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The Effect of a Neoprene Knee Sleeve and Knee Ligament Taping On Proprioception for University Level Footballers

(Dissertation submitted under the SCRAM area)

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ABSTRACT

This investigation intended to identify the effect of a neoprene knee sleeve and knee ligament tape on proprioception within male university level footballers. It was hypothesised that the neoprene knee sleeve and knee ligament taping would show a significant difference in joint reproduction ability compared to no external supports. Additionally, a null hypothesis was implemented which suggested there would be no significant difference between the neoprene knee sleeve and knee ligament taping technique. Footballers from the Cardiff Metropolitan University first to fifth teams participated within the study (n=10). The study comprised of a single group, with all participants completing the joint angle reproduction tests under three conditions; control, neoprene knee sleeve and knee ligament tape. The tests were carried out with 7 days between each condition to reduce the learning effect and limit familiarisation. The joint angle reproduction tests were carried out on an isokinetic dynamometer, where the participant was seated and had to actively reproduce three angles; 30°. 45° and 60° of knee flexion. The participant had three attempts at reproducing each target angle, totalling 9 repetitions. From this a mean absolute error score was created from the three attempts at each angle. A combined medial collateral ligament and lateral collateral ligament taping technique was the chosen method of taping for the knee ligament taping condition, whilst the neoprene knee sleeve was a standard ‘off the shelf’ neoprene knee sleeve. Subjects wore shorts and were barefooted, and the dominant leg was the used as the test leg. Mean absolute error scores were analysed using a repeated measures ANOVA to determine if the results were significant. Results of the ANOVA found that there were no significant differences ($p < 0.05$) between the control condition and the neoprene knee sleeve, or the knee ligament taping conditions. Additionally, a Bonferroni Post-Hoc test was administered to determine whether there was any significance between the two external support methods, however no significant difference was established. Further research into this area should investigate the use of functional proprioceptive testing to test the efficacy of the external knee supports, as well as broadening the subject area to different sports, participation level and gender, to increase the statistical power of the subject area.

Chapter 1

Introduction

1.1 Introduction

Football is one of the most popular sports in the world, with an estimated 265 million registered players as of 2006 (Alentorn-Geli et al., 2009). With that number still growing, the incidence of injury will consequently increase, with football documented to have a higher incidence of injury than most team sports such as rugby, field hockey and basketball (Wong, 2005). Hawking (2001) also revealed that playing competitive football will leave you 1000 times at risk of injury compared to industrial occupations, henceforth football is generally regarded as a high risk sport. Football is an intermittent intensity contact-collision sport characterised by sprinting, jumping, walking and jogging (Ferguson & Collins, 2010). Biomechanically, the knee is exposed to both extrinsic and intrinsic forces, which in turn will further increase the susceptibility for injury, these could include playing surface, footwear or internal agents such as proprioception (Ogard, 2011).

1.2 Proprioception

Proprioception can be defined as the perception and position of body parts in the space around them, independent of vision (Tortora, 2006). The term proprioception is generally used as an umbrella term for joint position sense and Kinaesthesia (Hall and Brody, 2005). Controlling this positioning are specialised mechanoreceptors, also known as ‘proprioceptors’, which are located in both active and passive structures of joints in the body (Ferrel, 1987). These mechanoreceptors are present in all synovial joint capsules and ligaments, as well as in the dynamic structures of tendons in voluntary muscles (Rose and Christina, 2006). The contribution of the proprioceptors located in joints and muscles allows the central nervous system to gain proprioceptive feedback. This feedback can allow the central nervous system (CNS) to alter movements, which could prevent muscle injury through overloading, whilst at the same time maintaining posture and refining movement of joints (Tortora, 2006).

Poor balance, proprioception deficits, or lack of neuromuscular control have all been identified as predictors of injury risk in the lower limbs of athletes. Proprioception has been identified as a risk factor for injury in athletes (McGuine et al., 2000), and therefore it is important that prevention strategies are implemented. It has been shown that injury prevention strategies for footballers can reduce injury incidence (Gonell, Romero & Soler, 2015), Therefore justifying the testing of proprioception to assess any innate proprioceptive decrements.

1.3 Tape

Despite the lack of evidence about the efficacy of rigid tape, it is a widely used technique for the prevention of injury by practitioners (Kneeshaw, 2002). Zinc-Oxide tape is the most commonly used type of rigid tape, fixed with strong adhesive, and made so the tape is permeable, allowing skin to breathe and moisture to escape (Kiel, 2012) When applied, rigid zinc-oxide tape is generally used to stabilise a joint and minimise movement (Kiel, 2012). This type of tape can be applied using different techniques, and using different levels of tension. The higher the tension of the tape, the greater amount of force is needed to injure or destabilise the joint (Hardy et al, 2008). Whilst the main use of zinc-oxide tape is for mechanical support, it has been found that application of tape to the skin will improve proprioception (Perlau, Frank and Fick, 1995) whilst at the same time encouraging muscle activation, compared to other external supports such as braces and sleeves.

1.4 Neoprene Knee Sleeve

Neoprene knee sleeves are widely available and obtainable, and have been suggested to promote improved and safer performance during strenuous activity (Herrington, 2005). Despite being mechanically weak, the improved perceptions of stability when wearing knee sleeves contributes to their widespread use. It has also been suggested that the compression provided by the elastic used within the sleeves will improve proprioception, through stimulation of the skin (Barrett, Cobb and Bentley, 1999). The integrity and efficacy of these sleeves has been investigated on injured and non-injured participants, with mixed results (Barrett, Cobb and Bentley, 1999; Birmingham et al., 2000; Jerosch and Prymka, 1996)

1.5 Testing Procedure

Using isokinetic machines is considered one of the best methods for determining proprioception, due to their high validity, and ability to provide reliable, objective data (Keskula et al.,1996). This investigation employed the isokinetic machine to assess footballer's proprioception through joint angle reproduction, at three different angles of knee flexion; 30°, 45° and 60°. The joint reproduction tests will be done under three conditions of nothing on the knee, a neoprene knee sleeve and knee ligament tape.

Chapter 2

Literature Review

2.1 Anatomy and Epidemiology of knee ligament injuries

2.1.1. Anterior Cruciate ligament

The proximal portion of the anterior cruciate ligament (ACL) originates from the posteromedial aspect of the lateral femoral condyle, and is directed distally and anteriorly within the knee to attach into the intercondylar notch on the tibia. (Laskowski, 2013) The ACL prevents excessive internal tibial rotation and provides rotary control, whilst providing secondary restraint for the collateral ligaments in valgus and varus rotation (Smith, Livesay and Woo, 1993). If the knee is forced into any of the aforementioned positions injury can occur, whether this be with contact, for example a football tackle, or without contact, such as landing from a jump (Viskontas et al., 2008).

Injury to the ACL has received the most attention in literature surrounding knee injury. Incidence of ACL injury are the highest amongst knee injury occurrence in footballers, and also the most debilitating. Football specific studies in previous years have found that a high percentage of players under investigation gave up football because of poor knee function or fear of a new injury (Bjordal et al., 1997). In one epidemiological study carried out using Iranian professional footballers, injury to the ACL accounted for 53.2% of all knee injuries (Rahnama, Bambaeichi and Daneshjoo, 2009). This epidemiology uses professional footballers, this provides limitations in regards to the forthcoming study, due to this investigation involving university footballers. Because university sport is not professional, university teams will train considerably less than professionals, who could be more susceptible to injuries due to the increased demand on joints and musculature. ACL injury also accounts for the most time spent injured and unable to play (Daniel et al., 1994). Louboutin et al., (2009) also reveals that ACL tears have been found to lead to degenerative changes in the knee such as osteoarthritis. This high incidence of ACL injury, alongside the debilitating nature of the injury highlights the importance for an injury prevention strategy for the knee, especially in a sport such as football.

2.1.2. Medial collateral ligament

The medial collateral ligament (MCL) attaches proximally on the medial epicondyle of the femur, and moves distally and attaches onto the medial condyle of the tibia (De Maeseneer et al., 2000). The fibres consist of two parts – these are the superficial MCL (sMCL) and deep MCL (dMCL), which is attached to the medial meniscus (Phisitkul et al., 2006) Mechanism of injury for the MCL is excessive valgus force to the knee. The MCL is commonly injured alongside the ACL and the Medial Meniscus simultaneously, this is often referred to as the 'Unhappy Triad' (Ferguson and Collins, 2010)

Often overlooked within the football literature, the MCL has been identified as one of the most common injuries throughout a season (Ekstrand, Hagglund and Walden, 2009). Research conducted by Lundblad et al. (2013) in association with UEFA (Union of European Football Associations) investigated 346 MCL injuries within professional footballers and found that almost 70% of all MCL injuries occurred during contact. This is expected within the game of football, as a result of a tackle or collision with external impact on the upper part of the lower leg. This study by Lundblad et al. (2013) also reveals that a significant amount of these injuries occurred in the last 15 minutes of a game, it was hypothesised that this is due to fatigue and decreased reaction speed, causing lack of precision and technique when making a tackle. Lundblad et al. (2013) further revealed how frequent contact MCL injuries are in football, with the percentage of contact related MCL injuries (70%) in this study achieving approximately the same percentage as non-contact related ACL injuries (63%) in a similar study by Walden et al. (2010).

2.1.3. Lateral collateral ligament

The lateral collateral ligament (LCL) is an important lateral stabiliser of the knee, which prevents excessive Varus force, as well as external rotation during extension (Moulton, Geeslin and LaPrade, 2015) The femoral attachment of the LCL is located on the lateral epicondyle of the femur, with fibres extending posteriorly and anteriorly in a fan-like fashion (LaPrade et al., 2003) it is then directed distally, where it attaches to the lateral aspect of the fibular head, with fibres extending further onto the peroneus longus fascia (Terry and LaPrade, 1996)

There is a paucity of information into LCL injuries in football, Research into knee injuries in football has suggested that the LCL is usually injured alongside posterior cruciate ligament injuries, due to the direction of force needed to injure these ligaments (Ferguson and Collins, 2010). Additional research supplied by Moore et al. (2011) found that within a sample of academy age footballers, 11% of all ligament sprains occurred at the LCL, compare this to the MCL in the same study which accounted for 77% of all ligament injuries. This highlights the low incidence of LCL injuries within younger athletes. The age range within this study (8-17), albeit sport specific is difficult to use in this investigation which uses university aged participants, Schmikli et al (2011) investigated the difference in injuries between junior (4-17) and senior (18-35) male footballers in the Netherlands. The researcher revealed that the incidence of injury was twice as high in the senior group as opposed to the junior group, it was hypothesised that this was due to higher intensity of practice and match play in the senior group. Consequently, it is difficult to generalise the results of Moore et al's (2011) study to offer support for this investigation, however this research is worth noting because it is sport specific.

2.1.4. Posterior cruciate ligament

The posterior cruciate ligament (PCL) provides support in the knee by preventing posterior translation of the tibia and fibula in relation to the femur (Amis et al., 2006). Consisting of two parts or 'bundles' these are the anterolateral bundle (ALB) and the Posteromedial bundle (PMB) (Van Dommelen and Fowler, 1989). The ligament originates on the femur within the intercondylar notch, along the anterolateral aspect of the medial femoral condyle (Rosenthal et al., 2012). The ligament is directed distally and posteriorly, where it attaches along the posterior intercondylar fossa in the region of the posterior tibial plateau (Edwards, Bull, & Amis, 2007)

Research into PCL injury has gained less attention in injury and orthopaedic literature in comparison to ACL injuries, despite its importance in maintaining normal knee function (Geissler and Whipple, 1993; Covey, Sapega and Sherman, 1996). In order to injure the PCL there must be anterior force inducing posterior translation on the tibia and fibula in relation to the femur (Wind, 2004). Hyper extension of the knee is also a mechanism of injury for the PCL (Ferguson and Collins, 2010). Taking this into account, within football the goalkeeper is most at risk of suffering a PCL injury due to the threat of a rushing opponent providing an anterior blow to the knee. This scenario has been supported in research conducted by (Schulz et al., 2003) who discovered that within a study of PCL injuries, 18% of all football-related injuries were suffered by the goalkeeper. This highlights the sport specificity and rarity of the injury.

2.2 Research into Knee Ligament Injury in football

There is extensive research investigating the epidemiology of knee injuries in football. Football is described as an intermittent, high intensity contact sport, characterised by rapid acceleration and deceleration, pivoting, jumping, kicking and tackling (Arnason et al., 2004). The high emphasis based on pivoting, deceleration and contact increases the susceptibility of injury for footballers, especially at the knee joint. Research collated by Ferguson and Collins (2010) suggest that in competition, knee injuries can account for 15 – 19% of all injures, this includes strains of the muscles around the knee, sprains and contusions. Further research has revealed that within all major injuries suffered within football, injuries to the knee account for a staggering 58% (Arnason, Gudmundsson and Johannsson, 1996; Lüthje et al., 1996; Hawkins and Fuller, 1998). Research into the epidemiology of knee injuries in football however is equivocal. The studies that investigate occurrence and incidence of injuries each have different protocol regarding injury definition and the way that the information is collected. Therefore, it is difficult to compare the data, as some conduct using 'per 1000 hours' (Arnason, Gudmundsson and Johannsson, 1996) whilst others assessed injury per season (Hawkins and Fuller, 1998; Walden et al., 2010). Additionally, there is a difference in how the results are quantified, for example some invesigations present their data in percentages, whilst others present data as actual figures, thus highlighting the reliability and repeatability issues within this type of data collection.

Although there is a plethora of literature regarding the knee in football, there has been little consistency in the ability level of the participants. Studies investigating knee injury have been carried out in Iceland, Sweden, Iran and England. The majority of these studies also focus on the elite level within that countries league system. The issue with using these studies as a comparison is that the ability levels of these 'elite' performers will vary. An elite level performer in the first tier of English football will have significantly better support systems, recovery methods and training standards, than that of an elite Icelandic first tier performer. Additionally, the literature that uses professional footballers cannot be generalised to the population within this investigation, however, it will give a greater understanding on what to expect.

2.3 Proprioception

The term 'proprioception' is used to define the combination of movement (Kinaesthesia) and joint position sense (JPS), and is commonly defined as the ability to control movement of the joint (Friden et al., 2001). Proprioception within the body is mediated by neural mechanoreceptors (Grob et al., 2002). Mechanoreceptors role are to convert physical energy through tension, into nervous signals (Zimny, Schutte and Dabezies, 1986). Mechanoreceptors are vital for control of movement and postural changes, whilst simultaneously providing feedback to the central nervous system (CNS) regarding the condition of the joint (Zimny, 1988). These mechanoreceptors are found throughout the soft tissue of an individual, including the musculotendinous unit, joint capsule, meniscus and ligaments (Lephart, Pincivero and Rozzi, 1998).

Within the ligamentous structures of the knee, there are four types of mechanoreceptors. These are Ruffini receptors, Pacini receptors, Golgi-like tension receptors and free nerve endings (Duthon et al., 2005). These receptors all have a proprioceptive function, and provide the sensory element of the neural pathway when signalling knee postural changes (Duthon et al., 2005). Excessive postural changes such as rapid valgus and varus movements at the knee can lead to ligamentous injury (Koga et al., 2010). This highlights the importance of these mechanoreceptors in the prevention of injury. Further evidence highlighting the importance of proprioception in the prevention of injury comes from Caraffa et al., (1996). This investigation was a controlled study with a sample of 600 football players from 40 semi-professional or amateur teams, and found that daily, progressive, proprioceptive training using wobble boards significantly reduced the incidence of ACL injuries. This information highlights the importance of proprioceptive function within football. And additionally highlights the need for proprioceptive training. Although the following investigation does not focus on proprioceptive training, this supporting research is important due to the proprioceptive function of the neoprene knee sleeve that will be used. Additionally, the study uses a large sample of footballers from all ability levels. University football ranges from recreational to sub-elite, whilst competitive at all levels, the ability level from the fifth team to the first team will be significantly different. Therefore, a study such as Caraffa et al (1996) which uses a range of standards of footballer is very applicable and is reliable to use due to its ability to generalise to more than one population.

2.4 Use of Knee Taping

Very little is known about the effectiveness of taping for ligament support in healthy or injured knees, research into taping the ankle has suggested the only benefit of the practice of strapping and taping is psychological, Investigations by Sawkins et al (2007) and Delahunt et al (2010) found no significant differences in performance of the SEBT (star excursion balance test) test against a placebo and a control group. Sawkins et al (2007) found that although there were no differences in performance, perceptions of stability, confidence and reassurance during functional tests were positively influenced by ankle tape and placebo groups ($P<.0001$). Delahunt (2010) also found that confidence increased for 56% of participants ($P = .002$) under both tape conditions. This highlights the psychological effects of taping, whilst also dismissing the supposed biomechanical benefits of taping. Research using performers with knee ligament injuries however often report the positive biomechanical effect of taping, despite previous research suggesting otherwise. Proprioception in these patients has been shown to be significantly increased by such external support (Barrett et al, 1991), probably by stimulation of mechanoreceptors, which appears to induce the sensation of stability. Research by Engstrom and Renstrom (1998) further reveals the lack of supporting research for knee taping for footballers, by stating that there were no positive effects of knee taping or bracing. Studies into taping the ankle however could offer support for this method. Jerosch et al. (1995) found that ankle taping did improve foot positional awareness, which can assist in the prevention of ankle sprains. This highlights the effect taping can have on a joint structure.

In terms of taping improving proprioceptive ability for the knee ligaments, the literature again is scarce, however considerable evidence comes from studies into the ankle joint and anterior knee. (Miralles et al., 2010) Found that proprioception was improved with the application of tape to the ankle. This study albeit based on the ankle, can be used as support for this investigation due to the methodology. Firstly, the mean age of participants for the aforementioned study was 23.2 (S.D 4.2) thus being very similar to university aged individuals. Research has shown proprioception deteriorates with age (Deshpande et al., 2003), consequently it is important to use supporting evidence that samples young participants. Secondly the study in question uses JPS to measure proprioception, this measure is used in this investigation, enhancing the reliability of this protocol.

Taping for patellofemoral pain is more commonplace than taping for knee ligaments in the literature. Callaghan et al. (2002) investigated proprioception in the knee with patellar taping, and found that participants with low proprioceptive ability improved significantly whilst wearing the tape. This investigation also used the isokinetic dynamometer to analyse JPS and joint angle reproduction. This research suggests that taping does improve proprioception, albeit for the patellar, therefore perhaps this research could be generalised for taping techniques for the ligamentous structures of the knee. The literature presented is not sport specific, and there has been very little research at taping for the knee for footballers. Further research into knee proprioception with taping should address a sport, this will therefore offer more support to the sport based literature as opposed to the clinic based.

2.5 Use of Knee Bracing

The effects of knee braces and sleeves on proprioception, performance and injury prevention during sport have been extensively researched, with varying results. Research has focused mainly on Prophylactic Knee Braces (PKB's) with a lesser focus on neoprene knee sleeves. PKB's differ slightly to sleeves, PKB's generally have a metal frame and firm plastic shells with a fixed hinge reducing degrees of movement, whereas the knee sleeves enhance stability through compression (Mortaza et al., 2012). This compression is thought to enhance proprioception by enhancing stimulation of mechanoreceptors in the skin (MacRae, Cotter and Laing, 2011; Kruger, Coetsee and Davies, 2004).

A study conducted by Birmingham et al. (1998) testing joint angle replication (proprioception), revealed that 72% of subjects felt that the sleeve improved their overall test performance when replicating joint angles during open kinetic chain knee extension in seated and closed kinetic chain leg press. A follow up study by Birmingham et al. (2000) enhances support for this information by suggesting neoprene knee sleeves enhanced knee joint position sense during active reproduction. Within the former investigation by Birmingham et al (2000) the testing was conducted on young, (24 years +/- 2 years) healthy participants. As previously mentioned this is important for maintaining sample reliability. Further support is gathered from McNair, Stanley and Strauss, (1996) who studied normal, non-injured subjects and found an 11% improvement in JPS at the knee whilst wearing a 'knee sleeve type brace'. There are however contrasting studies that present no significant positive improvements when wearing orthoses at the knee. Jerosch and Prymka (1996) investigated people who suffered meniscal injuries and found the application of a brace did not alter JPS. This however could be attributed to the fact that the injury/area of focus was the meniscus, and not the ligamentous structures.

2.6 Appraisal of Isokinetic dynamometer when testing proprioception

In studying the field of proprioception, there are several methods that have been employed, with each method providing merits and limitations. Electrogoniometry, 2D video analysis and isokinetic dynamometry are the three most researched methods, Studies such as Birmingham et al., (1998; 2000) employed the isokinetic dynamometer to analyse joint position sense, which is the method chosen for this study.

Kiran et al., (2010) investigated isokinetic dynamometry to test proprioception (joint position sense) against the two aforementioned measures of JPS (electrogoniometry and 2D video analysis). Results of this investigation found that isokinetic dynamometry achieved 'good to excellent' correlations between electrogoniometry (0.63-0.92). 2D video analysis on the other hand held only 'fair' results (0.41-0.63) against the other two methods. This data indicates the validity of the dynamometer method and warrants its inclusion in this investigation. Nevertheless, there are limitations to the use of this method, the isokinetic dynamometer is a seated, non-weight bearing activity, therefore has been criticised due to its non-functional nature (Kiran et al., 2010). Despite these issues, the use of a dynamometer is considered as the gold standard for testing, because it gives the researcher complete control over what is being tested, and in terms of measurement, it is one of the most precise measures (Stark et al., 2011)

2.7 Direction of Further Research

In terms of football and proprioceptive research, there is a distinctive lack of research that supports the use of knee bracing and taping, this is reinforced by findings by Engstrom and Renstrom (1998) who revealed no supporting research into taping or bracing of knees, for footballers. Additional research provided by Mortaza et al. (2012) also highlights the lack of supporting research within a sample of healthy, uninjured participants. Comparison of a neoprene knee sleeve to a no-brace condition and a PKB group found no negative effects of sleeves compared to PKBs, but similarly no significant difference or effect on participant performance were observed during functional and isokinetic tests at the knee. Gerrard (1998) reviewed the types of external knee supports available in rugby union, in particular bracing and taping, and found a paltry of research into taping the knee, Gerrard (1998) suggested that due to the movement of the knee, tape becomes ineffective after short bouts of exercise and loses its prophylactic function. Despite the lack of supporting research taping is one of the most popular injury prevention methods for school, university and professional teams, with some American institutions spending tens of thousands of dollars on athletic tape (Anderson et al., 1992)

Due to the aforementioned lack of research support for taping, and the equivocal nature of research between knee sleeves and PKB’s, it allows for a comparison between taping and another external knee support method. Furthermore, the use of preventative/protective measures for a non-injured athlete, and the benefits they provide is controversial. This henceforth opens the door to research that aims to clarify the use of taping and bracing as a preventative measure (Frontera, 2003).

2.8 Aims and Objectives

The aims and objectives of this investigation were to see whether the use of a neoprene knee sleeve, or rigid knee ligament support tape would improve a footballer's proprioceptive ability. Additionally, comparison of the two different interventions (tape and knee sleeve) could inform individuals as to which method of support is more beneficial.

2.9 Hypothesis

From reviewing the literature, several hypotheses can be created for this investigation.

H1: Wearing rigid knee ligament tape will improve proprioceptive ability in the knee compared to no tape

H2: Wearing a neoprene knee sleeve will improve proprioceptive ability in the knee compared to wearing no sleeve

Null: There is no difference in proprioceptive performance between taped, and sleeve conditions compared to the knee with no external support.

Chapter 3

Methods

3.1 Participants

Ten university level footballers playing for any one of the five university football teams at Cardiff Metropolitan University volunteered for participation in this study. Nine of the ten players were outfield players; Defenders (n=4), Midfielders (n=3) and Attackers (n=2) with one goalkeeper. The average age (20.8 years +/- 0.92), height (179.39cm +/- 4.97) and weight (77.57kg +/- 6.32) were recorded. All subjects were provided with an information sheet stating the objectives of the study and were asked to sign a consent form before participating in the study in order to gain informed consent. Participants were also excluded if they had any of the following contraindications.

- Knee ligament damage in the dominant leg
- Serious lower leg injury in the last year
- Neurological issues
- Tape allergy

3.2 Experimental Summary

This study was a quantitative, repeated measures, same subject design with control, independent and dependant variables. The study was conducted over three weeks during the football season. Testing for the participants was over three sessions, with seven days in-between each intervention. The control variable was the knee with no tape or bracing. The independent variables for this investigation are the two interventions on the knee.

- Knee with a neoprene knee sleeve
- Knee applied with knee ligament tape

The dependant variable was proprioception at the knee. Proprioception of the knee was measured by comparing target angles and the participants' attempt to reproduce the target angle, measured in degrees. The target angles were 30, 45 and 60 degrees. The results were measured as mean absolute error (MAE) between control and intervention sets of data.

3.3 Procedure

Subjects were informed prior to testing to wear shorts, and that testing would be conducted without shoes or socks on. Subjects were also allocated a time to attend the session. The testing was undertaken using a Cybex Norm Isokinetic Dynamometer (Cybex 350 Isokinetic Test and Exercise System). To carry out the test the dynamometer needs several adaptors; Knee/hip pad, contralateral limb stabiliser, knee and hip adapter and lumbar cushion. The position of the dynamometer was adapted depending on right or left leg dominance, and on limb length. The subject would sit on the dynamometer, with a strap holding the ankle and the thigh. Once the subject is secure and in position the range of movement (ROM) of the participant’s knee flexion and extension was tracked using HUMAC NORM software.

3.4 Measuring proprioception

Once all preliminary checks were completed the subject was then blindfolded. To initiate the test, the participant’s dominant leg was passively moved to one of the test angles (30°, 45°, 60° of knee flexion) by the examiner and held for five seconds. The subject was instructed to try and remember the target angle with the instruction ‘this is the position of your knee that I want you to remember’ after verbal confirmation of this instruction the participant's leg will be returned passively to the starting position of full extension. The participant then, in their own time, attempted to reproduce the target angle. Once the subject felt they had achieved their target position they were asked to verbally confirm this with ‘OK’ or ‘YES’. The subject then returned the leg to the starting position. The participant then repeated the movement a further two times, totalling 3 repetitions per test angle, or nine in total. The subjects were also allowed one practice attempt at 15° flexion, prior to initiation of the test. There should be seven days between each testing condition, so nothing on the knee – 7-day gap – knee sleeve condition – 7-day gap – knee tape condition.

Using the above protocol, the subject would then complete the same test whilst wearing a neoprene knee sleeve (KS06 Compression Knee Sleeve, Orthosleeve). The knee sleeve was applied by the examiner only to maintain inter-tester reliability. Seven days later the subject would complete the third intervention – knee ligament taping. The taping technique was adapted from Macdonald (2009) and is a combination of MCL taping and LCL tapinging methods. The tape used is listed below.

- Tan Zinc Oxide (Z/O) tape 3.8cm X 13.7m (Tiger tan tape, Tiger Tapes ©)
- White Z/O tape 3.8cm X 13.7m (Tiger tape, Tiger Tapes ©)
- Hypafix 5cm X 10m (Hypafix ®, Smith & Nephew Healthcare Ltd)

Hypafix was placed around the thigh, around 3 inches above the base of the patella, and around the calf, around 2 inches below the tibial tuberosity. White Z/O was then placed around the thigh and calf at these anchor points. For the MCL support two overlapping strips of white Z/O tape were directed medially and posteriorly from the tibial tuberosity, over the medial joint line, to attach on the proximal anchor. Two more overlapping strips of white Z/O were then placed at the posterior medial aspect of the distal anchor, directed anteriorly and proximally to form a cross over the medial joint line.

This technique was repeated on the lateral side, for the LCL support. Two strips of White Z/O tape directed from the tibial tuberosity to the posterior lateral side of the thigh, crossing the lateral joint line. Two more overlapping strips of white Z/O are placed from the posterior lateral calf directed over the lateral joint line, and attaches to the proximal anchor above the patella.

Two overlapping vertical strips from distal to proximal anchor were applied to the medial and lateral sides of the knee for added support. Tiger tan tape was applied over the anchor points to secure the supporting strips. Figure 1 below shows the finished article prior to testing. The subject will then complete the protocol outlined above.

Figure 1 - Anterior (left) Medial (centre) and Lateral (right) views of tape protocol

3.5 Statistical Analysis

All data was accrued through excel and Statistical Package for the Social Sciences (SPSS) statistical software. During testing all data was accumulated and saved onto a Microsoft Office Excel spreadsheet. Participants were recorded as a numerical value (1-10) instead of their name in order to protect anonymity. For each condition (bare knee, sleeve, knee tape), the three attempts at each joint angle (30°, 45°, 60°) were combined to create a mean absolute error score (MAE). From this the scores for the testing were transferred to SPSS for further analysis. A one-way repeated measure analysis of variance (ANOVA) was used to compare variables; bare knee, neoprene knee sleeve tape and knee ligament tape within each joint angle (30°, 45°, 60°) with a significant value set at <0.05.

Chapter 4

Results

4.1 Introduction

The purpose of the study was to understand the difference between different external supports for the knee and the effect they had on proprioception, whilst reproducing joint angles on a dynamometer. All data was collated and the mean absolute errors for the conditions were analysed using a one way repeated analysis of variance test (ANOVA). This was done to determine if there was a significant difference between control condition and the sleeve and taping interventions. Pairwise Comparison was also employed for the data to see if there was any significant difference between interventions.

4.2 Subjects

Ten Subjects from the University Football Teams 1st XI – 5th XI agreed to participate in the study and complied with all procedures and conditions. Descriptive Statistics for these participants are presented in Table 1.

Table 1: Descriptive Statistics for the participants (n=10)

	Age (years)	Height (cm)	Weight (kg)
Mean (Standard Deviation)	20.8 (± 0.92)	179.39 (± 4.97)	77.57(± 6.32)

4.3 Joint Reproduction Tests

Figure 2 displays the mean absolute error scores for each attempted joint angle against intervention on the knee. Observation of this figure suggests there is a small difference between the different knee supports, and the error at each joint angle. However, in order to determine whether the difference was significant, an analysis of variance was needed to define this.

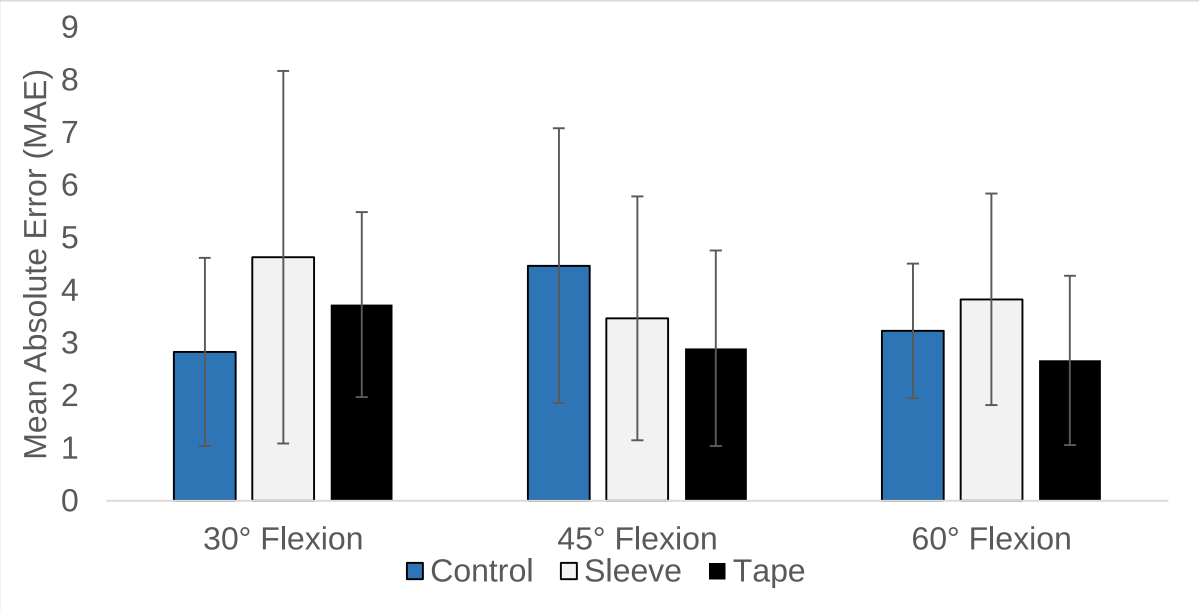

Figure 2: Mean absolute error scores for each angle attempted, and for each condition of the knee.

4.4 Test Angle 30°

At each joint angle, the participant had three attempts to reproduce the angle. For the test angle of 30° the three attempts were merged to create a mean absolute error score, this was completed for each condition of the knee. This data for the 30° testing angle is presented in Table 2 below.

Table 2: Mean absolute error and standard deviation for control condition (n=10)

	Control	Sleeve	Tape
Mean Absolute Error (MAE)	2.83 ± 1.79	4.47 ± 3.54	3.23 ± 1.76

4.4.1 One Way Repeated ANOVA

A one way repeated measure ANOVA was employed to identify whether there were any significant differences between each knee condition at 30° of knee flexion. Mauchly's test of sphericity revealed that sphericity could not be assumed ($p = 0.015$) at the level of significance set, which was $p=0.05$. therefore, Greenhouse-Geisser was used as an adjustment, setting the significance at p = 0.240. This shows no significance observed for each condition at 30° flexion.

4.5 Test Angle 45°

The three attempts for each condition at the test angle of 45° of knee flexion are displayed below in Table 3, Mean absolute error and standard deviation were collated.

Table 3: Mean absolute error and standard deviation for sleeve condition (n=10)

	Control	Sleeve	Tape
Mean Absolute Error (MAE)	4.63 ± 2.61	3.47 ± 2.32	3.83 ± 1.86

4.5.1 One Way Repeated ANOVA

A second one way repeated measure ANOVA was used to discover any significant differences within the three conditions at 45° of knee flexion. With significance set at $p<0.05$, Mauchly's test of sphericity was ran to determine sphericity. The level of sphericity was found to be p = 0.552, therefore sphericity can be assumed. From this sphericity was set at p = 0.568, henceforth no significance was found at the test angle of 45°.

4.6 Test Angle 60°

Mean absolute error and standard deviation were collated for the three knee conditions at the test angle of 60°. The means were formed from the three attempts at reproducing 60° of knee flexion. These are displayed in Table 4 below.

Table 4: Mean absolute error and standard deviation for tape condition (n=10)

	Control	Sleeve	Tape
Mean Absolute Error (MAE)	3.73 ± 1.28	2.90 ± 2.01	2.67 ± 1.61

4.6.1 One Way Repeated ANOVA

A final one way repeated ANOVA was run to determine any significance between the results for the testing angle of 60° with significance set at $p = 0.05$. Mauchly's test of sphericity was employed to measure sphericity, the test revealed sphericity was measured at $p = 0.547$, henceforth sphericity could be assumed, as it is above the level of significance ($p = 0.05$). With sphericity assumed, a significance value of $p = 0.158$ was given, therefore there is no significant difference within this testing angle, as the value is higher than $p<0.05$.

4.7 Summary

Using the above results, it is evident that there were no significant differences between the knee condition variables, at any of the three angles that the participant attempted to reproduce. With significance set at $p<0.05$, all testing angles achieved higher than this figure. Furthermore, a Bonferroni Pairwise comparison was run to analyse any differences between conditions, for example control versus sleeve, sleeve versus tape, control versus tape. Similarly, this also showed no significance between the conditions, at any of the three testing angles, this is displayed in Table 5.

Table 5: Significance of pairwise comparisons between conditions (n=10)

	Significance between conditions at each testing angle (p<0.05)		
	30°	45°	60°
Control versus Sleeve	P =0.708	P =0.657	P = 0.609
Control Versus Tape	P =1.000	P = 1.000	P = 0.114
Sleeve Versus Tape	P = 0.587	P = 1.000	P = 1.000

Chapter 5

Discussion

5.1 Purpose of study

The Purpose of this study was to see if the use of a neoprene knee sleeve or knee ligament tape improved proprioceptive ability in young, uninjured footballers. As previously mentioned the occurrence of injury for footballers is high (Wong, 2005). Ferguson & Collins (2010) also highlighted that knee ligament injuries account for around 15% of all football injuries. This henceforth highlights the susceptibility for injury that the knee holds. The study aimed to see if employing these knee support methods had any effect on proprioception, having poor proprioceptive ability has been linked to a higher risk of injury (McGuine et al., 2000). Therefore, testing proprioception was used to assess the efficacy of each knee support. In a wider sense, the study was used to see if the neoprene knee sleeves, and knee ligament tape could be worn as a preventative measure as opposed to a treatment option.

5.2 Hypothesis

There were several hypotheses created for this investigation, from the literature it has been suggested that taping and bracing at the knee and ankle improve proprioception for young healthy individuals (Jerosch et al.,1995; Miralles et al., 2010). Therefore, it was assumed that a neoprene knee sleeve, and a knee ligament taping technique would improve proprioception compared to the control condition, respectively. Additionally, due to the lack of literature comparing the two methods against each other, a null hypothesis was created which stated that there would be no difference in proprioception between a neoprene knee sleeve and knee ligament tape. The primary outcome for this investigation was that there was no significant difference in reproduction of joint angles between any of the conditions; control, neoprene knee sleeve and knee ligament tape. This section will aim to discover the factors that contributed to these results, and explain why they may have occurred.

5.3 Explanation of Findings

5.3.1 Testing Procedure

The testing procedure used in this investigation using the isokinetic dynamometer has been used extensively in the literature (Birmingham et al, 1998, 2000; Kiran et al., 2010). In the study conducted by Kiran et al (2010), which assessed three methods of joint position testing at the knee, suggested that for seated non-weight bearing angle reproduction tests, the isokinetic dynamometer is the most consistent method of doing so, this henceforth warranted its inclusion in the study. Although the isokinetic dynamometer is very effective for joint position sense testing, it is worth noting that the isokinetic dynamometer is calibrated to an error of 1°, therefore would not have recorded any error for each attempt that was within 1°. This reduced sensitivity to angular change could have had an impact on the results as it would have reduced the absolute error scores of each participant.

5.3.2 Proprioception

As previously identified, proprioception is governed by mechanoreceptors which lie in the muscle spindle fibres and joint capsules (Rose and Christina, 2006). During active movement, mechanoreceptors in muscle spindles play a dominant role in the conscious effort to reproduce joint angles (Staines et al., 1997). For example, in this investigation, participants would perform knee flexion to reproduce the target angles, therefore the hamstring group would be the muscle concentrically contracting to flex the knee. It has been suggested that during active movement, interference in signals from the joint tissue and mechanoreceptors in the surrounding muscle groups can cause changes to the kinaesthetic information supplied back to the muscle from the CNS. Investigation by Collins et al (1998) found that the ability to detect an electrical twitch was diminished during a reaching task, and voluntary wrist movements. Further evidence for this comes from Wise et al (1998) who found a similar effect in the forearm, with participants less able to detect movement of the forearm when the muscles of the elbow are co-contracted. Although these investigations may involve different testing procedures, it could potentially offer a similar explanation to the results in this investigation, with interference of afferents potentially caused by mechanoreceptors of the knee joint capsule, and the quadriceps muscle group.

In regards to proprioception, the mean age of the sample (20.8 ± 0.92) could offer some insight as to why the results were so insignificant. It is well documented that proprioceptive ability is diminished with age (Ribeiro & Oliveira, 2007). Barrack et al (1984) investigated proprioception at the knee joint for a group of professional ballet dancers, and found that joint position sense was significantly enhanced in the young members of the group. A plethora of literature has also looked at the knee joint, and the effects of ageing it has on proprioception, Hurley, Rees & Newham (1998) investigated Joint position sense, balance tests, and functional tests on young, middle aged and elderly individuals, and found a significant decline ($r = 0.603$; $P < 0.001$) in joint position sense for the older group, compared to the younger and middle aged group. This was the same for the functional tests and balance scores. From the literature, it is fairly accepted that the age is a factor in the decline of proprioception at the knee (Kaplan et al, 1985; Marks, Quinell & Wessel, 1993), therefore for this investigation, it is fair to say that the young males that completed this investigation should not have poor proprioception, thus giving reason as to why there was no significance in the results.

In addition to the age of the participants within the investigation, injury status of the participants could have an impact on the results, as previously mentioned before, damage to the mechanoreceptors in the muscle fibres, ligaments and joint capsules has been shown in the literature to reduce proprioception (McGuine et al., 2000). In this investigation, the sample were uninjured during testing, and were excluded if any injury to the dominant leg occurred. The aim of the investigation was to see if wearing the external knee support would prevent injury, however it is important to note that the use of the knee sleeve, and application of tape are widely used as a treatment method and for the rehabilitation of ligamentous knee injuries (Paluska & McKeag, 2000). Research conducted on professional footballers in Nigeria found that balance was significantly worse on the injured leg compared to the non-injured leg of the athlete with lower limb musculoskeletal injury. This is supported by research by Evans et al (2004), who found that injured participants demonstrated balance deficits on their injured leg, compared to the non-injured leg for patients with Lateral ankle sprains. Although balance testing is different to joint position tests, and the latter investigation focuses on the ankle, balance or kinaesthesia comes under the umbrella term of proprioception, so the literature supports the idea that injury disturbs proprioception.

This information could offer an explanation as to why the results were not significant, due to the participants in this investigation having no injury, no proprioceptive deficits should have been observed. Henceforth, the external supports had no effect on the proprioceptive ability, both positively or negatively.

5.3.3 Knee Ligament Tape and Neoprene Knee Sleeve

This investigation intended to discover whether the use of an external knee support would improve proprioception for footballers, and which method (taping or neoprene knee sleeve) is most effective. Due to the findings reporting no significant changes in proprioception it brings into question the efficacy of the external knee supports. Knee taping is a method that is prevalent in sport. The literature shows extensive support for taping for patellar tracking (Callaghan et al, 2002; Baker et al, 2002) and for support of the ankle and subtalar joints (Jerosch et al., 1995; Miralles et al., 2010). Conversely, for support of the knee ligaments the literature is scarce, and support is minimal. This investigation showed no improvements compared to the un-taped condition, nor did it show any significant difference to the neoprene knee sleeve. This therefore suggests that taping the knee is not an effective measure of injury prevention. One reason for this could be the durability of the tape, with Frankney et al (1993) suggesting that up to 50% of the tapes function is lost after 15 minutes of exercises such as jumping, pivoting and running, movements important within football. Although the testing for this investigation was open-kinetic chained and not using functional movements, it is important to note how little time it takes for tape to become inefficient.

For the use of a neoprene knee sleeve, Kaminski et al (1996) looked at injury free subjects, and found no effect of a knee brace on active and passive joint angle replication, this is further highlighted by Birmingham et al (2000) who only found significance in non-axially loaded open kinetic chain joint angle reproduction, with no significance for loaded reproduction tests, which additionally raises the issue of the functionality of the testing procedures. Research by Bottoni et al (2013) also finds similar results to this investigation, showing that knee supports do not positively or negatively influence knee proprioception of uninjured active subjects. This evidence, alongside the evidence from this investigation indicates that neoprene knee sleeves have no positive or negative effects on proprioception, so should not be prescribed or advised for use if the individual is uninjured.

5.4 Limitations and Direction of Further Research

For this investigation the sample were (n=10) young, male footballers from the university teams. First of all, it is important to note the size of the group, sample size is always a matter of compromise between available resources such as time and availability and the objectives of the investigation. Having a small sample for this investigation ensured safety and validity was high, however due to the ease of the testing, a larger sample would have been desirable for this type of testing. The small sample meant that the results were hard to interpret due to the lack of statistical power, potentially with a larger sample a trend may be discovered from the results. The investigation was aimed at footballers due to the high incidence of knee injuries in the sport (Ferguson and Collins, 2010), however, sports such as rugby, basketball and American football also have high incidence of knee ligament injuries, and the use of external knee supports in these sports is also documented (Gerrard, 1998). Restricting the sample to footballers therefore limits the ability to generalise the results to other sports. This investigation also only used males as the sample, the decision to only use males was one based on ease of recruitment, however conducting the same study on women participants may have produced different results. Females are at higher risk of knee ligamentous injury, particularly ACL and MCL injuries. This fact has been highlighted by an investigation by Arendt & Dick, (1995) who investigated knee injury patterns of male and female collegiate soccer and basketball players. They found that for both sports over a period of four years, women suffered more than twice as many ACL injuries than the men in the same sport. This phenomenon could be attributed to several possibilities, such as limb alignment (Arendt & Dick, 1995) muscle strength, and joint ligament laxity (More et al., 1993). The significantly higher susceptibility to knee ligament injury could therefore offer an opportunity to investigate preventative measures for knee injuries in females.

Further research into this area should take into consideration the sample, firstly a larger sample is required to enhance the statistical power of the results. Secondly, widening the criteria to all team sports, or all contact sports could allow for comparison of the results between different sports, this potentially could offer information as to is a performer from one sport more susceptible to injury than the other, and which sport would benefit more with the use of preventative measures. Similarly, further research could be done comparing males and females, due to the increased risk of female knee injury, testing the effects of external knee supports could provide information for a female population.

In terms of the testing procedure, despite its high validity and precision, it must be noted that the Isokinetic dynamometer is not a functional test, therefore lacks ecological validity (Han et al, 2016). Having the participant strapped to the machine, and with vision blocked, means the testing does not reflect normal functioning of the proprioceptive system in a real world situation, where footballers move freely in normal weight-bearing condition, with both visual and auditory information available (Han et al., 2016) The open-kinetic chain movement is good for assessing JPS however if the results are to be applied to a competitive game environment, the test must reproduce some of the demands of football. Han et al (2016) reviews the effect of several different testing procedures for proprioception, including joint position reproduction, and a testing method called active movement extent discrimination assessment (AMEDA). From the literature, the AMEDA test method would be a more effective method for assessing proprioceptive performance during active functional movements that occur in sport. Football is a game where in terms of proprioception, signals and stimuli are changing every second, AMEDA testing was developed to analyse the response to a stimulus in the presence of uncertainty (Faisal, Selen and Wolpert, 2008). This therefore makes such testing very ecological valid due to the influence of extraneous variables, which would be present in a football situation. Further research into testing external knee supports for sporting performers should use functional tests, or at least a combination of functional and clinical testing. Cameron and Adams (2003) assessed the movement discriminations for kicking of Australian Rules footballers, essentially the proprioception of the kicking leg of the participant. In this investigation, they used a functional test where the individual, without any visual cues, would perform a kicking motion, whilst making contact with a stop plate, this assessed the control of the limb, which requires proprioception. A test such as the one used in Cameron and Adams (2003) would be an appropriate functional test which could determines proprioception at the knee due to the fact that it is weight bearing, working at the knee, and it mimics the kicking demands of football.

As previously stated, injury has a negative effect on proprioception. This investigation used healthy, uninjured individuals, whilst this was acceptable for the study as it was looking at prevention of injury, however the study could have benefitted from introducing stress to the knee and surrounding muscles, such as a fatigue protocol. During a football game, fatigue is experienced due to the demands of the game (Reilly, Drust & Clarke, 2008). Several investigations have demonstrated a significant decline in knee proprioception after a fatigue protocol (Roberts et al., 2004; Lattanzio et al., 1997). It is thought that fatigue effects the response of the mechanoreceptors within muscle fibres, and diminishes their ability to detect changes in limb movement, and joint position (Hiemstra, Lo & Fowler, 2001). Changela, Selvamani & Ramaprabhu (2013) conducted a simple cycling test ensuring the participant exceeded 60% of their predicted maximal heart rate, and found that proprioception declined following the fatigue protocol, compared to before the fatigue was induced. Further investigation should induce fatigue before testing proprioception to attempt to improve ecological validity and make it more applicable to a real footballing situation.

Chapter 6

Conclusion

6.1 Conclusion

The purpose of this investigation was to see whether the use of a neoprene knee sleeve or knee ligament support taping could enhance proprioception at the knee in a sample of university level footballers. The aim was to see if these methods could be used as a preventative measure, and secondly, see whether one support is more effective at enhancing proprioception than the other.

Football is the most popular sport in the world (Alentorn-Geli et al., 2009), played by all ages at different ability levels. Knee injury for football is prevalent in all levels of participation, accounting for 15-19% of all injuries (Ferguson & Collins, 2010). Furthermore, the game of football is a high intensity, intermittent contact sport which demands the performer to jump, pivot, sprint, and tackle, thus, demonstrating that football is a high risk sport. Furthering this, it is well accepted in the literature that poor or diminished proprioception can lead to injury (McGuine et al., 2000; Gonell, Romero & Soler, 2015). Therefore, by identifying proprioception as a weakness, it gives reasoning for preventative measures to be implemented to reduce chance of injury. Knee ligament taping and neoprene knee sleeves are some of the most commonly used external supports for the knee, despite there being a lack of support for each measure. This therefore allowed for a comparison between the two methods to determine their efficacy.

The main findings of this investigation was that there was no significant difference between the control condition and any of the external knee supports, nor was there any significance between the neoprene knee sleeve and knee ligament tape (see Table 5). The results therefore support the null hypothesis, which states there would be no difference between the two external supports. There are many factors which may have impacted the lack of significance of the results, one being the lack of participants within the study (n=10), which would have reduced the statistical power of the investigation. Other external factors such as the age of the sample, non-injury status of the individuals and fatigue level may also have affected the results. As previously discussed, all these factors all have an effect on proprioception. For example, Hurley, Rees & Newham (1998) discovered that elderly individuals have poor proprioception compared to middle aged and younger individuals, the sample in the present study had a mean age of 20.8 (±0.92) years therefore should not present with poor proprioception, thus demonstrating why the external supports had no significant effect. Additionally, the fact that the participants were healthy, uninjured and unfatigued meant that their proprioceptive ability would not have been damaged or diminished. Henceforth demonstrating why external supports, which are generally used for enhancing proprioception in participants with knee injuries, would have no effect in this case as a preventative measure for non-injured participants.

In summary, the use of a neoprene knee sleeve and knee ligament taping on young, healthy, uninjured footballers had no effect on proprioception. Additionally, the study offers no support for either method against the other as a method of knee ligament support. Further research into this area must take into account several aspects, particularly using functional testing to determine the efficacy of these external knee supports against each other, in order to mimic real-life. Also, this research suggests that the external knee supports offer no improvements in proprioception for uninjured participants, therefore further research should attempt to disrupt the proprioceptive ability of the participants, for example introducing muscular fatigue to the muscles acting at the knee. Practically, the present investigation could inform individuals who wish to, or already use external knee supports that there is no difference between the two methods that were tested, allowing them, alongside other research and personal preference to make an informed decision as to which support if any, they wish to use.

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APPENDICES

APPENDIX A

PARTICIPANT CONSENT FORM

Reference Number:
Participant name or Study ID Number:
Title of Project: The effect of knee ligament taping and neoprene knee sleeves on proprioception for university level footballers.
Name of Researcher: Tom Burden

Participant to complete this section: **Please initial each box.**

1. I confirm that I have read and understand the information sheet for the above 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 I am free to withdraw at any time, without giving any reason. ☐

3. I am aware of the risks of the investigations, and are willing to carry out the investigation regardless of these risks. ☐

4. I agree to disclose any relevant medical history if queried ☐

5. I agree to take part in this study ☐

______________________________ ________________
Signature of Participant Date

______________________________ ________________
Name of person taking consent Date

____
Signature of person taking consent

** When completed, 1 copy for participant & 1 copy for researcher site file*

APPENDIX B

PARTICIPANT INFORMATION SHEET

A. Research Question

"The effect of knee ligament taping and neoprene knee sleeves on proprioception for university level footballers"

B. Aims

- The aims of the study are to test whether the different type of knee support will affect proprioception (joint position sense), and the difference between the three conditions.
- You will complete three conditions – control, knee sleeve and tape.

C. Timing

- You will be required to attend NIAC at a pre-determined time agreed by both you the participant, and me, the researcher.
  The time it will take to complete the procedure will be 20-40 minutes per person depending on the condition. The longer session is due to the time needed to apply the tape to the knee.

D. Recruitment

- Recruitment of participants will be from the university football teams.

E. Benefits

- Will provide the participant with useful knowledge on the prevention of knee injury and the importance of proprioception for footballers.

F. Risks

The main risk of this investigation is the pain caused by the removal of the tape, which can cause short term pain. You are entitled to drop out whenever you please.

G. Financial

- There are no financial inducements for this investigation

H. Confidentiality

- During the investigation, no names, medical history, age, weight or test result will be disclosed to anyone but yourself. When data is input to the statistical analysis software, name, and age will be replaced with numbers or letters.

APPENDIX C

SPSS OUTPUT FOR 30° FLEXION

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Condition	Sphericity Assumed	14.484	2	7.242	1.548	.240
	Greenhouse-Geisser	14.484	1.214	11.931	1.548	.246
	Huynh-Feldt	14.484	1.302	11.122	1.548	.246
	Lower-bound	14.484	1.000	14.484	1.548	.245
Error(Condition)	Sphericity Assumed	84.219	18	4.679		
	Greenhouse-Geisser	84.219	10.926	7.708		
	Huynh-Feldt	84.219	11.721	7.185		
	Lower-bound	84.219	9.000	9.358		

Key

Condition 1 – Control

Condition 2 – Sleeve

Condition 3 - Tape

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-1.633	1.286	.708	-5.404	2.138
	3	-.401	.615	1.000	-2.205	1.403
2	1	1.633	1.286	.708	-2.138	5.404
	3	1.232	.881	.587	-1.353	3.817
3	1	.401	.615	1.000	-1.403	2.205
	2	-1.232	.881	.587	-3.817	1.353

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

SPSS OUTPUT FOR 45° FLEXION

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Condition	Sphericity Assumed	7.109	2	3.554	.583	.568
	Greenhouse-Geisser	7.109	1.757	4.046	.583	.549
	Huynh-Feldt	7.109	2.000	3.554	.583	.568
	Lower-bound	7.109	1.000	7.109	.583	.465
Error(Condition)	Sphericity Assumed	109.714	18	6.095		
	Greenhouse-Geisser	109.714	15.814	6.938		
	Huynh-Feldt	109.714	18.000	6.095		
	Lower-bound	109.714	9.000	12.190		

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	1.166	.882	.657	-1.422	3.754
	3	.799	1.237	1.000	-2.831	4.429
2	1	-1.166	.882	.657	-3.754	1.422
	3	-.367	1.161	1.000	-3.772	3.038
3	1	-.799	1.237	1.000	-4.429	2.831
	2	.367	1.161	1.000	-3.038	3.772

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

SPSS OUTPUT FOR 60° FLEXION

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Condition	Sphericity Assumed	6.265	2	3.133	2.045	.158
	Greenhouse-Geisser	6.265	1.754	3.571	2.045	.166
	Huynh-Feldt	6.265	2.000	3.133	2.045	.158
	Lower-bound	6.265	1.000	6.265	2.045	.186
Error(Condition)	Sphericity Assumed	27.568	18	1.532		
	Greenhouse-Geisser	27.568	15.790	1.746		
	Huynh-Feldt	27.568	18.000	1.532		
	Lower-bound	27.568	9.000	3.063		

Pairwise Comparisons

Measure: MEASURE_1

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	.831	.605	.609	-.944	2.606
	3	1.065	.438	.114	-.219	2.349
2	1	-.831	.605	.609	-2.606	.944
	3	.234	.601	1.000	-1.528	1.996
3	1	-1.065	.438	.114	-2.349	.219
	2	-.234	.601	1.000	-1.996	1.528

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

APPENDIX D

APPENDIX D-1 EXCEL RAW DATA

participant	Group	30°			30° mean	45°			45° mean	60°			60° mean
1	Control	5	2	3	3.33	7	14	5	8.67	6	5	1	4.00
	Sleeve	8	12	12	10.67	3	6	10	6.33	2	0	8	3.33
	Tape	6	8	4	6.00	2	2	1	1.67	4	3	7	4.67
2	Control	3	1	1	1.67	1	1	2	1.33	2	4	4	3.33
	Sleeve	0	1	0	0.33	0	3	6	3.00	4	4	6	4.67
	Tape	0	0	1	0.33	2	5	5	4.00	1	2	0	1.00
3	Control	3	2	2	2.33	5	2	2	3.00	1	7	5	4.33
	Sleeve	5	3	5	4.33	1	3	0	1.33	4	5	8	5.67
	Tape	2	4	6	4.00	1	2	2	1.67	1	6	6	4.33
4	Control	0	3	4	2.33	1	5	1	2.33	4	1	2	2.33
	Sleeve	2	6	4	4.00	1	1	1	1.00	2	1	2	1.67
	Tape	2	6	6	4.67	6	8	8	7.33	0	2	0	0.67
5	Control	1	5	3	3.00	5	6	9	6.67	4	2	3	3.00
	Sleeve	1	1	5	2.33	6	7	10	7.67	1	3	1	1.67
	Tape	4	3	4	3.67	2	1	2	1.67	0	1	1	0.67
6	Control	0	2	0	0.67	2	3	4	3.00	2	6	3	3.67
	Sleeve	3	2	2	2.33	5	5	5	5.00	4	0	1	1.67
	Tape	2	1	1	1.33	2	5	5	4.00	2	2	5	3.00
7	Control	2	1	6	3.00	3	10	12	8.33	0	3	1	1.33
	Sleeve	1	1	3	1.67	0	1	6	2.33	1	1	1	1.00
	Tape	2	2	2	2.00	2	4	3	3.00	2	2	3	2.33
8	Control	6	8	7	7.00	3	3	7	4.33	4	6	5	5.00
	Sleeve	4	2	4	3.33	1	2	2	1.67	1	1	0	0.67
	Tape	4	8	2	4.67	4	7	4	5.00	2	3	0	1.67
9	Control	1	0	2	1.00	4	5	9	6.00	5	5	5	5.00
	Sleeve	10	10	12	10.67	0	0	5	1.67	3	6	10	6.33
	Tape	4	3	4	3.67	5	5	5	5.00	4	3	5	4.00
10	Control	2	4	6	4.00	3	1	4	2.67	4	6	6	5.33
	Sleeve	4	5	6	5.00	5	4	5	4.67	0	1	6	2.33
	Tape	2	2	2	2.00	5	7	3	5.00	4	7	2	4.33