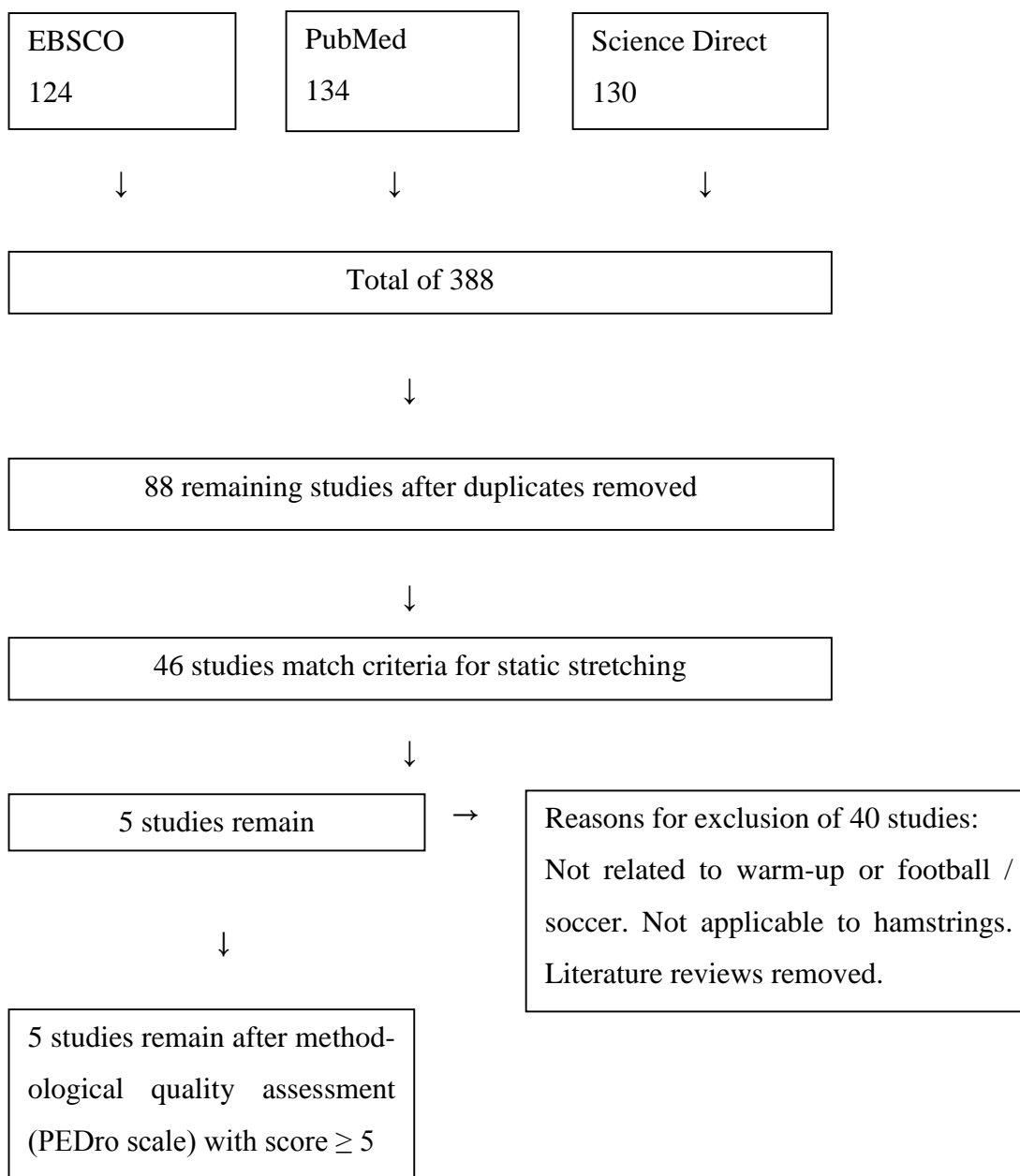


Figure 9. Flow diagram of study selection

### 8.3 Methodological Quality Assessment

Once the study selection process was complete, PEDro, a methodological quality assessment tool was used to determine the quality of the remaining studies. PEDro is the abbreviation for the Physiotherapy Evidence Database, a free online database containing over 32,000 studies which have been assessed using the PEDro scale. The PEDro scale uses 11 different criteria, of which 10 are used for the final score, with the first criteria excluded. (Website of Physiotherapy Evidence Database Free Online, 1999).

The assessment was made by two independent researchers, who assessed the quality of each of the five articles. Following the independent assessment, agreement was made on all criteria, with four of the studies achieving a score of 5, and the fifth study achieving a score of 6. It was determined that all articles would be accepted in the review.

Table 3. Methodological quality assessment using PEDRo Scale

Study	1	2	3	4	5	6	7	8	9	10	11	Score
Alikhajeh 2012	1	1	0	1	0	0	0	1	0	1	1	6/10
Alikhajeh et al. 2012	1	0	1	1	0	0	1	1	0	1	1	7/10
Alikhajeh et al. 2012	1	1	0	1	0	0	0	1	0	1	1	6/10
Alikhajeh et al. 2011	1	1	0	1	0	0	0	1	0	1	1	6/10
Pagaduan et al. 2012	1	1	0	1	0	0	0	1	0	1	1	6/10

All studies achieved at least a score of 5, as the first category is not included in the final score. The PEDro scale suggests studies with a minimum score of 6 are deemed to have moderate – high validity. For this study, all articles with a score of 5 or above were accepted in the review process.

Table 4. Summary of the included articles

Author & year of publication	Purpose of the study	Study design	Subjects	Methods	Results	Limitations
Alikhajeh 2012	Etiology	Controlled study	Twenty male soccer players aged $17.4 \pm 0.685$ years RS	20 participants separated into 4 groups. Each group completed one warm-up then rested 48 hours before completing a different one. 4 categories: 1 Static warm-up with 2 minute active rest 2 Dynamic with 2 minute active rest 3 Dynamic with 5 minute passive rest 4 Dynamic with 15 minute passive rest Following each warm-up design, participants performed a standing long jump which was measured in cm.	The dynamic warm-up with a 5 minute rest (3) achieved the highest results, with a score of $221.45 \pm 15.4$ cm. The dynamic warm-up with a 2 minute walk before the long jump (2) also achieved a higher score of $219.87 \pm 14.68$ . In comparison, the static warm up (1) and dynamic warm-up with 15 minute rest (4) achieved the lowest scores with $215 \pm 13.48$ and $215.3 \pm 13.47$ retrospectively.	Limited amount of participants who were all aged under 18 years old who may not be fully grown. The length of warm-up time could be perceived as relatively short when relating it to a warm-up in preparation for a football match. Although it refers to a previous study, it does not

						state the exercises performed. The study does not explore the reasons as to why the results are what they are.
Alikhajeh et al. 2012	Etiology	Controlled study	Twenty elite level male high-school soccer players aged 16 – 18 years	<p>Three stretching protocols;</p> <ol style="list-style-type: none"> <li>1 Static stretching</li> <li>2 No stretching</li> <li>3 Dynamic stretching</li> </ol> <p>Participants performed in one warm up followed by the test. 48 hour rest then different stretching protocol followed by testing. All stretching protocols followed a general warm-up which involved jogging, side-steps, backward jogging, followed by three-quarter pace agility and sprint runs over 4 minute period.</p> <p>Testing included three performance tests:</p>	<p>Significant improvement in time recorded in flying 20m sprint and zig-zag sprint when participants performed dynamic stretching in comparison to no stretch or static stretching. No significant results recorded in stationary 10m sprint.</p>	<p>Warm-up before stretching protocols involved dynamic movements before testing.</p>

				<p>1 Stationary 10m sprint</p> <p>2 Flying 20m sprint</p> <p>3 20m zig zag course involving three turn points of 100 degrees.</p>		
Alikhajeh et al. 2012	Etiology	Controlled study	120 male amateur level soccer players aged $17.5 \pm 0.58$ years.	<p>Participants separated into 4 different groups; PSS – passive static stretching, ADS – active dynamic stretching, ASS – active static stretching, SDS – static dynamic stretching. Warm-up involved 10 minute jog, followed by 2 x 20m sprints from standing start with 2 minute rest in between. Stretching protocols followed the first two sprints, then two more sprints performed and measured.</p>	<p>Similar times recorded in pre-stretching sprint time across all four groups. Post-stretching times improved in ADS group from <math>3.71 \pm 0.1</math> to <math>3.65 \pm 0.65</math>. SDS group also saw reduced time from <math>3.72 \pm 0.94</math> to <math>3.68 \pm 0.45</math>. 20m sprint times in static stretching groups increased. PSS pre-stretching time of <math>3.71 \pm 0.11</math> to post-stretching time of <math>3.76 \pm 0.54</math> and ASS from <math>3.72 \pm 0.18</math> to <math>3.75 \pm 0.96</math>.</p>	Amateur level footballers all of whom were aged under 18 years. Participants only participated in one stretching protocol. Improved reliability if each group performed all stretching programmes.
Alikhajeh et al. 2011	Etiology	Controlled study	Twenty male soccer players aged	20 participants separated into 4 groups. Each	The group with dynamic stretching followed by	Limited amount of participants

			17.4 ± 0.685 years volunteered and randomly selected.	group completed one warm-up then rested 48 hours before completing a different one. 4 categories: 1 Static warm-up with 2 minute active rest 2 Dynamic with 2 minute active rest 3 Dynamic with 5 minute passive rest 4 Dynamic with 15 minute passive rest Following each warm-up design, participants performed a standing start 20m sprint which was timed and recorded.	a 2 minute active rest (2) achieved the quickest time of 3.61 ± 0.13, followed by the dynamic stretching group with 5 minute passive rest (3) with a time of 3.66 ± 0.11. The static stretching group with 2 minute rest (1) achieved a time of 3.74 ± 0.94, and lastly the dynamic stretching group with 15 minute rest (4) achieved a time of 3.76 ± 0.09.	who were all of a young age – under 18 years. Not compared to different distances, only 20m.
Pagaduan et al. 2012	Etiology	Controlled study	Twenty-nine male soccer players age: 19.4 ± 1.1 years with competitive experience of 6.5 ± 2.1 years	Seven different protocols used with 48 hour rest in between. Two of the protocols did not include general warm up which consisted of a 5 minute run with increase in pace. Protocols were: 1 No warm up 2 General warm up	Significantly higher jump achieved following protocol 3 – general warm-up with dynamic stretching – 39.1cm. No warm-up and passive static stretching achieved lowest scores of 33.7cm and 34.3cm respectively.	Limited sample size where participants were required to perform at an early time compared to when a football match would take place.

				<p>3 General warm up and dynamic stretching</p> <p>4 General warm up and dynamic stretching and static stretching</p> <p>5 Static stretching</p> <p>6 Static stretching and general warm up</p> <p>7 Static stretching, general warm up and dynamic stretching</p> <p>Following each protocol there was a 1 minute rest before Counter movement jump performance assessed.</p>		
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RS = randomly selected; CMJ = counter movement jump performance

#### 8.4 How does static stretching of the hamstring muscles in a warm-up affect performance among football players?

The purpose of this review was to research the current evidence and summarise the influence static stretching of the hamstring muscles has on performance specifically among football players, as well as determine which type of stretching is best suited for a warm-up prior to performance. All five studies included in this review support the theory that static stretching can inhibit performance where explosive power is required, whereas dynamic stretching can in fact improve the initial explosive power required in jumping and short distance sprinting.

Alikhajeh (2012) explored four different warm-up protocols which included three dynamic warm-ups with varying times of rest, and one static stretching programme. The four groups included static stretching with a 2 minute rest, dynamic stretching with a 2 minute rest, dynamic stretching with a 5 minute rest, and dynamic stretching with a 15 minute rest. With a sample group of 20 high school football players, they were required to perform a standing long-jump. Participants performed each warm-up programme in groups of 5, with a 48 hour rest in between completing each programme. The results showed that a dynamic warm-up with a 5 minute passive rest period was more effective in explosive power performance. The static stretching programme achieved the lowest score with a mean of 215cm in comparison to the dynamic warm-up which achieved a mean score of 221.45cm.

In a similar study Alikhajeh (2012) investigated the same stretching protocols, but with the aim to find out the effects on 20m acceleration and maximal speed performance. 20 participants were separated into four groups and participated in each stretching protocol group with a 48 hour rest in between each testing procedure. The four groups included static stretching with a 2 minute rest, dynamic stretching with a 2 minute rest, dynamic stretching with a 5 minute rest, and dynamic stretching with a 15 minute rest. In this case, the best results in sprint performance were shown in the dynamic stretching with a 2 minute rest group with a time of 3.61 seconds. Static stretching showed an average time of 3.74 seconds. This supports the previous study in suggesting that static stretching can negatively affect performance in football players.

Alikhajeh (2012) conducted a study looking at the effects different stretching warm-up protocols had on 20m sprint performance among 120 amateur level football players. All participants completed a 10 minute warm-up run, followed by two 20m sprints with the times recorded. Following the pre-stretch sprints, the participants were divided into four separate groups of 30 where each group were provided with a specific stretching programme. The four groups included; passive static, active dynamic, active static, and static dynamic. In this study both the active static and passive static stretching groups produced a reduction in performance of the 20m sprint as the times increased from pre-stretching times of 3.72 and 3.71 seconds to 3.75 and 3.76 seconds. This suggests static stretching can inhibit sprint performance and acceleration from a standing start.

In a similar study, Alikhajeh et al (2012) investigated the effects of different stretching protocols on 10m acceleration, 20m maximal speed, and agility performance among 20 elite level male football players. All participants completed the protocols on three different days. The general warm-up for all three groups involved multi-directional running, agility drills and full-pace sprints. The dynamic and static stretching groups also participated in 6 minutes of flexibility exercises, but not the no stretching group. Interestingly, the no stretching protocol achieved the fastest acceleration time over a 10m distance from stationary. There was no significant difference between the dynamic and static stretching groups. However during the zig zag agility runs and 20m flying start sprints the dynamic stretching group achieved significantly faster times than the static stretching and no stretching groups. In the test for 20m maximal speed, the static stretching group achieved an average time of 3.74 seconds in comparison to the dynamic stretching group who achieved a mean time of 3.61 seconds. This supports Alikhajeh's (2012) previous study suggesting static stretching can reduce sprint performance.

Pagauan et al (2012) investigated the effects of different stretching protocols on CMJ (counter measure jump performance). With a sample group of 29 participants, all of whom had at least four years of football experience and were aged  $19.4 \pm 1.1$  years, the study investigated six different warm-up protocols and one without a warm-up, followed by three maximal CMJ jumps with a three minute rest period between jumps. The findings concurred with Alikhajeh's (2012) study investigated different warm-up protocols on CMJ performance. The warm-up programme that did not involve a general warm-up, but only static stretching achieved the lowest CMJ score from the six warm-up protocols, although achieved a higher score than the group in which there was no warm-up at all. In comparing the general warm-up group with the passive static stretching group, there was on average a 3.7cm difference. This supports the previous studies in suggesting static stretching is not as effective as dynamic movements. However it should be noted that the static stretching group achieved on average a better score of 0.6cm compared to when the group did not perform any kind of warm-up.

### 8.5 Which type of stretching should be performed in a warm-up prior to performance?

Based on the evidence gathered, the five studies concur with the opinion that dynamic stretching is a better alternative to static stretching with improvements in performance in CMJ performance, agility runs, 10m acceleration, as well as 20m sprints. Hough et al (2009) conducted a study comparing the effects of static stretching, no stretching, and dynamic stretching on vertical jump (VJ) performance. Their results support the studies in suggesting that static stretching should be excluded from a warm-up in activities that require vertical jumping, such as football.

Although it is important to note that one study (Alikhajeh, 2012) found that static stretching as part of a warm-up does not have as negative an impact on performance in a 20m sprint in comparison to dynamic stretching with a 15 minute rest. Similarly with CMJ performance, there is no significant difference in performance when comparing static stretching with a 2 minute rest, to dynamic stretching with a 15 minute rest (Alikhajej, 2012). Therefore it could be argued that the time between the end of the warm-up and beginning of performance is something that should be considered.

The studies do not indicate that static stretching has a negative impact on performance, but suggest dynamic stretching for movements that require explosive power are better suited to being implemented in a warm-up that require these actions.

## 9 CONCLUSION

Dynamic stretching proved to provide significantly better results in performance for explosive power actions in comparison to static stretching. Therefore the application of dynamic stretching as part of a warm-up is more likely to assist in performance in comparison to static stretching. As a sport, football demands explosive power actions such as jumping, sharp turns, and sprinting. In each activity that was examined in the studies, dynamic stretching consistently provided better results in performance.

Two of the studies compared static stretching to no stretching and found that there were no significant differences. This suggests that although static stretching does not necessarily improve performance, it appears that it does not reduce performance either. The results from this could be interpreted that dynamic stretching is a better alternative to static stretching when looking at improvements in movements that require explosive power, although static stretching does not impair performance.

More studies in this area are required, as although the results from the evaluated studies concur that dynamic stretching provides better results, it is not known how it affects in a longer period of time, such as the length of a football match where multiple jumps and sprints are required.

## 10 DISCUSSION

It is currently still common to see professional level football teams use static stretching as part of a warm-up. However it is gradually becoming less popular among football coaches as the science behind it is becoming better known. The reason I chose this as my topic to investigate was due to the interest I have in finding out whether static stretching impacted performance in comparison to other forms of stretching, specifically, dynamic stretching. Once I drew up the study plan, it enabled me to progress smoothly with the thesis process.

To begin with, I found it difficult to narrow down the topic. Although as the thesis progressed, it became easier to narrow it down with the research I conducted. Gathering the data itself also proved to be challenging, as I had quite a strict search criteria I needed to abide to. At first I was planning on investigating the changes specifically within the muscle during different time periods of when a static stretch is held. However I decided to focus more on whether static stretching affects performance levels in comparison to other forms of stretching.

Through the search process and the strict search criteria, only five studies remained which is quite surprising. Reasons for this are varied. It is due to the strict search criteria in which only free full text articles were accessed from within the last five years. From the five accepted studies, it should be noted that only one achieved a PEDro score of 6/10, whilst the other four achieved scores of 5/10. Due to the limited collection of available data for this review, further study is required.

The aim of this review was to review the literature from the last five years to find out whether static stretching affected performance, and which method of stretching is best advised for a warm-up among football players. The five studies concurred that dynamic stretching had a better effect on explosive performance in comparison to static stretching. However due to the limited collection of results, it would appear that further research is required, especially with regards the effects of static stretching over an extended period of time as footballers require the attributes of both explosiveness and endurance.

One aspect which needs further research is the resting period between warm-up and performance. Within football it is quite common that participating in a match does not directly follow a warm-up. For instance if the warm-up finishes 15 minutes before a match kick-off time, the results from this review have shown that the effects of dynamic stretching are reduced.

Based on the results from this review, there is also limited information about the changes within the hamstring muscles, and a lack of explanation as to why static stretching affected explosive performance. The studies hypothesise with previous studies, but do not conduct physiological research into the muscle changes, such as temperature, and range of motion.

The stretching protocols from the data collected focus on the lower limbs, but not specifically the hamstring muscles, as it is difficult to isolate the hamstrings from other muscles that are used for explosive power in jumping and sprinting such as the gluteals, quadriceps, and gastrocnemius among others. Further studies could investigate muscle flexibility and range of motion, as these too are important components for performance in football.

Further investigations could also consider the length of time of static stretching. As these studies included static stretching for one muscle group for a period of 15-30 seconds, it would be interesting to compare this to shorter and longer periods of stretching time. Only one of the studies investigated static stretching for 30 seconds, whereas the remaining four studies investigated 15 seconds and 20 seconds. Pinto et al (2014) found that static stretching for a period of 60 seconds had detrimental effects on CMJ performance in comparison to static stretching for 30 seconds. However shorter static stretching times such as 10 seconds could also be investigated, as there is limited research available.

From the research I gathered, four of the five accepted studies were conducted by the same author. It could be argued that this provides greater validity of the results as it is likely the author used similar dynamic and static stretch protocols. However it could also be said that a greater variation in stretching exercises would provide more detailed results into the effects of alternative stretching methods.

The limitations with the findings included a relatively small sample group size, all but one of which had under 30 participants. The participants themselves were of a young age, averaging between 17 and 19 years old. The participants in the studies played competitively, although it could be argued that it is not at a professional level and therefore possibly not as valid as it would be if professional football players had been used in the studies.

Although it may inhibit explosive power, further study is also required to determine whether static stretching as part of a warm-up can either reduce or increase the risk for potential injury. The studies included in the case do not include the psychological benefits of stretching. At professional level, athletes are required to perhaps play three games in a week, with long distance travelling. The feeling of static stretching often feels good and gives the feeling that stiffness is being reduced.

Another aspect to consider, is other forms of stretching such as ballistic which is high-speed and high-intensity and involves bouncing movements (Kisner and Colby, 2012, 89). In each of the studies, there was a direct comparison between static stretching and

dynamic stretching, however it would have been interesting to see a comparison with ballistic stretching as well.

## **REFERENCES:**

Alikhajeh, Y. 2012. The Effects of Different Warm-Up Protocols on Young Soccer Players' Explosive Power. *Procedia – Social and Behavioural Sciences* 46, 2742 – 2746. Referred 14.7.2015 [www.sciencedirect.com](http://www.sciencedirect.com)

Alikhajeh, Y, Rahimi, N.M, Fazeli, H, & Rahimi, R.M. 2012. Differential Stretching Protocols During Warm up on Select Performance Measures for Elite Male Soccer Players. *Procedia – Social and Behavioural Sciences* 46, 1639 – 1643. Referred 14.7.2015 [www.sciencedirect.com](http://www.sciencedirect.com)

Alikhajeh, Y, Rahimi, N.M, Fazeli, K, & Fazeli, H. 2012. The Effect of Different Warm-up Stretch Protocols on 20m Sprint Performance in Trained Soccer Players. *Procedia – Social and Behavioural Sciences* 46, 2210-2214. Referred 14.7.2015 [www.sciencedirect.com](http://www.sciencedirect.com)

Alikhajeh, Y, Ramezanzpour, M.R, & Moghaddam, A. 2011. The Effect of Different Warm-up Stretch Protocols on Young Soccer Players' Sprint. *Procedia – Social and Behavioural Sciences* 30, 1588-1592. Referred 14.7.2015 [www.sciencedirect.com](http://www.sciencedirect.com)

Alter, M.J. 1998. *Sport Stretch*. United States of America, Human Kinetics. Referred 6.10.2015.

[https://books.google.fi/books?id=89FUREpWL\\_oC&pg=PA6&dq=stretch+reflex+hamstrings&hl=en&sa=X&redir\\_esc=y#v=onepage&q=stretch%20reflex%20hamstrings&f=false](https://books.google.fi/books?id=89FUREpWL_oC&pg=PA6&dq=stretch+reflex+hamstrings&hl=en&sa=X&redir_esc=y#v=onepage&q=stretch%20reflex%20hamstrings&f=false)

Anderson, R.A. & Anderson, J.E. 2010. *Stretching*. 30<sup>th</sup> Anniversary Edition. California, USA: Shelter Publications Inc. Referred 9.10.2015.

[https://books.google.fi/books?id=wzbOq\\_pWqVYC&printsec=frontcover&dq=stretching&hl=en&sa=X&redir\\_esc=y#v=onepage&q=stretching&f=false](https://books.google.fi/books?id=wzbOq_pWqVYC&printsec=frontcover&dq=stretching&hl=en&sa=X&redir_esc=y#v=onepage&q=stretching&f=false)

Baechle, T.R. & Earle, R.W. 2008. *Essentials of Strength Training and Conditioning*. Third Edition. Leeds: Human Kinetics

- Bangsbo, J 2003. *Fitness Training in Soccer*. Spring City. Reedswain Publishing.
- Berg, K. 2011. *Prescriptive Stretching*. United States of America. Human Kinetics.
- Blahnik, J. 2011. *Full-Body Flexibility*. United States of America. Human Kinetics.
- Da Costa Santos, C.M, De Mattos Pimenta, C.A, & Nobre, M.R. 2007. The PICO Strategy for the Research Question Construction and Evidence Search. *Journal Rev Lat Am Enfermagem*, 508-511. Referred 15.10.2015.  
[http://www.scielo.br/scielo.php?script=sci\\_arttext&pid=S0104-11692007000300023&lng=en&nrm=iso&tlng=en](http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0104-11692007000300023&lng=en&nrm=iso&tlng=en)
- Hawkins, R. 2004. *Fitness for Football*. London. Hodder & Stoughton.
- Hough, P.A, Ross. E.Z, & Howatson, G. 2009. Effects of dynamic and static stretching on vertical jump performance and electromyographic activity. *Journal of Strength and Conditioning Research*, [Online]. 23 (2), 507-512. Referred 20.2.2016  
<http://www.ncbi.nlm.nih.gov/pubmed/19204571>
- Jarmey, C. 2008. *The Concise Book of Muscles*. Second Edition. Chichester: Lotus Publishing. Referred 9.10.2015  
[https://books.google.fi/books?id=E7FE6jG1EmEC&pg=PA5&dq=the+muscle+book&hl=en&sa=X&redir\\_esc=y#v=onepage&q=the%20muscle%20book&f=false](https://books.google.fi/books?id=E7FE6jG1EmEC&pg=PA5&dq=the+muscle+book&hl=en&sa=X&redir_esc=y#v=onepage&q=the%20muscle%20book&f=false)
- Jarvis, M. 2015 *Strength and Conditioning for Football*. First Edition. London: Bloomsbury Publishing Plc
- Khan, K.S., Kunz, R., Kleijnen, J., & Antes, G. 2003. Five Steps to Conducting a Systematic Review. *Journal of the Royal Society of Medicine*. 118-121. Referred 10.10.2015. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC539417/>
- Kisner, C & Colby, L.A. 2012. *Therapeutic Exercise Foundations and Techniques*. Philadelphia. F.A. Davis Company.

Madden, C.C, Putukian, M, Young, C.C, & McCarty, E.C 2010. Netter's Sports Medicine. Philadelphia. Saunders Elsevier.

McGinnis, P. Biomechanics of Sport and Exercise, 2013, 3<sup>rd</sup> Edition, USA: Human Kinetics, p.305

Moran, O. & Arechabala, I. (2012) Stretching Exercises Encyclopedia. Twelfth Edition. Maidenhead: Meyer & Meyer Sport

Norris, C.M. 2007. The Complete Guide to Stretching. Third Edition. London: A & C Black

Pagaduan, J.C, Pojskic, H, Uzicanin, E, & Babajic, F. 2012. Effect of Various Warm-Up Protocols on Jump Performance in College Football Players. Journal of Human Kinetics 35, 127-132. Referred 14.7.2015 [www.ncbi.nlm.nih.gov](http://www.ncbi.nlm.nih.gov)

Page, P. 2012 Current Concepts in Muscle Stretching for Exercise and Rehabilitation. International Journal of Sports Physical Therapy 7(1), 109–119. Referred 22.6.2015 <http://www.ncbi.nlm.nih.gov>

Pinto, M.D, Wilhelm, E.N, Tricoli, E, Pinto, R.S, & Blazevich, A.J 2014. Differential Effects of 30- Vs. 60-Second Static Muscle Stretching on Vertical Jump Performance. The Journal of Strength and Conditioning Research 28 (12), 3440-6. Referred 5.3.2016 [www.researchgate.net](http://www.researchgate.net)

Reilly, T. 2006. The Science of Training – Soccer: A Scientific Approach to Developing Strength, Speed and Endurance. First Edition. Oxon: Routledge p.36

Roetart, E.P & Ellenbecker T.S. 2007. 43-44. Complete Conditioning for Tennis. Human Kinetics. United States of America. Referred 25.7.2016 [books.google.co.uk](http://books.google.co.uk)

Sayers, A. 2008. Tips and Tricks in Performing a Systematic Review. The British journal of General Practitioners. 136. Referred 10.10.2015.

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2233974/>

Tortora, G.J & Grabowski. S.R. 2000. Principles of Anatomy and Physiology. Ninth Edition. United States of America. John Wiley & Sons, Inc.

Tortora. G.J & Grabowski, S.R. 2009. Principles of Anatomy and Physiology. Twelfth Edition. United States of America. John Wiley & Sons, Inc.

Walker, B. 2013. The Anatomy of Stretching. Second Edition. Nutbourne, United Kingdom: Lotus Publishing. Referred 25.9.2015 <https://books.google.co.uk>

Woods, C., Hawkins, R.D., Maltby, S., Hulse, M., Thomas, A., & Hodson, A. 2004. The Football Association Medical Research Programme: an audit of injuries in professional football - analysis of hamstring injuries. Journal of Sports Medicine. 38, 36-41. Referred 12.7.2015

<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1724733/pdf/v038p00036.pdf>

Ylinen, J. 2008. Stretching Therapy for Sport and Manual Therapies. 1<sup>st</sup> English Edition. China: Elsevier

Young, W.B & Behm, D. 2002. Should Static Stretching Be Used During a Warm-Up for Strength and Power Activities? Strength and Conditioning Journal. 24 (6), 33-37. Referred 12.2.2016 [www.researchgate.com](http://www.researchgate.com)

Website of Australian Sports Commission, 2010. Referred 12.8.2015. <http://www.ausport.gov.au>

Website of Bath University, 1994. Referred 1.7.2015  
[http://people.bath.ac.uk/masrjb/Stretch/stretching\\_2.html](http://people.bath.ac.uk/masrjb/Stretch/stretching_2.html)

Website of NHS, 2012. Referred 15.6.2015  
<http://www.nhs.uk/Livewell/c25k/Pages/how-to-stretch-after-a-run.aspx>

Website of CSP, 2012. Referred 12.7.2015  
<http://www.csp.org.uk/search/all/warm%20up>

Website of BBC Sport, 2005. Referred 27.6.2015.

[http://news.bbc.co.uk/sport2/hi/health\\_and\\_fitness/4286612.stm](http://news.bbc.co.uk/sport2/hi/health_and_fitness/4286612.stm)

Website of Core Walking, 2013. Referred 14.7.2015 <http://corewalking.com/the-ham-strings-and-the-calves/>

Website of Four Four Two Performance, 2015. Referred 6.8.2015 <http://performance.fourfourtwo.com/fitness/reo-coker-the-complete-warm-up>

Website of Physiotherapy Evidence Database Online, 2015. Referred 22.7.2015 <http://www.pedro.org.au/english/downloads/pedro-scale/>

Website of Sports Scientists, 2010. Referred 25.6.2015. <http://sportsscien-tists.com/2010/06/physiology-of-football-profile-of-the-game/>

Website of the American Academy of Orthopaedic Surgeons, 2009. Referred 29.6.2015 <http://www.orthoinfo.aaos.org/topic.cfm?topic=A00408>

Website of Central and North West London NHS, 2011. Referred 1.7.2015. <http://www.cnwl.nhs.uk/wp-content/uploads/Arthritic-Knee-Advice.pdf>

Website of Yoga Evolution, 2014. Referred 1.7.2015 <https://www.evolutionyoga.com/happens-stretch/>

Website of Office for National Statistics, 2015. Referred 14.9.2015 <http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/mid-2014/sty---overview-of-the-uk-population.html>

Website of Sport England, 2015. Referred 14.9.2015 <http://www.sportengland.org/research/who-plays-sport/by-sport/>

## APPENDICES

### PEDro scale

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1. eligibility criteria were specified	no <input type="checkbox"/> yes <input type="checkbox"/> where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no <input type="checkbox"/> yes <input type="checkbox"/> where:
3. allocation was concealed	no <input type="checkbox"/> yes <input type="checkbox"/> where:
4. the groups were similar at baseline regarding the most important prognostic indicators	no <input type="checkbox"/> yes <input type="checkbox"/> where:
5. there was blinding of all subjects	no <input type="checkbox"/> yes <input type="checkbox"/> where:
6. there was blinding of all therapists who administered the therapy	no <input type="checkbox"/> yes <input type="checkbox"/> where:
7. there was blinding of all assessors who measured at least one key outcome	no <input type="checkbox"/> yes <input type="checkbox"/> where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no <input type="checkbox"/> yes <input type="checkbox"/> where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	no <input type="checkbox"/> yes <input type="checkbox"/> where:
10. the results of between-group statistical comparisons are reported for at least one key outcome	no <input type="checkbox"/> yes <input type="checkbox"/> where:
11. the study provides both point measures and measures of variability for at least one key outcome	no <input type="checkbox"/> yes <input type="checkbox"/> where:

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The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (Verhagen AP *et al* (1998). *The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology*, 51(12):1235-41). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.