THE PATRIOT PROGRAM: A DYNAMIC WARM-UP FOR THE RISK REDUCTION OF ANTERIOR CRUCIATE LIGAMENT INJURIES IN HIGH SCHOOL FEMALE BASKETBALL PLAYERS

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The Patriot Program: A Dynamic Warm-Up for the Risk Reduction of Anterior Cruciate Ligament Injuries in High School Female Basketball Players

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ABSTRACT

**Background:** Female athletes have a higher risk of tearing their ACL verse male athletes in planting cutting sports at a similar level. Multiple ACL risk reduction programs have been developed but have not specifically targeted female high school basketball players.

**Objective:** Determine the effectiveness of a coach run, dynamic warm up program on the risk reduction of ACL injury in female high school basketball players.

**Participants:** The participants in this study are a sample of convenience of seventeen high school female basketball players.

**Study Design:** Repeated measures with time as the independent variable with three levels.

**Methods:** Pre-season, mid-season and post-season data collection included: measurement of lower extremity strength, calculation of hamstring/ quadriceps ratio, core strength, measurement of Q-angle, measurement of subtalar neutral, and performing the Landing Error Scoring System (LESS). Additionally, during the first data collection, participants were educated about ACL injury, preventative mechanisms, and instructed in the Patriot Program.

**Results:** Significant changes (p<0.05) were seen in knee flexion strength, hamstring quadriceps ratio, lower core strength, and LESS. No significant changes were noted in other dependent variables.

**Conclusion:** A multifaceted dynamic warm-up including sports activities that target modifiable risk factors associated with ACL injury may effectively reduce the risk of ACL injury in female high school basketball players.

**Suggested Keywords:** sport specific, coach administered, multifaceted prevention program, plyometric, in season training
Introduction

Anterior cruciate ligament (ACL) injury occurs with a 4- to 6-fold greater incidence in female athletes compared with male athletes. The greater incidence of ACL injury in women, coupled with the 10-fold increase in high school and 5-fold increase in collegiate sport participation in the past few decades, has led to a rapid rise in ACL injuries in female athletes.1-4

ACL reconstructions are among the most common sports medicine procedures performed in the United States each year and are costly, estimated at $17,000 to $25,000 for each individual, including rehabilitation. Given that 38,000 female athletes injure their ACL each year, an estimated total of $646 million to $950 million is spent every year on female ACL injuries. Not only is the cost for ACL injury repair of concern, but an ACL injury could result in the loss of an entire season of sports participation, meaning the loss of scholarship funding, and potentially, long-term disability.1

The ACL is located in the center of the knee joint capsule and functions to prevent the tibia from moving too far anteriorly. The ACL originates posteriorly on the femur on the lateral wall of the intercondylar notch and inserts anteriorly on the tibial condyle, crossing anteriorly of the posterior cruciate ligament (PCL). At full knee extension, the slight lateral rotation of the tibia tightens the ACL.5 Noncontact mechanisms of ACL injury have an occurrence rate of 72% and contact mechanisms, 28%. A noncontact mechanism is classified as a sudden deceleration prior to a change of direction or landing motion.5 A contact mechanism is classified as a varus force resulting in a valgus collapse of the knee.5 Most ACL injuries, both noncontact and contact in origin, are sustained at heel strike with the knee close to full extension.6 There are many factors including structural differences, hormonal...
differences, musculature differences, and mechanical differences between males and females that make females more susceptible to ACL injury.

Non-modifiable risk factors predisposing females to ACL injury include structural differences and hormonal differences. Structural characteristics that place the ACL at risk that tend to be more prominent in females are an increased quadriceps angle (Q-angle) of 15° or greater, poor biomechanical alignment of the lower extremities, a smaller intercondylar notch, and increased joint laxity. Hormonal differences may account for the increased joint laxity and also have an effect on the overall composition and health of the ACL.

The Q-angle is the angle between the femur and the tibia and is measured from anterior superior iliac spine (ASIS), to mid-patella, to tibial tuberosity. Females tend to have a larger Q-angle than males because a wider pelvis is beneficial for child bearing. A normal Q-angle for females is 15-20° and for males is 10-15°. The increased Q-angle of females in comparison to males places excess rotational forces on the medial aspect of the knee. During a sudden deceleration, or decrease in velocity in which the foot it planted abruptly, the increase in Q-angle can increase the chance of ACL strain and injury.

Other biomechanical considerations of the lower extremities, including increasing foot pronation, knee valgus, and femoral anteversion, can contribute to increased risk of female ACL injury. A larger Q-angle coincides with foot pronation and creates excess femoral internal rotation forces on the knee or creates excess tibial external rotation, causing increased load on the medial aspect of the knee and thus, increased tension on the ACL. Knee valgus, a condition in which the knees are positioned inward, commonly called “knock knees”, results in an increased load on the ACL. Lastly, femoral anteversion, a condition in which the femur is positioned in excessive internal rotation, causes mal-alignment to all other
joints down the kinetic chain as well as increased stresses and forces, particularly on the knee.  

A smaller intercondylar notch is another structural characteristic predisposing females to ACL injury. The femoral notch is the space where the ACL is located, and females tend to have smaller femoral notches than males with the mean notch for females to be $13.9 \pm 2.2$ mm and for males $15.9 \pm 2.5$ mm. It is unknown why a smaller intercondylar notch is correlated with higher incidence of ACL injury, but may be due to the shearing effect of the intercondylar notch against the ACL. 

Hormonal differences in females may account for the increased joint laxity. Studies have found a significant association between ACL injury and the phase of the menstrual cycle with more ACL injuries occurring during the ovulatory phase of menstruation. In addition, collagen synthesis and fibroblast growth is known to be imperative to ACL health, but increasing estrogen concentrations significantly reduce these processes, effecting the overall composition and health of the ACL. Thus, the hormonal increase in estrogen during the ovulatory phase of menstruation will decrease collagen synthesis and fibroblast growth, increasing laxity to all ligaments of the body including the ACL. This ligamentous laxity of the ACL causes the knee joint to be increasingly susceptible to translation of the tibia on the femur, a motion that is normally prevented by the ACL. 

Modifiable risk factors predisposing females to ACL injury include musculature differences and mechanical differences. Musculature characteristics that are more prominent in females, that place the ACL at risk, include imbalanced muscular strength and imbalanced muscular recruitment. Mechanical differences of jump landing position of females additionally place the ACL at a greater risk for injury.
Female athletes frequently demonstrate imbalances in muscular strength and recruitment between hamstrings and quadriceps which can increase the risk of ACL injury. The normal hamstring to quadriceps (H/Q) strength ratio is between 50-80%, with 100% being equal strength.¹ This means the hamstrings are usually weaker than the quadriceps which is partly due to the quadriceps being a larger muscle that is used more frequently in daily activity. Females tend to have lower H/Q strength ratios compared to men and furthermore, female athletes may have an even lower hamstring to quadriceps ratio compared to untrained female athletes because of dominant quadriceps.¹ As the quadriceps contract to extend the knee, the hamstrings act as the antagonist to control the anterior translation of the tibia on the femur and stabilize the knee. If the hamstrings are weak, the contraction of the quadriceps and resultant knee extension may be too forceful, causing damage to the knee joint and ligaments.¹,¹³

Females tend to have increased quadriceps activation, decreased hamstring activation, and tend to perform lower extremity athletic movements such as running, jumping, and cutting with decreased hip and knee flexion. Consequently, females must rely more heavily on ligaments rather than musculature for lower extremity athletic movements as the muscle recruitment is limited.¹,⁶ The majority of jump landing techniques of females are limited in sagittal plane movement as demonstrated by decreased hip and knee flexion landing pattern, and greatest in frontal plane movement. Jump landing techniques of females in the frontal plane tends to be accompanied by heavy reliance on the adduction movement of knee valgus to decelerate the body mass from the jump. A combination of deceleration into a hard landing and knee valgus following a jump results in an increase in force to the medial aspect of the
knee and an increased strain on the ACL. Poor jump landing techniques place heavy reliance on the ACL in order to control the landing, thus increasing the risk of ACL injury.\textsuperscript{14}

According to the Lower Extremity Scoring System (LESS) a proper jump landing technique should include the following at initial contact: symmetrical landing utilizing a toe-to-heel strike, knee flexion greater than 30°, knee alignment centered over mid-foot, trunk flexion greater than 30°, feet shoulder width apart and trunk centered over hips.\textsuperscript{14} Displacement of knee flexion should remain greater than 30° and knee alignment should remain centered over mid-foot.\textsuperscript{14} These attributes allow the ACL to function within its limits without providing increased stress, thus decreasing its risk for injury.

Modifiable risk factors predisposing females to ACL injury can be changed over time to decrease the chance of injury. ACL injury prevention programs that focus on dynamic stretching and proper jump landing techniques have the capability to improve muscle performance and muscle imbalances to reduce the risk of ACL injury.\textsuperscript{3,16,17}

ACL injury prevention programs are most commonly set up as a warm-up routine to increase joint range of motion, increase muscle-tendon range, decrease muscle stiffness, increase body temperature and heart rate, and increase responsiveness of nerves to ultimately improve muscle performance.\textsuperscript{18,19} A great deal of thought goes into making a routine that encompasses all the activities needed to achieve these bodily responses as well as the length of time it takes to complete them.

Researchers have looked at the amount of time a warm-up takes to perform as well as the intensity it is performed at. It is found that a warm-up routine between 5 and 15 minutes followed by 5 minutes of recovery is generally sufficient for players to feel prepared for game intensity activity. The intensity that has been found to be beneficial is between 40-60%
of VO₂ max. It can be difficult to gauge activity based on VO₂ max so an active warm-up at moderate intensity, below game level performance, is thought to improve performance as long as fatigue is not induced.¹⁹,²⁰

The order of activities of a warm-up routine have been manipulated and studied to find the best way to increase muscle performance and reduce the risk of injury. Many warm-ups consist of submaximal running, stretching, and periods of sport specific skill based drills.²⁰ Calisthenics such as squatting and lunging movements are also performed and can be paired with running drills that challenge movements in forward and lateral planes.¹⁹ Quick change of direction movements are also performed to prepare the muscles and joints for sport like actions.¹⁹ It was found that a warm-up order consisting of dynamic stretching, followed by progressive movements, and ending with sport specific activities was beneficial as long as fatigue was not induced.¹⁹

One major component of all warm-up routines is stretching. Stretching is important when it comes to minimizing the risk of injury during sports by enhancing muscle flexibility. Muscle flexibility allows muscles to accommodate to stressors and improve effectiveness and efficiency of their actions.²¹ The two main types of stretching that are commonly seen in basic warm-up routines are static and dynamic. Static stretching is defined as elongating a muscle to minor discomfort or tolerance and sustaining that position for a length of time, usually 30 seconds.²⁰-²² Dynamic stretching is rhythmically moving a limb through its available range, at a controlled slow tempo.²¹-²³

Static stretching has been looked at by a number of researchers. Bandy et al. found that static stretching is more beneficial than dynamic stretching in increasing hamstring flexibility.²¹ They focused on the length of time to hold a static stretch and found that 30
seconds of static stretching is comparable to 1 minute of stretching and produces more benefits than only 15 seconds. Other researchers have found supporting evidence that static stretching is more beneficial, but it has also been reported to hinder muscle performance. Taylor et al. theorized that there is an inhibitory effect on the muscles that can occur after static stretching but can dissipate if it is followed by a more sport specific activity. This suggests that if static stretching is going to be incorporated into a warm-up routine, it should optimally be done before moderate intensity game assimilated activities to prepare an athlete for game intensity performance.

There is considerable evidence to support static stretching, but there are also studies that refute its effectiveness. Static stretching is hypothesized to increase the muscle-tendon compliance beyond its effective length. This increased compliance reduces the rate of force transmission and decreases the muscles performance. Other studies compare static and dynamic stretching and determine what effects they have on activity performance such as jumping and running. In one study, static stretching was found to be detrimental to jumping and can decrease jumping height due to the decreased muscle performance and rate of force transmission. Conversely, dynamic stretching is thought to increase muscle power output in two possible ways.

One theory is that dynamic stretching can increase muscle temperature and tissue perfusion which increases the transmission rate of nerve impulses. Taylor et al. found that a dynamic warm-up elevated muscle temperatures significantly more than static stretching. This increase in muscle temperature led to more rapid and forceful muscle contractions. Externally heating a muscle however, did not produce equivalent muscle contractions. This leads to the idea that perfusion is the likely cause behind the muscle response, not the muscle
temperature itself. The second theory is that when muscle contraction is used in a dynamic warm-up, there is increased neural activity in the dorsal spinal nerve roots leading to more rapid and forceful response in the activated muscle. A more rapid and forceful response in muscle activation can lead to an increase in athletic performance as well as supporting the knee joint in jumping and cutting activities. The increased muscle perfusion and increased neural activity of dynamic stretching during a warm-up routine may provide more benefits than static stretching.

Another large component of a warm-up routine is sport specific activities which have improved performance of athletes as well as reduced the risk for injury. Improvements have been found in running speed, jumping height, muscle force, and overall fitness testing performance. Warm-ups that consist of “practice” or sport specific maneuvers such as jumping activities, allow for better performance of jumping when playing sports. The theory is that practicing the activity allows for “opening-up” of neural pathways which facilitate motor unit activation; therefore, performing these activities during a warm-up, assists in improving explosive performance which carry over to game intensity activities. By incorporating activities that mimic actual sport movements in a warm-up routine, the athlete’s muscles should be prepared for the dynamic movements and different loads placed on the joints in high intensity situations like cutting, jumping, and pivoting during practice and games.

When practicing different maneuvers in a warm-up it is important to maintain good form to ensure the muscle activation is efficient and mimics the manner in which the muscle will be used to minimize injury. During cutting maneuvers, Hewett et al. recommended that basketball players decelerate before cutting to decrease the amount of strain placed on the
The sport of basketball requires a lot of decelerating and quick cutting maneuvers in comparison to other sports like soccer or softball. For example, basketball players perform these movements continuously throughout a game when they transition to defense, cut through the lane, or set a pick. If they are performing the movement improperly in the game, they are predisposing themselves to injury.

A program used to reduce the risk of an ACL injury should include sport specific activities that include the unique skills of the sport. In theory, practicing sport specific skills correctly during a warm-up should prepare the body to execute those skills correctly during competition. In addition to helping reduce the risk of ACL injury, introducing sport specific training may help increase athlete and coach compliance with preventative ACL programs. ACL prevention research is headed in the direction of identifying the need for sport specific training.

One of the limiting factors of previously developed ACL injury prevention programs is their inability to improve athletic performance. Although the programs may have yielded a decrease in ACL injury incidence, it is difficult to convince a coach or competitive athlete to participate in a program with only preventative applications. To enhance compliance, a sports specific component should be added to ACL prevention programs. This allows the athlete to practice previously learned injury prevention techniques while introducing components of the sport. Based on the literature, it is beneficial to have both dynamic stretching and sports specific activities in a warm up program to help prevent the risk of an ACL injury.

Of all the prevention programs currently in the literature, the study of highest quality was a prevention program designed as a warm-up including plyometrics, strengthening,
stretching, and agility drills. This study approached a significant difference between the control and intervention groups, with the intervention group showing an ACL injury rate 3.3 times less than the control. In contrast, a study that only addressed plyometric based exercise did not find a significant difference between the treatment group and the control group. Multifaceted training programs designed as warm-up routines have been shown to be most effective in preventing ACL injury in female athletes. Based on relevant research papers, some of the training factors incorporated into such warm-ups should include plyometric/jump landing training, neuromuscular training, flexibility, balance/proprioception training, and sport specific training.

Plyometric training focuses on proper jump landing techniques and quick, accurate movements. It allows the muscles, connective tissues, and nervous system to effectively carry out the stretch-shortening cycle of a muscle contraction while focusing on proper technique and body mechanics. A stretch-shortening cycle occurs when a muscle goes through an eccentric then concentric movement. During plyometric training athletes perform multiple concentric and eccentric movements when jumping or cutting. By practicing these movements the athlete develops a more efficient stretch-shortening cycle allowing the muscle to function more efficiently.

Incorporating plyometric activity where athletes practice multidirectional movements with correct technique will improve muscular efficiency by encouraging muscle dominant neuromuscular adaptations to correct any neuromuscular imbalances. For example, athletes that practice correct jump landing techniques through plyometric training will strengthen the muscles required to perform this movement correctly with better neuromuscular balance. An optimal quad-hamstring ratio can reduce the valgus stress placed on the knees reducing the
risk of ACL injury.\textsuperscript{27,29} Such training will better prepare an athlete for multidirectional sport activities where they are required to perform quick plyometric movements. This is especially important for female basketball players because their sport includes a plethora of jumping and cutting movements which could predispose an athlete to injury if not performed with correct technique.

Neuromuscular training incorporates strengthening specific muscle groups to ensure proper joint alignment, biomechanics, and joint stability. Past research\textsuperscript{30,31,27} has shown that prevention programs that incorporate strengthening are among the most effective. Strength training has positive effects on bones, ligaments, tendons, by improving bone density and increasing the tensile strength of ligaments and tendons thereby decreasing the risk of injury. Imbalances in muscular strength and recruitment including a poor quadriceps to hamstring ratio are modifiable risk factors for ACL tear.\textsuperscript{27} Specific strength training that targets weak musculature can improve a female’s quadriceps to hamstring ratio thereby reducing their risk of injury. Additionally, improved muscular strength will enhance athletic performance and make an athlete’s movements more effective.\textsuperscript{27}

Other prevention programs use video feedback to address corrections in jump landing techniques and education to reduce the risk of ACL injury.\textsuperscript{27,32} Athletes were encouraged to alter their jump landing techniques to softly land on their toes and monitor their knee over the toe position. Landing too abruptly with the knees too far over the toes places a greater stress on the ACL by forcing it to assist in deceleration of the femur while it is being stretched beyond it’s comfortable range of motion. Hewett et al.\textsuperscript{27} found that “education and enforced awareness of dangerous position and mechanisms of ACL injury have also been shown to decrease ACL injuries;” therefore, both education about correct jump landing techniques and
implementation of plyometric training with correct knee positioning will promote the reduction of the risk of ACL injury.\textsuperscript{27,32}

Flexibility measures the length a muscle has in comparison to normal values. Having good flexibility is important in athletes to ensure that the muscles are functioning at maximum capacity. Decreased flexibility will limit a muscle’s range of motion; thereby, limit the muscle’s ability to contract which decreases the force of contraction.\textsuperscript{29} Decreased flexibility can also affect muscular balance and biomechanical alignment predisposing the individual to injury. A study\textsuperscript{29} showed that ensuring proper flexibility can improve some of the biomechanical properties associated with ACL injury including knee range of motion, knee stability, and hamstring to quadriceps ratio.

In searching for programs that were designed to decrease the risk of ACL injury, three prevention programs were identified to be statistically significant in a systematic review conducted by Noyes et al.\textsuperscript{33} in 2011 in reducing ACL injuries in female athletes. Research has shown that a multifaceted approach is imperative for the program to be effective. The three programs that fit this multifaceted description are the Prevent Injury, Enhance Performance Program (PEP), Sportsmetrics, and the FIFA 11 program. These programs were developed using the training interventions of stretching, proprioception, strengthening, plyometric, and agility drills. Each of these programs were examined to find components that would be most appropriate for incorporation into a warm up program that would lower the risk of ACL injury in high school female basketball players.

The PEP program’s main focus is to address the feed-forward mechanism, the ability to anticipate external forces or loads to stabilize the joint, which protects the structures inherent to that joint.\textsuperscript{16} During the 2000 soccer season, the PEP program showed an 88\%
decrease in ACL injuries in participants enrolled in the program, and a 74% reduction of ACL injury during the 2001 soccer season.\textsuperscript{16} The PEP program is made up of basic warm-up activities, five stretching techniques for the trunk and lower extremity, three strengthening exercises, five plyometric activities, and three soccer specific agility drills. The program emphasizes soft landings and deep hip and knee flexion as opposed to landing in lower extremity extension.\textsuperscript{16} This program takes twenty minutes to complete and is performed three times per week for a duration of eight weeks, twelve weeks, or throughout the full season.\textsuperscript{16} After examining the PEP program, the aspects that were chosen to be included in the new warm-up program, The Patriot Program, were hamstring stretches, walking lunges, and forward hops to the dynamic warm-up because it incorporates stretching, strengthening, and plyometrics into the dynamic warm-up.

The Sportsmetric program is designed to refine neuromuscular control of the lower extremity.\textsuperscript{33} The program focuses on teaching athletes proper techniques for jumping and landing which include soft landing and using neuromuscular control to avoid valgus collapse. The workouts are supplemented by weight lifting workouts that aim to improve muscle imbalances in the lower extremities. The program is completed three days per week over a six week period. Each session is 90-120 minutes long. The program incorporates a dynamic warm-up, plyometrics, structured strength training, and flexibility. The unique component of this program is that sport specific training interventions can be added. In the case of female basketball players, specific cutting and deceleration components would be added.\textsuperscript{33} This program is conducted six weeks prior to the start of the particular season. The aspect of the Sportsmetrics program used in The Patriot Program is the quick feet agility drill. This aspect was chosen because it encourages the athlete to perform quick lateral movements with quick
chopping steps, which allows for practice of more controlled movements. Basketball players must perform these quick lateral movements continuously during the course of a basketball game.

The FIFA 11 program was developed by the International Footballers Federation. The main focus of the program was to improve awareness of neuromuscular control during standing, running, planting, cutting, jumping, and landing. They encouraged quality of the movements and put emphasis on core stability, hip control and proper knee alignment to avoid excessive knee valgus during both static postures and dynamic movement. The program takes twenty minutes to complete and is to be conducted on non-game days during the season. The program has three distinct phases. The first phase is running exercises at a slow speed combined with active stretching and controlled contacts with a partner. The second phase consists of six different sets of exercises including strength, balance, and jumping exercises. All exercises have three levels of increasing difficulty. The third phase is speed running combined with soccer specific movements with sudden changes in direction.

Prior to the program being implemented, the coach gets a three hour instructional course on the program, allowing for the program to be conducted by the coach. In developing The Patriot Program dynamic warm-up, aspects used form the FIFA 11 program included time to administer the warm-up, a coach conducted warm-up, and days in which the warm-up is to be implemented.

Using these three statistically significant ACL injury risk reduction programs as a multifaceted frame work, a thorough literary review was conducted to identify additional components that would help to develop a comprehensive dynamic workout. The extensive
literary review yielded multiple articles that identified components that would help to develop a thorough dynamic warm-up.

In development of the dynamic warm-up, traditional warm-up activities were used such as jogging forward and backwards at a moderate intensity to help prepare the body for higher intensity activities. Dynamic stretches to the hamstrings and quadriceps were added because, as explained previously, dynamic stretching has been shown to be more effective than static stretching in preparing an athlete for competition. Additionally, stronger muscles that are balanced around each joint are able to perform more explosive and efficient movements for longer periods of time and the risk of injury is reduced. Specific strengthening activities that were chosen for inclusion in the dynamic warm-up were alternating lunges and turn squats. Plyometrics and agility activities are a major component in the multifaceted dynamic warm-up approach. The plyometric and agility drills that were chosen for the dynamic warm-up were broad jumps, karaoke, and lunge jumps. Sports specific activities are important in a dynamic warm-up because it mimics the activities that the athlete will be expected to perform during competition. Exposure to these activities at a moderate intensity will allow for the athlete to adjust to these movements during game intensity. With the three statistically significant ACL injury risk reduction programs used as the framework which was then coupled with the literary review, gave way to a comprehensive dynamic warm-up entitled The Patriot Program.

Similarly to the FIFA a program, The Patriot Program is designed to be conducted by the team coaches and assistants after an instructional demonstration of the program. The coaches and team participate in the initial instruction as well as attend an educational session.
that discusses ACL injury and outlines the importance of the Patriot Program as a multifactorial approach to ACL risk reduction.

Although The Patriot Program incorporates the multifaceted attributes from previous risk reduction programs, The Patriot Program is different in several ways. The first difference is that the whole program is a single phase dynamic warm-up that contains the aspects identified by the literature and previous studies, including neuromuscular training, flexibility, plyometrics, agility, and sport specific interventions, into a twelve to fifteen minute warm-up. The participant continually moves from one element to the next.

Another unique aspect of the program is that it can be performed on game days. It is designed to only need half of a typical high school basketball court, there is no equipment needed for this program besides basketballs that would be used normally. The other programs are performed three times per week for a minimum of eight weeks. The Patriot Program will be performed five to six times per week, before practices and games. Many of the programs are conducted and completed prior to the start of the particular sport season. With The Patriot Program being conducted over the course of the basketball season, the benefits of the program may be seen throughout the season.

The last major difference between The Patriot Program and the other previously outlined programs is the sport specific training interventions. Typical basketball movements such as dribbling, shooting and defensive drills that encourage quick changes in direction, deceleration, cutting and jumping with double and single leg landings with proper form were incorporated. Basketball specific training interventions were added to have the participants placed in typical basketball type situations so that the body can become accustomed to the stresses and forces that will be placed on it during normal basketball competition. It was
important to make this program fun and specific to the population to enhance compliance, addressing one of the limitations identified by previous studies.\textsuperscript{33,34,36}

The purpose of this study was to develop and implement a comprehensive dynamic warm-up routine to reduce the risk of ACL injuries in high school female basketball players. It was hypothesized that dynamic stretching combined with sports specific activities would impact the identified risk factors for ACL injury in female high school athletes. At the completion of The Patriot Program, it is hypothesized that the participants will exhibit improved jump landing techniques, improved H/Q strength ratios, improved lower extremity strength, which may reduced the risk of ACL injuries.

**Methods**

Participants:

This study was approved by The Sage Colleges Intercollegiate Review Board. A total of twenty-seven student athletes were recruited from a sample of convenience from a nearby high school. Female athletes on the junior varsity and varsity basketball team at who meet the inclusion and exclusion criteria were recruited for this study. The inclusion criteria are as follows: (i) female athlete on the high school girls basketball roster, (ii) signed parental consent form, (iii) signed participant assent form, and (iv) up-to-date sports physical. Exclusion criteria includes: (i) lack of parental consent form, (ii) lack of assent form, (iii) lack of up-to-date physical, and (iv) pregnancy.

Research Design:

This study was a repeated measure design with three levels and time as the independent variable. There was no control group as all participants underwent the same
intervention. Three data collection points were taken over the course of a basketball season to examine the effect of a dynamic stretching program on the measured variables which are the identified risk factors for ACL injury.

Procedure:

The study took place at The Sage Colleges in Troy, NY. Participants traveled to The Sage Colleges three times over the course of the 2012-2013 basketball season for preseason, midseason, and postseason data collection. During the first visit, after preseason data collection, participants were verbally educated about ACL injury and prevention mechanisms. Following the educational session, participants were taught The Patriot Program. The Patriot Program is as follows:

1. Starting at locker room, complete one full lap, jogging at about 50% intensity- 288 feet
2. After completing the lap, line up on the baseline
3. From the baseline, jog to half court with 50% intensity – 47 feet
4. From the half court, backpedal to the baseline – 47 feet
5. From the baseline, perform Frankensteins (participant flexes both arms to 90°, reciprocal leg kick to the hand) to half court – 47 feet
6. From the half court, perform butt kicks (participant brings heel to buttocks reciprocally) to the baseline – 47 feet
7. From the baseline, perform forward alternating lunges to half court – 47 feet
8. From half court, perform turn squats (participant faces sideline performs a squat, turns 180° to face the other sideline, performs a squat, and repeats to the baseline) – 47 feet

9. From baseline, perform karaoke steps (participant sidesteps to the left quickly initiating with the left foot while crossing the right foot behind; alternate to right foot forward with right foot back) to half court – 47 feet

10. From half court, perform lunge jumps (participant performs a forward lunge; when in the lowered position, push off the front leg into to jump up and land softly on both feet; alternate front foot) to baseline – 47 feet

11. Captain’s drill – participant of the team will lead the drill; the leader will stand at center mid court while the rest of the team assembles into three lines facing the leader; participants start in “defensive position” and the leader cues participants in the following directions:
   a. Quick feet – when leader performs stationary dribbling, participants are in defensive position and alternate toe taps as quickly as possible
   b. Defensive slides – multiple directions (forward, backwards, side to side, diagonal) – when leader dribbles in any direction, participants mirror the direction of the leader in defensive slides
   c. Shot blocks – when leader pump fakes (pretends to shoot the ball), participants will yell, “Shot!” put one hand up to block the fake shot, then turn around to box out

12. All participants return to baseline, split up into two even lines at each corner of the court
13. Defensive diagonals- performed simultaneously on both sides – participants split into pairs with one participant in defensive stance and the other with a ball; the participant with the ball dribbles to the elbow of the free throw line, to the mid sideline, then to the center half court, while the participant without the ball guards the ball handler in the defensive position while performing defensive slides\textsuperscript{16,17,29,35,36}

14. At the mid half court, participants will pair up with participants from the other line, perform chest passes from mid half court to free throw line, where one participant will then bounce pass to the other participant to perform a layup\textsuperscript{17}

15. Repeat steps 13 and 14, switching sides so that all participants perform a layup on the left and right side of the basket

16. All participants return to baseline and split up into two even lines forming at the base of the paint

17. Elbow shooting drill – performed simultaneously on both sides – one participant will start at the elbow of the free throw line, the next participant will chest pass to the participant at the elbow who will catch the ball and shoot it; the passer will run out to block the shot while yelling, “Shot!” with one hand up, then turn around to box out the shooter while the shooter runs in to rebound the ball; from the box out position the passer will v-cut into the paint then return to the elbow to become the shooter\textsuperscript{17,34}

18. Repeat 19 - all participants should shoot from both sides of the court

19. Backboard team rebound drill – all participants line up in one line at the first block in the paint. The first person in line throws the ball up against the backboard. The second person in line will rebound the ball then throw it up against the backboard without letting their feet hit the ground. After throwing the ball up the person should
jog to half court then get back in line. The last person to get the ball should perform a layup. Program is concluded after the layup.\textsuperscript{16,17,29,36}

Data collection:

The following outcome measures were collected during data collection at pre-season, mid-season and post-season. Measurement of lower extremity strength using a hand held dynamometer, calculation of the H/Q ratio, core strength as measured by Kendal manual muscle testing, measurement of Q-angle with a standard goniometer, measurement of subtalar neutral as measured by inclinometer, and evaluation of neuromuscular jump landing techniques as measured by the LESS. Researchers performed all data collection as follows:

The lower extremity strength was measured bilaterally with a Nicholas handheld dynamometer (Model 01160, Lafayette Instruments, Lafayette, IN, USA). ICC values for handheld dynamometer range from 0.84 to 0.99.\textsuperscript{37} Researcher’s ICC value for lower extremity strength testing range from 0.88 to 1.00. After the participant was positioned, the participant pushed into the dynamometer for 5 seconds. There was a 10 second rest between the two trials and an average of the two trials was taken as the strength measurement.

Strength measurements were assessed bilaterally.

\textit{Hip extensors}: Participant in prone. On the leg to be tested, the knee was kept in neutral position, the dynamometer was placed two inches above the popliteal fossa and the participant was instructed to lift the leg off the table.

\textit{Hip abductors}: Participant in side lying with the leg to be tested toward the ceiling and elevated twelve inches from the plinth. The participant’s knee was in full extension and the hip was in neutral (zero degrees of flexion). The dynamometer was placed 2” above the lateral epicondyle.
**Hip external rotators:** Participant was seated with a gait belt around hips and chair to stabilize the pelvis (Appendix A). On the leg to be tested, the knee was bent to 90°. The dynamometer was placed 2” above the medial malleoli.

**Hip internal rotators:** Participant was seated with gait belt around hips and chair to stabilize the pelvis. On the leg to be tested, the knee was flexed to 90°. The dynamometer was placed 2” above the lateral malleoli.

**Knee flexors:** Participant was seated with gait belt around hips and chair to stabilize the pelvis. On the leg to be tested, the knee was flexed to 90°. The dynamometer was placed 2” above calcaneus.

**Knee extensors:** Participant was seated with gait belt around hips and chair to stabilize the pelvis. On the leg to be tested, the knee was flexed to 90° and placed in a gait belt attached to a dowel of the platform box. The dynamometer was placed on the distal tibia.

The H/Q ratio was calculated by dividing the average strength measurement of the hamstring by the average strength measurement of the quadriceps for each lower extremity.

Researchers examined core strength using Kendall Manual Muscle Testing for core strength. Researcher’s ICC values for upper (ICC=0.95) and lower abdominals (ICC = 0.99) were excellent using Kendall Manual Muscle Testing techniques. To test lower abdominal strength each participant laid supine. Researcher positioned the Jamar standard 8” goniometer (Model 7540, Sammons Preston, Bolingbrook, IL, USA) with the axis at the greater trochanter, found by palpation, on the right lower extremity, the stationary arm lined up along the trunk parallel to the plinth while the moving arm was lined up with the ipsilateral lateral femoral condyle, found by palpation. Researcher instructed participant to raise both legs to the vertical starting position, keeping their knees straight. The participant
was instructed to tilt their pelvis posteriorly to flatten their low back against the table by pulling their abdominal muscles in. While holding the low back against the table, the participant was instructed to slowly lower both legs to the stable surface. The examiner placed one hand on the participant’s low back to detect the moment the participant’s back arches, or when the pelvis moved into an anterior tilt. The angle between the stationary and moving arm was measured. A grade of Normal is given for 0° off the table. At a 15° angle from the table, the grade is recorded as Good+. An angle of 30° indicates Good+, 45° indicates Good-, 60° indicates Fair+, and 75° indicates a grade of Fair. To test the upper abdominals each participant laid supine on a treatment table. Participants started with their knees bent and hands clasped behind the head. Participants were instructed to do a slow abdominal curl continuing into a sit-up while keeping their trunk flexed, until they come to a full sitting position. If the participant was able to keep the trunk flexed while entering the hip flexion phase and come to a full sitting position, they were given a grade of 5 which translates to Normal. If the participant was unable to perform this motion with their hands behind their head, they were instructed to fold their arms across their chest then repeat the sit-up motion. If the participant could perform the sit-up motion into a full sitting position, with their hands across their chest, they were given a grade of 4 which is an equivalent of Good. If this motion cannot be completed, participants were then instructed to extend their arms at their sides and complete a sit-up to a full sitting position. This motion was given a grade of 3, which translates to Fair if completed. If the participant could only flex their trunk and perform a posterior pelvic tilt, they were given a grade of 2, meaning Poor. This procedure was performed two times. An average of the two scores was derived for analysis.
Researchers measured the Q-angle of each participant bilaterally, with the participant standing. Inter-tester reliability for Q-angle measurements in standing ranged from an ICC of 0.20–0.70. Researcher intra-tester reliability for Q-angle measurements in standing was an ICC of 0.99. To measure the participants’ Q-angle, small dots were drawn with a pen on the participants’ anterior superior iliac spine (ASIS), the midpoint of the patella, and on the tibial tuberosity which were identified through palpation. The axis of a Jamar standard 8” goniometer (Model 7540, Sammons Preston, Bolingbrook, IL, USA) was placed on the midpoint of the patella, the stationary arm was lined up with the ASIS and the moving arm was lined up with the tibial tuberosity. The acute angle between the stationary and moving arms of the goniometer was recorded. This procedure was performed two times. An average of the two scores was derived for analysis.

Researchers assessed subtalar neutral bilaterally through palpation with the participant in the standing position on a 30 centimeter in height box. Picciano et al. reported closed kinetic chain subtalar joint neutral testing (ICC = 0.15) to be more reliable than open kinetic chain subtalar joint neutral testing (ICC = 0.00). Researchers had an excellent intraclass ICC of 0.90 for closed kinetic chain subtalar joint neutral measurements. Researchers palpated each participant’s talus anteriorly until both medial and lateral aspects were felt equally. A Bubble Baseline Inclinometer (Fabrication Enterprises, White Plains, NY, USA) was used to measure the position of the calcaneus in standing subtalar neutral. The participant was then instructed to relax their foot to the normal resting position. Researchers re-measured the subtalar joint angle when the participant relaxed to determine whether the participant maintains true subtalar neutral, pronates, or supinates the foot/ankle
upon relaxation. This procedure was performed two times. An average of the two scores was used for analysis.\textsuperscript{41,42}

Researchers used the LESS to evaluate each participant’s neuromuscular jump landing technique. The LESS has an interrater reliability of 0.84.\textsuperscript{43} Researchers calculated their ICC to be 0.94 for evaluation of the LESS. To perform the LESS, each participant jumped from a box that was 30 centimeters in height to a line that was 50\% of the participant’s body height away from the box (Appendix B). Upon landing, the participant immediately jumped to a maximal vertical height (Appendix C). During task instruction, emphasis was placed on having the participant jump over the line that was marked on the floor. The participant was then instructed to jump as high as they could immediately after landing. No feedback or coaching was provided on their landing technique during testing unless the task was being performed incorrectly. After task instruction, the participant was allowed to perform the task as many times as needed until they performed the jump successfully. A successful jump was indicated by jumping off of both feet from the box, jumping forward but not vertically across the line from the box, landing with the entire foot of both legs on the ground, and completing the task in a fluid motion.\textsuperscript{15}

After completing two successful practice jumps the participant performed three jumps to be used for scoring. Jumps were performed one right after another. The participants were videotaped from both the front and the side using Sports Motion Pro Trainer System (Sports Motion, Cardiff, CA, USA) during these jumps. Each camera was placed 136 inches from the lens to the floor (See Appendix B). All researchers participated in scoring these jumps in accordance with the LESS scoring sheet (See Appendix D). Any discrepancy in scoring was
resolved by majority rule. An average of the three jumps was used as the participants LESS score. LESS scoring is graded as follows:\textsuperscript{15,43}:

\begin{itemize}
  \item $\leq 4$ excellent jump-landing biomechanics
  \item $> 4$ to $\leq 5$ good jump-landing biomechanics
  \item $> 5$ to $\leq 6$ moderate jump-landing biomechanics
  \item $> 6$ poor jump-landing biomechanics
\end{itemize}

During the second and third data collection participants were allowed to review their jumps via video feedback with a researcher. Participants were allowed to ask questions about their technique. The researcher pointed out incorrect form to the participants and instructed the participants on what they should work on to improve landings. When necessary, the researcher educated participants about which aspects of The Patriot Program would assist in correcting their particular jump landing technique.

**Data Analysis**

Data was analyzed with the use of SPSS 20.0 software. General Lineal Model with repeated measures ANOVA was used to find the effect of treatment on ACL risk reduction. Sphericity was assumed, Bonferroni correction was used to counteract the problem of multiple comparisons and the p-value was set at 0.05. Nonparametric tests were used because of the small sample size of 17 participants.

The study began with twenty-seven participants and concluded with a sample size of seventeen. Multiple factors led to an attrition rate of 37\% including: multiple ankle injuries, participants unable to attend data collection for personal reasons, and participants leaving the basketball program.
Results

Lower Extremity Strength:

Right knee flexion was statistically significant between preseason and midseason (p=.000), and between preseason and postseason (p=0.000). Right knee flexion was not statistically significant between midseason and postseason (p=0.476). Left knee flexion was statistically significant between preseason and midseason (p=0.000), and between preseason and postseason (p=0.000). Left knee flexion was not statistically significant between midseason and postseason (p=0.278). See Chart 1.

Right knee extension was not statistically significant between preseason and midseason (p=0.363), between preseason and postseason (p=0.885), and between midseason and postseason (p=1.000). Left knee extension was not statistically significant between preseason and midseason (p=0.867), between preseason and postseason (p=1.000), and between midseason and postseason (p=0.810).

Right hip extension was statistically significant between preseason and midseason (p=.005), but was not statistically significant between preseason and postseason (p=0.159) or between midseason and postseason (p=0.507). Left hip extension was not statistically significant between preseason and midseason (p=1.000), between preseason and postseason (p=0.391), and between midseason and postseason (p=0.978).

Right hip abduction was statistically significant between preseason and midseason (p=0.001); however, right hip abduction was not statistically significant between preseason and postseason (p=0.072), and between midseason and postseason (p=1.000). Left hip abduction was not statistically significant between preseason and midseason (p=0.215),
between preseason and postseason (p=3.150), and between midseason and postseason (p=1.000).

Right hip external rotation was not statistically significant between preseason and midseason (p=1.000), and between preseason and postseason (p=0.180); however, right hip external rotation was statistically significant between midseason and postseason (p=0.043). Left hip external rotation was not statistically significant between preseason and midseason (p=1.000), between preseason and postseason (p=0.964), and between midseason and postseason (p=0.578).

Right hip internal rotation was not statistically significant between preseason and midseason (p=0.507), between preseason and postseason (p=1.000), and between midseason and postseason (p=1.000). Left hip internal rotation was not statistically significant between preseason and midseason (p=0.131), and between preseason and postseason (p=1.000); however, between midseason and postseason left hip internal rotation was statistically significant (p=0.035).

**H/Q Ratio:**

The change in right H/Q ratio was statistically significant between preseason and midseason (p=0.000) and between preseason and postseason (p=0.000). The right H/Q ratio was not statistically significant between midseason and postseason (p=0.787). The left H/Q ratio was statistically significant between preseason and midseason (p=0.002), and between preseason and postseason (p=0.000). The left H/Q ratio was not statistically significant between midseason and postseason (p=0.063). See Chart 2.
Core strength:

The results for upper abdominal strength testing showed there was not a statistical difference in strength between the preseason and midseason (p=1.000), preseason and postseason (p=0.808), and midseason and postseason (p=0.647).

Results show lower core strength significantly improved from preseason to midseason (p=0.008) and from preseason to postseason (p=0.030). There was not a statistical difference in lower core strength from midseason to postseason (p=0.916) measurements. See Chart 3.

Q-Angle:

The right Q-angle measurements between the preseason and midseason (p=1.000), preseason and postseason (p=1.000), and midseason and postseason (p=1.000) data points showed no significant differences in the size of the Q-angle.

The left Q-angle measurements between the preseason and midseason (p=0.797), preseason and postseason (p=1.000), and midseason and postseason (p=1.000) data points showed no significant differences in the size of the Q-angle.

Subtalar Neutral:

A pairwise comparison revealed the right subtalar joint to have no significant findings from preseason to midseason (p=1.000), midseason to postseason (p=0.560), nor preseason to postseason (p=0.470). Additionally, the pairwise comparison revealed the left subtalar joint to have no significant findings from preseason to midseason (p=1.000), midseason to postseason (p=0.560), nor preseason to postseason (p=0.250) as well. Despite the non-significant findings, it is important to note the right and left subtalar joints have shown a steady trend toward neutral from preseason, midseason, and postseason. The right subtalar joint had a mean of 3.5° at preseason, 3.3° at midseason, and 2.9° at postseason. The left
The subtalar joint had a mean of 2.8° at preseason, 2.5° at midseason, and 2.1° degrees at postseason data collection.

**LESS:**

Although participants decreased their LESS scores during each data collection, there was only a significant difference (p=0.002) between preseason and postseason data collection. LESS scoring between preseason and midseason data collection was not significant (p=0.059) or between midseason and postseason data collection (p=0.111). See Chart 4.

**Discussion**

The purpose of this study was to develop and implement a comprehensive dynamic warm-up routine, known as The Patriot Program, to reduce the risk of ACL injuries in high school female basketball players. The Patriot Program incorporates the multifaceted attributes of previous ACL risk reduction programs including the PEP, Sportsmetrics, and FIFA. It was hypothesized that dynamic stretching combined with sports specific activities would impact the risk factors for ACL injury in female high school athletes, specifically improving lower extremity strength and muscle balance as well as the jumping mechanics required during practice and games. These were the two main focuses of the warm-up program.

When developing The Patriot Program, the first focal point was to improve overall strength and correct muscle imbalances of the lower extremity. Many high school athletes do not engage in a regular strength training program and participate in multiple sports. Many sports require the same movements and use the same muscle groups as basketball, furthering
inherent muscle imbalances, which will be reinforced when playing basketball. Muscle imbalances as well as lower extremity weakness can lead to serious lower extremity injuries.

The participants of the study did not perform a strength training program prior to beginning The Patriot Program. The participants of the study also participated in other basketball leagues, or participated in other sports including soccer. With the participants playing basketball all year round or playing a sport that requires similar movement patterns and muscle groups muscle imbalances will develop, because the strong muscles will continue to be strong and overcompensate for the weak muscles.

Data analysis of lower extremity strength yielded statistically significant findings for improved lower extremity strength of knee flexion bilaterally, hip extension bilaterally, hip abduction and external rotation on the right, and hip internal rotation on the left upon completion of The Patriot Program. This is in agreement with previously published studies, which have shown ACL injury prevention programs that incorporate strengthening, plyometric activities, agility drills, and dynamic stretches help to reduce ACL injuries. A systematic review by Noyes et al found that at the conclusion of an ACL risk reduction program increase in strength of the hip and knee musculature was observed.

The increase in right and left knee flexion strength was statistically significant between preseason and post season as well as preseason and midseason. This can be contributed to the components of The Patriot Program, and the multifactorial approach that was taken in development of the program. The components of The Patriot Program that would increase strength would be exercise such as squats, and lunges. These exercises increase the load on the lower extremity and increase muscle facilitation to adjust to the force
placed on the body. The hamstrings play a crucial role in dynamic knee stability by limiting anterior and lateral translation of the tibia on the femur as well as tibial rotation.\textsuperscript{45} If the hamstrings are not able to resist the translation of the femur on the tibia this will place increased stress on the ACL and increase the risk on an injury.

In addition to relative hamstring weakness, women also need increased time to reach maximum hamstring torque compared to men. This time is increased when the hamstrings are weaker and cannot reach maximum torque quickly enough to stabilize the knee.\textsuperscript{46} As the strength in the hamstrings increased from preseason to postseason, the hamstrings may be activated more quickly, which may contribute to lessening the risk of ACL injury.

Right and left knee extension strength was not statistically significant between preseason and postseason or between preseason and midseason. This may be attributed to the fact that research has shown that female athletes tend to have stronger quadriceps than they do hamstrings.\textsuperscript{1} Fifteen of the participants, took part in other sports that require the same movement patterns and muscle groups. Cutting and quick changes in direction are movements that female athletes preferentially increase their knee extensor moments over their knee flexor moments when performing sport tasks.\textsuperscript{47} Due to the fact that the participants came into the start of the program with strong quadriceps, significant improvement was not expected.

Right hip extension strength increase was statistically significant between preseason and midseason but not between preseason and postseason while left hip extension strength showed no statistically significant changes. The testing position for the hip extensors required the muscles to perform at end range in contrast to the warm up which strengthened the muscle in a midrange. The right hip extensors were found to be significant which would
indicate that there was an increase in strength at end range of the muscle given the significant findings.

One factor that may have contributed to significant findings on the right and non-significant findings on the left is leg dominance. Female athletes commonly have asymmetries between lower extremities. A study by Brophy et al. found significant side-to-side disparity in hip abductor strength in female soccer players that was not present in the male counterparts.\cite{48} Leg dominance may produce asymmetries during sport tasks. For instance, a study by Ford et al.\cite{49} found that the non-dominant lower extremity had a larger peak vertical ground reaction force during a drop vertical jump test, which would indicate the non-dominant side has a lack of neuromuscular control during the jump test. This lack of control would carry-over into sports specific activities including jump landings as well as cutting movements, on the non-dominant side. If the non-dominant leg accepted the same amount of force as the dominant leg, an injury is much more likely.\cite{49} This was seen not only with hip extension but with hip abduction, internal rotation and external rotation as well.

The increase in right hip abduction strength was statistically significant between preseason and midseason, but not between preseason and post season while left hip abduction strength was not significantly changed. Hip abductor strength has been identified as a possible influence on dynamic valgus collapse of the knee. The inability of the hip abductor muscles to keep the hip abducted during high demand single leg activities such as landing, cutting, or changing direction will allow the valgus collapse at the knee, increasing the risk for ACL injury.\cite{30} The increase in right hip abductor strength will help decrease the degree of valgus collapse which may decrease the forces on the ACL.
Right hip external rotation strength was statistically significant between midseason and post season but not significant between preseason and midseason or preseason and postseason. Left hip external rotation strength showed no statistically significant changes. With the lack of significant findings from preseason to post season, it is clear that this is an area of The Patriot Program that needs to be addressed further. Hip external rotator strength has been identified as a predictor of lower extremity injury.\textsuperscript{50} Gluteus maximus has an important role as the most powerful external rotator. Zazulak et al.\textsuperscript{51} found decreased gluteus maximus activity in women during single leg landings, which could lead to increased femoral internal rotation and subsequently increased knee valgus\textsuperscript{51} which is one of the risk factors ACL injury.

There were no statistically significant changes in right hip internal rotation strength while left hip internal rotation was statistically significant between midseason and postseason but not significant between preseason and postseason.

The change in the right and left H/Q ratio was statistically significant between preseason and post season as well as between preseason and midseason, but was not statistically significant between midseason and post season. One of the major risk factors for an ACL injury for female athletes is a muscle imbalance between the quadriceps and hamstrings. If the strength of the quadriceps greatly exceeds the strength of the hamstrings, then both the hamstrings and ACL become more susceptible to injury. Ideally, the hamstring quadriceps ratio would be 1:1 ratio.\textsuperscript{52} The hamstrings assist the ACL in stabilizing the knee and preventing anterior translation of the tibia on the femur. This anterior translation can occur during single leg landings, cutting, and quick changes of direction. If the H/Q ratio is low, less than 33\%,\textsuperscript{52} then increased anterior translation of the tibia can occur and in turn
place more shear force on the ACL.\textsuperscript{53} Data analysis suggests that The Patriot Program had a positive effect on the hamstring to quadriceps muscle imbalance.

Core strength was measured because supporting evidence in the literature stated that decreased core strength can be a factor for knee injury.\textsuperscript{54} Research suggests that the hip and trunk weakness of many female athletes reduces the ability to stabilize the hip and trunk during dynamic movements.\textsuperscript{55} This weakness can cause excessive and unnecessary movements of the hip into adduction and internal rotation causing increased stress on the ligaments in the knee.\textsuperscript{55} This research has highlighted the importance of stabilizing proximal core muscles to help prevent lower extremity injury.\textsuperscript{55} Other researchers state that core muscle fatigue may play a role in athletic injury and has been found to be a contributor to hamstring injuries.\textsuperscript{56}

During the course of our research, there were muscular improvements found in lower core strength. The statistically significant differences in lower core strength between preseason and postseason and preseason and midseason may be attributed to different exercises performed during The Patriot Program throughout the season. Anderson et al. did a study that looked at the core muscle activation during three different squat movements.\textsuperscript{57} Results showed that the core was activated during a squat movement which is in several exercises within The Patriot Program including turn squats and broad jumps. Another study mentioned a global test for core instability known as the “hop test.”\textsuperscript{56} The test consists of starting in a single leg squatting position and jumping off the floor with the one foot.\textsuperscript{56} This test is similar to the single leg movements during lunge jumps and layups within The Patriot Program.
A study done by Kulas et al.,\textsuperscript{61} looked at the activation of the core muscles during a jump from a 60 cm box. The activation of the abdominal muscles were recorded through an abdominal electromyography recording that indicated the abdominal muscles are contracting during the landing.\textsuperscript{61} This indicates that the plyometric aspects such as broad jumps, layups, lunge jumps, and in The Patriot Program can also effectively activate the core muscles. These studies support that there are several activities within The Patriot Program that effectively activate the core muscles. This increase in core strength can supplement the improvements seen in jump landing techniques through better control in hip and trunk stabilizers which are suggested to reduce the risk of ACL injury.\textsuperscript{55}

Specific core stability exercises in prevention programs for the prevention of athletic injuries have not been well studied. Based on this lack of evidence, researchers did not include specific core exercises; however, there are several studies that have examined the impact of core strengthening on athletic performance and types of exercise that will improve core strength.\textsuperscript{23,23,61}

An 8-week exercise program including trunk extension and side flexion improved trunk muscle endurance but had no effect on athletic performance.\textsuperscript{61} Another program of plyometric activities, speed activities, core strengthening exercises, balance and resistance training was performed over 6 weeks and showed improved stability, strength and athletic performance.\textsuperscript{61} Although The Patriot Program did not include every activity mentioned, it did include plyometric activities and squats which activate the core muscles.

No significant difference was found in upper core strength throughout the program. There are potentially two reasons that explain this. The first reason is that many of the girls scored a maximum or normal grade at preseason meaning that they could not improve on
their score. The Kendall method that was used to measure upper core strength may not have been specific enough to detect smaller changes in core strength over the season. The second reason for no significant changes could be the lack of specific upper core exercises in the program.

One aspect of The Patriot Program that may have contributed to the significance of the strength findings is the duration of the program. In a study by Myer et al.,\textsuperscript{61} researchers determined that a 7 week neuromuscular training program was effective in decreasing predetermined risk factors for ACL injuries, but he also found that it was not effective enough to reduce the levels for female athletes categorized as high risk for ACL injury.\textsuperscript{61} They determined that increased training volume or more specific training may be necessary for high risk female athletes to substantially decrease ACL injury risk.\textsuperscript{61} This is confirmed by other research, which has shown that in order to see neuromuscular changes with carryover of these changes that effect on ACL injuries, the program duration must be at least 6-8 weeks.\textsuperscript{16,48}

The Patriot Program was performed for 14 weeks throughout the participant’s basketball season. The Patriot Program was performed for 6 weeks from the preseason to midseason data collections. During this time researchers observed significant findings in the data. The program continued for another 8 weeks until the postseason data collection. At this time, researchers observed non-significant findings in all of the data except the hamstring strength bilaterally and the H/Q ratio bilaterally. Based on the significant findings between preseason and midseason and non-significant findings between midseason and postseason, the literature supports an increase in program intensity. An increase in program intensity may help avoid the plateau that researchers identified during the second half of the study.\textsuperscript{16,48}
Results indicate that the Q-angle measurements were not significant throughout the study. Researchers had anticipated these results because the Q-angle is identified as a non-modifiable risk factor. The Q-angle can be associated with increased femoral anteversion, lateral displacement of the tibial tubercle, and external tibial torsion. These three factors alone or in combination can cause a lateral pull of the patella by the quadriceps muscle. There is debate among research as to whether the muscle pull of the vastus medialis can impact the Q-angle, but there is not enough research to support this.

Additional non-significant findings were found for close kinetic chain subtalar joint neutral testing; however, results trended from a pronated subtalar position toward a neutral subtalar position. This may be partially attributed to the dynamic warm-up of The Patriot Program and partially attributed to the educational component of The Patriot Program.

The dynamic warm-up routine incorporated specific exercises targeted toward proper lower extremity alignment by restoring muscle balance. Abnormalities of the foot and ankle are related to abnormalities of the knee. The combination of excessive subtalar pronation and valgus displacement of the knee is commonly observed in high school female athletes. Specific exercises implemented in The Patriot Program that focused on restoring more normal biomechanics of these joints included Frankensteins, forward alternating lunges, turn squats, broad jumps, lunge jumps, and the captain’s drill including quick feet and defensive slides.

The significant findings for the H/Q ratio and LESS support the change in subtalar joint toward neutral on the jump landing mechanics and valgus displacement of the knee. An increased quadriceps muscle activation relative to hamstring muscle activation creates an anterior tibial translation resulting in internal rotation of the tibia and pronation of the
subtalar joint. As the participants’ H/Q ratios improved, the increased recruitment of the hamstring muscles resulted in a more balanced co-activation of the hamstring and quadriceps muscles; thus, less internal rotation of the tibia and less pronation of the subtalar joint may be assumed. The dynamic warm-up may have physiologically influenced both knee and ankle joint kinematics and alignment.

In addition, the educational component of The Patriot Program emphasized proper body mechanics of the lower extremities in both static and dynamic positions. At the first data collection prior to the initiation of the dynamic warm-up, participants were educated in a group setting on the structure of the ACL, mechanics of the knee, and proper jump landing technique. Following the second and third data collections of the LESS, using video analysis, researchers assessed and educated participants on their individual jump landing techniques. The verbal and visual educational components may have aided in the change of participant knee and ankle joint kinematics and alignment by giving participants the basic tools for the self-assessment of individual joint kinematics.

The result of the subtalar joint moving toward neutral and lack of ACL injuries is consistent with the literature. Beckett et al. conducted a study comparing navicular drop scores with ACL injured and non-injured subjects. Results of the study found ACL injured subjects to have greater amounts of subtalar joint pronation than non-injured subjects. Loudon et al. examined the correlation between static postural faults in female athletes and the prevalence of noncontact ACL injury. Results of the study found knee valgus, excessive navicular drop, and excessive subtalar joint pronation to be significant factors of the ACL injured subjects. Woodford-Rogers et al. determined a potential risk factor for ACL injury.
in high school and college athletes to be an increased navicular drop, suggesting increased subtalar pronation and increased anterior knee joint laxity.

Despite the non-significant findings, the difference seen in subtalar measurements is important to note. Right and left subtalar joints showed a steady trend toward neutral between data collections. From preseason to midseason data collection, a duration of six weeks, the right subtalar joint had a mean change of 3.5° to 3.3° and the left subtalar joint had a mean change of 2.8° to 2.5°. From midseason to postseason data collection, a duration of eight weeks, the right subtalar joint had a mean change of 3.3° to 2.9° and the left subtalar joint had a mean change of 2.5° to 2.1°. Perhaps implementing The Patriot Program for a longer duration with data collection periods greater than eight weeks in duration, the closed kinetic chain subtalar joint neutral testing would have shown significance.

Results show a significant decrease in LESS score between preseason and postseason data collections while LESS scoring between preseason and midseason was not significant. These improvements may be attributed to multiple factors including increased LE strength, decreased H/Q ratio, increased core strength, and participant education pertaining to jump landing techniques. Increased LE strength of the hip abductors, hip extensors, and knee flexors help improve knee stability. During jump landing the hip abductors are needed to prevent valgus collapse at the knee. At the same time, the hip extensors are working eccentrically and the knee flexors work concentrically to allow the participant to move into an athletic squat. Increasing the strength of these essential muscles can improve the knee’s stability and alignment during jump landing movements and lower the participants LESS score.27
The improved stability of the knees can also be seen through an increase in the H/Q ratio. With a H/Q ratio closer to one the quadriceps muscle and the hamstring muscle are working synergistically. This will help balance the muscular forces placed on the knee during jumping. If the quadriceps were working harder than the hamstrings there would be more anterior stress placed on the knee encouraging the tibia to translate anterior over the femur. This imbalanced position compromises the ACL. Therefore, increasing the H/Q ratio allows the muscles to work as a more effective team, decreasing the stress placed on the ACL.\textsuperscript{1,13,14}

In addition to improved LE strength the improved lower core strength leads to improved trunk control. When an individual is able to actively control their trunk they require less stabilization from the muscles of the LE. This allows the kinetic chain to function more efficiently decreasing the stresses placed on the ACL.\textsuperscript{1,27}

During the preseason data collection researchers educated the participants about the risk factors associated with ACL through an oral presentation with demonstration. This education focused on proper jump landing techniques. Following the education session, researchers were able to observe and correct participant’s jump landing technique when instructing participants in The Patriot Program. Educational intervention continued at the midseason data collection where researchers allowed participants to watch their LESS jumps in slow motion and provided verbal feedback about improper technique. Past research\textsuperscript{67} supports the theory that the combination of videotape feedback with both the researcher and the participant collaborating together will lead to more significant changes in jump landing techniques. Although the multiple means of providing education cannot be isolated as the sole cause of significant LESS improvement it should be noted as a possible factor for LESS improvement.\textsuperscript{27}
Participants’ median LESS scores decreased throughout the data collection points; preseason (9.56), midseason (8.45) and post season (7.39). Although there was significant improvement, researchers need to further examine why participants scored so poorly on the LESS. Evaluating the data further shows some within group differences as the season progresses. At the preseason data collection prior to any educational intervention 100% of participants displayed poor jump landing techniques as measured through LESS scoring. At midseason 12% of participants scored moderate while the remaining 88% scored poor. At the postseason data collection 6% scored good, 12% scored moderate, and 82% scored poor. Although the majority of participants still qualify as having poor jump landing techniques following the conclusion of The Patriot Program, participants showed an improvement in jump landing techniques.

The LESS is a valid and reliable tool that considers multi-planar motions to assess overall jump-landing techniques. Participants who score poorly on the LESS are typically female, have decreased hip and knee motion, increased knee valgus, increased hip internal rotation, and decreased knee stability. All of these factors correlate with an increased risk of an ACL injury. The Patriot Program sought to address these factors through a multifactorial approach that past research has found to be most effective. Research supports plyometric based activities as a factor closely correlated with jump landing techniques and decreasing LESS scores. Current literature supports the theory that neuromuscular training programs that incorporate plyometrics are correlated with a reduction in ACL injuries. Mandebaum et al reported an 88% decrease in ACL injury in their subjects who completed the PEP program, a twenty minute warm-up that included a plyometric component. Myer
et al conducted a meta-analysis that concluded neuromuscular training was an effective prophylactic measure especially when implemented during early adolescence.\textsuperscript{68}

There is some discussion within the literature about the level of intensity required to have an effect on ACL risk reduction.\textsuperscript{27} One study\textsuperscript{4} stated that low intensity plyometric training programs can improve landing mechanics thereby reducing ACL injury risk. However, A meta-analysis conducted by Hewet et al. stated that ACL prevention programs must incorporate “high intensity plyometric movements that progressed beyond footwork and agility in the intervention”\textsuperscript{27}. The study goes on to identify that prevention programs must be performed more than once a week for at least six weeks.\textsuperscript{27} One study reports that a plyometric prevention program failed to have an effect on ACL injury rates; however, the prevention program was only performed twice a week and lacked any other preventive factors.\textsuperscript{3}

Plyometric training that improves jump landing techniques is a topic well discussed in the literature. The current trend in ACL prevention programs is to use a multifaceted approach with plyometrics as a cornerstone within the prevention program. The Patriot Program aimed to do just that by using plyometric training as a building block of the prevention program then providing multiple means of jump landing education to the participants, and building upon basic jump landing techniques by introducing sports specific movements.

The Patriot Program is most unique in regard to the sport-specific training. Typical basketball movements of dribbling, shooting and defensive slides with quick changes in direction were implemented with a heavy emphasis on proper form during deceleration, cutting, and jump-landing techniques. Basketball specific training is necessary for the player to become accustomed to the natural stresses and forces the sport of basketball employs.
Emphasizing proper form and body mechanics that is incorporated into a basketball specific warm-up will carry over into a basketball competition and effect athletic performance.\textsuperscript{1,32,34,36} The literature reports a decrease in athletic performance as an adverse result of ACL prevention programs. One study stated that implementing an ACL prevention program as a warm-up routine has minimal influence on improving performance.\textsuperscript{25} In the past, researchers have spent the majority of their research efforts trying to identify what factors are most important to include within an ACL prevention program. They did not intend for the programs to improve athletic performance but aimed at preventing injury. As ACL research has evolved over the past few decades, multifaceted programs aimed at prevention have become very successful.\textsuperscript{16} However, athlete compliance to these injury prevention programs have been reported as low as 28\%, while compliance to performance enhancing training programs can range from 80\% to 90\%.\textsuperscript{27} The researchers in this study did not address performance enhancing mechanisms within The Patriot Program. Instead The Patriot Program encouraged compliance through education, allowing the team’s coaches to run the program, including sport specific elements within the program and designing the program to be used as a warm up routine.

**Limitations**

Researchers identified multiple limitations to this study. The study’s participants were a sample of convenience chosen with the expectation of a large sample size; however, due to a high attrition rate (37\%), the study concluded with a small sample size (n=17). The repeated measures design of the study was a limitation as there was no control group to compare data. Additional limitations included that the participants were located in a different
state than the researchers. This limited interaction between researchers and participants in accordance to state practice acts. It also increased travel time and complicated scheduling data collection resulting in unequal amounts of time between midseason and postseason data collection.

The Patriot Program was designed as a coach administered program. This afforded ease of administration for researchers and participants. Unfortunately, it elicited study limitations as researchers were unable to monitor participants performing The Patriot Program and cannot attest if they were performing the exercises correctly or at the desired intensity required for sport activity. In addition, researchers cannot accurately state how often The Patriot Program was implemented.

Possible changes for future research could include more appropriate outcome measures, adding a control group and monitoring performance of the program.

**Further Research**

After the conclusion of this study researcher have identified multiple areas for further inquiry. Future research should implement an experimental study design with an established control group and a large sample size. Dynamic warm-up programs should be monitored for appropriate intensity levels and adjusted throughout the season in accordance with athlete performance. Perhaps a two tiered multifaceted dynamic warm-up program would be more appropriate. The second tier would be of increased intensity to prevent the plateau effect and include aspects of performance enhancement to increase compliance. In addition to increasing intensity, future research should investigate the inclusion of further educational components that incorporate visual and verbal feedback for the participant. Allowing ACL
prevention programs to be coach administers has positive and negative attributes. Additional inquiry is needed in this area to determine effectiveness.

**Conclusion**

The Patriot Program was a unique dynamic warm-up that appeared to be effective in reducing some of the risk of ACL injury. Over the course of the 2012-2013 basketball season, no ACL injuries were reported. The Patriot Program significantly improved lower extremity strength, improved core strength, and improved jump landing techniques. Researchers conclude a multifaceted dynamic warm-up including sport specific activities that target modifiable risk factors associated with ACL injury may effectively reduce the risk of ACL injury in female high school basketball players.
References


Chart 1

Knee Strength

- Preseason
- Midseason
- Postseason

Right Extension: 1. Right Extension: 5.7794
Left Extension: 1.2
Right Flexion: 8.9382
Left Flexion: 5.3853
Postseason: 0.44912
Midseason: 8.15
Presession: 16

[Bar graph with data points for right and left extension and flexion in different seasons.]
Chart 2

Hamstring Quad Ratio

- Preseason
- Midseason
- Postseason

Right:
- Preseason: 0.4
- Midseason: 0.71
- Postseason: 0.7771

Left:
- Preseason: 0.4153
- Midseason: 0.6118
- Postseason: 0.7724
Chart 3

Lower Core Strength

- Preseason
- Midseason
- Postseason

Angle: Preseason
- 42.117

Postseason
- 49.764

Midseason
- 48
Chart 4

LESS Jump Score

- Preseason: 9.537
- Midseason: 8.452
- Postseason: 7.394
Appendix A
Appendix B
Appendix C
Appendix D
1. Knee Flexion @ Initial Contact
   ___ Greater than 30° (0)
   ___ Between 20-30° (+1)
   ___ Less than 20° (+2)

2. Knee Flexion Displacement
   ___ Greater than 30° (0)
   ___ Between 20-30° (+1)
   ___ Less than 20° (+2)

3. Knee Valgus @ Initial Contact
   ___ Knees over mid-foot (0)
   ___ Knees over great toe (+1)
   ___ Knees over great toe (small) (+2)
   ___ Knees over great toe (large) (+3)

4. Knee Valgus Displacement
   ___ Knees over mid-foot (0)
   ___ Knees over great toe (+1)
   ___ Knees over great toe (small) (+2)
   ___ Knees over great toe (large) (+3)

5. Trunk Flexion @ Initial Contact
   ___ Greater than 30° (0)
   ___ Between 20-30° (+1)
   ___ Less than 20° (+2)

6. Lateral Trunk Flexion @ Initial Contact
   ___ Trunk centered over hips (0)
   ___ Lateral deviation of trunk over hips (+1)

7. Ankle Plantar Flexion @ Initial Contact
   ___ Toe-to-heel, toe strike (0)
   ___ Flat foot (+1)
   ___ Heel-to-toe, heel strike (+2)
   *if asymmetrical, score 1st foot to contact

8. Foot Position @ Initial Contact
   ___ Toes straight ahead (0)
   ___ Toes in (+1)
   ___ Toes out (+1)
   *if asymmetrical, score 1st foot to contact

9. Stance Width @ Initial Contact
   ___ Shoulder width (0)
   ___ Less than shoulder width (+1)
   ___ Greater than shoulder width (+1)

10. Foot Contact Symmetry
    ___ Symmetric (+0)
        ___ Asymmetric (+1)

11. Joint Displacement (Overall)
    ___ Large ("soft landing") (0)
    ___ Average (+1)
    ___ Small ("stiff landing") (+2)

12. Overall Impression
    ___ Excellent (0)
    ___ Average (+1)
    ___ Poor (+2)