A Hamstring Emphasized Strengthening Program for Female Collegiate Athletes

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Abstract

Fifteen female collegiate softball players from a Midwestern, Division III National Collegiate Athletic Association institution, participated in the study. The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes. A pre- and post-test measurement of strength was calculated using an isokinetic machine. The results indicated that sixty-six percent of the participants improved their hamstring strength and ultimately improved their quadricep hamstring ratio.
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Chapter 1: Introduction

A Hamstring Emphasized Strengthening Program

As a certified athletic trainer, the researcher had observed numerous injuries over her career. An all too common occurrence were injuries to the knee, especially the anterior cruciate ligament (ACL). These injuries could have been prevented to some extent. The researcher observed that collegiate female athletes had slight to no knowledge about the effect that the quadriceps and hamstrings have on the knee. Female athletes were more likely to have quadriceps and hamstring strength ratio issue that lead to a knee injury. Therefore, a project was created to examine the value of a hamstring emphasized strengthening program for collegiate female athletes.

Statement of Problem

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball.

The research questions were:

1. What are the quadriceps and hamstrings and what is the optimal ratio of these muscles working together as a unit according to the professional literature reviewed?

2. According to the professional literature, what injuries occurred when the quadriceps/hamstring ratio was not optimal?
3. What were the different exercises that composed the hamstring emphasized strengthening program according to the professional literature reviewed?

4. How did the implementation of a hamstring emphasized strengthening program benefit the collegiate female athlete?

**Justification**

This project was completed in an attempt to enhance Division III female collegiate athletes on the importance of hamstring strength in order to decrease injuries to the knee, mainly the ACL. As a certified athletic trainer it was detected that if female athletes had tremendously strong quadricep muscles then their chance of injury to the knee and ACL was increased. The main role of a certified athletic trainer was to prevent injuries. Therefore, this project was implemented in order to decrease injuries to one of the main body parts used in daily life, the knee, and a major component of the knee, the ACL. This project was also intended to inform female athletes of the possible risk of injury to the ACL if the hamstrings were not emphasized in strengthening programs. Thus, the outcome of this project could possibly provide female collegiate athletes who participated in this study with an increased familiarity with the quadricep: hamstring ratio, increased hamstring strength, therefore provided the potential to decrease their risk of injury to the knee and ACL.

**Definition of Terms**

- Quadricep Muscle- The quadriceps are made up of four muscles: the Rectus Femoris, Vastus Medialis, Vastus Intermedius, and Vastus Lateralis. It is known as a primary mover and its main function is to flex the knee.
- **Hamstring Muscle** - The hamstrings are made up of three muscles; the Semitendinosus, Semimembranosus, and the Biceps Femoris. The hamstrings support the quadriceps, as well as provide dynamic stability during knee flexion.

- **Anterior Cruciate Ligament (ACL)** - "Stretches from the anterior aspect of the intracondyloid fossa of the tibia just medial and posterior to the anterior tibial spine in a superior, posterior direction to the posterior medial surface of the lateral condyle of the femur. The ACL is a critical stabilizer that prevents: anterior translation (movement) of the tibia on a fixed femur, posterior translation of the femur on a fixed tibia, internal and external rotation of the tibia on the femur, and hyperextension of the tibia" (Anderson, Hall and Martin, 2005).

- **NCAA** - "The National Collegiate Athletic Association (NCAA) is a voluntary organization through which the nation's colleges and universities govern their athletics programs. It is comprised of institutions, conferences, organizations and individuals committed to the best interests, education and athletics participation of student-athletes. This section of the Web site contains more details about the Association, its goals and members, and corporate partnerships that help support programs for student-athletes" (NCAA, 2009).

- **Division III Institution** - "Colleges and universities in NCAA Division III place highest priority on the overall quality of the educational experience and on the successful completion of all students' academic programs. They seek to establish and maintain an environment in which a student-athlete's athletics activities are conducted as an integral part of the student-athlete's educational experience. They also seek to establish and
maintain an environment that values cultural diversity and gender equity among their student-athletes and athletics staff” (NCAA, 2009).

- **Optimal Ratio:** This is the ratio that the Quadriceps (60) and Hamstrings (40) should be modeled by. The 60/40 ratio is where the Quadriceps are recruited 60% of the time and the hamstrings 40% of the time, primarily during knee extension and general activity. Realistic ranges average around a 75/35 ratio.

- **Isokinetic Machine:** A machine used to assess muscle strength. A tool that allows a researcher to compare contrasting musculature. Therefore, the main purpose of these machines was to compare the strength and workload of muscles that acted on specific body parts, mainly those involved in divergent movements.

**Limitations and Appropriate Use of Results**

There were limitations that affected this project. First, this project was implemented at a small private National Collegiate Athletic Association (NCAA) Division III instution with an enrollment of around one thousand students. Therefore, the number of participants to contribute in the study was limited. Hence, the number of female athletes was also restricted. Furthermore, the time allotted to collect the data and complete the project was limited and could have played a role in the overall outcome and results of the project. Thus, the results of this project may not be generalized to additional populations.

A great deal of research has been done in relation to strength, especially the ratio of strength in the quadriceps and the hamstrings. There had also been extensive research related to injuries related to deficiencies in these ratios. Most of these injuries involve the knee and result
from overuse. However, sometimes ligamentous damage can occur, especially to the Anterior Cruciate Ligament, also known as, the ACL. Therefore, a hamstring emphasized strengthening program can not only prevent injuries from occurring, but can also provide numerous and lasting benefits to the female collegiate athlete.
Chapter II: Review of Literature

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball.

The research questions were:

1. What are the quadriceps and hamstrings and what is the optimal ratio of these muscles working together as a unit according to the professional literature reviewed?

2. According to the professional literature, what injuries occurred when the quadriceps/hamstring ratio was not optimal?

3. What were the different exercises that composed the hamstring emphasized strengthening program according to the professional literature reviewed?

4. How did the implementation of a hamstring emphasized strengthening program benefit the collegiate female athlete?

A great deal of research has been done in relation to strength, especially the ratio of strength in the quadriceps and the hamstrings. There had also been extensive research related to injuries connected to deficiencies in these ratios. Most of these injuries involve the knee and result from overuse. However, sometimes ligamentous damage can occur, especially to the Anterior Cruciate Ligament, also known as, the ACL. Therefore, a hamstring emphasized strengthening program can not only prevent injuries from occurring, but can also provide numerous and lasting benefits to the female collegiate athlete. This problem was addressed from
three research questions that concentrated on explaining the quadriceps and hamstrings, the optimal ratio of these muscles when they worked together, what injuries could potentially occur if this quadriceps: hamstrings ratio is less than optimal and specific exercises that would be included in a hamstring emphasized strengthening program. The first research question addressed the quadricep: hamstring relationship.

_Research Question #1: What are the quadriceps and hamstrings and what is the optimal ratio of these muscles working together as a unit according to the professional literature reviewed?_

**Quadriceps and Hamstrings**

In order to answer research question #1, a review of literature was conducted. The quadriceps and hamstrings work as a unit to flex and extend the knee. The quadriceps are made up of four muscles: the Rectus Femoris, Vastus Medialis, Vastus Intermedius, and Vastus Lateralis. The hamstrings, which also aid in hip flexion, are made up of three muscles; Semitendinosus, Semimembranosus, and the Biceps Femoris. In knee flexion the quadriceps are referred to as agonist, the muscles that perform the desired movement or primary movers and the antagonist, the muscle that oppose or reverse a particular movement the hamstrings (Anderson, Hall and Martin, 2005). Overall, the quadriceps muscles contract concentrically, this is where the muscle fibers shorten and the angle of the joint associated with them decreases, whereas, the hamstrings contract eccentrically, and the muscle resists its own lengthening and the joint angle decreases (Anderson et al., 2005). In dealing with these particular muscles of the quadriceps and hamstrings, the joint affected is the knee. According to Tourny-Chollet and Leroy (2002);
during ball kicking the knee extension is in open chain activity. The hamstring muscles contract eccentrically and pull back the tibia to prevent its displacement on a forward translation and on an internal rotation. Excessive internal rotation is induced by the contractile strength of the quadriceps when the knee is close to full extension. The hamstrings possess the capacity to significantly increase the dynamic stability of the articulation during a fast powerful knee extension (p.184).

Therefore, the hamstrings play an extremely important role in the function and capacity of the knee and subsequent structures, primarily the ACL. Tourney-Chollet et al. (2002) then go on to elaborate further;

The maximal eccentric strength of the hamstrings divided by the maximal concentric strength of the quadriceps forms the dynamic control ratio, or the Hecc/Qcon functional ratio. This ratio is an indicator of the breaking function of the hamstrings during an extension of maximal quadriceps strength (p.183).

This ratio is also referred to the agonist: antagonist or torque ratio. This ratio has a specific parameter known as the optimal ratio.

**Optimal ratio.** There are many articles relating to this specific musculature and its ratio, all of which provide enormous amounts of information and statistics which tried to explain and decipher ways to not only achieve an optimal ratio, but provide insight on how to prevent injuries from occurring if the ratio is less than optimal. The optimal ratio of quadriceps to hamstring strength is 60/40, whereas the quadriceps are recruited 60 percent of the time and the hamstrings are recruited 40 percent of the time. According to the professional literature, there are two different ratios, the functional ratio and the conventional ratio. Aagaard, Simonsen, Magnusson, Larsson & Dyhre-Poulsen (1998) state: “the hamstring: quadriceps strength ratio is
calculated by dividing the maximal knee flexor (hamstring) moment by the maximal knee extensor (quadriceps) moment measured at identical angular velocity and contraction mode” (p.231). Torque is a force that has a central role in these ratios. Torque, as defined by Anderson et al. (2005); “is a rotary force, the product of a force and its moment arm or moment” (p.773). A great example of this is the relationship between a wrench and a bolt. Holcomb, Rubley, Lee and Guadagnoli (2007) stated; “the functional ratio is determined by dividing the maximal eccentric hamstring peak torque by the maximal concentric quadriceps peak torque’ (p.42). Holcomb et al. (2007) goes on to address how the conventional ratio is calculated by “dividing the maximal concentric hamstring peak torque by the maximal concentric quadriceps peak torque” (p.42). The functional ratio is of more importance because it addressed more realistic, concurrent movements of the quadriceps and hamstrings, as opposed to the conventional that addressed both concentric movements of the differing muscles. In other words, the functional ratio is the more practical ratio to apply to most sport science settings. Consequently, a ratio that is not optimal or close to optimal can be a cause for concern, especially to the female gender.

Several factors influenced this ratio: gender, participation or non participation in a sport or activity, type of sport or activity that is being participated in, physical maturation, injury, and access to the latest and most up to date equipment, also known as an isokinetic device.

Isokinetic measures. In order to measure the strength of the quadriceps and hamstrings; an isokinetic device was used. According to Anderson et al. (2005) “isokinetic training, or accommodating resistance, allows an individual to provide muscular overload and angular movement to rotate a lever arm at a controlled velocity or fixed speed” (p.213). These machines are known by brand names such as Biodex, Kin-Com and Cybex. These machines are used because they allow the patient and examiner to get immediate feedback about the body part or
musculature that is being studied. Anderson et al. goes on agree “coupled with a computer and appropriate software, torque motions curves, total work, average power and torque-to-body weight measurements can be instantaneously calculated to provide immediate, objective measurement to the individual and examiner” (p.213). Therefore, the main purpose of these machines was to compare the strength and workload of muscles that acted on specific body parts, mainly those involved in agonist and antagonist movements. This is supported by Hewett, Myer and Zazulak (2008); in that “isokinetic testing assesses the ability of the agonist-antagonist musculature to co-contract during reciprocal extension-flexion motions” (p.453). However, certain standards are used to obtain the measurements.

In regards to taking measurements, specific parameters are used. Most quadricep: hamstring ratios are measured in degrees per second. According to Tourny-Chollet et al. (2002): “the isokinetic strength measures are often evaluated at several angular speeds generally between 30°-s⁻¹ and 300°-s⁻¹” (p.184). Most of the research used the measurements of 240°-s⁻¹, 180°-s⁻¹, and 60°-s⁻¹ for concentric contractions and 120°-s⁻¹ and 60°-s⁻¹ for eccentric contractions. The full range of motion for the quadriceps and hamstrings was 180°, where 0° equals full extension. A bilateral comparison was necessary so that if one leg is injured and being assessed for possible muscle atrophy, the results can be compared to the healthy leg of the individual. However, some extenuating circumstances can have an effect on this ratio.

Certain conditions can make these degrees differ. Some possible precursors could be an injury, and to what degree and magnitude this injury is, which leg is dominant, and the type of machine being used to assess the measurement. Obviously, the general action of measuring this ratio was similar, however the type of machine used might not be calibrated the same or could be outdated. Most of these machines were purchased to last for numerous years. Nevertheless,
technology is ever changing and these alterations on the machines could impact the results that were obtained.

In summary and as indicated by the professional literature reviewed, the quadriceps and hamstrings play a major role in the function of the knee (Tourny-Chollet et al., 2002) and these muscles have an optimal ratio that can be measured by two separate ratios: a functional ratio, and a conventional ratio (Aagaard et al., 1998). It was also discovered that torque elicits an enormous impact on the quadriceps: hamstring ratio. In addition, isokinetic devices were used to determine this ratio and certain parameters were used when evaluating and measuring the quadriceps: hamstring ratio (Tourny-Chollet et al., 2002). These ratios along with the isokinetic devices can elicit results of a ratio being not optimal, therefore setting up the second research question.

Research Question #2: According to the professional literature, what injuries occurred when the quadriceps/hamstring ratio was not optimal?

Problems with deficiency. In order to answer research question #2, a review of literature was conducted. When the quadriceps: hamstring ratio is not optimal potential injury can occur. Of course, the ratio is not the only factor that can play into this possible injury scenario. The aspects such as gender, physical maturation, participation in a sport or activity, and the type of sport or activity that is being participated in were all precursors. Out of all of these factors, gender and type of sport are the areas that have received the most attention in the literature. In regards to the nature of the hamstrings themselves and gender, Ebben (2009) affirmed;

the hamstring muscle group is the most frequently injured, representing approximately 12 to 24% of all athletic injuries. These injuries may be due to disproportionate training
performed for the quadriceps, with hamstring strains occurring more frequently in those
who demonstrated hamstring weakness, and lower quadricep:hamstring strength ratios
(p.84).

Hence, females tend to have a lower strength ratio, therefore they were at an increased risk for
sustaining a hamstring injury. In contrast, most of the literature that was reviewed concentrated
on the potential injury to the Anterior Cruciate Ligament (ACL). Holcomb et al. (2007)
suggested “if the strength of the quadriceps significantly exceeds the strength of the hamstrings,
then both the hamstrings and the ACL become more susceptible to injury” (p.41). Holcomb et al.
(2007) then went on to elaborate further; “when the quadriceps are stronger than the hamstrings,
excessive anterior translation may occur during dynamic activities, and the ACL will experience
higher shear forces and if the hamstrings are too weak to counteract this force, an ACL injury is
likely” (p.41). Hence, the strength of the hamstrings is directly correlated with the incidence of
ACL injuries. The ACL’s primary function is to limit the amount of forward displacement of the
tibia, relative to the femur. This is supported by Hewett et al. (2008);

the agonist of the ACL is the hamstrings, while the antagonist is the quadriceps, which
increases strain on the ACL in the lower half of the knee flexion range, (0-45°).
Therefore, dynamic stability is contingent upon hamstrings co-activation to resist anterior
translation and tibial rotation resulting from quadriceps contraction and is likewise
potentially dependent on hamstring: quadricep ratio” (p.453).

In addition, the hamstrings are like the “breaks” when the knee extends, they tell the knee when
to stop and help to slow down the activation of the dominant quadricep muscle. Thus, if the
“breaks” are not strong enough to withstand the forceful flexion of the knee, the next thing to
stop this force is the ACL, and in most cases this ligament is not strong enough, on its own, to counteract this imbalance that is occurring, which unfortunately results in injury to the ACL.

Other factors such as gender, maturity and the type of sport or activity that is being participated in can be precursors to a quadricep: hamstring imbalance. In regards to gender and maturity, Ahmad, Clark, Heilmann, Schoeb, Gardner, and Levine (2006) reported that; “female athletes tend to be quadriceps dominant in both strength and muscle-firing patterns” (p.373) and that “girls after menarche increase their quadriceps strength greater than their hamstring strength, which may put them at risk for ACL injury” (p.373). This is supported by Devan, Pescatello, Faghri, and Anderson (2004) where; “female athletes have decreased thigh musculature when compared with male athletes, possibly altering kinematics during landing and may result in injury” (p.263). Further gender issues are: increased Q-angle, the angle of the quadriceps force and the patella, and genu recurvatum, which is the hyperextension of the knee (Anderson et al., 2005).

The type of sport or activity that is being participated in can be a mitigating precursor in the quadriceps: hamstring imbalance. Obviously, sports or activities that require a lot of lower extremity strength, kicking motions, and agility can predispose an athlete to injury. Therefore, soccer, track and field, basketball, volleyball and cross country athletes are the most susceptible. Hence, the athletes participating in these sports, especially females, need to have a hamstring emphasized strengthening program implemented into their routine in order to prevent injury.

According to the professional literature that was reviewed the problems with a deficiency in the quadriceps: hamstring ratio can result in an injury to the ACL. (Ebben, 2009 and Holcomb et al., 2007). Gender is a main precursor to the imbalance in the quadriceps: hamstring ratio. The
type of sport or activity that is being participated in, can also lead to a predisposition to injury (Ahmad et al., 2006 and Devan et al., 2004). In the next section specific hamstring exercises were presented and explained so that this deficiency was corrected and the deficiencies were reduced.

**Research Question #3: What were the different exercises that composed the hamstring emphasized strengthening program according to the professional literature reviewed?**

In order to answer research question #3, a review of literature was conducted. It was determined that a hamstring emphasized strengthening program provided a benefit to optimizing the quadricep: hamstring ratio. Ebben (2009) stated: “training the quadriceps disproportionately to the hamstrings may inhibit hamstring co-activation, reduce joint stability and increase anterior tibial translation in response to strong quadriceps forces” (p.85). Ebben (2009) then goes on to explain; “hamstring resistance training reduces magnitude of the hamstring-to-quadriceps muscle imbalance, which may prevent muscle strains and ACL injuries” (p.85). Thus, a strengthening program that concentrates on the hamstrings can provide numerous benefits, the greatest in the prevention of damage to the ACL.

As suggested by Ahmad et al. (2006) a “strengthening program that emphasizes hamstring activation in a closed-chain fashion have been shown to be beneficial in injury-prevention programs” (p.373). Closed chain exercises are where “the distal segment of the extremity is an erect weight bearing position” (Anderson et al., 2005). Thus, velocity and torque are more controlled; shear forces are reduced, while postural and dynamic stabilizers are made easier (Anderson et al., 2005). All of which are benefits when trying to prevent an injury to the ACL. Some of these exercises were seated leg curls, squats, lunges, exercise ball leg curls,
hamstring lowers, step-ups with weight, superman's with ankle weights strapped on as well as stool scoots with ankle weights. All of these exercises concentrated principally on knee flexion and hip extension, which were the main actions of the hamstrings.

As stated by the professional literature, a hamstring emphasized strengthening program provided benefits, especially to the female athlete. Devan et al. (2004) confirmed “correcting hamstring imbalances through strength training and conditioning may be key to preventing knee injuries among female athletes” (p.267). While Holcomb et al. (2007) agreed “a poor hamstring: quadriceps ratio can increase the risk of injury to the hamstrings and ACL, therefore a hamstring specific resistance training program should be prescribed” (p.46). Hence, this program should contain closed chain exercises that concentrate on knee flexion and hip extension.

In summary, review of literature was conducted to answer the questions. Most of the literature that was reviewed concurred that some sort of hamstring strengthening program should be implemented in order to prevent injuries from occurring, especially to the ACL and to make improvements in muscular inequalities that exist in the athlete. A hamstring specific strengthening program is a must for those high level athletes participating in a sport that requires agility and leg musculature. Collegiate athletes, particularly those of the female gender would all benefit from a hamstring emphasized strengthening program since their quadriceps tend to be stronger on the whole, than the hamstrings.
Chapter III: Methods

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball.

The research questions were:

1. What are the quadriceps and hamstrings and what is the optimal ratio of these muscles working together as a unit according to the professional literature reviewed?

2. According to the professional literature, what injuries occurred when the quadriceps/hamstring ratio was not optimal?

3. What were the different exercises that composed the hamstring emphasized strengthening program according to the professional literature reviewed?

4. How did the implementation of a hamstring emphasized strengthening program benefit the collegiate female athlete?

To answer research question #8, a hamstring emphasized strengthening program was implemented with members of a collegiate softball team. A pre- and post- test assessment of strength was calculated using an isokinetic machine, in order to obtain a quadricep: hamstring ratio.

Fifteen female collegiate softball players participated in the study. The head softball coach and the associate athletic director at the college, along with the director of a physical therapy clinic at a local medical center granted permission for the researcher to conduct this
study. A consent form from the college (see appendix A for the college consent form) as well as a consent form from the physical therapy clinic at a local medical center (see appendix B for medical center consent form) was signed by each athlete that was participating in the study.

The strengthening program consisted of eight sessions over a four week period. It included the following exercises: seated leg, curls, squats, lunges, exercise ball leg curls, hamstring lowers, step-ups with weight, superman's with ankle weights strapped around their ankles, as well as stool scoots with ankle weights. Pre- and post- implementation strength measurements were taken on an isokinetic machine, results were obtained and then charted on an excel spreadsheet and bar graph.

Participants

Fifteen female collegiate softball players from a Midwestern, Division III National Collegiate Athletic Association institution, participated in the study. All of the athletes were members of the softball team and had no prior experience with a hamstring emphasized strengthening program. The athletes’ ages ranged from 18-22 years old and had been playing competitive softball for at least five years.

Intervention

A hamstring emphasized strengthening program was designed for female collegiate athletes that were members of the softball team. Information for the strengthening program was gathered from numerous sources including research articles and textbooks concentrating on strength and conditioning and exercise physiology as well as sports medicine. The researcher
focused on the quadricep: hamstring ratio, possible complications if this ratio was not close to optimal, and specific exercises that made up the hamstring emphasized strengthening program.

The study took place over four weeks where the athlete performed the desired exercise two times a week for a total of eight exercise sessions. The desired exercises consisted of: seated leg curls, squats, lunges, exercise ball leg curls, hamstring lowers, step-ups with weight, superman's with ankle weights strapped around their ankles, as well as stool scoots with ankle weights. These exercises were performed at three sets of fifteen. This parameter was set, as it is a general starting point for building strength. All of these exercises concentrated principally on knee flexion and hip extension, which were the main actions of the hamstrings.

**Leg Curls.** The athlete completed the leg curl on a leg curl machine. The seated leg curl took place on a leg curl machine. The athlete was instructed to lie prone with her heel under the roller pad and have her hands grasp the hand grip bars below the padded bench in which she lied upon. The athlete then initiated the hamstring curl by bringing her heels and ankle upward in a fluid motion towards the buttocks. This was held in this position for approximately two seconds and then lowered back down to the starting position in the same fluid motion. According to Ebben (2009); “leg curl exercises resulted in the greatest hamstring activity” (p.87).

**Squat Method.** The athletes were instructed to perform the squat method using a barbell. The athlete began by standing erect with their feet flat on the floor. The athlete’s feet were shoulder width apart and the barbell was placed on the back of the neck, and stretched across the length of the shoulders. The athlete placed her hands on the bar in a palm up, closed grip. The athlete was then instructed to lower herself down in the same motion as if they were going to be sitting on a chair. She was instructed to make sure that her knees were aligned over the middle of her foot and that her thighs remained in a parallel direction with the ground.
**Lunges.** Lunges were performed one of two ways. First, the lunges were executed from a stationary position where the athlete would simply lunge forward with the right foot making sure the knee was at a 90 degree angle, directly over the toes and the thigh was parallel with the floor. While this motion was taking place the opposite knee was at a 90 degree angle, physically touching the ground, and the thigh was perpendicular to the floor. The athletes’ hands were placed on her hips. The athlete would then push off and up, back into the upright starting position. This was repeated with the other leg. The second type of lunges were moving lunges. This was done the same way as the stationary lunge however the athlete pulled the opposite leg forward to meet the other leg that was in the lunge.

**Exercise ball leg curls.** Exercise ball leg curls involved the use of a medium sized exercise ball. The athlete, while lying supine, placed her heels in the middle of the ball so her legs were elevated in the air. The athlete then lifted her buttocks up and off of the ground so her legs were at a 45 degree angle from the ground and proceed to place her hands underneath the small of her back and buttocks. The athlete then proceeded to bring her heels in towards the midline of her body, therefore, bending her knees and performing the action of a hamstring curl. Finally, the legs were extended back to the starting position. During this entire motion the buttocks never touched the ground.

**Hamstring Lowers.** Hamstring lowers were performed by the athlete kneeling on a soft surface. The athlete’s lower legs and ankles were held down by another person, in this case a teammate. The athlete was then instructed to fall forward, while keeping the torso upright, straight and flat. This motion was to be done as slow as possible. With this motion being performed slowly the athlete was essentially using their hamstrings as breaks to keep them from
falling forward. Finally, the athlete would cushion her fall by outstretching her hands, falling forward on them therefore reducing the impact as much as possible.

**Step-ups.** The step-up exercise involved a box about two feet tall and two ten pound weights. The athlete would grasp the ten pound weights, in her hand, and hold them by her hips in a natural and relaxed position, while proceeding to step up onto a box. During the step, the athlete pushed up and off of one leg that was on the floor, and stepped up onto the box with the opposite leg. Once on the box, the athlete needed to make sure that the knee was at a 90° angle while the midline of the knee was over the toes. The athlete would then bring the opposite leg up and proceed to stand erect. This was then repeated with the opposite leg.

**Superman’s.** Superman’s were performed also using a weight. However, in this case the weights were strapped to the athletes’ ankles. The superman exercise was performed by having the athlete lie prone on her stomach. The athlete then lifted up the opposite leg and opposite arm at the same time to approximately six inches off of the ground. For example, if the athlete was lifting her right arm up, then her left leg would be lifted up simultaneously. This was then repeated using the reverse arm and leg that was used previously.

**Stool scoots.** Stool scoots were done on an indoor track adjacent to the weight room at the college. These also involved the use of the ankle weights. The weights were strapped to the athletes’ ankles. The athlete was seated on an adjustable height stool with four wheels on the bottom. Once seated, the stool was adjusted so that the athletes’ feet were flat on the ground and their knees were at a perfect 90° angle. The athlete was then instructed to pull herself forward using her heels for two laps around the track. One lap around the track is one-hundred and twenty meters. Therefore, the athletes carried out this stool scoot for a total of two hundred and forty meters.
Instruments

A pre- and post-test assessment of strength was calculated using an isokinetic machine at a physical therapy clinic located at local medical center. These measurements were obtained and recorded under the supervision of a medical center employee. This employee was currently a Licensed Certified Athletic Trainer and has been referred to as “John” throughout this project. The pre-test measurements, on the fifteen female collegiate softball players, took place on February 25th, 2009. The post-test measurements were obtained on April 7th, 2010. These measurements consisted of measuring the strength of the quadriceps compared to the hamstrings. This was done by having the athlete flex and extend their knee while being strapped to the isokinetic machine. The pre-test measurements were obtained prior to the intervention and the post-test measurements were obtained following the completion of the intervention.

Procedures

Approval, in writing, from the head softball coach (see appendix C for the letter of permission from the head softball coach) and associate athletic director (see appendix D for the letter of permission from the associate athletic director) was granted for the researcher to conduct this study with these athletes. The fifteen participants were members of college softball team. The hamstring emphasized strengthening program was explained, in detail, and live demonstration of the exercises that would be implemented was performed on the morning of February 23rd, 2009. A consent form from the college (see appendix A for the consent form) as well as a consent form from the medical center (see appendix B for the consent form) was signed by each athlete that was involved in the study. These documents were signed before the athlete began to participate in the study.
Once the fifteen softball players gave consent to participate in the study and consent was granted by the associate athletic director and the head softball coach, a time and day was set up to take the pre-test strength assessment measurements. This was organized through John at the medical center. A preliminary meeting, on January 29th 2010, was arranged in order to review the equipment, assess how measurements were going to be taken along, and to become familiarized with the machine, as well as, address any paperwork issues, such as developing the informed consent form, and making sure that the project would be approved through the medical centers IRB and the colleges IRB.

Consent forms, for both the college and the medical center, were signed upon arrival for the pre-test measurements on February 25th, 2010. These consent forms gave the researcher, college, and the medical center approval to use these female athletes in the study. The athletes’ strength was then assessed using the isokinetic machine. The athlete was instructed to sit in the seat that was attached to the machine with their back flat against the seatback and their legs dangling and relaxed. The athlete’s dominant leg was then strapped to the seat and their lower leg was placed onto the small lever arm. The lower leg rested on a foam pad and a strap was placed around the ankle to make sure that the leg would move in a fluid motion with the arm as well as, limiting any unwanted movements that could possibly interfere with the measurements. The arm was attached to the isokinetic machine. This attachment site was centered at the midline of the knee. The athlete was then instructed, by the researcher, on when to begin maximally extending and flexing their knee. The athlete repeated this three times and the mean was calculated for each athlete. The mean of those three measurements was the number that was used in the project. This entire procedure was supervised by John. The hamstring emphasized strengthening program was then implemented and closely monitored for four weeks. The same
procedure was followed when post-measurements were obtained following the completion of the intervention.

**Timeline**

During the months of September and October the literature was reviewed pertaining to the quadricep: hamstring ratio, the success of past studied hamstring emphasized strengthening programs, as well as possible complications that can arise from a discrepancy in this ratio. The desired outcome of this research was to become more informed about the quadricep: hamstring ratio and how to potentially improve this ratio if it is not in the desired optimal range.

In November and December, after a thorough review of the professional literature, a hamstring emphasized strengthening program was developed. The researcher determined the participants for the study. Fifteen members of college softball team agreed to participate in this study. It was discovered, through a review of literature, that specific exercises benefited the hamstrings more than others. These exercises were incorporated into the hamstring emphasized strengthening program, which was designed specifically for the female collegiate athlete.

At the end February, following the process of obtaining consent from the athletes, approval from college officials, and IRB approval, the intervention was initiated. The four-week hamstring emphasized strengthening program began on March 1st, 2010 and continued until April 2nd, 2010. During this time period the participants were asked to complete the hamstring emphasized strengthening program two times per week, for a total of eight sessions. All sessions were closely monitored by the researcher and John. At the end of the four weeks post-test strength measurements were obtained on April 7th, 2010.
Data Analysis

The data for this project was obtained by pre- and post-test measurements of strength. The pre-test and post-test mean of three scores was the final product used for the data. These measurements were taken on an isokinetic machine. An excel spreadsheet was developed to record and report the data. A bar graph was also used to show the difference between the pre- and post-test measurements.

The strength ratios were obtained by dividing the maximal concentric hamstring peak torque by the maximal concentric quadriceps peak torque (Holcomb et al., 2007). This was assessed using the isokinetic machine in which the athlete flexed and extended the knee against resistance. The average of three measurements was the number used for the data. The results were charted on a bar graph that compared the pre-test strength number to the post-test strength number.

Conclusion

In order to answer research question #8 a hamstring emphasized strengthening program was implemented with female collegiate athletes enrolled at a small, Midwestern college. Fifteen female collegiate softball players participated in the study. The hamstring emphasized strengthening program was implemented for four weeks. A total of eight exercise sessions were performed. During these exercise sessions the following exercises were executed: seated leg curls, squats, lunges, exercise ball leg curls, hamstring lowers, step-ups with weight, superman’s with ankle weights strapped around their ankles, as well as stool scoots with ankle weights. Pre- and post-test measurements of strength were calculated using an isokinetic machine.
Chapter IV: Results

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball.

The research questions were:

1. What are the quadriceps and hamstrings and what is the optimal ratio of these muscles working together as a unit according to the professional literature reviewed?

2. According to the professional literature, what injuries occurred when the quadriceps/hamstring ratio was not optimal?

3. What were the different exercises that composed the hamstring emphasized strengthening program according to the professional literature reviewed?

4. How did the implementation of a hamstring emphasized strengthening program benefit the collegiate female athlete?

To answer research question #12, a hamstring emphasized strengthening program was implemented with female members of a small collegiate softball team. Pre- and post test strength measurements were obtained by the researcher, of the fifteen participants’ hamstrings in their dominant leg. The data used for this project were the ratio of the hamstring strength in comparison to the quadriceps strength. This was assessed both pre- and post- implementation of the strengthening intervention.
After the hamstring program was completed the pre- and post-test strength scores were compared and differences were established. This difference was determined by comparing the pre-test strength measurements mean to the post-test strength measurements mean. The scores, differences and percentage of increase between the pre-and post-test hamstring strength ratio’s are listed in Figure 1. These differences are also compared in a bar graph in Figure 2. The pre-test strength ratios are represented by the color blue. The post-test strength measurements are in red, the difference between the two are symbolized by the color green and the color purple represents the percentage of strength that was gained, or in some cases lost.

<table>
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<th>Participant</th>
<th>Pre-test Mean</th>
<th>Post-test Mean</th>
<th>Difference Between Mean</th>
<th>% of Increase or Decrease</th>
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<td>68.4</td>
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</table>

*Figure 1. Pre- and Post-Test Hamstring Strength Measurements Means: Differences and Percentages.*
The data indicated that sixty-six percent of the participants improved their hamstring strength.

*Figure 2.* Pre- and Post-Test Hamstring Strength Measurements Bar Graph: Outcomes, Differences and Percentages.

The data indicated that most of the participants had an increase in hamstring strength following the implementation of the hamstring emphasized strengthening program.

The data showed that out of the fifteen participants, ten participants improved their quadricep hamstring ratio after participating in the hamstring emphasized strengthening program that was implemented by the researcher. Overall, there was an increase in hamstring strength in sixty-six percent of the participants. Six participants showed significant strength gains. Significant strength gains were those that had a twenty percent or more increase in strength.
Five participants showed a decrease in strength. All participants had either an increase or decrease in strength, not one subject stayed the same.

Conclusion

A study was conducted to determine if a hamstring emphasized strengthening program would benefit a female collegiate athlete participating in the sport of softball. Data collected indicated that the use of a hamstring emphasized strengthening program would provide lasting benefits to the female collegiate athlete participating in the sport of softball. Pre- and post-test strength measurements were taken, results were analyzed and inferences were made. A table of the results and a bar graph were created to visually represent the data. The data supports the researcher’s hypothesis that the implementation of a hamstring-emphasized strengthening program would not only improve the strength of the hamstrings, but also bring the quadriceps: hamstring ratio closer to optimal. This is discussed further in Chapter V.
Chapter V: Discussion

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball.

The research questions were:

1. What are the quadriceps and hamstrings and what is the optimal ratio of these muscles working together as a unit according to the professional literature reviewed?

2. According to the professional literature, what injuries occurred when the quadriceps/hamstring ratio was not optimal?

3. What were the different exercises that composed the hamstring emphasized strengthening program according to the professional literature reviewed?

4. How did the implementation of a hamstring emphasized strengthening program benefit the collegiate female athlete?

A hamstring emphasized strengthening program was implemented with female members of a small collegiate softball team. Pre- and post-test strength measurements were obtained and means calculated for each, by the researcher, of the fifteen participants’ hamstrings in their dominant leg. The data used for this project was the ratio of the hamstring strength in comparison to the quadriceps strength. This was assessed both pre- and post- implementation of the strengthening intervention.
Meaning of Findings

Fifteen female collegiate softball players from a small Division III NCAA institution participated in the study. Sixty-six percent of the participants that were involved in the hamstring emphasized strengthening program improved their hamstring strength. This high percentage of increase might suggest that a hamstring emphasized strengthening program can be beneficial to the female collegiate athlete participating in the sport of softball.

However, there were some athletes that had a decrease in strength. Thirty-three percent of the participants experienced a decrease in strength. This could have been attributed to a number of factors. These factors included a possible existing hamstring strain that might have occurred sometime during the four week program, the time and date of data collection and the chance of human error in working with the isokinetic machine.

Hamstring Strain. A pre-existing injury to the hamstrings could have altered the results. An injury of this magnitude can decrease an athlete's strength significantly. This decrease in strength will lead to an even greater imbalance between the quadriceps and hamstrings, therefore causing the results to change.

Time and Date. The pre-test measurements were conducted in the early morning. Post-test measurements were conducted in the early evening. In the morning, the athlete could have experienced a lack of flexibility since they had not been up and moving for the most of the day. The post-test measurements conducted in the early evening gave the athlete a chance to be mobile and got blood and oxygen flowing to the prospective muscles throughout most of the day.

Machine. The measurements were taken on a machine. The machine is connected to a computer that computes the data that is obtained from the machine. This computer could have
malfunctioned and an incorrect reading could have occurred. The machine could have malfunctioned as well, perhaps by moving slightly during testing, or not going through the entire range that was specified.

**Human Error.** Human error could have also occurred during testing. The researcher might have made a mistake and not put in the right parameters to start, or when writing down the numbers could have possibly mixed them up, or not recorded the numbers accurately. Also, the machine might have been moved or set-up slightly differently than when the pre-test measurements were taken.

**Summary**

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball. Fifteen female collegiate softball players from a Midwestern, Division III National Collegiate Athletic Association instution, participated in the study. All of the athletes were members of a small NCAA Division III softball team and had no prior experience with a hamstring emphasized strengthening program.

Approval, in writing, from the head softball coach (see appendix C for the letter of permission from the head softball coach) and associate athletic director (see appendix D for the letter of permission from the associate athletic director) was granted for these athletes to partake in this study of a hamstring emphasized strengthening program. A consent form from the college (see appendix A for the consent form) as well as a consent form from the medical center (see appendix B for the consent form) was signed by each athlete choosing to participate in the study.
The hamstring emphasized strengthening program began on March 1st, 2010 and concluded four weeks later on April 2nd, 2010. A total of eight exercise sessions were performed. Each session was closely monitored by the researcher. During these exercise sessions the following exercises were executed: seated leg curls, squats, lunges, exercise ball leg curls, hamstring lowers, step-ups with weight, superman's with ankle weights strapped around their ankles, as well as stool scoots with ankle weights. Upon completion of the strengthening program, post-test strength measurements were taken. Results from both the pre- and post-test strength measurements were analyzed and results were determined. The data suggested that the implementation of a hamstring emphasized strengthening program for female collegiate athletes participating in the sport of softball would had been proven to be beneficial.

Recommendations

There are several recommendations for a future study. These included selecting participants from other collegiate sports teams both male and female, and athletes from other Division I and Division II colleges and universities. Additional recommendations include implementing a strengthening program over a longer period of time and increasing the number of exercises to be performed within the strengthening program.

Participants. Using participants from a variety of collegiate teams would allow the researchers to compare and contrast the impact that a certain sport has on the quadricep: hamstring ratio. For example, a soccer player does more running than a softball player, due to the nature of the game itself. Hence, the soccer player would be more prone to having a stronger lower body on the whole. Also, the game of soccer involves a kicking motion, which requires the flexion and extension of the knee, the main action of the quadriceps and hamstrings. It would
also be beneficial to study basketball players. The nature of the game of basketball involves copious amounts of running and jumping and lower extremity strength, therefore being another major sport to study.

**Gender.** The comparison of males to females could provide further insight as well. Males tend to be stronger on the whole, so it would be beneficial to study the gender aspect in regards to the strength of the hamstrings in order to see if gender plays a significant role in the quadriceps: hamstring ratio.

**Size.** A recommendation for future studies would be the inclusion of athletes from a bigger college or university, Division I or Division II, be studied. The small size of the Division III level and restrictions placed on these non-scholarship athletes could have played a role in the results that were obtained. Athletes at a larger instution usually have some sort of financial assistance, therefore their level of skill is rewarded more advanced than that of a Division III athlete. The bigger, faster, stronger theory applies to athletes at these instutions. From the researchers personal experience in both the smaller and larger collegiate settings, limitations are placed on training sessions at Division III schools due to academic requirements, whereas at The Division I and Division II levels training sessions are longer and more intense and less emphasis is placed in academia.

Division I and II athlete’s workout plans are generally scheduled for a longer period of time and a greater emphasis is placed not only on skill development, but to also maintain physical fitness by participating in sport specific strengthening programs. These programs are on average performed up to three times per week. If emphasis is placed in those sports and their
strengthening programs on the hamstrings, the rate at which the hamstrings would increase their strength would be increased hence, the quadricep: hamstring ratio would be closer to optimal.

**Time Period.** Another recommendation was implementing a strengthening program for a longer period of time. The current study was only implemented during a four week period. A program of eight weeks might be more beneficial to the athlete. Even the addition this program into pre-season and even all of in-season would provide the greatest benefit of all. The longer the period of time the athlete has to participate in the study the more comfortable and confident they will become with actually performing the desired exercises as well as improving their overall strength.

**Number of Exercises.** Finally, the researcher recommended that more exercises be used in the hamstring emphasized strengthening program. The current study only used eight basic exercises. While these exercises were sufficient for the present study, further research would benefit from an increase in the number of exercises that were to be performed. Some of the exercises to be used in a future study could be more complex. For example, the good morning exercise would be an additional exercise that could be used to strengthen the hamstrings. The good morning exercise requires that the participant assume a stance like the squat method, however instead of actually squatting down the participant would flex at the hips and bend the torso forward until it is parallel with the ground. This would be accomplished while maintaining their feet flat on the floor and shoulder width apart. The participant would then return to the starting position. This would be performed in one fluid motion. There are many other advanced exercises to strengthen the hamstrings and would be beneficial if implemented into a more
sophisticated hamstring emphasized strengthening program. These include stiff leg dead lifts, single leg stiff dead lift, and Russian Curls.

Conclusion

The purpose of this project was to determine if the implementation of a Quadriceps/Hamstring strengthening program would benefit female collegiate athletes at a NCAA Division III institution participating in the sport of softball. Pre- and post-test measurements of strength were taken on an isokinetic machine located at a physical therapy clinic at a local medical center. Female collegiate softball players participated in the study of a hamstring emphasized strengthening program. Pre- and post-test measurements of strength were analyzed and results were obtained. As a result of analyzing the data, it was determined that a hamstring emphasized strengthening program might prove to be beneficial to the female collegiate softball player. The researcher developed several recommendations for future research in the realm of the quadricip: hamstring ratio.
References


Appendix A

Consent Form for the College

Consent to Participate in Research Project.

Title of study: A Hamstring Emphasized Strengthening Program for Collegiate Female Athletes
Principle researcher: Jessica M. White

This study involves the implementation of a strengthening program concentrating on the hamstrings. The purpose of this study is to fulfill the requirements of a master's degree from The Defiance College by completing the project option. The results from this study can help future generations of athletes realize the importance of hamstring strengthening in order to reduce the risk of possible injury. This study will reiterate the need to concentrate on the hamstrings during lower body resistance training.

The subjects participating in this study will meet as a group to explain the study. Information will be presented on the program, including a live demonstration of how to perform the desired exercises. The athletes will then take part in a pre-test assessment of strength by using an isokinetic machine. The program will be implemented for 4 weeks at a rate of 2 times per week, for a total of 8 sessions. A post-test assessment of strength will then be measured, again using the same isokinetic machine. The results will then be analyzed.

The benefits to the athletes participating in this study can be the decline of the possibility of injury and improvement of strength in the hamstrings. The only risks associated to this study could be an increase in muscle soreness in the lower legs.

Your results will be confidential. You will not be asked to put your name on the pre or post-test assessment of strength. All communication will take place face to face or over the telephone.

The results of the study will be given to you by contacting the primary researcher, Jessica M. White.

You must be at least 18 years of age to participate in this study.

Your participation in the study is voluntary and you are free to withdraw at any time without penalty. If you have questions about the study you may contact Jessica M. White at (330)388-9651.

You are to keep one copy of this consent form.

I, ____________________________, agree to participate in this study.

(participant's printed name)

__________________________

(participant's signature) (Date)
Appendix B
Consent Form for the Medical Center

Signatures:

You are making a decision whether or not to participate in this study. Your signature indicates that you have read and understood the information provided above, have had all your questions answered, and have decided to participate.

__________________________________________
Printed Name of Subject

__________________________________________  ________________
Signature of Subject  Date

__________________________________________  ________________
(If Applicable) Printed Name of Legally Authorized Representative  Relationship to Subject

__________________________________________
Signature of Legally Authorized Representative  Date

__________________________________________
Printed Name of Person Obtaining Consent

__________________________________________
Signature of Person Obtaining Consent  Date

YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP

If you have any questions concerning this study or consent form beyond those answered by the investigator, including questions about the research, your rights as a research subject or research-related injuries, please feel free to contact the ProMedica Health System Institutional Review Board at 419-291-5362.
Appendix C

Consent Form from Head Softball Coach at College

February 1st, 2010

Jodie Holava, M.Ed, ATC
Head Softball Coach
The Defiance College
701 N. Clinton St
Defiance, Ohio 43512

Dear Coach Holava,

This letter will confirm our recent conversation about my master's project and the volunteer participation of your Division III softball, female collegiate athletes. I am completing my project entitled “The Implementation of a Hamstring Emphasized Strengthening Program to Collegiate Female Athletes.” I would like your permission to implement my program, subject your athletes to a pre and post-test analysis of strength, analyze the results and use these results in my project and to further my knowledge of the ratio of quadricep to hamstring strength.

The requested permission extends to any future revisions and editions of my project. Your signing of this letter will confirm that you give me Jessica M. White, permission to use your softball athletes for my project.

If these arrangements meet your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Sincerely,

Jessica M. White

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

__ Jodie Holava, M.Ed., ATC __

Date: __________________
Appendix D
Consent Form from Associate Athletic Director College

February 1st, 2010

Jenni Morrison
Interim Athletic Director
The Defiance College
701 N. Clinton St.
Defiance, Ohio 43512

Dear Ms. Morrison

This letter will confirm our recent conversation about my master’s project and the volunteer participation of the Division III softball team consisting female collegiate athletes from The Defiance College. I am completing my project entitled “The Implementation of a Hamstring Emphasized Strengthening Program to Collegiate Female Athletes.” I would like your permission to implement my program, subject these athletes to a pre and post-test analysis of strength, analyze the results and use these results in my project and to further my knowledge of the ratio of quadriceps to hamstring strength.

The requested permission extends to any future revisions and editions of my project. Your signing of this letter will confirm that you give me Jessica M. White, permission to use these softball athletes for my project.

If these arrangements meet your approval, please sign this letter where indicated below and return it to me in the enclosed return envelope. Thank you very much.

Sincerely,

Jessica M. White

PERMISSION GRANTED FOR THE USE REQUESTED ABOVE:

__________________________

Jenni Morrison

Date: _____________________