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<tr>
<th><strong>Student name</strong></th>
<th>Sara Ruth Morgan</th>
<th><strong>Student ID</strong></th>
<th>ST1001822</th>
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<td><strong>Supervisor</strong></td>
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#### Title and Abstract
Title to include: A concise indication of the research question/problem.  
Abstract to include: A concise summary of the empirical study undertaken.

#### Introduction and literature review
To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/question; an indication of any research expectations, (i.e., hypotheses if applicable).

#### Methods and Research Design
To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.

#### Results and Analysis
To include: description and justification of data treatment/data analysis procedures; appropriate presentation of analysed data within text and in tables or figures; description of critical findings.

#### Discussion and Conclusions
To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.

#### Presentation
To include: academic writing style; depth, scope and accuracy of referencing in the text and final reference list; clarity in organisation, formatting and visual presentation

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CARDIFF METROPOLITAN UNIVERSITY
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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT CONDITIONING, REHABILITATION AND MASSAGE

RECOVERY OF CALF MUSCLE STRENGTH FOLLOWING A LATERAL ANKLE SPRAIN.

(Dissertation submitted under the discipline of SCRAM)

SARA RUTH MORGAN

ST10001822
SARA RUTH MORGAN

ST10001822

SCHOOL OF SPORT

CARDIFF METROPOLITAN UNIVERSITY
RECOVERY OF CALF MUSCLE STRENGTH FOLLOWING A LATERAL ANKLE SPRAIN.
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Abstract

Context: Lateral ankle sprains are the most common injury in sport and medical care. A lateral ankle sprain can result in a loss of proprioception, range of motion and strength of the ankle. **Aim:** To provide insight into whether plantarflexion strength is reduced following a lateral ankle sprain. **Participants:** 23 participants (Female = 13, Male = 10) between the ages of 18 and 24. All experienced a unilateral lateral ankle sprain with no complications and had no other lower limb problems following the ankle injury. Participants had returned to sport for a minimum of three months and a maximum of 36 months. **Method:** Participants performed as many one legged standing calf raises as possible at 60% of body weight. The procedure started with the right leg and then repeated on the left leg. **Results:** There was a significant \( P < 0.05 \) difference between the injured and non-injured ankles. **Conclusion:** The non-injured ankles performed a higher number of calf raises than the injured ankles. This suggests that there is a plantarflexion strength defect present following a lateral ankle sprain.
CHAPTER 1

INTRODUCTION
1. Introduction

The ankle is a complex anatomical structure involving many bones, joints and ligaments, which interact to provide both stability and support for the leg (Harris & Ranson, 2008). Additionally, the structure allows movement of the foot, which is key for weight-bearing, and locomotion of the body (Harris & Ranson, 2008). Both the medial and lateral sides of the ankle are superficial thus, making them vulnerable and very accessible to injury mechanisms (Harris & Ranson, 2008).

Many studies have documented that the most common injury in sport and medical care is the lateral ankle sprain (Wolfe, Uhl, Mattacola & McCluskey, 2001; van Rijn, et al, 2008; Hertel, 2000; Willems, et al, 2005; McGuine & Keene, 2006; Cooke, Lamb, Marsh & Dale, 2003). A lateral ankle ligament sprain accounts for three to five percent of all accident and emergency attendance in the United Kingdom (Cooke, et al, 2003). This equates to an estimated 5,600 ankle sprain incidents each day in the United Kingdom. A hypothetical cost of the ankle sprain to the United Kingdom’s National Health Service is estimated at around £5.2 million (Bridgman, et al, 2003). It is not only in the United Kingdom that ankle injuries are a costly problem. In the United States of America an annual health care cost of two billion dollars is spent on ankle injuries (Waterman, Belmont, Cameron, DeBerardio & Owens, 2010). It is estimated that worldwide one ankle sprain occurs per 10,000 people a day (Waterman, et al, 2010).

The mechanism of injury of a lateral ankle sprain is overload of the lateral ligaments when the joint is in its most unstable and vulnerable position (Wolfe, et al, 2001). This overloading of the lateral ligaments results in pain and loss of function. There are many factors that can increase the chances of sustaining an ankle sprain the most common is history of previous injury as re-injury rate is as high as 80% (Hertel, 2000). As re-injury is so prevalent it is important to understand what effects the injury has on the ankle joint so that rehabilitation can be as effective as possible. It has been documented that the effects of an ankle sprain may last up to three years (van Rijn, et al, 2008).
An ankle sprain results in loss of proprioception at the ankle due to damage caused to the connective tissues involved in the injury. This results in a decrease in sense position and also a balance defect, which produces an increase in postural sway (Hertel, 2000). Another effect that has been documented after an ankle sprain is a loss in range of motion, and in particular a loss in dorsiflexion range of motion (Hertel, 2000). Additionally, a weakness in ankle muscle strength post ankle sprain has been found (Holme, et al, 1999; Fox, Docherty, Schrader & Applegate, 2008).


Many studies have used the calf raise test to assess eccentric and concentric muscle action of calf. Most studies that have used the calf raise test have used participants that are either healthy or have achilles tendon disorders (Hébert-Losier, Newsham-West, Schneiders & Sullivan, 2009). The calf raise test is also an effective test method for studying the effects of an ankle sprain on the isotonic strength of the plantarflexor muscles of the ankle.

A one legged calf raise test can be utilised to assess eccentric and concentric muscle action of the calves in an individual that has suffered from a unilateral lateral ankle sprain. The results from the injured and non-injured sides could then be compared. This may provide insight into whether plantarflexion strength is reduced following a lateral ankle sprain.
CHAPTER 2

LITERATURE REVIEW
2. Literature review

2.1 Anatomy of the ankle

There are three joints that make up the ankle, the talocrural, inferior tibiofibular and subtalar joints. The inferior tibiofibular joint involves the articulation of the distal ends of the tibia and fibula. It allows a small amount of movement and the joint is stabilised by the anterior and posterior inferior tibiofibular ligaments and the interosseous ligament. The subtalar joint involves the talus and calcaneus bones of the foot. The subtalar joint allows for gliding and rotation, which are involved in foot inversion and eversion. The lateral, medial, posterior and interosseous talocalcaneal ligaments are involved in the stabilisation of the joint (Drake, Vogl & Mitchell, 2010). The talocrural joint, also known as the ankle joint, is synovial in type involving the talus of the foot and the distal surfaces of the tibia and fibula (Figure 1). The talocrural joint is a hinge joint allowing dorsiflexion and plantarflexion of the foot. The upper surface of the talus is curved in a shape of a half-cylinder and covered by hyaline cartilage (Drake, et al, 2010). This shape fits into the bracket-shaped socket formed by the distal ends of the tibia and fibula (Figure 2). The articular face of the talus is much wider anteriorly compared to posteriorly. Consequently, the talus fits tighter into the socket when dorsiflexed compared to when plantarflexed. Thus, the joint is most stable when dorsiflexed (Drake, et al, 2010). The joint is stabilised by the medial and lateral ligaments.
The medial ligament, also known as the deltoid ligament, is large, strong and triangular in shape. The ligament attaches above the medial malleolus and fans out into a triangular shape attaching between the tuberosity of the navicular and the medial tubercle of the talus (Figure 3). The medial ligament is subdivided into four parts, the tibionavicular, the tibiocalcaneal, the posterior tibiotalar and the anterior tibiotalar (Drake, et al, 2010). The lateral ligament is subdivided into three parts, anterior talofibular ligament, posterior talofibular ligament and calcaneo Tibiotalar ligament (Figure 4). The anterior talofibular ligament attaches from the anterior border of the lateral malleolus to the adjacent talus (Drake, et al, 2010). The posterior talofibular ligament runs from the malleolar fossa on the medial side of the lateral malleolus to the posterior process of the talus (Drake, et al, 2010). The calcaneo Tibiotalar ligament spans from the malleolar fossa on the poster medial side of the lateral malleolus to the tubercle of the lateral surface of the calcaneus (Drake, et al, 2010).
The muscles of the leg are divided into three compartments, lateral, anterior and posterior. There are two muscles in the lateral compartment involved with movement at the ankle. Fibularis longus is involved with eversion and plantarflexion and fibularis brevis is involved with eversion of the foot (Drake, et al, 2010). The anterior compartment is mainly responsible for dorsiflexion at the ankle. The muscles in the compartment are tibialis anterior responsible for dorsiflexion and inversion, extensor hallucis longus responsible for dorsiflexion and extension of the hallucis, extensor digitorum longus responsible for dorsiflexion and extension of the four lateral toes and fibularis tertius responsible for dorsiflexion and eversion (Drake, et al, 2010). The posterior compartment is involved with plantarflexion. The muscles responsible in this compartment for plantarflexion are gastrocnemius, plantars, soleus and tibialis posterior (Drake, et al, 2010). Tibialis posterior is additionally involved with inversion of the foot.
2.2 Incident rate of ankle sprains

The ankle joint is one of the most common sites for acute musculoskeletal injuries, with sprains accounting for 75% (Wolfe, et al, 2001; van Rijn, et al, 2008). The general public have an incident rate of between five and seven sprains per 1,000 people a year (Waterman, et al, 2010). It is estimated that in the United States of America that 23,000 ankle sprains occur each day (Hubbard & Hicks-Little, 2008; Braun, 1999; van Rijn, et al, 2008). In the Netherlands studies have discovered that each year an estimated 600,000 people per year sustain ankle injuries, an incident rate of 12.8 patients per year. (van Middelkoop, van Rijn, Verhaar, Koes & Bierma-Zeinstra, 2012; van Rijn, et al, 2008). In the United Kingdom between 5,000 and 5,600 ankle injuries a day are estimated to occur (van Rijn, et al, 2008; Cooke, et al, 2003). A study on emergency departments in the United Kingdom documents that lateral ankle ligament sprains account for three to five percent of all emergency department attendance (Cooke, et al, 2003). From these studies it can be seen that ankle injuries are a common occurrence globally. Approximately worldwide one ankle sprain occurs per 10,000 people per day (Waterman, et al, 2010).

The most frequently injured body part during physical activity is the ankle, accounting for 10 to 30% of all sporting injuries (Fong, Hong, Chan, Yung & Chan, 2007; Wolfe, et al, 2001; Chu, et al, 2010; Waterman, et al, 2010). In sport as with the general public ankle sprains are the most common type of ankle injuries (McGuine & Keene, 2006; Thacker, et al, 1999; Waterman, et al, 2010). In most sports ankle sprains accounts for 80% (Chu, et al, 2010) but, in some sports it may be as great as 100% of ankle injuries (Fong, et al, 2007). Most studies name the lateral ankle sprain the most common type of ankle injury accounting for 15 to 45% of all sporting injuries (Hertel, 2000; Willems, Witvrouw, Verstuyft, Vaes, & Clercq, 2002; Malliaropoulos, Ntessalen, Papacostas, Longo, & Maffulli, 2009).

A study by Fong, et al, (2007) reviewed the injury patterns in 70 different sports with a total of 201,600 participants. The authors reported that out of the 70 sports ankle injuries were reported to be the most common injury in 24 (34.3%) of the sports. The authors additionally reported that out of 43 sports in the study 33 (76.7%) reported that ankle sprains were the most common injury. Fong, et al,
(2007) states that during games the incident rate of ankle injuries in football were the highest at 34.82, followed by rugby with 14. A study reviewing ankle sprains in 100 professional football players reported the rate of ankle injuries in football to be between 14 and 17% of all football injuries (Fousekis, Tsepis & Vagenas, 2012). A football association audit of injuries across two seasons including 91 professional football clubs in the English Premier League reported that 17% of all injuries were to the ankle (Woods, Hawkins, Hulse & Hodson, 2003). These two studies support Fong, et al, (2007) findings that ankle injuries are extremely prevalent during football. A study reviewing injury rates during the 2003 Rugby World Cup observed that the ankle was the second most frequently injured body site with an incident rate of 14 injuries per 1,000 player game hours during the tournament (Best, McIntost & Savage, 2005). This study only reviewed male players therefore further research is required to review female injury patterns. Another study observing incident, nature and circumstances of injuries in New Zealand Rugby clubs states that ankle injuries are most common during rugby training session accounting for 14% of all injuries (Bird, et al, 1998). This study included a mixture of 356 male and female participants. Again these two studies support Fong, et al, (2007) findings that ankle injuries are prevalent during rugby, particularly during training.

2.3 Factors that cause ankle sprains

Sporting injuries are multi risk incidents with many different risk factors interacting to cause an injury (Willems, et al, 2005). The mechanism of injury for a lateral ankle sprain is a combination of plantarflexion and inversion at the ankle joint (Wolfe, et al, 2001). This movement puts an overload of tension on the ligaments of the lateral aspect of the talocrural and subtalar joints of the ankle resulting in a lateral ankle sprain (Hertel, 2000).

Many studies have noted that sports involving running, cutting, jumping and sudden stopping movements have an increase chance of ankle sprain (McGuine & Keene, 2006; Woods, et al, 2003). An increase in frequency of these movements will enhance the chance of injury. Additionally, if the movements are performed repeatedly on one foot the chance of injuring that ankle is heightened (Thacker, et al, 1999). Hence, Willems, et al, (2005) found that 59% of ankle sprains occurred on the dominant foot, suggesting that the dominant ankle is more prone to sprains.
A study by Waterman, *et al.*, (2010) observed that 14.5% of females suffered from an ankle sprain were as only 9.2% of males in the study obtained the injury. This could be a consequence from the increase risk of injury due to increased Q-angle of the knee, common in females (Braun, 1999). Additionally, studies have shown than fluctuations of female sex hormones are related to changes in ligament mechanical properties such as ligament laxity (Zazulak, Pateno, Myer, Romani & Hewett, 2006; Harmon & Ireland, 2000). This increase in ligament laxity increases the risk of ligamentous injuries. The study by Waterman, *et al.*, (2010) had many limitations, one being limited patient history, therefore, the study could not fully exclude all participants, which sustained ankle sprains prior to joining the United States Military Academy. Secondly, recurrent sprains during the study period were not included in the results. Finally, multiple contributors evaluated the patients’ injuries, which may decrease the consistency of diagnosis of the ankle sprain and consequently reliability of the results. Fousekis, *et al.*, (2012) found that extrinsic factors such as direct contact with an opponent, inadequate warm-up, shoes and playing on artificial turf increase the risk of ankle injuries. It has been recommended that high-top shoes are worn during sport to decrease the risk of injury as they have enhanced support around the ankle joint compared to traditional footwear (Thacker, *et al.*, 1999).

Willems, *et al.*, (2005) identified that males with slower running speed, reduced cardio respiratory endurance, balance, dorsiflexion strength and range of motion, coordination and faster muscle reaction time are at greater risk of sprains. As this study concentrated on males it cannot be assumed that this is the case for females. Additionally, the study only made an association between ankle sprains and some intrinsic risk factor, therefore more research is needed into the causes of ankle sprains. A decrease in cardio respiratory endurance is found to cause earlier fatigue leading to a reduction in the protective effectiveness of musculature on the ligaments (Willems, *et al.*, 2005). Consequently, conditioning programmes that improve cardio respiratory endurance may reduce the risk of injury. Holme, *et al.*, (1999) notes the importance of balance exercises as they are reported to improve balance, which is noted as a risk factor in numerous studies (McGuine & Keene, 2006; Willems, *et al.*, 2005) but, also postural control which decreases risk of injury (Holme, *et al.*, 1999). A reduction of dorsiflexion has been noted as a risk factor in
addition to muscle imbalance across the joint, for example, elevated eversion to inversion strength ratio or lowered dorsiflexion to plantarflexion ratio causes injury (Braun, 1999). Studies have additionally found that men with a higher body mass index are at an increase risk of ankle injury, whereas with females no significant differences were found between different body mass indexes and risk of injuries (Waterman, et al, 2010).

The most common risk factor for an ankle sprain is history of the injury (Thacker, et al, 1999). It has been noted that risk of re-injury is high at a rate of 80% (Hertel, 2000). Willems, et al, (2002) state that the reasons why ankle sprains tend to recur are unclear. However, Hertel, (2000) suggested that recurrence of ankle sprains are due to functional instability and mechanical instability of the joint. In a more recent study by Malliaropoulos, et al, (2009) history of ankle injuries and a premature return to sport are identified as key factors to recurrence of ankle sprains.

2.4 Effects of an ankle sprain
As with most sporting injuries an ankle sprain results in pain, loss of playing or working time and medical expenses (Fong, et al, 2007). An ankle sprain can be graded into three classifications depending on the severity of the injury. Generally sprains are graded on the severity of the signs and symptoms of the injury (Wolfe, et al, 2001). A grade I tear involves a partial tear of the ligament with mild tenderness and swelling, slight or no function loss and no mechanical instability. A grade II tear involves an incomplete tear of the ligament with moderate pain and swelling with some loss in function and mild mechanical instability. A grade III tear involves a complete tear of the ligament with severe swelling, total loss of function and severe mechanical instability. A study by McGuine and Keene, (2006) used the number of days lost from participation due to the ankle sprain to class how severe the injuries were. The authors reported that for a minor sprain, one to seven days were lost, for a moderate sprain eight to 21 days were lost and for a severe sprain more than 21 days were lost. The mean number of days lost were 7.6 days ranging from two to 26 days. One of the strengths of this article was it used a large mixed sample size of 765, with a split of 523 girls and 242 boys, however, the male participants were outnumbered by female participants by a ratio of 2 to 1. As this
The study was aimed at basketball and football players in high school. It is very focused at these two sports therefore could not be used across other sports, and also due to the uneven ratio was biased to females.

Initially, after an ankle sprain, range of motion is lost due to the swelling caused by the trauma of the injury (Wolfe, *et al.*, 2001). Due to this loss of range of motion the strength of the ankle is also reduced (Holme, *et al.*, 1999). In addition to swelling there is pain. Studies have established that during the first two months pain rapidly decreases after which it continues to decrease but at a much slower pace (van Middelkoop, *et al.*, 2012; van Rijn, *et al.*, 2008). A study by Hertel, (2000), identified several factors that following a lateral ankle sprain results in functional instability. The factors identified were balance defect resulting in an increase in postural sway, decreased ability to sense position of the ankle joint, delayed activation of the peroneal muscles in response to sudden inversion, weakness of the muscles which evert or invert the ankle and loss in dorsiflexion range of motion. Other studies have also identified a defect in ankle strength after ankle injury (Fox, *et al.*, 2008; Holme, *et al.*, 1999). A study by Holme, *et al.*, (1999), found that six weeks after the ankle injury there was a significant difference in isometric strength between the injured and non-injured ankle. The authors found that there was a significant difference between strength in the injured and non-injured side for plantarflexion, eversion and inversion but no difference found for dorsiflexion. All of the participants that took part in the study were examined by the same sports medicine physician grading their injury into four classes. These athletes undertook the same rehabilitation programme and the non-injured leg served as a control for the study. These three factors decrease the effects of extraneous variables making the results more reliable and valid. A drawback with the study is that it does not document the dominant foot of the participants. This could affect the results as other studies have documented differences between dominant and non-dominant sides (Sepic, Murray, Mollinger, Spurr, & Gardner, 1986; Fugl-meyer, Sjöström, & Wähby, 1979). Another study by Fox, *et al.*, (2008), supports the finding that plantarflexion strength decreases after an ankle injury. The authors discovered that there was a deficit in plantarflexion torque in participants with functional unstable ankles. This study also supports the finding that dorsiflexion strength is not affected, as the study did not find any deficit in dorsiflexion torque. Furthermore it
was discovered that there were no deficits in eversion and inversion torques, which contradicts the findings of the study by Holme, *et al.*, (1999). This study involved 20 participants, 12 females and eight males, with unilateral history of ankle instability and a control group of 20 participants, 15 females and five males, with no history of the injury. This was a different design to the study by Holme, *et al.*, (1999). The split of males to females was uneven in both groups of participants and therefore results are biased towards females. This could be a problem as females could react differently to an ankle sprain compared to males. Another limitation was that the inversion and eversion footplate of the dynamometer used to test strength enabled excess movement depending on the size of the foot. Thus the testing was not constant for all feet sizes, this could be the reason for the conflicting findings.

In a study by Braun, (1999), most participants reported that six to 18 weeks after the injury they were still having symptoms of ankle instability, ankle weakness, pain or swelling. The most common complaint was of ankle weakness. Another study identified that mechanical stability did not occur until at least six weeks to three months after injury (Hubbard & Hicks-Little, 2008). A limitation with this study is that it did not directly measure ligament healing but measured mechanical laxity of the ligament producing an indirect measurement of ligament healing. Van Rijn, *et al.*, (2008) conducted a three year post injury follow up which found that some patients were still experiencing symptoms from their initial injury.

### 2.5 Tests for ankle strength

Many studies have used the calf raise test to assess the function of the calf muscle-tendon unit and detect weakness in the plantarflexion muscles (Hébert-Losier, *et al.*, 2009). A study carried out by Svantesson, Österbery, Thomeé and Grimby, (1998) was aimed at evaluating the fatiguing process of the calf muscles and standardising the calf raise test. The authors clearly identified that several areas of the test require standardisation. Firstly, the velocity of the movement should be made constant. Secondly, the standing position should be at 10° dorsiflexion which will allow for greater range of motion at the joint. Finally, the height of the calf raise should be observed and be constant throughout the study. Height will influence performance, for example a low range of motion would result in less work during each calf raise resulting in the ability to perform greater
amounts of calf raises. Additionally, this study involved a 10 minute warm up protocol and provided the participants to become familiar with the activity before testing began. All of these factors helped to standardise the testing and therefore made the results more reliable. A limitation of this study is that it only had 10 healthy females between the ages of 19 and 28 as participants. As there are only female participants in the study the calf raise test may not be effective at testing calf strength in males. Therefore, more testing with greater numbers of participants, a mixture of genders and a wider range of age is needed to establish whether the test is an effective method of testing calf strength. Additionally, a limitation with the procedure is that it had no standardised termination protocol, it is terminated due to exhaustion alone.

Another study by Lunsford and Perry, (1995) tried to establish the normal value of calf raises that a healthy individual could accomplish. Similar to the study by Svantesson, et al, (1998), this study standardised the velocity of the movement to a rate of one calf raise every two seconds, this rate was also used in other studies (Ross & Fontenot, 2000). In addition to the areas of test standardisation identified by Svantesson, et al, (1998), Lunsford and Perry, (1995) identified several factors which would determine if the test should be terminated. The first factor was, if the subject leaned or pushed down on the examiner, the second was, if the subject's knee flexed, the third was, if the plantarflexion range decreased by more than 50% of the starting range of motion and finally, if the subject asks to stop. In comparison to the study by Svantession, et al, (1998), this study had a large mixed subject group of 203 with a split of 122 males and 81 females and a wider age range between 20 and 59. Firstly they concluded that the calf raise test was the best way of measuring calf muscle function in males and females, as body weight is a good equaliser. Males can produce more force than females but as they are heavier the numbers of calf raises achieved are similar to females. The authors concluded that 25 repetitions is the normal value of calf raises in both males and females. As this study had a large mixed subject group it allows the assumption that 25 repetitions is a valid ‘normal’ amount of calf raises for males and females between the ages of 20 and 59. A limitation of this study is that it only tested the dominant leg, which in this case was mainly the right leg. It was stated that previous studies have identified that the non-dominant side is stronger than the dominant side (Sepic, et
al, 1986; Fugl-meyer, et al, 1979). As a result of this it would appear reasonable to suggest that a measure of both dominant and non-dominant would have been useful.

A more recent study was carried out on gait and calf muscle endurance in patients with severe chronic venous insufficiency (Van Uden, van der Vleuten, Kooloos, Haenen, & Wollersheim, 2005). This study used the calf raise test following a protocol from previous studies similar to Svantesson, et al, (1998) and Lunsford and Perry, (1995). The calf raise test was effective and concluded that these patients demonstrated a decrease in calf muscle endurance. The calf raise protocol was standardised addressing the factors identified in the Svantesson, et al, (1998) study. The study included 15 patients and 19 healthy control participants, although only 11 patients and 15 control participants took part in the calf raise test, which is a very small sample size. However, this study shows that the calf raise test is an effective way of identifying a difference in calf muscle function between patients and healthy participants. This study did not document the dominant foot of the participants, but in contrast to other studies (Sepic, et al, 1986; Fugl-meyer, et al, 1979) this study found no differences in the number of calf raises between left and right legs therefore the documentation of dominant foot was irrelevant.

2.6 Reliability of the calf raise test
A study by Ross and Fontenot, (2000) was executed to determine the test retest reliability of the standing calf raise test. The study found that between the two test trials that there was only an average difference of 1.32 repetitions. The authors found that there was no significant differences between the results of the two test trials and therefore concluded that the standing calf raise test was a stable and reliable measure of calf performance. The study involved 17 healthy participants which were all cadets enrolled in the United States Air Force Academy, because of this all participants were of equal physical fitness as they all participated in rigorous physical activity at least five times a week. They were all free from lower limb injuries for at least 12 months. Additionally, the right foot was dominant for all participants, which made the test more reliable as it has been identified that there is a difference in strength between dominant and non-dominant sides. A flaw with the study was the small sample size of only 17 and the unequal ratio of males to
females, 13 males to only four females. As there are three times more male participants in this study compared to females the study is biased towards males. Further studies with a larger sample size and an equal gender ratio would be beneficial. The study also states that more research is required to determine whether the standing calf raise test can detect functional deficiencies in participants recovering from lower limb injuries.

In addition to the study by Ross and Fontenot, (2000), a study by Dennis, Finch, Elliott and Farhart, (2008) has provided a reliability assessment of the tests used for musculoskeletal screening protocol used in cricket and potentially in a range of other sports. One of these tests being the calf raise test. As the calf raise test is a measure of muscular endurance and requires maximal effort, multiple trials to assess reliability are not suitable. Therefore, the participants in the study only completed one trial, which was videoed and simultaneously examined by both observers. The video was then examined by both observers creating a second ‘trial’. The observers in the study did not stop the participants during testing they just noted the number of calf raises where the test would normally be terminated. The study concluded that the calf raise test is reliable with only one observer and additionally has a high inter-observer reliability, therefore, allowing for multiple observers recording measurements. Once more a limitation with this study is the low number of participants, being only 10. This is due to the setting of the study being a high performance Australian cricket team targeting cricket fast bowlers. However, as noted in the study these musculoskeletal screening protocols, such as the calf raise test, can potentially be used in a range of other sports.

A systematic review of the calf raise test by Hébert-Losier, et al, (2009), observed a total of 49 articles, 25 of which comprised a total of 1422 normal participants and 34 articles contained a total of 1524 participants affected by either orthopaedic or medical pathologies. This large spread of studies observing different types of samples and methods is a strength of the study allowing for greater understanding of the calf raise test and reliability of the test. The study states that reliability of the calf raise test can be increased by standardising the executive protocol, which reduces the variation of the test parameters. The importance of standardising variables such as body position, height of raise, velocity of the movement and
termination criteria have been strongly encouraged. A limitation with this study was despite many of the articles scoring low in the quality assessment they were still included reducing the quality of the study.

2.7 Hypothesis
The aim of this study is to use the one legged calf raise test which has been shown to be reliable (Dennis, et al, 2008; Ross & Fontenot, 2000) to assess whether plantarflexion strength is fully regained after a lateral ankle sprain. It is hypothesised that plantarflexion strength is not fully regained after a lateral ankle sprain.
CHAPTER 3

METHOD
3. Method

3.1 Pilot study

The pilot study had two aims which were to: 1) find the optimal body weight percentage that results in an average of 15 repetitions in a one legged straight calf raise test for a healthy ankle, and 2) test the reliability of a seated one legged calf raise test.

The study used six participants, three females and three males. The participants must not have experienced any lower limb problems in the last year and be between the ages of 18 and 25. Each participant was of moderate fitness, defined in this study as involvement in at least two half an hour sessions of activity a week. Body weight and dominant foot were documented before they completed a standardised warm up. The warm up before the tests included a five minute cycle followed by three sets of 15 repetitions calf raises and two sets of 15 seconds straight and bent leg calf stretches.

Firstly a one legged straight calf raise test was performed on the Smith’s machine loaded with 60% of the participant’s body weight, to the closest 2.5kg. Each participant then performed as many repetitions of one legged straight calf raises as possible, while bare foot and starting with the right leg. Throughout the movement knee extension was maintained and the height of the calf raises were observed and kept constant. The ankle started in a 12° dorsiflexion position using a standardised Flexerciser™ and finished when full range of motion was reached. A metronome (MetroTimer) timed the frequency of the calf raises, one cycle contained a one second ascending period and one second descending period. The test concluded if the participant’s knee started to flex, if the plantar flexion range of movement decreased more than 50% of the starting range of movement or participant asks to stop. Maximum repetitions for the right ankle were then collected. After a two minute rest the test was repeated on the left leg.
After a five minute rest a seated one legged calf raise test was performed on the Smith’s machine loaded with the participant’s body weight, to the closest 2.5kg. Each participant then performed as many repetitions of seated one legged calf raises as possible, while bare foot and starting with the right leg. Throughout the movement the height of the calf raises were observed and kept constant. The ankle again started in a 12° dorsiflexion position using a standardised Flexerciser\textsuperscript{TM} and finished when full range of motion was reached. A metronome (MetroTimer) timed the frequency of the calf raises, one cycle contained a one second ascending period and one second descending period. The test concluded if the plantar flexion range of movement decreased more than 50% of the starting range of movement or participant asks to stop. Maximum repetitions for the right ankle were then collected. After a two minute rest the test was repeated on the left leg.

The results from the first test, one legged straight calf raise test, displayed the average score of repetitions with a load of 60% body weight to be 15.33 to two decimal places. Therefore, from these results it was concluded that a load of 60% body weight was adequate for testing. The results of the second test, seated one legged calf raise test, displayed a wide range of repetition scores. Therefore, from these results it was concluded that the test was not reliable and consequently would not be used during testing.

3.2 Participants

23 participants (females = 13, males = 10) between the ages of 18 to 24 were used in this study. They have experienced a lateral ankle sprain resulting in a minimum loss of seven days and a maximum of three months of training and competition. The participants must have only experienced an ankle injury on one side of the body and not have experienced any other lower limb problems in the period after sustaining the ankle sprain. This reduces the effects of other lower limb injuries on the results. No complications should have been experienced with the ankle sprain such as surgery or fractures. Before participation the participants must have returned to their sport for a minimum of three months and a maximum time after return to sport for participation in this study was 36 months. Each participant was of
moderate fitness, defined in this study as involvement in at least two half an hour sessions of activity a week.

3.3 Instruments

A Smith’s machine, Figure 5, (an Olympic bar which is attached and guided along vertical rails) using a 10kg bar was used, as it improved stability during the calf raise movement (McKechnie, Young & Behm, 2007). A metronome (MetroTimer) was used to create a standardised frequency for the calf raises. A Flexerciser™ ramp, Figure 6, was used to create 12° of dorsiflexion for the starting position of the ankle.

Figure 5. Smith’s machine used for testing.
3.4 Procedure
Each participant filled out a consent form and completed a Physical Activity Readiness Questionnaire (PAR-Q). Body weight, height, dominant foot, number of days lost due to injury and injured ankle were documented before they completed a standardised warm up. The warm up started with a five minute cycle followed by two sets of 10 repetitions of calf raises and two sets of 15 seconds straight and bent leg calf stretches.

The Smith’s machine was loaded with 60% of the participant’s body weight, to the closest 2.5kg. Each participant then performed as many repetitions of one legged straight calf raises as possible, while bare foot and starting with the right leg. Throughout the movement knee extension was maintained and the height of the calf raises were observed and kept constant. The ankle started in a 12° dorsiflexion position using a standardised Flexerciser™ and finished when full range of motion was reached. A metronome (MetroTimer) timed the frequency of the calf raises, one cycle contained a one second ascending period and one second descending period. The test concluded if the participant’s knee started to flex, if the plantar flexion range of movement decreased more than 50% of the starting range of movement or participant asks to stop. Maximum repetitions for the right ankle were then collected. After a two minute rest the test was repeated on the left leg.
3.5 Data analysis

A paired T-test was conducted using SPSS statistics software to detect whether there was a significant difference in strength between the injured ankle and non-injured ankle. The significance level for a difference to be considered was set at a $P$ value less than 0.05.
CHAPTER 4

RESULTS
4. Results

4.1 Participants
23 participants were included in the study, with a gender split of 13 females to 10 males. The mean age of the group was 20.7 (± 1.33) years (range 18 – 24 years). The mean height and weight for the group was 171.2 (± 8.16) cm (range 156.2 – 183.5 cm) and 76.0 (± 14.84) kg (range 52.0 – 118.9 kg) respectively. 21 participants were dominant on the right leg while two were dominant on the left leg. 14 participants had injured their right ankle and nine participants had injured their left.

4.2 Calf raise test
Figure 7 shows that the mean number of repetitions on the injured ankle (12.65 ± 4.12) was lower than on the non-injured ankle (16.26 ± 4.77). Table 1 shows the results that were produced using the paired t-test. A $P$ value = 0.0001 ($t = 5.747$) ($P > 0.05$) meaning that the difference in the mean number of repetitions performed on the injured and non-injured ankle are significant.
Figure 7. The mean values and standard deviation for the number of repetitions of calf raises on the injured and non-injured ankles.

Table 1. Table of paired t-test outputs.

<table>
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<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
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<td>NonInjured - Injured</td>
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<td>3.01</td>
<td>5.747</td>
<td>22</td>
<td>0.000</td>
</tr>
</tbody>
</table>
CHAPTER 5

DISCUSSION
5. Discussion

The lateral ankle sprain has been identified in many studies as the most common injury in both sport and medical care (Wolfe, et al., 2001; van Rijn, et al., 2008; Hertel, 2000; Willems, et al., 2005; McGuine & Keene, 2006; Cooke, et al., 2003). History of the injury has been documented as the most common risk factor for lateral ankle sprains (Thacker, et al., 1999), resulting in a high re-injury rate (Hertel, 2000). Due to this fact it is important to understand what affects the injury has on the ankle. One of the effects following a lateral ankle sprain is the loss of ankle strength (Holme, et al., 1999; Fox, et al., 2008). Therefore, this study is aimed to investigate whether plantarflexion strength is reduced following a lateral ankle sprain.

5.1 Main findings

The results of the study found that the non-injured ankle performed a higher number of calf raises repetitions than the injured ankle. A paired t-test on these results found the difference in number of repetitions to be significant ($P < 0.05$). These findings therefore suggest that a plantarflexion strength defect is present following a lateral ankle sprain. Consequently, the hypothesis that plantarflexion strength is not fully regained after a lateral ankle sprain is accepted. This finding that there is a defect in isotonic plantarflexion strength following a lateral ankle sprain complements the findings by both Holme, et al., (1999) and Fox, et al., (2008). Holme, et al., (1999) found a defect in isometric plantarflexion strength while, Fox, et al., (2008) found a defect in eccentric plantarflexion strength following ankle sprains.

5.2 Sample selection

The number of participants in the study ($n = 23$) was fairly low. This low sample size can affect the reliability of the results (Berg & Latin, 2008), making the generalisation of the results across a population difficult (Fields & Hole, 2008). Therefore, in future studies a larger sample size is required to increase reliability and to allow for generalisation of the results across the population.
The current study observed a mixed gender sample (females = 13, males = 10), similar to past research on ankle strength after injury (Fox, et al, 2008; Homle, et al, 1999). These studies therefore do not take into consideration gender differences. It has been documented that females are at higher risk of lateral ankle sprains compared to males (Waterman, et al, 2010). Therefore, further research is required to investigate whether males and females are affected the same or differently after the injury.

The age range in the current study was narrow, only observing participants between the ages of 18 and 24 years. This narrow age range was a result of recruiting student participants from Cardiff School of Sport. However, this age range is similar to the study by Fox, et al, (2008) which had an average age of 20.65 ± 2.64. As the current study focuses on such a narrow age range it is difficult to generalise the results across all age groups. Thus, future research in this area should study whether there is a difference in how various age groups are affected by a lateral ankle sprain.

Some studies that have examined the factors that cause lateral ankle sprains and their effects have focused on a certain sport (Malliaropoulos, et al, 2009; McGuine & Keene, 2006; Fousekis, et al, 2012). The findings from these studies are therefore difficult to generalise across different sports. Thus, the current study recruited participants from various sporting backgrounds. This allowed the current results to be easily generalised across different sports.

5.3 Dominant leg
The dominant foot of the participants were documented in the current study, similar to the study by Fox, et al, (2008). It could be seen that there was a higher incidence rate of lateral ankle sprains sustained on the dominant ankle. This supports the findings by Willems, et al, (2005) that 59% of lateral ankle sprains occur on the dominant foot. However, the current study was unable to identify whether the non-dominant ankle was stronger than the dominant side as suggested in previous studies (Sepic, et al, 1985; Fugl-meyer, et al, 1979). This was due to no base line measure of ankle strength before the injury. As there may be a difference in strength between dominant and non-dominant ankles it would be
beneficial in future research to collect a base line measure of ankle strength before the injury. Consequently, a re-test of ankle strength following the injury would be more reliable taking into consideration differences in strength before injury.

5.4 Grade of injury
The current study graded the lateral ankle sprain on the number of days lost from participation, same as the study by McGine and Keene, (2006). However, other studies (Holme, et al, 1999) have graded the lateral ankle sprain of each participant in the study through examination of the injury from the same sports medicine physician. This increased the consistency of the grading, thus increasing reliability. This study observed all the different grades of lateral ankle sprains together. This allowed the results to be generalised across lateral ankle sprains as a whole. However, the three ankle sprain grades recognised by Wolfe, et al, (2001) presented distinct signs and symptoms for each grade. Consequently, the amount of ankle strength defect after a lateral ankle sprain may vary between grades. Thus, future research could test groups with different lateral ankle sprain grades to identify any differences in ankle strength defect after an injury.

5.5 Duration of return to sport
This study observed participants that had returned to sport for a minimum of three months to a maximum of 36 months. A minimum of three months was used as a study by Hubbard and Hicks-Little, (2008) found that mechanical stability of the ankle ligaments is not regained until at least six weeks to three months. The maximum return was set at 36 months, as a study by van Rijn, et al, (2008) discovered that some effects of an ankle sprain might last up to 36 months. A study by Holme et al, (1999) measured isometric ankle strength six weeks and four months after the injury. Therefore, the current study enhances knowledge on the effects of a lateral ankle sprain on ankle strength over a longer time frame than previous studies. However, future research could document ankle strength at different intervals following an injury to discover whether ankle strength improves with the duration of time playing sport.
5.6 Rehabilitation following injury

Many studies have observed the effects of rehabilitation on lateral ankle sprains (Bleakley, et al., 2010; Chinn & Hertel, 2010). The main aim of rehabilitation is to attempt to regain full range of motion, muscle strength and neuromuscular coordination following the injury (Bleakley, et al., 2010; Chinn & Hertel, 2010). A study by Bleakley, et al., (2010) found that the type of rehabilitation has an effect on the speed and amount of range of motion, muscle strength and neuromuscular coordination regained. Therapeutic exercises in the first week obtained better results than standard functional intervention. A study by Chinn and Hertel, (2010) supports that therapeutic exercises are beneficial in the rehabilitation of all lower limb injuries, not purely ankle sprains.

The current study did not question the participants on whether they completed any rehabilitation after the injury. The unknown participation in rehabilitation of participants could explain how a few of the participants gained a higher number of repetitions in the calf raise test on the injured ankle. It would therefore be beneficial for future studies to question the participants on whether they have completed any rehabilitation and if so what type. The results from different types of rehabilitation and no rehabilitation could then be compared. Thus, finding the most beneficial form of rehabilitation following a lateral ankle sprain.

5.7 Test procedure

The test procedure in this study used the standing calf raise test. The standing calf raise test has been utilised in many studies to assess function of the calf muscle-tendon unit (Hébert-Losier, et al., 2009). The majority of these studies employed the standing calf raise test to observe differences in calf strength in healthy participants or participants suffering from achilles tendon disorders (Hébert-Losier, et al., 2009). Studies by Ross and Fontenot (2000) and Dennis, et al., (2008) have both provided a reliability assessment of the standing calf raise test. The authors of both studies concluded that the standing calf raise test was a stable and reliable measure of calf performance. Additionally, a systematic review of the standing calf raise test by Hébert-Losier, et al., (2009) stated that standardising the executive procedure could increase the reliability of the test. This would reduce the variation of the test parameters.
A study by Svantesson, *et al.*, (1998) identified areas of the standing calf raise test which should be standardised. These standardised areas were followed in the test procedure executed. Firstly, the velocity of the movement was maintained constant through the use of a metronome. Secondly, the starting position was set at 12° of dorsiflexion using a standardised Flexerciser™ ramp. Finally, the height of the calf raises were observed and maintained constant through the testing procedure. Additionally, the standardised termination protocol identified by Lunsford and Perry (1995) was used in the test procedure. These factors were, one, if the participant’s knee started to flex, two, if the plantar flexion range of movement decreased more than 50% of the starting range of movement or, three, if participant asks to stop. As the test procedure followed the standardisation rules it can be assumed that the test procedure used in this study was reliable.

A limitation with the test procedure was that it was difficult to assess accurately whether the range of movement decreased more than 50% of the starting range of movement. As this was identified as a termination factor for the protocol it may have decreased reliability of the results. To increase reliability of the procedure further in future studies it may be beneficial to use a marker at 50% of the starting range of motion. The visual marker will make it easier for the observer to accurately assess a decrease in movement. Additionally, more than one observer could be used with each one noting the termination number of the calf raises and then an average of their results calculated to determine the final score. Using multiple observers and calculating an average score would enhance the reliability of the results.

5.8 Practical Implications
The results of the current study complement the findings of Fox, *et al.*, (2008) and Homle, *et al.*, (1999) that plantarflexion strength is reduced after a lateral ankle sprain. The test procedure used in the study has been shown to be a reliable method of assessing calf strength performance (Ross & Fontenot, 2000; Dennis, *et al.*, 2008). Therefore, this testing procedure could be used at different stages of rehabilitation programmes to assess their effectiveness of improving ankle strength. This would be a useful marker for the participants taking part in the
rehabilitation to increase motivation. It would also be useful for the rehabilitator as they could then adapt the programmes to maximise strength benefits of the injured ankle.

5.9 Future studies
There were some limitations with the current study, which have been identified previously in this section. The following section recommends some alterations to the study which should be considered in future research. These recommendations will help to enhance current knowledge about the effects of lateral ankle sprains on muscle strength.

The current study used a small, mixed gender sample with a narrow age range. To allow the results of future studies to be easily generalised across populations a larger sample size with a wider age range is required. It would be beneficial to additionally compare the results of different age groups to investigate whether age has an effect on the amount of ankle strength lost following a lateral ankle sprain. It would also be useful to observe whether there are any differences in the amount of ankle strength lost between genders.

Future studies could collect base line measures of ankle strength using the calf raise test at the beginning of a season. Then when a participant obtains a lateral ankle sprain during the season ankle strength can be re-tested. This method would be more reliable than the current process as it would take into consideration any differences in dominant and non-dominant ankle strength. The process could then be extended with re-tests of ankle strength at certain time intervals. This could then establish whether ankle strength increases with time.

The current study observes all the different ankle sprain grades as one group. However, it would be interesting to compare the results of different lateral ankle sprain grades to find whether the grade of the injury has an effect on the amount of ankle strength lost following the injury. To increase consistency with the grading it would be advised to use the same medical physician to examine all of the participants’ injuries.
The final recommendation for future studies would be to standardise the rehabilitation following the injury. The calf raise test could then be used to investigate whether a certain type of rehabilitation programme enhances ankle strength. Additionally, ankle strength of participants that have not undertaken any rehabilitation could be compared to those who have. This would give insight to whether ankle rehabilitation is beneficial to gain ankle strength after a lateral ankle sprain.
CHAPTER 6

CONCLUSION
6. Conclusion

The aim of the current study was to provide insight into whether plantarflexion strength is reduced following a lateral ankle sprain. An ankle sprain is documented as the most common injury in both sport and medical care (Wolfe, et al., 2001; van Rijn, et al., 2008; Hertel, 2000; Willems, et al., 2005; McGuine & Keene, 2006; Cooke, et al., 2003). The main cause of a lateral ankle sprain is the history of the injury. Re-injury rates of an ankle sprain are reported to be as high as 80% (Hertel, 2000). Therefore, it is important to understand what effects the injury has on the ankle. Past research has documented a loss of proprioception, range of motion and muscle strength following the injury (Hertel, 2000; Holme, et al., 1999; Fox, et al., 2008). Previous studies on the effects of an ankle sprain on muscle strength have only observed isometric and eccentric strength (Holme, et al., 1999; Fox, et al., 2008).

The current study found that there was a significant ($P < 0.05$) difference between the number of calf raises performed on the non-injured and injured ankles. The non-injured ankle performed a higher number of calf raises than the injured ankle. This suggests that plantarflexion strength is not fully regained following a lateral ankle sprain. The standing calf raise test used in the study has been found to be a reliable assessment of calf muscle strength (Ross & Forntnot, 2000; Dennis, et al., 2008). Therefore, the results of the study can also be assumed to be reliable. Additionally, the standing calf raise test could be used by rehabilitators to assess whether the rehabilitation programmes they are using are effective in enhancing ankle muscle strength.

In conclusion this study was beneficial in providing an insight into the loss of isotonic plantarflexion strength after a lateral ankle sprain. However, the study did have some limitations, which have been identified in the discussion with some recommendation in how to improve the study. The recommendations identified should be considered in future research, as they will help to enhance current knowledge on the effects of lateral ankle sprains on muscle strength.
CHAPTER 7

REFERENCES
7. References


APPENDICES
APPENDIX A

PARTICIPANT INFORMATION SHEET
Appendix A: Participant Information Sheet

Project Title: Recovery of calf muscle strength following a lateral ankle sprain.

This document provides a run through of:

1) The background and aim of the research.
2) My role as the researcher.
3) Your role as a participant.
4) Benefits of taking part.
5) Risks of taking part.
6) How data will be collected.
7) How the data / research will be used.
8) Participant criteria.

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

1) Background and aims of the research
As lateral ankle sprains are very common in sport, accounting for as much as 10-15% of all sporting injuries. I would like to discover whether plantar-flexor muscle strength recovers fully following a lateral ankle sprain.

2) My role as the researcher:
I will be conducting a warm up followed by a maximal strength test on both ankles.

3) Your role as a participant:
Your role is to complete the test to the best of your ability. The strength testing will firstly include a 5 minute warm up on a cycle bike, practice calf raises and straight leg and bent leg calf stretching which will be followed by maximal strength test.

4) Benefits of taking part:
The information we obtain from this study we will be able to conclude whether plantar-flexor muscle strength is regained after a lateral ankle sprain or not. With this information rehabilitation programs can be improved.

5) Risks of taking part:
As the study requires the participants to undertake a maximal strength test this may result in some muscle soreness.

6) How data will be collected
A score for each test will be collected by the researcher for the injured and non-injured ankle and entered into a spread sheet.

7) How the data / research will be used:
In agreeing to become a voluntary participant, you will be allowing me to use your score for each test and include them within a larger data set that includes the data of other participants. Your personal data will be anonymous and will not be reported alone, but within the total sample of participants.

8) Participant criteria:
- Between the ages of 18 to 25.
- Experienced a lateral ankle sprain resulting in a minimum loss of seven days and a maximum of three months of training and competition.
- Must have only experienced an ankle injury on one side of the body.
- Not have any other lower limb problems.
- No complications should have been experienced with the ankle sprain such as surgery or fractures.
- Returned to their sport for between three to 36 months.
- Must be of moderate fitness level, active for half an hour at least twice a week.

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

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

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

Sara Ruth Morgan:
Email: ST10001822@outlook.uwic.ac.uk
APPENDIX B

PARTICIPANT CONSENT FORM
Appendix B: Participant consent form

Title of Project: Recovery of calf muscle strength following a lateral ankle sprain.
Name of Researcher: Sara Ruth Morgan

Participant to complete this section: Please initial each box.

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

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

3. I also understand that if this happens, our relationships with the Cardiff Metropolitan University, or our legal rights will not be affected.

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

5. I agree to take part in this study on does plantar-flexor muscle strength recover fully following a lateral ankle sprain.

__________________________________
Name of Participant

__________________________________  ____________
Signature of Participant Date

__________________________________
Name of person taking consent Date

__________________________________
Signature of person taking consent
APPENDIX C

PHYSICAL READINESS QUESTIONNAIRE (PAR-Q)
Appendix C: Physical Activity Readiness Questionnaire (PAR-Q)

Physical Activity Readiness Questionnaire (PAR-Q)

If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you significantly change your physical activity patterns. If you are over 69 years of age and are not used to being very active, check with your doctor. Common sense is your best guide when answering these questions. Please read carefully and answer each one honestly: check YES or NO.

<table>
<thead>
<tr>
<th>Please tick either YES or NO</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
<tr>
<td>2. Do you feel pain in your chest when you do physical activity?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
<tr>
<td>3. In the past month, have you had a chest pain when you were not doing physical activity?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
<tr>
<td>4. Do you lose your balance because of dizziness or do you ever lose consciousness?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
<tr>
<td>5. Do you have a bone or joint problem (for example, back, knee, or hip) that could be made worse by a change in your physical activity?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
<tr>
<td>6. Is your doctor currently prescribing medication for your blood pressure or heart condition?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
<tr>
<td>7. Do you know of any other reason why you should not do physical activity?</td>
<td>Yes ☐</td>
<td>No ☐</td>
</tr>
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</table>

If yes, please comment: ________________________________

YES to one or more questions: You should consult with your doctor to clarify that it is safe for you to become physically active at this current time and in your current state of health.

NO to all questions: It is reasonably safe for you to participate in physical activity, gradually building up from your current ability level. A fitness appraisal can help determine your ability levels.

I have read, understood and accurately completed this questionnaire. I confirm that I am voluntarily engaging in an acceptable level of exercise, and my participation involves a risk of injury.

Signature

Print name

Date

Having answered YES to one of the above, I have sought medical advice and my GP has agreed that I may exercise.

Signature

Date

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the 7 questions.
APPENDIX D

PARTICIPANT RAW DATA
## Appendix D: Participant Raw Data

<table>
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<tr>
<th>Subject No.</th>
<th>Gender</th>
<th>DOB</th>
<th>Age</th>
<th>Sports</th>
<th>Body Weight (kg)</th>
<th>Height (cm)</th>
<th>Dominant Foot</th>
<th>Side of injury</th>
<th>Number of Reps</th>
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APPENDIX E

SPSS PAIRED T-TEST OUTPUTS
Appledix E: SPSS Paired T-Test outputs

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E - 1