AN INVESTIGATION INTO TWO MODES OF ECCENTRIC HAMSTRING TRAINING ON PARAMETERS OF STRENGTH AND FATIGUE RESISTANCE

David John Roche[1]
Sports Rehabilitation, University of Salford, Directorate of Sport
RocheInjuryClinic@outlook.com

We suggest you to cite this article as:
Roche, D. J. 2018. An investigation into two modes of eccentric hamstring training on parameters of strength and fatigue resistance. *Junior Scientific Researcher*, Vol IV, No. 1, pp. 99-120.

Abstract

Purpose: *Despite the high incidence of hamstring strain injuries in several popular sports, definitive research on their causation and prevention is limited. Studies show fatigue and also hamstring eccentric weakness as causes for hamstring injuries. It begs the question "which way may be the best to train hamstrings to prevent injury.* ***Methods:*** *Eccentric hamstring peak torque and angle of peak torque toque were measured using the Kin Com dynamometer at 60˚s-^{1}/s (type, 125 AP, Chattanooga, TN, USA) before and after a modified L.I.S.T fatigue protocol. Participants were divided into two groups and underwent four weeks of eccentric hamstring training, then retested. The strength group used Nordic Hamstring Curls and the endurance group used Assisted Nordic Hamstring Curls.* ***Results:*** *The results showed a significant difference in peak torque in both groups (strength- .00, Endurance- .01). Both groups did not show a significant difference in angle of peak torque, however the results showed an increase to longer muscle lengths of 18.28% and 26.95% for endurance and strength groups respectively* ***Conclusions:*** *The strength training intervention shows the greatest improvement on both peak torque and angle of peak torque.*

Keywords: *Eccentric, Hamstring, Nordic Hamstring Curl, Angle Peak Torque, Strength, Endurance*

[1] Final Year Dissertation, submitted to the School of Health Care Professions in partial fulfilment of the requirements for the degree of Bsc (Hons) Sports Rehabilitation. 21th April 2015

Acknowledgements

I would like to thank my dissertation supervisor Martyn Matthews for all his guidance, encouragement and motivational talks throughout this process. I would like to thank Laura and Steve for the help and staying behind many evenings during testing and re-testing. Finally, I would like to thank all members of the University of Salford Football Club that were involved in this study.

Introduction

Hamstring strain injuries (HSI) are one of the most common musculoskeletal injuries sustained during sporting activities at every level from high school to professional (Shankar, Fields, Collins, Dick, & Comstock, 2007; Price, 2004). Woods *et al.* (2002) stated that 12% of all professional football injuries are HSI with a financial burden of around £74.7 million per year. HSI usually means a player missing a significant amount of playing time (Woods, 2004a). Normal recurrence rates are between 12% and 31% within one year of returning to sport (Petersen, 2005), though that can rise as high as 54.5% (Sherry and Best 2004a). Furthermore, player performance has been found to be greatly reduced following return from HSI in elite Australian footballers (Verrall GM, *et al.* 2006).

It has been suggested that muscle fatigue can lead to HSI (Lieber and Friden, 1988; Davis and Bailey, 1997). A study by Woods (2004b) reported 47% of match-play hamstrings strains happened during the final 15 minutes of each half in English professional footballers. Poor eccentric (ECC) muscular strength has also been suggested as a risk factor regularly associated with HSI (Mjolsnes, Arnason, osthagen, Raastad, & Bahr, 2004; Croisier, Forthomme, Namurois, Vanderthommen, 2002). Furthermore, a decrease in the optimum knee angle – the knee angle at which hamstring peak torque (PT) occurs – is proposed as a potential risk factor for HSI (Proske, Morgan, Brockett and Percival, 2004a). EMG analyses during sprinting show that muscle activity is highest during the late swing phase. This is when the hamstring muscles work eccentrically to slow the forward motion of the leg, as well as during foot-strike, in the transition from ECC to concentric muscle action (Mann, 1981; Jönhagen, Ericson, Németh, & Eriksson, 1996). Therefore, it has been suggested that ECC overload can cause tearing in the muscle-tendon unit (Garrett, 1990).

Despite the high incidence of HSI in several popular sports, definitive research on their causation and prevention is limited (Bahr, 2003). With studies showing fatigue induced ECC weakness, lack of ECC strength and a decrease in optimal angle of peak torque (APT) to be a cause for HSI, It begs the question "which way may be the best to train hamstrings to prevent HSI?"

With this in mind we will use two training protocols, one to improve ECC PT and APT with a strengthening protocol and the other to improve ECC PT and APT with an endurance protocol. We will then report our findings for the best way train hamstrings to prevent HSI.

Literature Review

Hamstring Anatomy

The hamstrings are a group of four muscles (Carlson, 2008). Three originate at the ischial tuberosity and then diverge to attach distally to the knee (The Biceps Femoris long head, Semimembranosus and Semitendinosus). The forth muscle, the short Head of Bicep Femoris arises from the lateral intermuscular septum and attaches distal to the knee (Carlson, 2008). The function of the long head of biceps is the movements of flexion and lateral rotation of the leg at the knee and to extend, adduct, and laterally rotate the thigh at the hip. The short head is primarily a leg flexor with the thigh extended (Mann, Shabat, Friedman, 2007). The semitendinosus functions as a flexor and internal rotator of the calf at the knee. The function of the semimembranosus is to adduct, extend and medially rotate the thigh at the hip (Mann, *et al.* 2007).

The relationship between injury and hamstring strength

The hamstrings effectively have to multitask as they must change from functioning eccentrically, to decelerate knee extension in the late swing phase, to concentrically, becoming an extensor of the hip joint (Agre, 1985). It has been proposed that this rapid changeover from ECC to concentric function of the hamstring is when the muscle is most vulnerable to injury (Verral, 2001).

Hamstring strength training is generally used in the prevention and rehabilitation of HSI (Sherry and Best, 2004b). Early authors concluded that HSI could be predicted. They said that an above 10% bilateral deficit in hamstring isometric strength would lead to HSI (Burkett, 1970; Christensen & Wiseman, 1972). Similar work concluded that isometric strength with a lower quad to hamstring ratio was also a precursor to injury (Yamamoto, 1993). However there have been some contradicting studies also. Liemohn (1978) prospectively found no divergences in isometric hamstring/quadriceps ratios between hamstring injured and non-injured groups of track and field athletes. These contradicting results may have come from too small a group size, the level of athlete or the way they tested the subjects for strength.

Another muscle imbalance thought to be a cause of HSI is the hamstring to quadriceps strength ratio. A study by Heiser, Weber, Sullivan, Clare, & Jacobs (1984) stated that HSI could be predicted by a muscle imbalance of Hamstring concentric/Quadriceps concentric. This way of predicting HSI isn't an ideal way to measure as it is not functionally comparable to sport. During running the hamstring works eccentrically to slow down the limb being moved by concentric quadriceps action, this also applies vice versa, showing no functional relationship between hamstring concentric action and quadriceps action (Osternig, Hamill, Lander, & Robertson, 1986). In a later study, muscle strength performance disorders were isokinetically detected in about 70% of cases after HSI. This underlined an ECC PT deficit and a significant reduction of a mixed ECC hamstring/ concentric quadriceps ratio (Croisier and Crielaard, 2000).

When sprinting, the deceleration phase shortens, requiring a higher ECC activation of the hamstrings to compensate the forward momentum of the leg (Garrett, 1990). If the hamstrings have insufficient ECC strength to decelerate the limb during the latter part of the swing phase, ECC overload could cause tearing in the musculo-tendinous unit (Garrett, 1990). Therefore it makes sense to train the hamstrings for ECC strength.

The relationship between Fatigue and Injury

Reduced muscle strength, brought on by fatigue, has been argued to increase the chance of injury (Greig, 2008), in particular HSI (Sutton, 1984; Worrell, 1994). Research has demonstrated fatigue induced alterations to the biomechanics of running (Lloyd, 2006), including decreased hip flexion and thigh angular velocity and increased knee extension during swing phase of the stride (Sprague and Mann, 1983). This basically means a reduced range of movement. The muscles loss of force limits its ability to absorb repeated loading while running, this loss of force increases the risk of injury due to fatigue (Sallay, Friedman, Coogan, & Garrett, 1996). The multiple ECC contractions combined with the continuing decrease in PT due to fatigue will damage the muscle progressively and can lead to a major soft tissue injury (Brockett, Morgan, & Proske, 2004).

A study on English professional footballers reported that HSI occurred during competition represented 62% of all reported hamstring injuries (Woods, 2004c), especially in the final quarter of matches (Hawkins, 2001). This study notes the time when most injuries occur but offers no information on prevention of HSI. A recent study stated that fatigue occurred progressively in soccer players muscles and therefore maximum force decreased progressively from the beginning to the end a simulated game (Rahnama, Reilly, Lees, & Graham-Smith, 2003). The findings indicate that a simulated soccer-specific exercise protocol reduced the capacity of hamstring working ECC to generate force. This was shown in the reduction of PT. This study reliably showed the progressive effect of fatigue on ECC hamstrings by taking measurements pre, middle and post-game. There is limited research in the area of improving muscle endurance to combat fatigue induced injury. Most tests are done to show fatigue but no training prevention to combat fatigue.

Strength and Endurance Training

Traditional resistance training involves high load, low repetition, whereas endurance training involves low load, high repetition, these differences produce distinct physiological changes in the trained musculature that is needed for each sporting environment (McCafferty and Horvath, 1977).

There is a constant debate ongoing about how to train for strength. A study by Kraemer, Adams, Cafarelli (2002) in the 'Progression Models in Resistance Training for Healthy Adults' concluded that the best way to train for strength was to use multiple sets and reps of 6-12 and load of 85% one rep max. Further studies backed up the idea of using high load with low reps with a rest period of two-three minutes (Bird, Tarpenning, & Marino, 2005; Berger, 1962; Kraemer & Ratamess, 2004; Ostrowski, Wilson, Weatherby, Murphy, & Lyttle, 1997; (Huczel & Clarke, 1992). The same studies recommended the best way to train for endurance was to perform one-three sets of 12-15 reps with a brief resting period of 30 seconds. Research has also stated that lighter loads and higher reps (12-15 RM) were effective for building muscle endurance (Campos *et al* 2002; Stone and Coulter, 1994; Tanaka, Costill, Thomas, Fink, & Widrick, 1993).

Nordic Hamstring Curls

A simple ECC hamstring strength training exercise that has been further developed by Mjølsnes *et al.* (2004) is known as the ''Nordic hamstring Curl'' (NHC)

(Figure 1). This exercise can be done in the field without the use of any equipment except a partner to secure legs. It has been shown to increase the ECC strength in the hamstring muscles and creates a rightward shift in the length-tension relationship (Brockett, Morgan and Proske, 2001a). Studies across a range of sports have reported beneficial outcomes from the use of NHC. A study by Brooks (2006) on elite rugby players and a study by Arnason *et al.* (2008) on professional footballers showed a decrease in the frequency and severity of HSI after NHC training. There is limited research looking at whether or not the dominant leg is doing more than its fair share during a NHC.A study by Iga, Fruer, Deighan, Croix, & James (2012) used EMG to observe the activity of each leg muscle group and report back. They found no significant difference in the activity. However they did not print any kinetic data which would have been useful. The Assisted Nordic Hamstring Curl (ANHC) (Figure 2) is designed allow a greater range of motion for the participant to work in. The ANHC involves the use of an elastic band secures under the arms and around the chest. This provides a delay in to the break point and in turn allows the participant to train at longer muscle lengths (Matthews, Jones, Cohen, & Matthews, 2015a).

Figure 1 Nordic Hamstring Curl

Figure 2 Assisted Nordic Hamstring Curl

Peak Torque and Angle of Peak Torque

Peak torque is the single maximum amount of torque produced by muscular action as the limb passes through a range of motion (Kannus, 1994). The APT is simply the angle at which the PT occurs (Brockett, Morgan and Proske, 2001b).

It has been suggested that ECC exercise may reduce hamstring injury rates as the muscles are trained to shift the PT–angle curve toward longer muscle lengths (Brockett, Morgan, & Proske, 2001c). This shift in optimum length has been argued to be a protective adaptation for future muscle strain injuries in sport (Proske, Morgan, Brockett, & Percival, 2004). This means the muscle will be able to generate more force to decelerate and control the limb while it is at an extreme lengthened position, thus reducing injury risk.

A limited number of studies have used an extended training intervention to test these theories. They are usually one session of high repetitions with no follow up. To my knowledge, there have not been any studies on endurance training and PT relationship with an extended intervention been done before. In terms of measurement testing, it's useful to know what the maximum PT is and also at what angle it occurs. This way the results of any training intervention implemented can be clearly seen upon retesting.

Methodology

Overview

Aim: To assess the effect of a high load/ low repetition and a low load / high repetition training intervention on ECC hamstring PT and APT before and after fatigue, before and after the intervention.

ECC hamstring PT and APT were measured using the KinCom dynamometer at 60˚s-^{1}/s (type, 125 AP, Chattanooga, TN, USA) before and after a ball sport specific fatigue protocol, (The Loughborough Intermittent Shuttle Test) (Nicholas, Nuttall and Williams, 2000). The L.I.S.T was modified to suit the amateur status of the participants and time constrictions of the testing lab. The participants underwent a 45 minute version of the protocol. Participants were then divided into two groups and underwent four weeks of targeted hamstring training.

Participants

Participants were recruited as volunteers from the University of Salford Football Teams. The study required a minimum of 20 physically active males randomly assigned into two groups, (Strength (n11) 22.9+3.7yrs, 183.9+7.2m, 84.7+8.9kg) (Endurance (n9) 22+2.9yrs, 178.4+6.8m, 84.7+8.9kg). A recruitment poster (appendix 1) was displayed at the University.

Exclusion criteria included: present injuries, major operations and muscle or tendon injuries within the past year. A Participant Information Sheet was handed out before any of the study was carried out (appendix 2). Participants selected then filled out a physical activity readiness questionnaire (appendix 3). Applicants selected also signed a consent form prior to data collection (appendix 4). Furthermore, approval for the study was acquired in agreement with the University's Ethics Committee procedures (University Ethics Panel, Salford University, UK).

Warm Up

Before using the Kin Com Dynamometer, a five minute warm up was performed in the human performance lab consisting of general stretching, running and jogging.

Procedure

Having familiarised the participants with the methods of testing, each participant attended the performance lab for isokinetic assessment. Participants were asked to avoid caffeine or eating two hours prior to testing and also not to undergo any strenuous activity 48 hours prior to assessment.

Each participant was seated on the Kin Com Dynamometer (type, 125 AP, Chattanooga, TN, USA) in order to measure ECC hamstring PT (Force x Moment Arm (Nm)) and APT. Testing was conducted on the participant's dominant leg. The participants were then placed in approximately 90˚ hip flexion and 90˚ knee flexion; moving through a range of 90˚ to 0˚ of knee extension. This position is commonly used by researchers (Askling C et al 2003; Brockett CL et al 2004). The lever arm was aligned with the knee joint line (parallel to lateral epicondyle) and the shin pad attached above the malleoli. The Kin-Com was then adapted in accordance to the participants' limb length. We ensured the participants' knee was overhanging by two inches over the seat and that shorts were being wore. The lever arm length (metres) for each participant was taken. Each participant's thigh, waist and torso were strapped to eliminate extraneous movement. The participant was then instructed to fully extend their leg manually and hold in place. The leg weight shown was noted in order to be eliminated later on when evaluating gravitational correction, in order to correctly give the ECC hamstring PT value. The forward and backward speed was 60˚/s. The participant was then instructed to give three maximal repetitions with a rest of 30 seconds in between. The best score from the three repetitions was taken. These values were measured pre and post fatigue and pre and post intervention. The results were scientifically analysed and compared at the end of the four week study.

Fatigue Protocol

Following the Isokinetic testing on the Kin Com Dynamometer, each individual participant underwent a modified (Loughborough Intermittent Shuttle Test (Nicholas, Nuttall and Williams, 2000) fatigue protocol. To ensure total fatigue, after completing the L.I.S.T each participant underwent a jog then sprint exercise until they could not complete on 20 meter sprint fully. The participants were then retested on the Kin Com Dynamometer. This was performed on the first and last day of the study.

Strength Intervention

The strength group performed a total of three sets of four NHC with a two-minute rest between each set at a load that allows only performance of four reps. The sets and reps are in line with research ('Progression Models in Resistance Training for Healthy Adults', 2002; Bird, Tarpenning, & Marino, 2005; Berger, 1962; Kraemer & Ratamess, 2004; Ostrowski, Wilson, Weatherby, Murphy, & Lyttle, 1997).This protocol was performed two times a week for four weeks. Participants were progressed by increasing load (weighted vest).

Endurance Intervention

The endurance group performed four sets of 15 ANHC using a large rubber band secured around the participant's chest below the arms. They had a 30 second rest between sets. The sets and reps are in line with 'Progression Models in Resistance Training for Healthy Adults', (2002) and other noted research (Campos *et al* 2002; Stone & Coulter, 1994; Tanaka, Costill, Thomas, Fink, & Widrick, 1993; Bird, Tarpenning, & Marino, 2005; Huczel & Clarke, 1992). This protocol was performed two times a week for four weeks. Participants were progressed by increasing sets and reps.

Measurements, data and data analysis

This pilot study looks at a participants design with two specific protocols to follow. The data set was analysed using SPSS v 16.0 for windows (Chicago, Ill). A paired sample T-Test was carried out as this is the appropriate approach to analyse data accurately. The normality of data collected was ratified using the Shapiro Wilks test. The alpha level was set at $p \leq 0.05$ as this is commonly recognised in all scientific research papers. Significance was shown when p equals or is less than the alpha level (.05).

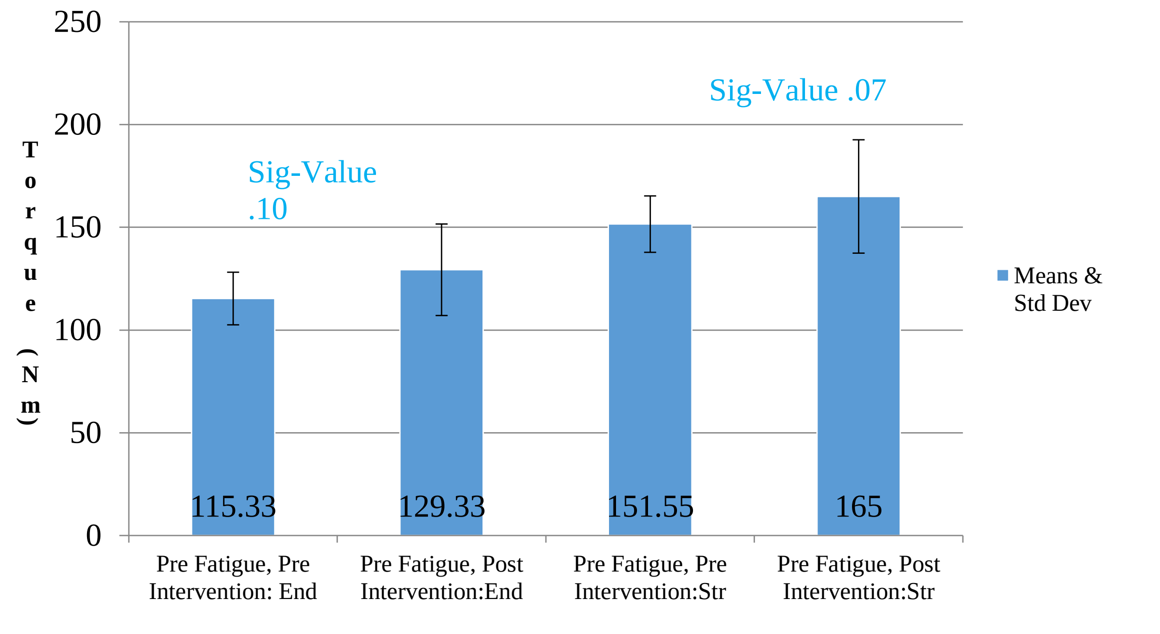
For this pilot study, six participants were randomly selected to attend two testing sessions approximately 72 hours apart in order to confirm test-retest reliability. This was achieved by calculating the Intra-class Correlation Coefficient, Standard Error of Measurement and Smallest Detectable Difference. The Performance Lab was booked for the training intervention twice a week. The Kin Com machine and performance track was used on the first day and the last day of testing. A large elastic band was booked to perform ANHC.

Results

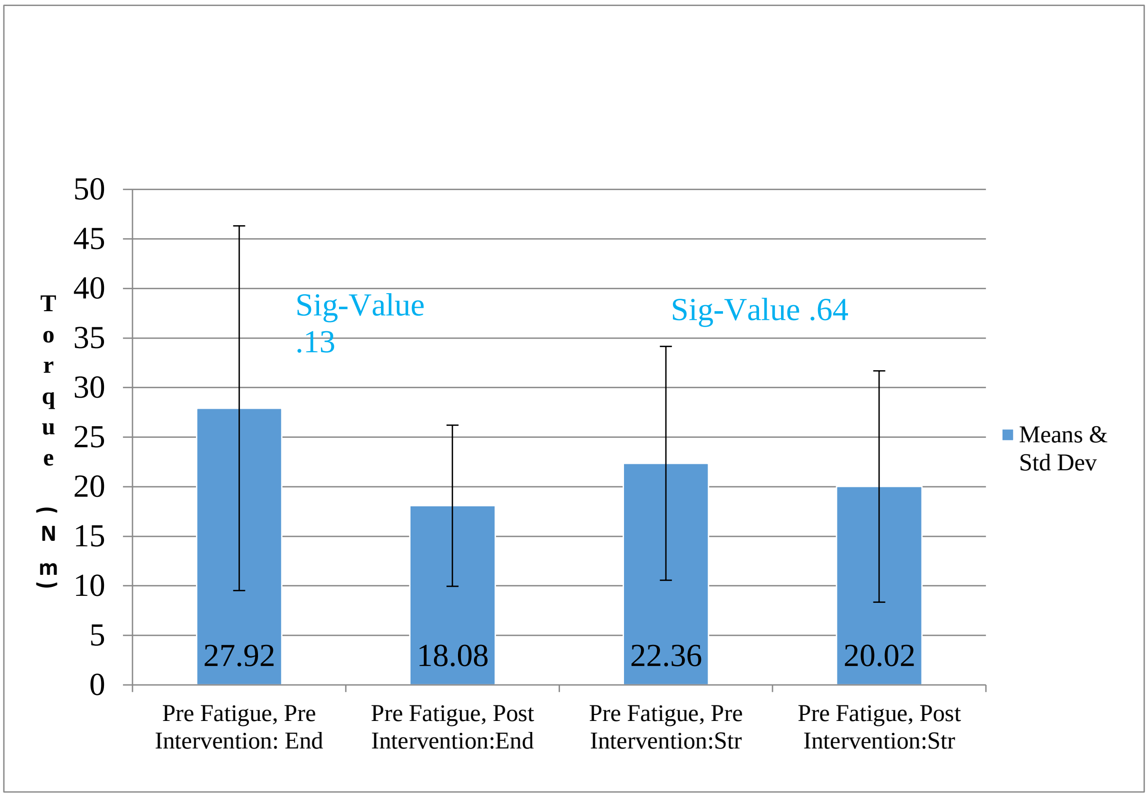
There is no significant difference found in PT pre fatigue for both pre and post intervention in both groups, **See Table 1** (Endurance: pre intervention- 115.33+12.80 Nm, post intervention- 129.33+22.27 Nm, sig- .10) (Strength: pre intervention_ 151.55+13.72 Nm, post intervention_ 165+27.58Nm, sig-value .07). There is no significant difference found in APT pre fatigue for both pre and post intervention in both groups, **See Table 2** (Endurance: pre int, pre fat 27.92+18.40°, post int, pre fat 18.08+8.13°, sig-value .13) (Strength: = pre fat, pre int 22.36+11.80°, pre fa, post int 20.02+11.67°,sig-value .64).

The results of the study show both groups record a significant difference regarding PT post fatigue, pre and post intervention in both groups. **See Tables 3 & 4** (Endurance: pre intervention, post fatigue- 117.67+21.56 Nm, post intervention, post fatigue- 135.67+22.204 Nm, sig-value .01) (Strength: pre intervention, post fatigue- 117.67+21.56 Nm, post intervention, post fatigue- 135.67+22.20 Nm, sig-value .00). When the means are broken down into percentages difference we observed a 13.26% and 17.17% increase in the endurance and strength groups respectfully.

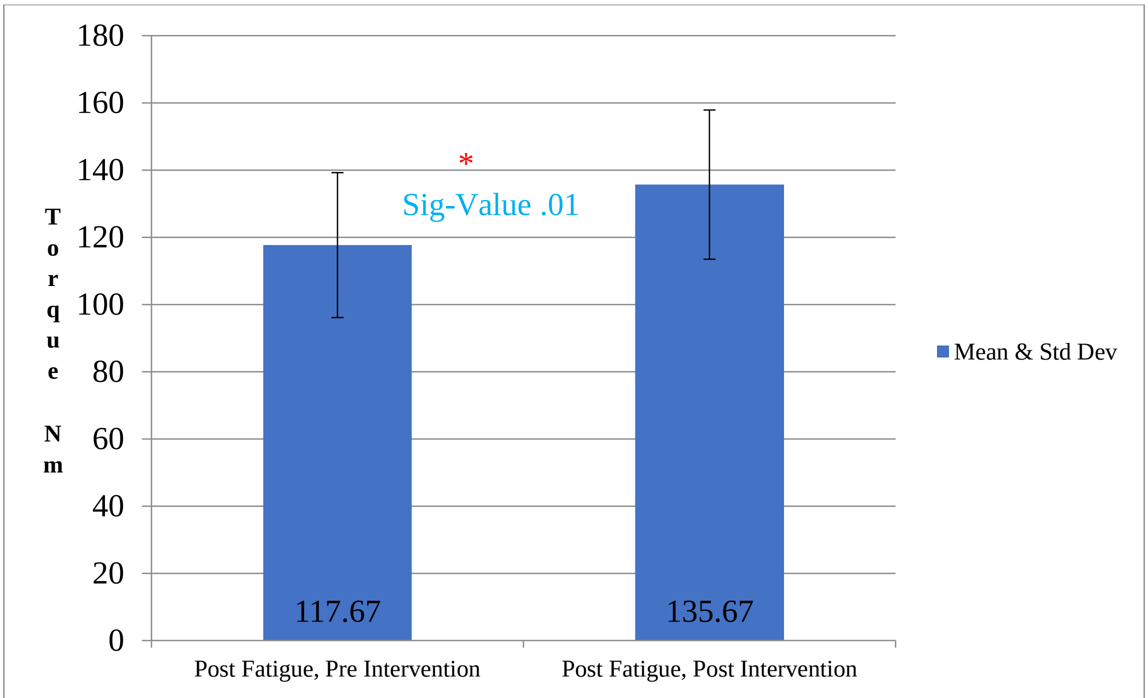
There was no significant difference observed in the APT in either group post fatigue, pre and post intervention **See Table 5 & 6** (Strength group: post fatigue, pre intention 23.52+10.97 °, post fatigue, post intervention 17.18+9.04°, sig-value .19, Endurance Group: pre intervention, post fatigue 22.81+16.5°, post intervention, post fatigue 18.64+11.6°, sig-value .50). However, when the means were broken down into percentages to view changes, an increase of knee extension to where APT occurred of 26.95% and 18.28% was noted for the strength and endurance group respectfully.



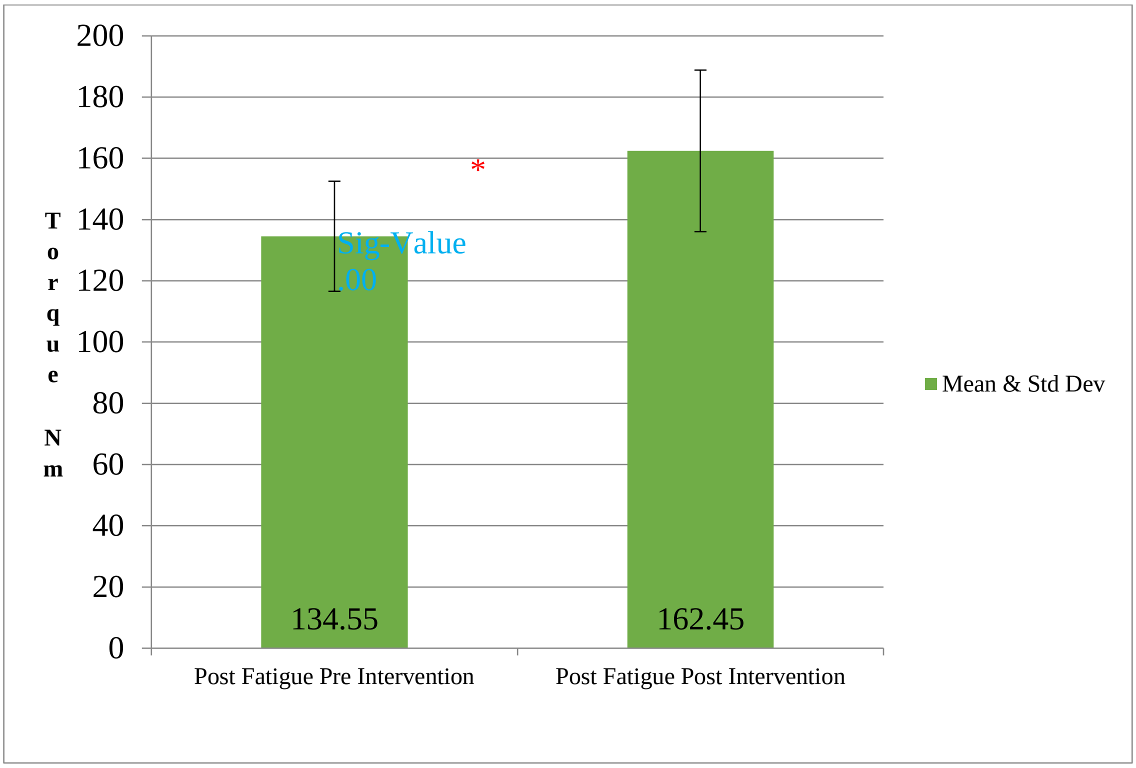
Graph 1 Eccentric Peak Torque Pre Fatigue, Pre & Post Intervention for Both Groups



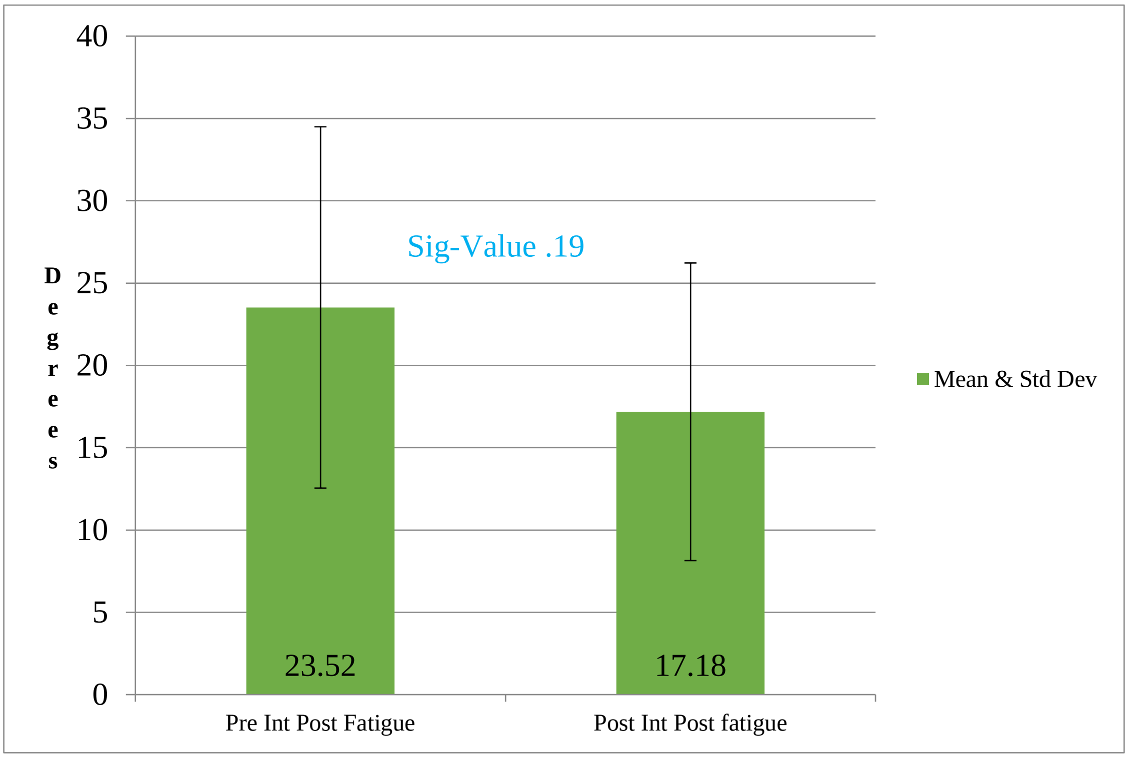
Graph 2 Eccentric Angle Peak Torque Pre Fatigue, Pre & Post Intervention for Both Groups



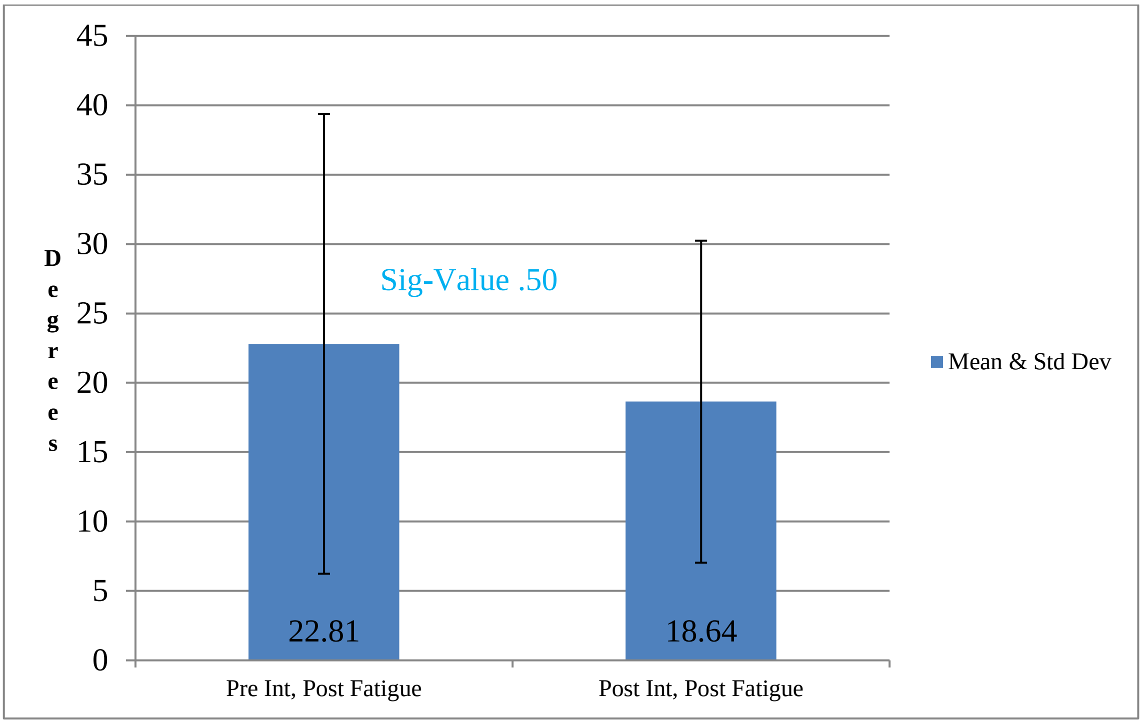
Graph 3 Eccentric Peak Torque Post Fatigue, Pre & Post Intervention for Endurance Group



Graph 4 Eccentric Peak Torque Post Fatigue, Pre & Post Intervention for Strength Group



Graph 5 Eccentric Angle Peak Torque Post Fatigue, Pre- & Post Intervention for Strength Group



Graph 6 Eccentric Angle Peak Torque Post Fatigue, Pre & Post Intervention for Endurance Group

Discussion

The purpose of this study was to use two ECC types of hamstring training interventions (Strength group using NHC and Endurance group using ANHC) and report on which one may be the best to prevent HSI. There were no significant differences found for PT or APT for the pre fatigue, pre and post intervention with either group (**Table 1 & 2**). This may demonstrate that there were no changes in the hamstrings PT or APT during everyday activity. There were large standard deviations noticed in the PT and especially the APT sections for pre fatigue pre and post intervention. This may be attributed to the familiarizing effect of the participants on retesting.

Numerous studies have used NHC to improve ECC PT and APT (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2007c; Askling, Karlsson, & Thorstensson, 2003b: Gabbe, Branson, & Bennell, 2006b). This is one of the first studies to use an ANHC exercise. By using the ANHC, in theory, we would be able to get more reps and sets. This would allow us to achieve the parameters of endurance style interventions via reps, sets and recovery times (Matthews, Jones, Cohen, & Matthews, 2015b). In both groups there was a significant difference found in PT post fatigue, pre and post intervention (**Table 3 & 4**). There were no significant differences found in the APT at any stage of the intervention in both groups. However, there were changes to a more extended knee angle where the APT occurred. They are most noticeable in post fatigue, pre vs post intervention results (**Table 5 & 6**). This study is in line with current studies that show an improvement in PT and APT using the NHC (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2007d; Clark, Bryant, Culgan, & Hartley, 2005b).

Although there was no significant difference observed, both groups showed a positive shift in APT to more extended lengths. This was demonstrated by an increase of 18.28% and 26.95% for endurance and strength groups respectively. Brughelli *et al* (2010) stated that ECC training interventions can have a positive effect on the length-tension relationship of the hamstrings. This will not only increase the amount of PT produced, but shift the APT to longer muscle lengths where it may be susceptible to injury (Malliaropoulos *et al*., 2012; Schmitt, Tim, McHugh, 2012), in turn reducing HSI (Petersen, Thorborg, Nielsen, Budtz-Jorgensen, & Holmich, 2011; Arnason, Andersen, Holme, Engebretsen, & Bahr, 2007b). As both interventions are successful in doing so in a four week period we should then look at which has the greater improvement in PT and APT. In this study the strength group (**Table 5**) showed a shift to longer lengths of 6.34 degrees while the endurance group (**Table 6**) showed a 4.1 degree shift. These findings are in line with (Clark, Bryant, Culgan, & Hartley, 2005) who found a 6.5 degree shift in hamstrings after a four week intervention using NHC. Brockett, Morgan, & Proske, (2004b) proposed that if the optimal length can be improved through ECC training then the limb can be more controlled through a full range of movement, hence reduce HSI risk. A significant amount of studies have looked at trying to identify a way to predict HSI. The most common area looked at is muscle strength (Croisier, Ganteaume, Binet, Genty, & Ferret, 2008a; Orchard, Marsden, Lord, & Garlick, 1997). Research has shown that ECC hamstring strengthening is the best way to decrease the chances of a HSI (Arnason, Andersen, Holme, Engebretsen, & Bahr, 2007a; Askling, Karlsson and Thorstensson, 2003; Gabbe, Branson and Bennell, 2006), our study seems to back that up. However, our study has shown that ANHC have a similar increase in PT and APT in a short space of time. It may be worth looking at this type of exercise in future to reduce the risk of HSI in endurance sports like football, rugby and basketball. Research may be fixating on improving ECC PT and APT via strength. Other studies have reported other ways to decrease HSI risk. A study by Croisier, Ganteaume, Binet, Genty, & Ferret (2008b) using concentric and ECC training have shown a decrease in HSI. Furthermore, research by Arnason, Andersen, Holme, Engebretsen, & Bahr (2007b) noted that by incorporating a warm up and stretching alongside an eccentric training programme would greatly reduce the risk of HSI. These studies highlight the fact that there are many factors involved in reducing HSI risk so a more open minded approach is needed.

Limitations

A longer training intervention would have been preferable. This would have allowed us to see some further changes and how PT and APT progress in both groups. The study did not take into consideration that some participants may have been familiar with NHC beforehand and this would have affected their results. The study did not allow for the fact that the endurance group were doing about 60 reps per session and therefore doing more volume of work than the strength group.

Conclusion

In conclusion, both training interventions increase PT and improve APT. The strength group showed a higher percentage increase in both means of PT and APT after the intervention. The strength training intervention shows the greatest improvement on both PT and APT, making it the best way to train hamstrings.

Further Research

Our study shows that by using an ANHC we can also improve PT and APT in a period of only four weeks. A season long intervention may greatly highlight the effects of the endurance group results. The ANHC achieved full range through every rep and in theory strengthened the outer ranges that the strength group could not have reached. This may mean, although the strength group had a better increase in PT and APT, the endurance group may have improved the hamstrings through the whole range while the strength group only improved the range they achieved until failure. Further research into the benefits of ANHC is needed.

References

1. Agre, J. C. (1985). Hamstring Injuries. *Sports Medicine*, *2*(1), 21–33. http://doi.org/10.2165/00007256-198502010-00003
2. Armstrong, R. B., Warren, G. L. and Warren, J. A. (1991) 'Mechanisms of Exercise-Induced Muscle Fibre Injury', *Sports Medicine*. Springer, 12(3), pp. 184–207. doi: 10.2165/00007256-199112030-00004.
3. Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L. and Bahr, R. (2007a). 'Prevention of hamstring strains in elite soccer: an intervention study', *Scandinavian Journal of Medicine & Science in Sports*, 18(1), pp. 40–48. doi: 10.1111/j.1600-0838.2006.00634.x.
4. Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L. and Bahr, R. (2007b). 'Prevention of hamstring strains in elite soccer: an intervention study', *Scandinavian Journal of Medicine & Science in Sports*, 18(1), pp. 40–48. doi: 10.1111/j.1600-0838.2006.00634.x.
5. Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L. and Bahr, R. (2007c). 'Prevention of hamstring strains in elite soccer: an intervention study', *Scandinavian Journal of Medicine & Science in Sports*, 18(1), pp. 40–48. doi: 10.1111/j.1600-0838.2006.00634.x
6. Arnason, A., Andersen, T. E., Holme, I., Engebretsen, L. and Bahr, R. (2007d). 'Prevention of hamstring strains in elite soccer: an intervention study', *Scandinavian Journal of Medicine & Science in Sports*, 18(1), pp. 40–48. doi: 10.1111/j.1600-0838.2006.00634.x
7. Askling, C., Karlsson, J. and Thorstensson, A. (2003a). 'Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload', *Scandinavian Journal of Medicine and Science in Sports*, 13(4), pp. 244–250. doi: 10.1034/j.1600-0838.2003.00312.x..
8. Askling, C., Karlsson, J., & Thorstensson, A. (2003b). Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. *Scandinavian Journal of Medicine and Science in Sports*, *13*(4), 244–250. http://doi.org/10.1034/j.1600-0838.2003.00312.x

9. Bahr, R (2003) 'Risk factors for sports injuries -- a methodological approach', *British Journal of Sports Medicine*, 37(5), pp. 384–392. doi: 10.1136/bjsm.37.5.384.
10. Bennell, K., Wajswelner, H., Lew, P., Schall-Riaucour, A., Leslie, S., Plant, D. and Cirone, J. (1998). 'Isokinetic strength testing does not predict hamstring injury in Australian Rules footballers', *British Journal of Sports Medicine*, 32(4), pp. 309–314. doi: 10.1136/bjsm.32.4.309.
11. Berger, R. A. (1962). Comparison Between Resistance Load And Strength Improvement. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *33*(4), 637–637. http://doi.org/10.1080/10671188.1962.10762117
12. Bird, S. P., Tarpenning, K. M., & Marino, F. E. (2005). Designing Resistance Training Programmes to Enhance Muscular Fitness. *Sports Medicine*,*35*(10), 841–851. http://doi.org/10.2165/00007256-200535100-00002
13. Brockett, C. L., Morgan, D. L. and Proske, U. (2001a). 'Human hamstring muscles adapt to eccentric exercise by changing optimum length', *Medicine and Science in Sports and Exercise*, pp. 783–790. doi: 10.1097/00005768-200105000-00017.
14. Brockett, C. L., Morgan, D. L. and Proske, U. (2001b). 'Human hamstring muscles adapt to eccentric exercise by changing optimum length', *Medicine and Science in Sports and Exercise*, pp. 783–790. doi: 10.1097/00005768-200105000-00017.
15. Brockett, C. L., Morgan, D. L. and Pr0ske, U. (2001c). 'Human hamstring muscles adapt to eccentric exercise by changing optimum length', *Medicine and Science in Sports and Exercise*, pp. 783–790. doi: 10.1097/00005768-200105000-00017.
16. Brockett, C. L., Morgan, D. L. and Proske, U. (2004a). 'Predicting Hamstring Strain Injury in Elite Athletes', *Medicine & Science in Sports & Exercise*, 36(3), pp. 379–387. doi: 10.1249/01.mss.0000117165.75832.05.
17. Brockett, C. L., Morgan, D. L., & Proske, U. (2004b). Predicting Hamstring Strain Injury in Elite Athletes. *Medicine & Science in Sports & Exercise*, *36*(3), 379–387. http://doi.org/10.1249/01.mss.0000117165.75832.05
18. Brughelli, M., Mendiguchia, J., Nosaka, K., Idoate, F., Arcos, A. L., & Cronin, J. (2010). Effects of eccentric exercise on optimum length of the knee flexors and extensors during the preseason in professional soccer players. *Physical Therapy in Sport*, *11*(2), 50–55. http://doi.org/10.1016/j.ptsp.2009.12.002
19. Burkett, L. N. (1970). 'Causative factors in hamstring strains',*Medicine & Science in Sports & Exercise*, 2(1). doi: 10.1249/00005768-197002010-00010.
20. Campos, G. E., Luecke, T. J., Wendeln, H. K., Toma, K., Hagerman, F. C., Murray, T. F., Ragg, K. E., Ratamess, N. A., Kraemer, W. J. and Staron, R. S. (2002). 'Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones', *European Journal of Applied Physiology*. Springer, 88(1-2), pp. 50–60. doi: 10.1007/s00421-002-0681-6.
21. Carlson, C. (2008a). 'The natural history and management of hamstring injuries', *Current Reviews in Musculoskeletal Medicine*. Springer, 1(2), pp. 120–123. doi: 10.1007/s12178-007-9018-8.
22. Carlson, C. (2008b). 'The natural history and management of hamstring injuries', *Current Reviews in Musculoskeletal Medicine*. Springer, 1(2), pp. 120–123. doi: 10.1007/s12178-007-9018-8.
23. Christensen C, Wiseman D. (1972). *Strength: The common variable in hamstring strain*. *Athletic Training* 7:36-40

24. Clark, R., Bryant, A., Culgan, J.-P., & Hartley, B. (2005a). The effects of eccentric hamstring strength training on dynamic jumping performance and isokinetic strength parameters: a pilot study on the implications for the prevention of hamstring injuries. *Physical Therapy in Sport*, *6*(2), 67–73. http://doi.org/10.1016/j.ptsp.2005.02.003
25. Clark, R., Bryant, A., Culgan, J.-P., & Hartley, B. (2005b). The effects of eccentric hamstring strength training on dynamic jumping performance and isokinetic strength parameters: a pilot study on the implications for the prevention of hamstring injuries. *Physical Therapy in Sport*, *6*(2), 67–73. http://doi.org/10.1016/j.ptsp.2005.02.003
26. Croisier JL, Crielaard JM. (2000). Hamstring muscle tear with recurrent complaints: an isokinetic profile. Isokin Exerc Sci. 2000;8:175-180
27. Croisier J.L, Forthomme B, Namurois M.H, Vanderthommen M, Crielaard J.M. (2002). Hamstring muscle strain recurrence and strength performance disorders. Am J Sports Med. 2002;30(2):199–203
28. Croisier, J.-L., Ganteaume, S., Binet, J., Genty, M. and Ferret, J.-M. (2008a). 'Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players: A Prospective Study', *The American Journal of Sports Medicine*, 36(8), pp. 1469–1475. doi: 10.1177/0363546508316764.
29. Croisier, J.-L., Ganteaume, S., Binet, J., Genty, M. and Ferret, J.-M. (2008b). 'Strength Imbalances and Prevention of Hamstring Injury in Professional Soccer Players: A Prospective Study', *The American Journal of Sports Medicine*, 36(8), pp. 1469–1475. doi: 10.1177/0363546508316764.
30. Gabbe, B. J., Branson, R. and Bennell, K. L. (2006a). 'A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football', *Journal of Science and Medicine in Sport*, 9(1-2), pp. 103–109. doi: 10.1016/j.jsams.2006.02.001.
31. Gabbe, B. J., Branson, R., & Bennell, K. L. (2006b). A pilot randomised controlled trial of eccentric exercise to prevent hamstring injuries in community-level Australian Football. *Journal of Science and Medicine in Sport*, *9*(1-2), 103–109. http://doi.org/10.1016/j.jsams.2006.02.001
32. Garrett, W. E. (1990). 'Muscle strain injuries', *Medicine & Science in Sports & Exercise*, 22(4). doi: 10.1249/00005768-199008000-00003.
33. Greig, M. (2008) 'The Influence of Soccer-Specific Fatigue on Peak Isokinetic Torque Production of the Knee Flexors and Extensors', *The American Journal of Sports Medicine*, 36(7), pp. 1403–1409. doi: 10.1177/0363546508314413.
34. Hawkins, R. D. (2001). 'The association football medical research programme: an audit of injuries in professional football', *British Journal of Sports Medicine*, 35(1), pp. 43–47. doi: 10.1136/bjsm.35.1.43.
35. Heiser, T. M., Weber, J., Sullivan, G., Clare, P. and Jacobs, R. R. (1984). 'Prophylaxis and management of hamstring muscle injuries in intercollegiate football players', *The American Journal of Sports Medicine*, 12(5), pp. 368–370. doi: 10.1177/036354658401200506.
36. Huczel, H. A., & Clarke, D. H. (1992). A comparison of strength and muscle endurance in strength-trained and untrained women. *European Journal of Applied Physiology and Occupational Physiology*, *64*(5), 467–470. http://doi.org/10.1007/BF00625069
37. Iga, J., Fruer, C., Deighan, M., Croix, M. D. and James, D. V. (2012). '"Nordic" Hamstrings Exercise – Engagement Characteristics and Training Responses', *International Journal of Sports Medicine*, 33(12), pp. 1000–1004. doi: 10.1055/s-0032-1304591.

38. Jönhagen, S., Ericson, M. O., Németh, G. and Eriksson, E. (1996). 'Amplitude and timing of electromyographic activity during sprinting',*Scandinavian Journal of Medicine & Science in Sports*, 6(1), pp. 15–21. doi: 10.1111/j.1600-0838.1996.tb00064.x.
39. Kannus, P. (1994). 'Isokinetic Evaluation of Muscular Performance',*International Journal of Sports Medicine*, 15(S 1), pp. 11–18. doi: 10.1055/s-2007-1021104.
40. Kraemer WJ, Adams K, Cafarelli E, *et al*. (2002). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 2002; 34: 364–80
41. Kraemer, W. J., & Ratamess, N. A. (2004). Fundamentals of Resistance Training: Progression and Exercise Prescription. *Medicine & Science in Sports & Exercise*, *36*(4), 674–688. http://doi.org/10.1249/01.mss.0000121945.36635.61
42. Lieber, R. L. and Friden, J. (1988). 'Selective damage of fast glycolytic muscle fibres with eccentric contraction of the rabbit tibialis anterior',*Acta Physiologica Scandinavica*, 133(4), pp. 587–588. doi: 10.1111/j.1748-1716.1988.tb08446.x.
43. Liemohn W. (1978). Factors related to hamstring strains. J Sports Med 18:71–6.
44. Lloyd, D. (2006). Moving away from traditional foci may help us understand sporting performance and injuries. *Journal of Science and Medicine in Sport*, *9*(4), 275–276. http://doi.org/10.1016/j.jsams.2006.05.026
45. Malliaropoulos, N., Mendiguchia, J., Pehlivanidis, H., Papadopoulou, S., Valle, X., Malliaras, P., & Maffulli, N. (2012). Hamstring exercises for track and field athletes: injury and exercise biomechanics, and possible implications for exercise selection and primary prevention. *British Journal of Sports Medicine*, *46*(12), 846–851. http://doi.org/10.1136/bjsports-2011-090474
46. Mann G, Shabat S, Friedman A,. Hamstring Injuries. Orthopedics. (2007). Jul;30(7):536-40;541-2.
47. Mann, R. V. (1981). 'A kinetic analysis of sprinting', *Medicine & Science in Sports & Exercise*, 13(5). doi: 10.1249/00005768-198105000-00010.
48. Matthews, M. J., Jones, P., Cohen, D., & Matthews, H. (2015a). The Assisted Nordic Hamstring Curl. *Strength and Conditioning Journal*, *37*(1), 84–87. http://doi.org/10.1519/ssc.0000000000000084
49. Matthews, M. J., Jones, P., Cohen, D., & Matthews, H. (2015b). The Assisted Nordic Hamstring Curl. *Strength and Conditioning Journal*, *37*(1), 84–87. http://doi.org/10.1519/ssc.0000000000000084
50. McCafferty, W. and Horvath, S. (1977). 'Specificity of exercise and specificity of training: a subcellular review', 48 (2).
51. Mjolsnes, R., Arnason, A., osthagen, T., Raastad, T. and Bahr, R. (2004). 'A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players',*Scandinavian Journal of Medicine and Science in Sports*, 14(5), pp. 311–317. doi: 10.1046/j.1600-0838.2003.367.x.
52. Nicholas, C. W., Nuttall, F. E. and Williams, C. (2000). 'The Loughborough Intermittent Shuttle Test: A field test that simulates the activity pattern of soccer', *Journal of Sports Sciences*, 18(2), pp. 97–104. doi: 10.1080/026404100365162.
53. Orchard, J., Marsden, J., Lord, S. and Garlick, D. (1997). 'Preseason Hamstring Muscle Weakness Associated with Hamstring Muscle Injury in Australian Footballers', *The American Journal of Sports Medicine*, 25(1), pp. 81–85. doi: 10.1177/036354659702500116.

54. Osternig, L. R., Hamill, J., Lander, J. E. and Robertson, R. (1986). 'Co-activation of sprinter and distance runner muscles in isokinetic exercise', *Medicine & Science in Sports & Exercise*, 18(4). doi: 10.1249/00005768-198608000-00012.
55. Ostrowski, K. J., Wilson, G. J., Weatherby, R., Murphy, P. W., & Lyttle, A. D. (1997). The Effect of Weight Training Volume on Hormonal Output and Muscular Size and Function. *The Journal of Strength and Conditioning Research*, *11*(3). http://doi.org/10.1519/1533-4287(1997)011<0148:teowtv>2.3.co;2
56. Petersen, J (2005) 'Evidence based prevention of hamstring injuries in sport', *British Journal of Sports Medicine*, 39(6), pp. 319–323. doi: 10.1136/bjsm.2005.018549.
57. Petersen, J., Thorborg, K., Nielsen, M. B., Budtz-Jorgensen, E., & Holmich, P. (2011). Preventive Effect of Eccentric Training on Acute Hamstring Injuries in Men's Soccer: A Cluster-Randomized Controlled Trial. *The American Journal of Sports Medicine*, *39*(11), 2296–2303. http://doi.org/10.1177/0363546511419277
58. Price, R. J. (2004). The Football Association medical research programme: an audit of injuries in academy youth football. *British Journal of Sports Medicine*, *38*(4), 466–471. http://doi.org/10.1136/bjsm.2003.005165
59. 'Progression Models in Resistance Training for Healthy Adults'. (2002). *Medicine and Science in Sports and Exercise*, 34(2), pp. 364–380. doi: 10.1097/00005768-200202000-00027.
60. Proske, U, Morgan, D., Brockett, C. and Percival, P (2004a). 'Identifying Athletes at Risk of Hamstring Strains and How to Protect Them', *Clinical and Experimental Pharmacology and Physiology*, 31(8), pp. 546–550. doi: 10.1111/j.1440-1681.2004.04028.x.
61. Proske, U, Morgan, D., Brockett, C. and Percival, P. (2004b). 'Identifying Athletes at Risk of Hamstring Strains and How to Protect Them', *Clinical and Experimental Pharmacology and Physiology*, 31(8), pp. 546–550. doi: 10.1111/j.1440-1681.2004.04028.x.
62. Rahnama, N, Reilly, T, Lees, A and Graham-Smith, P. (2003). 'Muscle fatigue induced by exercise simulating the work rate of competitive soccer', *Journal of Sports Sciences*, 21(11), pp. 933–942. doi: 10.1080/0264041031000140428.
63. Rhea, M. R., Alvar, B. A., Burkett, L. N. and Ball, S. D. (2003). 'A Meta-analysis to Determine the Dose Response for Strength Development', *Medicine & Science in Sports & Exercise*, 35(3), pp. 456–464. doi: 10.1249/01.mss.0000053727.63505.d4.
64. Sallay, P. I., Friedman, R. L., Coogan, P. G. and Garrett, W. E. (1996). 'Hamstring Muscle Injuries Among Water Skiers: Functional Outcome and Prevention', *The American Journal of Sports Medicine*, 24(2), pp. 130–136. doi: 10.1177/036354659602400202.
65. Schmitt, B. Tim, T. McHugh, M. (2012). 'Hamstring Injury Rehabilitation and Prevention of Reinjury Using Lengthened State Eccentric Training: A New Concept. *International Journal of Sports Physical Therapy*. 2012;7(3):333-341.
66. Shankar, P. R., Fields, S. K., Collins, C. L., Dick, R. W., & Comstock, R. D. (2007). Epidemiology of High School and Collegiate Football Injuries in the United States, 2005 2006. *The American Journal of Sports Medicine*,*35*(8), 1295–1303. http://doi.org/10.1177/0363546507299745
67. Sherry, M. A. and Best, T. M. (2004a). 'A Comparison of 2 Rehabilitation Programs in the Treatment of Acute Hamstring Strains',*Journal of Orthopaedic & Sports Physical Therapy*, 34(3), pp. 116–125. doi: 10.2519/jospt.2004.34.3.116.

68. Sherry, M. A. and Best, T. M. (2004b). 'A Comparison of 2 Rehabilitation Programs in the Treatment of Acute Hamstring Strains', *Journal of Orthopaedic & Sports Physical Therapy*, 34(3), pp. 116–125. doi: 10.2519/jospt.2004.34.3.116.
69. Sprague, P. and Mann, R. V. (1983). 'The Effects of Muscular Fatigue on the Kinetics of Sprint Running', *Research Quarterly for Exercise and Sport*, 54(1), pp. 60–66. doi: 10.1080/02701367.1983.10605273.
70. Stone, W. J. and Coulter, S. P. (1994). 'Strength/Endurance Effects From Three Resistance Training Protocols With Women', *The Journal of Strength and Conditioning Research*, 8(4). doi: 10.1519/1533-4287(1994)008<0231:seeftr>2.3.co;2.
71. Sutton, G. (1984). 'Hamstrung by Hamstring Strains: A Review of the Literature*', *Journal of Orthopaedic & Sports Physical Therapy*, 5(4), pp. 184–195. doi: 10.2519/jospt.1984.5.4.184.
72. Tanaka, H., Costill, D. L., Thomas, R., Fink, W. J., & Widrick, J. J. (1993). Dry-land resistance training for competitive swimming. *Medicine & Science in Sports & Exercise*, *25*(8). http://doi.org/10.1249/00005768-199308000-00011
73. Verrall, G. M. (2001). 'Clinical risk factors for hamstring muscle strain injury: a prospective study with correlation of injury by magnetic resonance imaging', *British Journal of Sports Medicine*, 35(6), pp. 435–439. doi: 10.1136/bjsm.35.6.435.
74. Verrall, G. M., Kalairajah, Y., Slavotinek, J. P. and Spriggins, A. J. (2006). 'Assessment of player performance following return to sport after hamstring muscle strain injury', *Journal of Science and Medicine in Sport*, 9(1-2), pp. 87–90. doi: 10.1016/j.jsams.2006.03.007.
75. Woods, C. (2002). 'The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of preseason injuries * Commentary', *British Journal of Sports Medicine*, 36(6), pp. 436–441. doi: 10.1136/bjsm.36.6.436.
76. Woods, C. (2004a). 'The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries', *British Journal of Sports Medicine*, 38(1), pp. 36–41. doi: 10.1136/bjsm.2002.002352.
77. Woods, C. (2004b). 'The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries', *British Journal of Sports Medicine*, 38(1), pp. 36–41. doi: 10.1136/bjsm.2002.002352.
78. Woods, C. (2004c). 'The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries', *British Journal of Sports Medicine*, 38(1), pp. 36–41. doi: 10.1136/bjsm.2002.002352.
79. Worrell, T. W. (1994). 'Factors Associated with Hamstring Injuries', *Sports Medicine*. Springer, 17(5), pp. 338–345. doi: 10.2165/00007256-199417050-00006.
80. Yamamoto, T. (1993.*) Relationship between hamstring strains and leg muscle strength. Journal of Sports Medicine and Physical Fitness* 33, 194–199.

Appendices

Appendices 1: Poster

Volunteers Wanted For Dissertation Research

Investigation into two types of hamstring training protocols on peak torque and fatigue resistance.

Do you play sport or like to keep fit…

Do you want to minimise the chance of injury while you train/workout….

Don't miss this chance!!

Our study will investigate two types of hamstring training protocols, one being strength training and the other endurance training by way of Nordic hamstring curls.
Why not become a part of a study that will scientifically prove which way is best to train hamstrings

If you would like to be a part of this study please contact me:
d.roche@edu.salford.ac.uk
k.heron@edu.salford.ac.uk
s.todd@edu.salford.ac.uk

Appendix 2: Participant Information Sheet

Study Title: An Investigation into Two Modes of Hamstring Training on Parameters of Strength and Fatigue Resistance

You are being invited to take part in a research study that we are undertaking as part of our BSc (Hons) Sport Rehabilitation Dissertation. Taking part is completely voluntary and you are free to drop out at any point during the study without stating a reason. You will be given at least 24 hours after reading this information sheet to decide whether you wish to participate in the study. If you do wish to take part you will be asked to sign a health questionnaire and consent form stating you have agreed to take part in the study.
Before you decide you should first understand why the study is being carried out and what it will involve you doing. If you have any questions or need a further explanation of the study feel free to ask at any point.
What is the purpose of the study?
The purpose of the study is to investigate which training protocol is better to train the hamstrings to prevent fatigue hamstring injuries.
Why have I been invited?
You have been selected as you are physically active and part of the University of Salford.
What will happen to me if I take part/what will I have to do?

The study is designed to run over four weeks. Firstly there will be a session of testing on the KinCom Dynamometer to see how much force you can create within your hamstrings. You will also have to undergo a fatigue protocol on the first and last day of the study. This will show us if fatigue has an effect on hamstring force production and its break point angle. A four week intervention phase where, two times a week you will be asked to carry out your assigned exercise under supervision. Each session will take place in the performance lab r at your training and should last no longer than ten minutes. The fatiguing protocol on the first and the last day will take place in the performance lab. Finally we will finish by once again retesting on the KinCom Dynamometer to see how much force your hamstrings produced and at which the angle of peak torque occurred, then comparing with the preliminary data to see if protocols had an effect on break point angle and peak torque pre and post fatigue.
Expenses and Payments?
No expenses will be provided nor payment.
What are the possible disadvantages and risks of taking part?

Whilst taking part in this study you may feel some minor discomfort and tenderness in your hamstring muscles as a side effect of the training intervention. However both testing days will require maximal effort and run the risk or injury. As the training protocol is implemented you may feel some soreness in your hamstrings that will pass quite soon.

What are the possible benefits of taking part?
This study may benefit you personally nevertheless the results will stand to increase your understanding of hamstring injuries and strategies on how to prevent hamstring strains in the future.
What if there is a problem?

If you have any concerns regarding the study please speak to us and we will do our best to answer any of your questions. If you are unhappy with any aspect of the study and wish to make a formal complaint, please contact the office for Health, Sport and Rehabilitation Sciences which can be found in the Allerton building on the first floor.
Will my taking part in the study be kept confidential?

All data collected will be kept confidential and only accessible to us the researchers. Data will be taken straight from the testing kit and put onto a password protected file. Your personal information will be stored in the same file only accessible by us. You will be assigned a number to your name so that your personal information is kept confidential. The data collected will be seen by our supervisor however he will not have access to your personal information. Your data will only be kept for the duration of the study and all copies will be deleted after it has been completed.
What will happen if I don't carry on with the study?
If at any point you decide that you no longer wish to take part in the study then any data collected from you will be deleted and not included in the final results. Once the data has been collected and analysed it will be used in our dissertation and therefore could possibly be published. No personal information will be used in the analysing of this data and you may request your results in which we can email them to you.
What will happen to the results of the research study?
The results will be put in our dissertation. These results may be published. Personal information will not be included in our results however participant my request there results via email, in which we would be obliged to do so.
Who is organising or sponsoring the research?
This research is organised by us and our supervisor. This study will be sponsored by the University of Salford.
Further information and contact details:
Additional information that participants may require:
1. General information about the research study:
David Roche <d.roche@edu.salford.ac.uk>
Kate Heron <k.heron@edu.salford.ac.uk>
Stefanie Todd <s.todd@edu.salford.ac.uk>
2. Advice as to whether you should participate:
David Roche <d.roche@edu.salford.ac.uk>
Kate Heron <k.heron@edu.salford.ac.uk>
Stefanie Todd <s.todd@edu.salford.ac.uk>
OR

Martyn Matthews <m.matthews@salford.ac.uk>
3. Who they should approach if unhappy with the study: <m.matthews@salford.ac.uk>

Appendix 3: Health Questionnaire
Isokinetic Testing Training Exercises Other…………………
(Please specify)

1. <u>Personal information</u>

Surname: …………………………… Forename(s): …………………………...
Date of birth: …………................... Age: ……………………..……………….
Height (cm): Weight (kg): …………….……………….

2. <u>Additional information</u>

a. Please state when you last had something to eat / drink……………………...
b. Tick the box that relates to your present level of activity:
Inactive ☐ moderately active ☐ highly active ☐
c. Give an example of a typical weeks exercise:
……………………………………………………………………………………...
d. If you smoke, approximately how many cigarettes do you smoke a day……..

3.	Are you currently taking any medication that might affect your ability to participate in the test as outlined?	YES	NO
4.	Do you suffer, or have you ever suffered from, cardiovascular disorders? E.g. Chest pain, heart trouble, cholesterol etc.	YES	NO
5.	Do you suffer, or have you ever suffered from, high/low blood pressure?	YES	NO
6.	Has your doctor said that you have a condition and that you should only do physical activity recommended by a doctor?	YES	NO
7.	Have you had a cold or feverish illness in the last 2 weeks?	YES	NO
8.	Do you ever lose balance because of dizziness, or do you ever lose consciousness?	YES	NO

9.	Do you suffer, or have you ever suffered from, respiratory disorders? E.g. Asthma, bronchitis etc.	YES	NO
10.	Are you currently receiving advice from a medical advisor i.e. GP or Physiotherapist **not** to participate in physical activity because of back pain or any musculoskeletal (muscle, joint or bone) problems?	YES	NO

11.	Do you suffer, or have you ever suffered from diabetes?	YES	NO
12.	Do you suffer, or have you ever suffered from epilepsy/seizures?	YES	NO
13.	Do you know of any reason, not mentioned above, why you should not exercise? E.g. Head injury (within 12 months), pregnant or new mother, hangover, eye injury or anything else.	YES	NO

Appendix 4: Consent Form

INFORMED CONSENT

The full details of the test have been explained to me. I am clear about what will be involved and I am aware of the purpose of the test, the potential benefits and the potential risks.

I know that I am not obliged to complete the test. I am free to stop the test at any point and for any reason.

The test results are confidential and will only be communicated to others once the data is fully analysed, with no identifiable individual data.