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Hamstring Training Effects on Strength Gains in NCAA Division I Varsity Soccer Players

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Andrea M. Chilcote

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HAMSTRING TRAINING EFFECTS ON STRENGTH GAINS IN NCAA DIVISION I VARSITY SOCCER PLAYERS

A Thesis Submitted in Fulfillment
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Thesis – KSS 5950

Andrea M. Chilcote, BS, ATC

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ABSTRACT

Those athletes who run at high speeds require eccentric strength when the hamstring muscles are in a lengthened state in order to absorb the increased forces, decreasing injury rate and performance deficits (Schmitt, Tyler & McHugh 2012). The purpose of this study was to determine if the intervention of an eccentric hamstring strengthening program would increase peak torque production in eccentric and concentric hamstring and quadriceps movements in Division I Men and Women Varsity soccer players.

Participants included 8 Division I soccer athletes (3 men, 5 women, mean age = 19.3 years (men) and 19.4 years (women), mean height = 71in (men) and 67.4in (women), mean weight = 166lbs (men) and 139.8lbs (women)). A W-Critical (One-Tail) test was run on the peak torque extension and flexion for eccentric and concentric movements comparing pre-test measurements to post-test measurements. A significant mean difference was found for concentric flexion of the non-dominant leg with a mean difference of -9.46. Other significant differences were found for peak torque where the pre-test had higher measurements. This included dominant extension at 150ft/lbs (mean difference = 9.42), dominant eccentric flexion at 60ft/lbs (mean difference = 15.28), non-dominant eccentric flexion at 150ft/lbs (mean difference = 4.74), dominant concentric flexion at 180ft/lbs (5.38) and non-dominant concentric flexion at 180ft/lbs (mean difference = 2.74).

Prior to completing the eccentric hamstring strengthening program, participants self-reported having a total of 63 lower leg injuries. During the spring season, no lower leg injuries were recorded for either men or women. It was concluded from the findings of this study that an eccentric hamstring strength training program had no effect on eccentric peak torque. An increase in non-dominant peak torque for concentric flexion at 60ft/lbs was found.

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CHAPTER I

INTRODUCTION

Statement of the Problem

Hamstring injuries are a debilitating plague in sports, accounting for 12-16% of all injuries in athletes with a re-injury rate reported as high as 22-34% (Schmitt, Tyler & McHugh 2012). These high rates are due to the amount of time needed for recovery, which affects athlete's performance and training schedule. Those athletes that participate in high speed running need eccentric strength when the hamstring muscles are in a lengthened state (Schmitt, Tyler & McHugh 2012). Sports such as basketball, baseball, football, track and field, soccer, rugby require the athlete to be engaged in high speed running. These athletes are at a higher risk of hamstring injuries because of the role eccentric contractions of the hamstrings have on running.

Many studies have shown that eccentric fatigue has negative effects on performance (Brockett, Warren, Gregory, Morgan & Proske 1997; Chen, Nosaka, Pearce & Chen 2012; Jonhagen, Nemeth & Eriksson 1994; Parr, Yarrow, Garbo & Borsa 2009; Skurvydas, Brazaitis, Kamandulis, Mickeviciene & Karanauskiene 2011). These studies have shown that not only is performance affected, but damage is occurring to these anatomical structures at the molecular level (Brockett, Warren, Gregory, Morgan & Proske 1997; Chen, Nosaka, Pearce & Chen 2012; Parr, Yarrow, Garbo & Borsa 2009). Research has recommended the importance of increasing eccentric hamstring strength as a potential injury prevention method to hamstring injuries (Askling, Karlsson & Thorstensson 2003; Hagglund, Walden & Ekstrand 2007; Kaminski, Wabbersen & Murphy 1998; Petersen; Thorborg, Nielsen, Budtz-Jorgensen & Holmich 2011; Schmitt, Tyler & McHugh 2012).

Rationale of the Study

The aim of this study was to record the effects of a weighted and functional four-week eccentric hamstring strengthening program on hamstring and quadriceps strength in Men's and Women's Division I Varsity Soccer players. These results were to be used for practical application by coaches, athletic trainers, and strength coaches in determining whether or not eccentric hamstring strengthening could be a beneficial aspect in a strength training program for athletes that experience strenuous eccentric loading of the hamstrings while this muscle group is in a lengthened state. Soccer athletes fit this description as they participate in high speed running and eccentric loading of their hamstrings in a lengthened state multiple times during a soccer game or practice.

Research Question

Are there any strength gains, eccentric or concentric, following a four-week eccentric hamstring strengthening program?

Statement of the Purpose

The purpose of this study was to determine the effects of a four week eccentric hamstring strengthening program on peak force production for both eccentric and concentric hamstring and quadriceps movements in Division I Men's and Women's Soccer players.

Hypothesis

Therefore after the participants complete the four-week eccentric hamstring strengthening program there will be an increase in peak torque production for both concentric and eccentric movements of the hamstring and quadriceps muscle group.

Limitations of the Study

This study was limited by the following:

1. The Biodex machine terminally malfuctioned before all subjects were able to complete the post-program measurements, dropping the original sample size (N = 41) to N = 5.
2. When performing on the Biodex machine the participants did not appear to be fully comfortable until the second speed for each leg for both concentric and eccentric settings.
3. No familiarization period was given for the participants to become accustomed to the Biodex machine.
4. The strengthening program was conducted for four weeks.

Delimitations of the Study

This study was delimitated by the following:

1. Participants were limited to NCAA Division I Varsity men's and women's soccer players.
2. The resistance used for each exercise was set at specific values for men and women rather than individualized for each participant.

Basic Assumptions

1. It was assumed that participants gave their best effort while performing all strengthening exercises.
2. It was assumed that all resistance selected was heavy enough to challenge the participant but not so heavy that they could not appropriately perform the exercise.
3. It was assumed maximal effort was given by participants during pre- and post-measurements.

Definition of Terms

1. *Bilaterally:* Pertaining to both the right and left sides of a structure.
2. *Concentric Contraction:* Occurs when the muscle produces force while shortening (Jonhagen, Nemeth & Eriksson 1994).
3. *Dominant:* The leg the participant indicated as the primary leg used to kick a soccer ball.

4. *Eccentric Contraction:* Occurs when the muscle produces force while lengthening (Jonhagen, Nemeth & Eriksson 1994).
5. *Fatigue:* The point where the participant can no longer complete the activity to the best of their ability.
6. Isokinetic: An exercise that provides variable resistance to a movement at a constant speed.
7. *Isotonic:* A contraction where the muscle remains under relatively constant tension while the length of the muscle changes.
8. *Passive:* No muscular contraction used to move a limb, movement is produced from an outside force.
9. *Non-dominant:* The leg the participant indicated was not their primary leg used to kick a soccer ball.
10. *Strain:* The result of excessive stretch often combined with simultaneous activation of a muscle.

CHAPTER II

REVIEW OF LITERATURE

This chapter reviews the literature related to hamstring muscle anatomy, hamstring muscle injury and addresses the need for eccentric hamstring strengthening programs. Related literature was organized into the following topic areas: overview of hamstring injury epidemic, hamstring muscle anatomy, and physiology of hamstring injury, role of eccentric muscle contractions in hamstring injuries, the role of eccentric hamstring strengthening and the reliability of the Biodex machine.

Overview of Hamstring Injury Epidemic

When looking at all muscles strains that occur in nearly all forms of team and individual sports involving the lower body, hamstring muscles strains are the most common (Clark, Bryan, Culgan & Hartley 2005; Greig & Siegler 2009; Kujala, Orva & Jarvinen 1997). Lower extremity intensive sports have a high demand for lower extremity speed and power such as soccer, sprinting and football and are at an increased risk for hamstring injury (Askling, Karlsson & Thorstensson 2002; Worrell 1994). When compared to other muscle strains, hamstring muscle strains result in the most missed participation time (Clark, Bryant, Culgan & Hartley 2005). Hamstring injuries are not only debilitating to athletes when they first occur, Hagglund et al (2006) found that athletes returning from hamstring injuries were almost three times as likely to experience an identical injury the next season, through documentation of an elite group of soccer players. Athletes who present with hamstring injuries that occurred in the late swing phase have characteristic deficits in knee flexion torques at moderate speeds (Stanton & Purdam 1989). When looking at injuries that occur to the lower extremity during training and matches for soccer players, Ekstrand & Gillquist (1983) found that 47% of the total 80% were hamstring injuries. It is clear that something must be done about this high rate of hamstring injury. It is pertinent to have a thorough understanding of the anatomy of the muscles, specifically the hamstring muscle group, prior to finding a solution.

Hamstring Muscle Anatomy

It is known that those muscles containing a higher amount of Type I fiber function predominantly help tonic and postural movements. Those muscles that have a higher percentage of Type II fibers are involved more in phasic or rapid activity. Looking at the muscle fiber content of the hamstring muscle group, Garrett, Califf & Bassett (1984) found that hamstrings have a higher percentage of Type II fibers when comparing them to the quadriceps muscle group. Since Type II muscle fibers are involved during exercises of higher intensity and force production it can be assumed that the hamstring muscle group is able to produce a greater intrinsic force while sustaining a large value of active tension than the quadriceps muscle group (Garrett, Califf & Bassett 1984).

The hamstring muscle group is made up of three different muscles: biceps femoris, semitendinosus and semimembranosus (Prentice 2011). These muscles are unique because all three muscles cross two different joints, making it more susceptible to large length changes. (Grey's Anatomy 1989). These muscles function together to assist in knee flexion and hip extension.

The biomechanics of the hamstring muscle group's active and passive tension during a running gait is relatively unique due to its biarticulate structure. Tension in a muscle is a direct result of the passive component, the muscle length, and the active component, the contractile activity. This means that the longer length the muscle is stretched to and the more active it is during this stretch will determine the amount of tension the muscle sustains during this time. When looking at the length and force production of the hamstring muscles during the running gait it is found that they are most active during a large portion of the swing phase and longer in the early stance. During these two phases the hip is in a flexed position and the knee is in an extended position, forcing the hamstring muscle group to be maximally stretched. During this flexed positon he hamstrings contract concentrically and the quads contract eccentrically (Coombs & Garbutt 2002). To summarize, during the swing phase and early stance phase of running the hamstring muscles are producing a high amount of active force while under maximal stretch (Garrett, Califf & Bassett 1984, Brughelli, Nosaka &Cronin 2008).

Physiology of Hamstring Injury

There are many different propositions to why the hamstring muscle group is so frequently injured. This includes things such as inflexibility, muscle fatigue, decreased strength, strength imbalances between the hamstrings and the quadriceps, inadequate warm-up, previous hamstring injury, lumbar spine and/or sacroiliac pathology and bilateral hamstring deficits (Askling, Karlsson &Thorstensson 2002; Mjolsnes, Arnason, Osthagen, Raastad & Bahr 2003; Stanton & Purdam 1989; Hennessy & Watson 1993; Coombs & Garbutt 2002). No one mechanism has been proven to be the number one cause of hamstring strains. Hennessy & Watson (1993) found that hamstring flexibility did not differ between injured and noninjured subjects, but there was a difference in lumbar lordosis. Although this study indicates that hamstring flexibility is no different between injured and uninjured individuals, a decrease in flexibility has not yet been ruled out as a possible cause for hamstring injuries.

The hamstring muscle group functions in multiple different ways. During extension the hamstring muscle group acts eccentrically providing a posterior pull on the tibia. This pull increases joint stiffness and reduces anterior laxity force, decreasing anterior tibial translation. This decrease in anterior tibial translation essentially is assisting the ACL in its functioning (Yasuda and Sasaki 1987). In this way the hamstrings help prevent overextension by allowing the leg to decelerate prior to full extension and stabilize the knee joint throughout the range of motion (Baratta, Solomonow, Zhou, Letson, Chuinard & D'Ambrosia 1988).

Although there is no absolute mechanism, it has been identified hamstrings are most often injured during the swing phase and the early stance phase of sprinting (Stanton & Purdam 1989). Hamstrings are injured mainly because of the aforementioned biarticulate anatomy that causes extreme lengthening during these phases of running where the hamstrings are producing the most active force. When looking at muscle-tendon tension, a muscle is known to sustain an injury when the level of tension supersedes the tension of the weakest structural element within the muscle (Garrett, Califf & Bassett 1984). During this high level of both passive and active tension the hamstring muscle is the most exposed to injury during a sprinting.

Taking this basic overload principle, it can be assumed that strength plays a large role in the amount of hamstring injuries sustained by those lower extremity athletes. Hamstring muscles must be able to absorb large amounts of force without failing in order to work without injury. Muscles that are able to absorb a high amount of energy are better able to avoid the amount of stretch that produces an injury during a high intensity activity (Mair, Seaber, Glisson & Garrett 1996). When the velocity of the muscle contraction is increased, the difference between eccentric and concentric maximum tension is increased while muscle unit activity remains fairly constant (Garrett, Califf & Bassett 1984). During the swing phase and the early stance phase of sprinting the hamstring muscle group is acting eccentrically. Any muscle functioning eccentrically must do so until all the energy from the moving limb is absorbed. Only then can concentric contractions begin (Mair, Seaber, Glisson & Garrett 1996). Eccentric contractions are an imperative topic point when discussing hamstring injuries for many different reasons.

Before looking at the role of eccentric hamstring contractions it is important to understand the relationship between quadriceps and hamstring contractions. The once agreed upon standard for hamstring to quadriceps strength ratio has generally been 0.6 (Coombs & Garbtt 2002). Coombs & Garbutt (2002) express that this number is wrong mainly because it assesses both concentric hamstring and quadriceps strength. Thinking along these lines is incorrect because the hamstrings and quadriceps never contract concentrically simultaneously. It is more correct to look at a ratio that involves quadriceps concentric strength to hamstring eccentric strength as these are the two actions that happen simultaneously. It has been found for those athletes with an increased percentage of fast twitch fibers the quadriceps concentric to hamstring eccentric ratio should be closer to 1.0 to allow for the hamstrings to effectively brake the leg in those faster sprinters (Coombs & Garbutt 2002).

The Role of Eccentric Contractions in Hamstring Injuries

Eccentric contractions are an imperative topic point when discussing hamstring injuries for many different reasons. Eccentric muscle contractions are different in many ways in comparison to concentric muscle contractions. An eccentric contraction occurs when the muscle is contracting during lengthening. A concentric contraction occurs when the muscle contracts during shortening (Jonhagen, Nemeth & Eriksson 1994). Eccentric contractions are capable of developing higher intrinsic forces within muscles than concentric contractions while using less oxygen at a comparable muscle unit activity (Jonhagen, Nemeth & Eriksson 1994; Stanton & Purdam 1989). When looking at the function of the hamstrings during running, they are primarily involved in braking and stabilization of the hip and knee joints, making them mostly active eccentrically (Mann, Moran & Dougherty 1986). Hamstrings contract eccentrically while quadriceps contract concentrically during leg extension (Coombs & Garbutt 2002). This is in comparison to the quadriceps muscle group which is mostly concentrically active during running. Muscles function eccentrically until the energy in the moving limb is absorbed and concentric function can begin (Mair, Seaber, Glisson & Garrett 1996). Since the hamstring muscle group functions most eccentrically during running and this has been purported to be when hamstring strains occur most often, it is important to understand the ways in which eccentric contractions work (Kaminski, Wabbersen & Murphy 1998). The next topics discussed will be structural and functional changes due to eccentric fatigue and the level of active force produced by an eccentric contraction

It is a common finding that eccentric contractions produce a greater amount of structural damage than concentric contractions. The series elastic component is placed under increased stress with quick eccentric contractions because increased tensions are produced with the same amount of motor unit activity than concentric contractions (Stanton & Purdam 1989). Brockett et al (1997) found that eccentric exercise at the elbow joint causes a change in the ability to judge low levels of force and different elbow angles. This is because during an eccentric contraction the lengthening of the muscle is unevenly distributed, causing some sarcomeres that are weaker to become overextended. This is because these sarcomeres are forced to take up a large fraction of the length change. These sarcomeres may not be able to recover a normal banding pattern after repeated eccentric contractions. This suggests that eccentric exercises cause irreversible damage to cells if an injury occurs.

One purported reportable sign of muscle damage is delayed onset muscle soreness (DOMS). After eccentric exercise many studies have found that DOMS occurs, indicating a possible increase in myofibril inflammation even when compared to concentric exercise (Dannecker, O'Connor, Atchison & Robinson 2005; Jonhagen, Nemeth & Eriksson 1994; Brockett, Morgan & Proske 2001; Kujala, Orava & Jarvinen 1997; Stanton & Purdam 1989). In correlation with DOMS, it has also been found that after performing eccentric exercise there is an increase in limb girth (Brockett, Morgan & Proske 2001). This could be indicative of the inflammatory response that occurs after eccentric resistance exercise. High-intensity eccentric exercise causes a cascade response of the inflammatory response, releasing proinflammatory cytokines, proteolytic enzymes and oxygen free radicals. This type of response is mimicking the acute musculotendinous strain injury response without the muscle even sustaining an injury. If an injury is sustained, the inflammatory response is even greater. Brockett, Morgan & Proske (2001) argue that a shift in length-tension relation is a more ideal way to measure muscle damage because it is not confounded by fatigue effects; it avoids the problem of uncertainty over the optimum length for a contraction and is more reliable in their experience.

Studying the effects of the Nordic hamstring exercise on length-tension relation, Brockett, Morgan & Proske (2001) found that there was a change in the angle-torque relationships. This caused the optimum angle for torque generation to shift towards a greater knee angle, or a longer muscle length. This change in the length-tension relation is a direct result of a disruption of sarcomeres in muscle fibers, which is why it was found immediately after exercise. As previously discussed, this length-tension relation shift happens towards the direction of longer muscle lengths. This is due to the sarcomeres lying in series within the still-contracting parts of the fibers increasing the muscle's series compliance. This change is beneficial because of the previously discussed active force production of the hamstring muscle group. The hamstring muscle group produces the highest active force during a lengthened state. Changing the optimum angle for torque generation to a longer state could potentially help decrease hamstring injuries.

Although disruption to sarcomeres can be beneficial by changing the length tension relationship, sometimes this disruption can cause injury. Similar to the results found by Brockett et al (1997), after eccentric exercise sarcomeres are damaged and some cannot recover to their normal banding pattern after. If the number of fibers that recover from this damage is larger than the number of fibers that die, no injury occurs. Those fibers that recover are able to contribute to the length-tension relation and were found to shift back to the control levels initially found within two days of the eccentric exercise. This damage to force-bearing structures caused by eccentric exercise can cause a decrease in voluntary induced muscle performance (Skurvydas et al 2009).

This muscle damage caused by eccentric exercise has been found to have detrimental effects on performance. Parr et al (2009) found with elbow flexors, eccentric isotonic exercise creates greater functional deficits such as decreases in strength and range of motion when compared to a concentric and eccentric isokinetic exercise. These deficits were found to have an effect on muscle strength reduction up to seven days after the eccentric exercise is performed. Greig & Siegler (2009) used a treadmill protocol and 10 professional soccer players as participants to induce the physical demands of the intermittent nature of a soccer game. With this protocol they found the peak eccentric torque able to be achieved by the participant decreased as a function of time. They found the greatest influence in the decrease in eccentric torque was the speed at which the participant was running. Faster speeds created the greatest decrease in peak torque. This study indicates that throughout soccer games eccentric fatigue is present. Skurvydas et al (2011) found a decrease in voluntary induced muscle performance occurred after completing eccentric exercise. It is clear that eccentric muscle activity can cause damage to intricate muscle structures while also having a detrimental effect on performance.

A well-researched component of eccentric exercise is the fatigue induced within the muscle after heavy bouts of eccentric exercise. Skurvydas et al (2011) found that eccentric fatigue can affect the ability of muscles to work efficiently and the efferent neuromuscular drive of human skeletal muscle is decreased after eccentric exercise. Their results found that contraction type defines length dependent changes after eccentric exercise. The increased fatigue at shorter lengths is evident only during concentric isokinetic contractions. It was also proposed that a decrease in force production at this shorter length could affect overall performance. Eccentric induced fatigue may lead to a decrease in the muscle's ability to absorb energy, increasing the risk of injury. The stronger a muscle is the more force it can absorb prior to failure when compared to a weaker muscle (Askling, Karlsson & Thorstensson 2003).

Mair et al (1996) proposed that the decreased ability of a muscle to absorb energy is the reason why fatigue could be a factor in muscle injury. Breaking down the stages of muscle stretching, a muscle's ability to absorb energy is decreased most significantly in the early stages of muscle stretching. What energy a non-fatigued muscle could be capable of absorbing at this length a fatigued muscle might require a change in the length in order to absorb that same amount of energy. This decrease in the muscle's ability to absorb energy is also related to a decrease in muscle contractile strength (Mair et al 1996). This increased change in length could possibly cause an injury (Mair et al 1996). Fatigue can also possibly affect the storage and retrieval of elastic energy. An efficient muscle function requires the muscle to stretch less and transfer this stress to the tendon (Mair et al 1996).

In addition to a change of length-tension relation, a change in the optimum angle for torque generation has been found which indicates that some muscle fibers are increasing in series compliance (Brockett, Morgan & Proske 2001). After eccentric exercise and sarcomere recovery some fibers do not completely shift back to the control level representing a training effect in the muscle towards a longer length-tension relation. This change in the length-tension relation could decrease the susceptibility of the muscle to injury (Brockett, Morgan & Proske 2001). When compiling training pre- or post-hamstring injuries those exercises that increase optimum length should be included to decrease the probability of hamstring injuries (Brughelli, Nosaka & Cronin 2008). In order to do this, eccentric exercise should be used as it is the only form of training that has been shown to consistently increase the optimum length of tension development (Brughelli, Nosaka & Cronin 2008).

The Role of Eccentric Hamstring Strengthening

An inconsistency in hamstring injury rehabilitation indicates a lack of knowledge regarding the mechanism of injury and factors that contribute to hamstring strain (Worrell 1994). One of the proposed risk factors for hamstring injuries is strength deficiency (Yamamoto 1993). If a muscle has an increased ability to absorb energy it is better able to avoid the amount of stretch that produces injury (Mair et al 1996, Stanton & Purdam 1989). Taking into consideration that nonfatigued muscles absorb much more energy in the early phases of stretching is important when developing an eccentric strength training program as an increase in eccentric muscle strength at shorter lengths could decrease injuries (Mair et al 1996). An interesting aspect of eccentric contractions is their ability to produce increased forces at 20% less oxygen consumption, carbon dioxide produce and energy expenditure than equal bouts of concentric work (Kaminski, Wabbersen & Murphy 1998, Stanton & Purdam 1989). Not only are eccentric contractions more efficient than concentric contractions, many studies have shown that addition of eccentric overloading to a training program increases not only eccentric contraction strength but also concentric contraction strength and overall performance more than concentric training alone (Kaminski, Wabbersen & Murphy 1998, Stanton & Purdam 1989; Askling, Karlsson & Thorstensson 2002). Brockett, Morgan & Proske (2001) pose the interesting observation that there are not many occasions during daily living where the hamstrings carry out eccentric contractions. This indicates that there is a need to add eccentric hamstring strengthening exercises to a training program in order to get the benefits of increased strength in eccentric hamstring contractions.

Studies have been done on eccentric training at other body parts, especially for Achilles tendinopathy pain. Allison & Purdam (2009) found that with the addition of eccentric exercise patients are more likely to show a positive outcome in pain than with concentric exercises alone. Participants in this study were also able to return to sport quicker than those participants who solely performed concentric training programs. Stanton & Purdam (1989) indicate that quick eccentric hamstring training may be more beneficial in strengthening the series elastic component. This is important because Cavagna et al (1977, 1976) found that an increase in running speed causes the contractile component of the muscle to play a progressively less important role in contrast to the elastic component.

Askling, Karlsson & Throstensson (2003) created a hamstring training program with eccentric overload using a YoYo flywheel ergometer for thirty male premier-league soccer players. Half of the soccer players performed the training program while the other half were assigned to a control group. What they found was those participants that performed the eccentric overload training program sustained less hamstring strain injuries and showed significant increases in strength and speed when compared to the control group. The aim of training should be to shift the point of hamstring to quadriceps ratio equality towards a more flexed knee joint position so there is an increased potential for stability through an increased range of motion (Coombs & Garbutt 2002).

Inspiration for this study was drawn from the research done by Brughelli, Nosaka & Cronin (2009) in an attempt to create a more sports-specific eccentric overload training program. Brughelli, Nosaka & Cronin (2009) developed a progressive eccentric overload strengthening program for a 24-year-old male Australian Rules football player. Exercises included eccentric box drops, box lunge drops, eccentric resisted pushes, eccentric towel pulls and weighted drop lunges. This 9-week program allowed for progression in repetitions and addition of weights. This took into account that an eccentric program is based on increasing the strength of the tendon by gradually overloading it in order to promote an increase in tensile strength. They also took into consideration the three basic principles of eccentric exercise: length of the tendon; the load on the tendon; and the speed of the exercise movement. In order to create a progressive eccentric exercise program these three factors must be modified (Dee et al 2011). Brughelli, Nosaka & Cronin (2009) found that the optimum angle of peak torque during knee flexion and knee extension decreased. Functionally, the participant in this study was finally able to return to play pain free.

Reliability of the Biodex Machine

The Biodex system 2 isokinetic dynamometer was chosen to be used to measure both eccentric and concentric hamstring and quadriceps strength for this study because of its availability and its reliability. Almosnino et al (2012) used forty-five healthy, physically active young adults for a protocol involving concentric and eccentric contractions of the knee extensors and flexors to evaluate peak moment, dynamic control ratios and the difference between eccentric and concentric ratio at two different angular velocities. What they found was by using the Biodex system 3 isokinetic dynamometer they were able to reproduce between day common strength indicies. They deemed the Biodex system 3 isokinetic dynamometer sufficient for measuring concentric and eccentric contractions and detecting strength changes as a result of targeted intervention for the knee musculature.

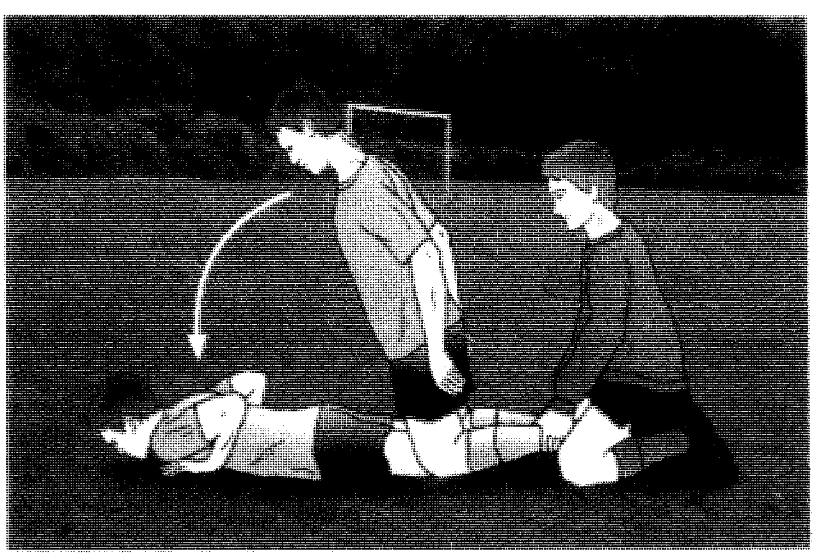
In addition to that research, McCleary & Andersen (1992) found that reliable measurements or reciprocal right knee extension and flexion peak torque can be obtained with the Biodex isokinetic dynamometer. What they also found was that extension peak torque must change by greater than 13.7ft-lbs and flexion peak torque must change by greater than 5.9ft-lbs between testing sections in order to be considered statistically significant results.

The Biodex machine is able to produce angle specific moment curves, which can provide a template to assess muscular and joint pathologies (Coombs & Garbutt 2002). It is especially useful because it can test and show both eccentric and concentric moments throughout a specific range of motion (Coombs & Garbutt 2002).

Nordic Hamstring Protocol

The Nordic hamstring exercise goes by many names and has been widely used to decrease hamstring injuries in sports. Many studies have shown that it increases performance, decreases hamstring injury rate and increases eccentric hamstring torque (Clark, Bryant, Culgan & Hartley 2005; Mjolsnes, Arnason, Osthagen, Raastad & Bahr 2004; Petersen, Thorborg, Nielsen, Budtz-Jorgensen & Holmich 2011; Schmitt, Tyler & McHugh 2012; Thorborg 2012). This exercise is performed in groups of two. One partner kneels on the ground while the other partner holds the kneeling partner's ankles to the ground. The kneeling partner then falls forward in a controlled manner, using their hamstrings eccentrically until they can no longer hold themselves up and must fall to the ground, catching themselves with their hands. See Figure 1 for a visual of this exercise.

Figure 1: Nordic Hamstring Exercise



CHAPTER III

METHODOLOGY

This study examined the effect of an eccentric hamstring training program on hamstring and quadriceps strength and the number and severity of lower leg injuries in NCAA Divison I Varsity men's and women's soccer players. The purpose of this chapter is to describe (a) participants and location, (b) measurements, (c) eccentric hamstring strengthening program.

Participants and Location

Participants included NCAA Division I Men's and Women's Varsity Soccer players (3 men, 5 women, mean age was 19.3 (men) and 19.4 (women), mean height was 71in (men) and 67.4in (women), mean weight was 166lbs (men) and 139.8lbs (women)). Participants were excluded if they sustained a lower leg injury during the study that prevented them from participating in their weight lifting or training sessions. Participants were given a demographics sheet to fill out (see appendix for copy). This included age, height, weight, position played, number of lower leg injuries sustained prior to this study, the amount of time missed because of indicated injuries (in days), and a question about current injuries that may affect the participant's ability to participate in the study.

Measurements

After completing both the consent form and the demographics form, participants underwent initial strength measurements. These measurements were performed bilaterally with a Biodex Multi-Joint System 2 AP machine and included concentric and eccentric measurements of both the quadriceps and hamstring muscle groups.

Participants performed a 10 minute warm-up on a cycle ergometer. Following the warm-up participants were fit into the Biodex machine. Participants were instructed to stay in a sitting position while they were being strapped to the machine. The angle of the trunk/thigh was set at 90°. Straps were be placed around the abdomen, around the thigh of the leg being tested, and around the calf of the leg being tested. Participants will be individually positioned into the Biodex machine as directed in the Biodex System 2 manual. All participants were fitted the same for the leg being tested. The rotational axis of the test leg knee was aligned with the Biodex hinge. Participants were asked to complete 6 maximal eccentric and 6 maximal concentric contractions for both left and right knee flexors and knee extensors at both $60° s^{-1}$ and $180° s^{-1}$ for concentric contractions and $60° s^{-1}$ and $150° s^{-1}$ for eccentric contractions.

For concentric contractions the participants were instructed to kick up and pull down on the lever as hard and as fast as possible, extending their leg first. For eccentric contractions participants were instructed to pull down against the resistance machine and push up against the machine as hard and as fast as possible, flexing their knee first. To ensure all participants provide maximal effort, they were provided with visual feedback from the Biodex machine and verbal encouragement from the primary investigator.

Eccentric Hamstring Strengthening Program

Participants completed a four-week progressive training program, consisting of four exercises. Participants reported three days a week to complete two exercises a day. All three days participants completed the Nordic hamstring exercise. In order to do this, participants were placed into groups of two. One partner kneeled on the ground while the other partner held the kneeling partner's ankles to the ground. The kneeling partner then falls forward in a controlled manner, using their hamstrings eccentrically until they can no longer hold themselves up and must fall to the ground, catching themselves with their hands. This exercise was completed each week at two sets by five repetitions.

Participants completed an eccentric Romanian Dead Lift one session during the week. The amount of weight chosen was different for men and women and increased by 5 lbs every week. For the men, the first week 135 lbs was used, the second week 140 lbs was used, the third week 145 lbs was used and the fourth week 150 lbs was used. For the women, they started week one using 80 lbs and progressed to 85 lbs for week two, 90 lbs for week three and 95 lbs for week 4. In order to ensure that it was an eccentric exercise, participants were instructed to complete the same form as a normal Romanian Dead Lift but allow for eight seconds when forward flexing the torso before returning to a standing position. Participants will be instructed to extend the torso at a normal speed.

Participants completed box falls one session during the week. The men used a box that was 24 in tall while the women used a box that was 18 in tall. Participants will be instructed to step off the box and allow both feet to hit the ground at the same time and immediately bend into a proper squat. For the first week participants completed one set of ten repetitions, for the second week participants completed one set of fifteen repetitions, for the third week participants completed two sets of ten repetitions, and for the final week participants completed one set of fifteen repetitions.

Participants completed a single leg Romanian Dead Lift with a dumbbell one session during the week. All men were instructed to use 30 lbs and all women were instructed to use 15 lbs. For the first week participants completed two sets of six repetitions, for the second week participants completed two sets of eight repetitions, for the third week participants completed two sets of ten repetitions, and for the final week participants completed two sets of twelve repetitions. After the four weeks participants reported again to repeat the initial measurement with the Biodex machine, ran by the primary investigator. These measurements were taken exactly as the first measurements. See Table 1 and 2 for a visual of the progression.

Table 1: Men's Training Progression

Men			
Week 1	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 1 x 10	Romanian Dead Lift (eccentric) #135, 2 x 5, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 6, 8s fall
Week 2	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 1 x 15	Romanian Dead Lift (eccentric) #140, 2 x 6, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 8, 8s fall
Week 3	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 2 x 10	Romanian Dead Lift (eccentric) #145, 2 x 7, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 10, 8s fall
Week 4	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 3 x 10	Romanian Dead Lift (eccentric) #150, 2 x 8, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 12, 8s fall

Table 2: Women's Training Progression

Women			
Week 1	Monday	Wednesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 1 x 10	Romanian Dead Lift (eccentric) #80, 2 x 5, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 6, 8s fall
Week 2	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 1 x 15	Romanian Dead Lift (eccentric) #85, 2 x 6, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 8, 8s fall
Week 3	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 2 x 10	Romanian Dead Lift (eccentric) #90, 2 x 7, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 10, 8s fall
Week 4	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 3 x 10	Romanian Dead Lift (eccentric) #95, 2 x 8, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 12, 8s fall

CHAPTER IV

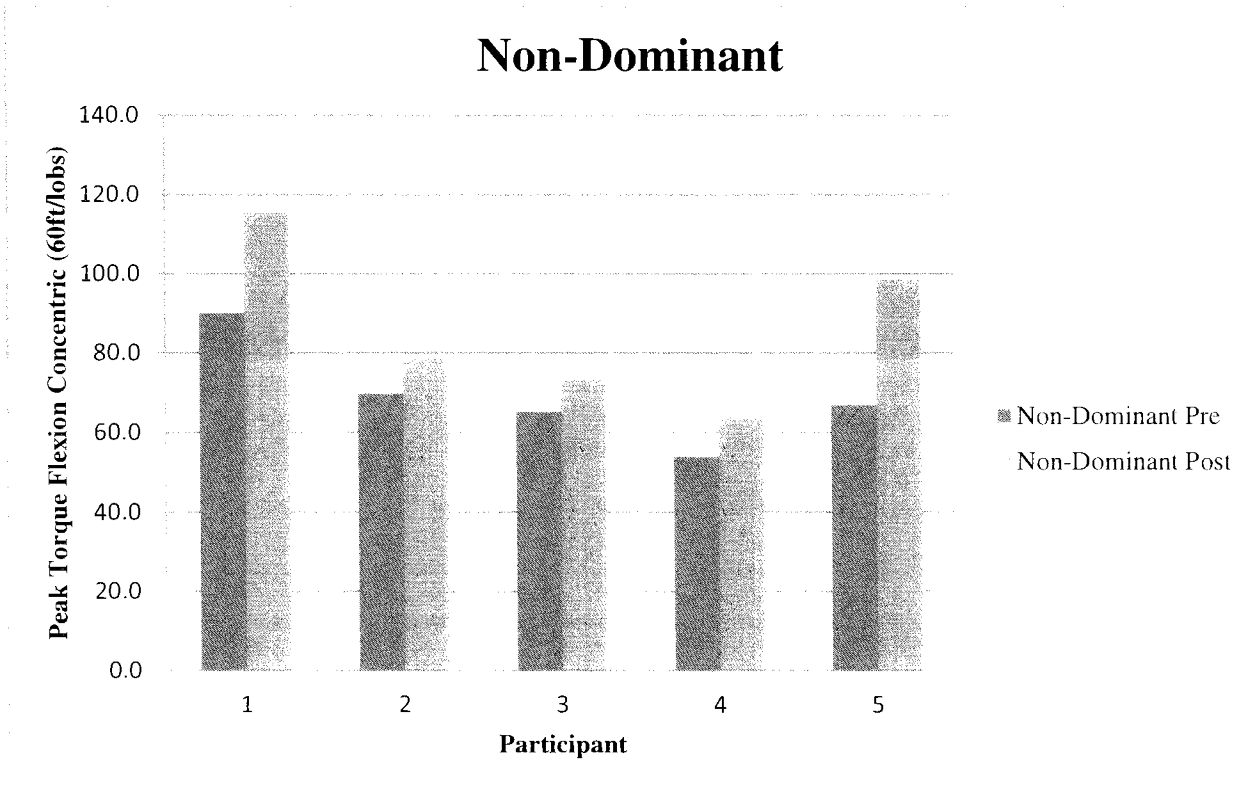
RESULTS

The purpose of this study was to record the effects of a weighted and functional four-week eccentric hamstring strengthening program on hamstring and quadriceps strength in Men's and Women's Division I Varsity Soccer players.

There were 41 subjects who completed the pre-measurements. While collecting post-measurements for this study the Biodex machine malfunctioned and became inoperable after only 9 subjects had completed the post-test measurements. Of these eight subjects, five were able to fully complete the three week training program. The three not fully able to complete the training program were unable due to injury or illness unrelated to the study or participating in their soccer programs.

A Wilcoxon Signed-Rank Test was performed to determine whether the pre-test and post-test peak force measurements were different for participants that completed the entire strength program. A one-tailed test of the mean differences was performed to determine if there were statistically significant differences between the mean measurements of the pre-and post-tests. With a sample size of $n = 5$, the critical W-Value was set at $p = .05$ and found to have a value of 0. A significant mean difference was found for concentric flexion of the non-dominant leg with the mean post-training torque difference of -9.46. This means the post-test had higher measurements on average (See Figure 1). Other significant differences were found for peak torque where the pre-test had higher measurements. This included dominant extension at 150ft/lbs (mean difference = 9.42), dominant eccentric flexion at 60 ft/lbs (mean difference = 15.28), non-dominant eccentric flexion at 150 ft/lbs (mean difference = 4.74), dominant concentric flexion at 180 ft/lbs (mean difference = 5.38) and non-dominant concentric flexion at 180 ft/lbs (mean difference = 2.74). See Tables 1, 2, 3 and 4 for all results.

Figure 1: Non-Dominant Peak Torque Flexion



Following are Tables 3, 4, 5 and 6 of the final results.

	Peak Torque Extension Concentric at 60 (ft/lbs)				Peak Torque Extension Eccentric at 60 (ft/lbs)			
	Dominant		Non-Dominant		Dominant		Non-Dominant	
Participant	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	169.8	173.1	143.7	158.9	88.5	90.1	78.4	86.5
2	106.7	101.1	113.7	103.4	45.7	65.6	75.8	87.0
3	107.8	118.2	41.7	55.8	80.9	80.5	66.6	86.8
4	91.6	95.3	101.5	82.7	47.2	58.9	94.0	73.4
5	133.9	119.6	111.0	118.8	87.7	98.6	94.7	120.2
Mean Difference	20.86		-1.08		4.40		-5.10	
Sum of pos. ranks	8.00		8.00		1.00		4.00	
Sum of neg. ranks	7.00		7.00		14.00		11.00	
Sample size	5.00		5.00		5.00		5.00	
W	7.00		7.00		1.00		4.00	
W-Critical (One-Tail)	0.00		0.00		0.00		0.00	
Signifcant:	No		No		No		No	

	Peak Torque Extension Eccentric at 150 (ft/lbs)				Peak Torque Extension Concentric at 180 (ft/lbs)			
	Dominant		Non-Dominant		Dominant		Non-Dominant	
Participant	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	88.6	92.3	89.4	89.9	104.5	100.4	92.7	105.5
2	60.9	66.7	87.1	91.6	53.8	59.0	56.5	63.3
3	84.6	87.5	65.6	91.2	67.6	67.5	48.1	50.1
4	49.9	69.1	62.5	55.5	73.4	67.8	71.7	68.3
5	96.6	99.9	114.0	101.7	78.2	97.1	71.2	84.2
Mean Difference	9.42		-7.88		16.50		4.74	
Sum of pos. ranks	0.00		7.00		7.00		2.00	
Sum of neg. ranks	15.00		8.00		8.00		13.00	
Sample size	5.00		5.00		5.00		5.00	
W	0.00		7.00		7.00		2.00	
W-Critical (One-Tail)	0.00		0.00		0.00		0.00	
Signifcant:	Yes		No		No		No	

	Peak Torque Flexion Concentric at 60 (ft/lbs)				Peak Torque Flexion Eccentric at 60 (ft/lbs)			
	Dominant		Non-Dominant		Dominant		Non-Dominant	
Participant	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	92.0	103.3	90.0	115.4	150.1	183.0	153.5	117.2
2	71.0	72.7	69.7	78.6	87.8	100.6	188.0	124.8
3	76.7	75.2	65.2	73.6	100.0	135.1	69.7	85.7
4	59.0	60.6	53.9	63.9	88.9	95.2	124.0	110.1
5	78.3	95.1	66.9	98.8	152.6	158.4	189.5	187.1
Mean Difference	2.70		-9.46		15.28		20.14	
Sum of pos. ranks	1.00		0.00		0.00		12.00	
Sum of neg. ranks	14.00		15.00		15.00		3.00	
Sample size	5.00		5.00		5.00		5.00	
W	1.00		0.00		0.00		3.00	
W-Critical (One-Tail)	0.00		0.00		0.00		0.00	
Signifcant:	No		Yes		Yes		No	

	Peak Torque Flexion Eccentric at 150 (ft/lbs)				Peak Torque Flexion Concentric at 180 (ft/lbs)			
	Dominant		Non-Dominant		Dominant		Non-Dominant	
Participant	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	164.3	159.3	170.1	167.7	64.1	91.5	59.0	81.7
2	121.1	90.7	176.9	145.7	48.4	49.5	41.1	50.4
3	124.9	143.5	93.8	89.0	55.9	64.8	55.4	61.2
4	100.2	97.9	130.4	116.2	43.9	50.6	47.2	50.5
5	157.1	132.7	181.0	180.0	62.1	76.3	63.0	82.7
Mean Difference	42.28		4.74		5.38		2.74	
Sum of pos. ranks	12.00		0.00		0.00		0.00	
Sum of neg. ranks	3.00		15.00		15.00		15.00	
Sample size	5.00		5.00		5.00		5.00	
W	3.00		0.00		0.00		0.00	
W-Critical (One-Tail)	0.00		0.00		0.00		0.00	
Signifcant:	No		Yes		Yes		Yes	

CHAPTER V

DISCUSSION

The purpose of this study was to record the effects of a weighted and functional four-week eccentric hamstring strengthening program on hamstring and quadriceps strength in Men's and Women's Division I Varsity Soccer players. Secondarily, this study aimed to record all lower leg injuries throughout the spring season following the four-week program.

Peak torque for eccentric hamstring and quadriceps contractions did not show an increase with the addition of the strength program in this study. An increase in peak torque for concentric flexion at 60 ft/lbs was found and this finding aligns with previous research.

Eccentric hamstring strengthening was chosen for this study for many reasons. There are many different propositions to why the hamstring muscle group is so frequently injured and strength deficits have been one possibility that continues to gain support through research. When looking at muscle-tendon tension, a muscle is known to sustain an injury when the level of tension supersedes the tension of the weakest structural element within the muscle (Garrett, Califf & Bassett 1984). Taking this basic overload principle, it can be assumed that strength plays a large role in the amount of hamstring injuries sustained by those lower extremity athletes. Hamstring muscles must be able to absorb large amounts of force without failing in order to work without injury. Muscles that are able to absorb a high amount of energy are better able to avoid the amount of stretch that produces an injury during a high intensity activity (Mair, Seaber, Glisson& Garrett 1996). The stronger a muscle is the more force it can absorb prior to failure when compared to a weaker muscle (Askling, Karlsson & Thorstensson 2003). Brockett, Morgan & Proske (2001) pose the interesting observation that there are not many occasions during daily living where the hamstrings carry out eccentric contractions. This indicates that there is a need to add eccentric hamstring strengthening exercises to a training program in order to get the benefits of increased strength in eccentric hamstring contractions.

A change in the optimum angle for torque generation has been found which indicates that some muscle fibers are increasing in series compliance (Brockett, Morgan & Proske 2001). After eccentric exercise and sarcomere recovery some fibers do not completely shift back to the control level representing a training effect in the muscle towards a longer length-tension relation. This change in the length-tension relation could decrease the susceptibility of the muscle to injury (Brockett, Morgan & Proske 2001). When compiling training pre- or post-hamstring injuries those exercises that increase optimum length should be included to decrease the probability of hamstring injuries (Brughelli, Nosaka & Cronin 2008). In order to do this, eccentric exercise should be used as it is the only form of training that has been shown to consistently increase the optimum length of tension development (Brughelli, Nosaka & Cronin 2008).

This study focused on the possibility of eccentric strength deficits being a predisposition for hamstring injuries. Eccentric strength was found in studies to decrease over time during activity. Greig & Siegler (2009) used a treadmill protocol and 10 professional soccer players as participants to induce the physical demands of the intermittent nature of a soccer game. With this protocol they found the peak eccentric torque able to be achieved by the participant decreased as a function of time. They found the greatest influence in the decrease in eccentric torque was the speed at which the participant was running. Faster speeds created the greatest decrease in peak torque. This study indicates that throughout soccer games eccentric fatigue is present. Skurvydas et al (2011) found a decrease in voluntary induced muscle performance occurred after completing eccentric exercise. It is clear that eccentric muscle activity can cause damage to intricate muscle structures while also having a detrimental effect on performance.

This study took into account that the hamstring to quadriceps ratio is an important ratio to consider when strengthening both muscle groups. The once agreed upon standard for hamstring to quadriceps strength ratio has generally been 0.6 (Coombs & Garbtt 2002). Coombs & Garbutt (2002) express that this number is wrong mainly because it assesses both concentric hamstring and quadriceps strength. Thinking along these lines is incorrect because the hamstrings and quadriceps never contract concentrically simultaneously. It is more correct to look at a ratio that involves quadriceps concentric strength to hamstring eccentric strength as these are the two actions that happen simultaneously. It has been found for those athletes with an increased percentage of fast twitch fibers the quadriceps concentric to hamstring eccentric ratio should be closer to 1.0 to allow for the hamstrings to effectively brake the leg in those faster sprinters (Coombs & Garbutt 2002). This idea of having a ratio of 1.0 for quadriceps and hamstrings is the reason this study measured peak torque for both quadriceps and hamstring muscle groups.

An inconsistency in hamstring injury rehabilitation indicates a lack of knowledge regarding the mechanism of injury and factors that contribute to hamstring strain (Worrell 1994). Taking into consideration that nonfatigued muscles absorb much more energy in the early phases of stretching is important when developing an eccentric strength training program as an increase in eccentric muscle strength at shorter lengths could decrease injuries (Mair et al 1996). An interesting aspect of eccentric contractions is their ability to produce increased forces at 20% less oxygen consumption, carbon dioxide produce and energy expenditure than equal bouts of concentric work (Kaminski, Wabbersen & Murphy 1998, Stanton & Purdam 1989). Not only are eccentric contractions more efficient than concentric contractions, many studies have shown that addition of eccentric overloading to a training program increases not only eccentric contraction strength but also concentric contraction strength and overall performance more than concentric training alone (Kaminski, Wabbersen & Murphy 1998, Stanton & Purdam 1989; Askling, Karlsson & Thorstensson 2002). This finding supports the finding in this particular study for an increase in peak torque during concentric flexion at 60 ft/lbs.

Inspiration for this study was drawn from the research done by Brughelli, Nosaka & Cronin (2009) in an attempt to create a more sports-specific eccentric overload training program. Brughelli, Nosaka & Cronin (2009) developed a progressive eccentric overload strengthening program for a 24-year-old male Australian Rules football player. Exercises included eccentric box drops, box lunge drops, eccentric resisted pushes, eccentric towel pulls and weighted drop lunges. This 9-week program allowed for progression in repetitions and addition of weights. This took into account that an eccentric program is based on increasing the strength of the tendon by gradually overloading it in order to promote an increase in tensile strength. They also took into consideration the three basic principles of eccentric exercise: length of the tendon; the load on the tendon; and the speed of the exercise movement. In order to create a progressive eccentric exercise program these three factors must be modified (Dee et al 2011). Brughelli, Nosaka & Cronin (2009) found that the optimum angle of peak torque during knee flexion and knee extension decreased. Functionally, the participant in this study was finally able to return to play pain free.

In addition to the Brughelli, Nosaka & Cronin (2009) study, this particular study was inspired by research done by Askling, Karlsson & Throstensson (2003). In this study, they created a hamstring training program with eccentric overload using a YoYo flywheel ergometer for thirty male premier-league soccer players. Half of the soccer players performed the training program while the other half were assigned to a control group. What they found was those participants that performed the eccentric overload training program sustained less hamstring strain injuries and showed significant increases in strength and speed when compared to the control group. The aim of training should be to shift the point of hamstring to quadriceps ratio equality towards a more flexed knee joint position so there is an increased potential for stability through an increased range of motion (Coombs & Garbutt 2002).

Finally, the Nordic hamstring exercise was chosen because it had been proven through many studies its reliability in increasing eccentric hamstring torque (Clark, Bryant, Culgan & Hartley 2005; Mjolsnes, Arnason, Osthagen, Raastad & Bahr 2004; Petersen, Thorborg, Nielsen, Budtz-Jorgensen & Holmich 2011; Schmitt, Tyler & McHugh 2012; Thorborg 2012).

Based on this study there is not sufficient data to support the eccentric hamstring strengthening program used has an effect on eccentric peak torque production for these participants. This study is at odds with the majority of research completed on implementing eccentric hamstring strengthening programs. It aligns with other research through the finding that concentric flexion peak torque increased.

Recommendations:

1. It is recommended that this study or a similar study be repeated to include more participants to add to the literature.
2. It is recommended that this study be repeated with similar participants.
3. It is recommended that this study be repeated using different measuring instrumentation.

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APPENDICES

Informed Consent Document:

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

Title: Eccentric Hamstring Training Effects On Strength Gains and Injury Rates in NCAA Division I Varsity Soccer Players

You are invited to participate in a research study conducted by *Andrea Chilcote* (primary researcher), Athletic Trainer from Eastern Illinois University. As a Division I Varsity Soccer player your participation in this research will provide invaluable data.

Your participation in this study is entirely voluntary. Please ask questions about anything you do not understand before deciding whether or not to participate.

- **PURPOSE OF THE STUDY**

The purpose of this study is to determine the effects of an eccentric hamstring strengthening program on the lengthening (eccentric) and shortening (concentric) strength of both quadriceps and hamstring muscle groups in Division I Men's and Women's Soccer players.

- **PROCEDURES**

This study will take place over a total of six weeks. All athletes will fill out a participant demographic information page and a participation waiver. Once the athletes who are willing to participate have turned in their paperwork they will be allowed to participate. At this time participants will be given a number that will allow Andrea Chilcote to track all necessary information for the study. The study will consist of four separate activities as outlined below:

1. Participant will complete an active warm-up. Participant will have both left and right quadriceps and hamstring strength measured using a Biodex Multi-Joint System AP 2.
2. Participant will complete a four week hamstring strengthening schedule as outlined in the tables following the contact information. The schedule will vary based on gender.
3. After completing the four week training session, participants will again have both left and right quadriceps and hamstring strength measured using a Biodex Multi-Joint System AP 2.

4. Participant will have all total days missed (including games and practices) for spring season due to lower leg injuries tracked by the Certified Athletic Trainer placed with their team by the Eastern Illinois University Sports Medicine program (see below for contact information). This information will be shared only with Andrea Chilcote and will be reported with no attachment to a name, but the number given to the participant at the beginning of the study.

- **CONTACT INFORMATION FOR CERTIFIED ATHLETIC TRAINERS**

Heidi Wlezien, MS, ATC, AT
Assistant Athletic Trainer
Eastern Illinois University
C: (815) 383-4804
O: (217) 581-3811

Brandon Platt, MS, LAT, ATC, CSCS, NREMT
Assistant Athletic Trainer
Eastern Illinois University
C: (219) 781-0138
O: (217) 581-591

- **STRENGTH PROGRAM; DETAILED**

Men			
Week 1	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 1 x 10	Romanian Dead Lift (eccentric) #135, 2 x 5, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 6, 8s fall
Week 2	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 1 x 15	Romanian Dead Lift (eccentric) #140, 2 x 6, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 8, 8s fall
Week 3	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 2 x 10	Romanian Dead Lift (eccentric) #145, 2 x 7, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 10, 8s fall
Week 4	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 24", 3 x 10	Romanian Dead Lift (eccentric) #150, 2 x 8, 8 s fall	Single leg Romanian Dead Lift (eccentric) #30 2 x 12, 8s fall

Women			
Week 1	Monday	Wednesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 1 x 10	Romanian Dead Lift (eccentric) #80, 2 x 5, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 6, 8s fall
Week 2	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 1 x 15	Romanian Dead Lift (eccentric) #85, 2 x 6, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 8, 8s fall
Week 3	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 2 x 10	Romanian Dead Lift (eccentric) #90, 2 x 7, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 10, 8s fall
Week 4	Monday	Tuesday	Thursday
	Nordic 2 x 5	Nordic 2 x 5	Nordic 2 x 5
	Box falls, 18", 3 x 10	Romanian Dead Lift (eccentric) #95, 2 x 8, 8 s fall	Single leg Romanian Dead Lift (eccentric) #15 2 x 12, 8s fall

• POTENTIAL BENEFITS AND RISKS TO SUBJECTS AND/OR TO SOCIETY

Short-term risks for this study to participants include acute injuries to the lower leg. Due to the stress caused by eccentric strength training it is much more difficult than concentric strength training and has the potential to cause injuries such as: strains, sprains, tendonitis, and fractures. Risk of injury is low when participating in this study. Participants will be monitored throughout the strength program by the assigned strength coach and the primary researcher. While the risk of injury remains low, should an injury occur as a result of participation the participant will be directed to the EIU Health Services along with the respective athletic trainer for treatment.

Participants in this study will potentially gain increases in both eccentric and concentric hamstring strength. This increase in strength will potentially decrease the likelihood of sustaining a lower extremity injury. The sport of soccer requires a great amount of eccentric hamstring strength due to the quick acceleration and deceleration athletes frequently undergo during a soccer game. Society will benefit from this research with the potential knowledge that eccentric exercises benefit not only eccentric strength but concentric strength in muscles as well. Adding this type of exercise to a strengthening program will potentially allow for greater strength gains in strength training programs. This research will help by defining an eccentric hamstring strengthening program that could be easily implemented in an in-season and out-of-season strength training program.

• CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of participant numbers. Once you fill out your demographic information, you will be assigned a participant number for the rest of the study. Any information collected from you for the rest of the study will have this number on it. The researcher will keep this data locked in the Lantz Athletic Training room when not in use. No one besides the researcher will have access to the data. The final results of the study will be released to the Kinesiology and Sports Studies department, but individual names will not be released.

- **PARTICIPATION AND WITHDRAWAL**

Participation in this research study is voluntary and not a requirement or a condition for being the recipient of benefits or services from Eastern Illinois University or any other organization sponsoring the research project. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind or loss of benefits or services to which you are otherwise entitled.

There is no penalty if you withdraw from the study and you will not lose any benefits to which you are otherwise entitled. If you become injured during this study and are no longer able to complete the program, your data will still be used and you will be dismissed from further participation in the study. In the unlikely event that there is an injury, participants will be referred to EIU Health Services and an athletic trainer, respective to their team.

- **RIGHTS OF RESEARCH SUBJECTS**

If you have any questions or concerns about the treatment of human participants in this study, you may call, write or e-mail:

Andrea Chilcote, ATC Eastern Illinois University 600 Lincoln Ave. Charleston, IL 61920 Telephone: (231) 724-0853 E-mail: amchilcote@eiu.edu	John Storsved HSD, ATC Eastern Illinois University 2506 Lantz Building Charleston, IL 61920 Telephone: (217) 581-2690 E-mail: jrstorsved@eiu.edu	Office of Research and Sponsored Programs 1102 Blair Hall Charleston, IL 61920 Phone: (217)581-2125

I voluntarily agree to participate in this study. I understand that I am free to withdraw my consent and discontinue my participation at any time. I have been given a copy of this form.

____

Printed Name of Participant

______________________________ ____________________

Signature of Participant Date

PARTICIPANT DEMOGRAPHICS

- Age: _______
- Height: _______
- Weight: _______
- Position: ________________________
- Number of injuries sustained to lower body within the last twelve months:
    - Right Side: _______
    - Left Side: _______
- How many **days** of participation did you miss because of these injuries (include both training days and game days): _______
- Do you have any known injuries that may affect your participation in this study?

  Yes　　　　　　　　　　No