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The Correlation Between Hip Abductor Strength and Functional Performance in Division I Female Collegiate Soccer Athletes

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THE CORRELATION BETWEEN HIP ABDUCTOR STRENGTH AND FUNCTIONAL PERFORMANCE IN DIVISION I FEMALE COLLEGIATE SOCCER ATHLETES

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ABSTRACT

Division I female soccer athletes have been documented to succumb to the greatest amount of lower extremity injuries, predominately ACL injuries. The risk for a lower extremity injury becomes greater when alterations to functional biomechanics are present. Specifically, the hip abductor strength has a crucial role in maintaining pelvic alignment. The purpose of this study was to determine if the hip abductor strength of a female athlete alters' biomechanics during functional performance. Thirty-two Division I female soccer athletes participated in this study (20±2yrs, 64.5±16.5kg, 166±14cm). Descriptive and anthropological statistics were recorded prior to participation. The athletes' isometric hip abductor strength was obtained through a side-lying protocol immediately followed by a Tuck Jump Assessment. The athletes were tested at three different points during the season (preseason, midseason, and postseason). A repeated measures ANOVA was performed for both the change in the functional performance and hip abductor strength over the season with a Pearson correlation used to analyze the relationship between functional performance and hip abductor strength. The results found significance in the change of strength over the season (Preseason-Midseason p=.000, Midseason-Postseason p=.000, Preseason-Postseason p=.001), no significance in the change of functional performance (Preseason-Midseason p=1.000, Midseason-Postseason p=.110, Preseason-Postseason p=.522), and a weak negative relationship between hip abductor strength and functional performance (Preseason-Midseason r=-.134, Midseason-Postseason r=-.306, Preseason-Postseason r=-.021). The study concluded hip abductor strength changes over the course of the season with a weak relationship between hip abductor strength and function performance.

This thesis is approved for recommendation
to the Graduate Council.

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DEDICATION

I would like to dedicate this project to my family. You have always offered support and encouragement through the good moments and the difficult moments. I would not be at this place in my life, and achieve the success I have, if I did not have the support system you offer me. I cannot put into words how grateful I am each and every day to have you in my life. Thank you for always being there for me.

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Chapter 1

Introduction

The human body can be described as a kinetic chain. The movement, initiated by the muscle, in one extremity of the body has a ripple effect on all the other extremities. Movement is initiated in the trunk and core region transferring the forces developed to the other extremities. If a strength deficit is present, the movement of the body can be impeded, especially during dynamic activity. This deficit, then, can lead to biomechanical alterations,] which become noticeable when performing functional tasks. Specifically if there is a strength deficit with the hip abductors, the hip will adduct. When the hip adducts, the rest of the lower extremity starts to compensate (Fredericson et al., 2000). Common compensations that occur from hip adduction is knee valgus, tibial external rotation, and foot pronation (Ireland, 1999). Depending on how great the biomechanical alterations are, the athlete performing the functional task can become susceptible to injuries predisposed by the pathomechanics of the body.

The hip musculature, specifically the hip abductors, play a significant role in maintaining correct biomechanical posture. This is due to the base of support the hip musculature provides to the pelvis. The hip abductors are comprised of the gluteus medius, gluteus minimus, and the tensor fascia latae with the upper to middle fibers of gluteus maximus aiding as a secondary abductor (Zazulak et al., 2005). If the hip abductor musculature contains a strength deficit, pelvic stability can become compromised (Kibler et al., 2006). Pelvic instability can compromised an athlete, placing the athlete at risk because a stable pelvic allows for effective functioning of the kinetic chain. Therefore, this stability deficit can elicit biomechanical alterations developed during the first initiation of movement and continuing through the kinetic chain.

Hip abductor muscle strength in females specifically has a direct effect on kinematic chain movement (Jacobs, Uhl, Mattacola, Shapiro, & Rayens, 2007). This relationship between strength and function in females questions the effect of kinematics on injury prevalence in female athletes. The effect of the hip abductor's strength on lower extremity injuries is a point of concern with anterior cruciate ligament tears (ACL) being one of the most frequent.

An ACL injury is one of the most prevalent injuries in athletics today. The ACL maintains a crucial role of stability in functional tasks by preventing anterior translation of the tibia on the femur along with resisting rotation (Duthon et al., 2006). Additionally the ACL is divided into two separate bundles, anteriormedial and posteriorlateral bundles, which become taut and relaxed at different point in the knee range of motion, adding to the multifunctional aspect of the ACL (Arnoczky, 1982). Specifically when the knee is in an extended position the anteriormedial bundle becomes relaxed while the posteriorlateral bundle is taut (Arnoczky, 1982). This relationship between bundles is important when looking at the mechanism of injury for it suggests that only one bundle of the ACL is preventing anterior translation when the knee is in full extension.

There are both intrinsic and extrinsic factors that may predispose an individual for a non-contact ACL injury. Intrinsic factors are inherent in the person's body and cannot be altered while extrinsic factors can be modified and altered. The strength of the athlete's hip musculature is an extrinsic factor that is key in preventing a biomechanical high-risk position due to the ability of the hip musculature strength to alter the lower extremity biomechanics if a deficit is present. In ACL prevention research, the hip has been a frequent topic of discussion. However, much of the research does not examine hip strength changes during the season. This potential change of strength through a season can place the athletes at greater risk during certain points in the season.

It is estimated that 70 to 80% of ACL injuries occur from a non-contact mechanism (Fauno et al., 2006). Frequently, ACL tears present as a non-contact injury where athletes decelerate, plant their foot, and twists their knee; this high-risk position is described to be the position of no return (Ireland, 1999). When an athlete plants his/her foot, pronation occurs which fixes the foot in the ground. The twist in the knee occurs through a valgus load applied to the knee where the tibia externally rotates while the femur internally rotates. The high-risk position places abnormal stress on the ligament and can result in a tear or a rupture. Concerning athletics, this type of movement is commonly found in soccer due to the required change of direction. Soccer players are commonly victims of ACL tears due to the planting and cutting nature of their sport (Alentorn-Geli, 2009). Arendt et al (1995) found that female soccer players are six times more likely to experience an ACL rupture. With the increased number of female participation in soccer in conjunction with the high rate of ACL tears, it is important to evaluate the hip musculatures role in this injury incident.

Statement of the Problem

The purpose of this research study is to determine if the hip abductor strength of a female athlete alters one's biomechanics during functional performance, therefore predisposing the athlete to an ACL injury.

Hypotheses

The hypotheses for the research study presented above are as followed:

1. Hip abductor strength during maximal effort will decrease as the season progresses

2. Functional performance while performing a tuck jump assessment will decrease as the season progresses
3. A positive correlation between hip abductor strength and functional performance will be found over the course of the season

Assumptions

Each participant will exhibit her greatest effort during testing.

Each participant can compete at the collegiate soccer level.

Each participant is free from injury at the time of testing.

Each participant is representative of the fitness level required for collegiate soccer.

Delimitations

This study was delimited to female members of a Division I collegiate soccer program but should apply to female collegiate soccer players across the United States.

Significance of the Study

The significance of this study is that it is an adjunct of the current literature that evaluates the effects the hip abductor musculature exhibits on kinematic function and how it can aid in decreasing risk. This study will examine the relationship of hip abduction strength and function over the course of a soccer season benefiting athletic trainers, strength coaches, soccer coaches and other support staff in regards to injury prevention; in addition it will be a beneficial addition to the current ACL injury prevention literature.

Chapter 2

Biomechanics

The biomechanics of an athlete plays a significant role in correct execution of functional task. This correct execution can lead to decreased risk of injury, such as ACL tears. However, females have been shown to possess biomechanical factors that predispose them to ACL injuries. (Ireland, 1999) As previously stated, no signal position of the high-risk movement alone will result in an ACL tear. However, different movements in the three planes of motion can place the body at risk. Due to this fact, it is important to understand what constitutes a high-risk position, and how this position continues through the kinetic chain.

Frontal Plane. The frequency of ACL tears in females has been attributed to extrinsic factors such as strength, conditioning, and equipment (Ireland, 1999). Research has revealed females often land in the position of no return during a functional task (Ireland, 1999). Frontal plane motion has been extensively researched as an ACL prevention factor. In the frontal plane, the amount of valgus movement at the knee has been show to be a precursor to ACL injuries in addition to the degree of hip adduction that concurrently occurs (Hewett et al., 2005; Ireland, 1999).

Greater movement in the frontal plane results in greater knee valgus (Jacobs, Uhl, Seeley, Sterling, & Goodrich, 2005). Knee valgus can be a high-risk precursor for injury when performing functional tasks. Upon performance of a sidestepping task, McLean et al. (2005) found that females demonstrated larger amounts of knee valgus. Excessive knee valgus places one in a high-risk position, increasing the chances of an ACL injury (Hewett et al., 2005).

When a hip abductor strength deficit is present, one is unable to maintain abduction, thus resulting in hip collapse due to hip adduction. In the position of no return one does not have control of the hip abductors, resulting in the hip moving into adduction (Ireland, 1999). Furthermore, the hip abductor strength affects pelvic stability (Leetun et al., 2004). Lack of pelvic control leads to excessive motion at the hip that subsequently affects the position of the knee. If the hip musculature is fatigued, it influences the knee movements in the frontal plane (Geiser, O'Conner, & Earl, 2010). Hip adduction is believed to be the main cause of the knee moving into the valgus position (Imwalle et al., 2009). Research has revealed that during cutting drills hip adduction affects the degree of knee valgus (Imwalle et al., 2009). Research has revealed that hip abductor strength plays a crucial role in maintaining correct biomechanical movement and avoiding the high-risk position. Between genders, females exhibit a decrease in peak torque output for the hip abductors along with an increase in knee valgus movement (Jacobs et al., 2007). These findings can be in part due to the greater dependence women place on the eccentric contraction of the hip abductors upon landing during running (Ferber et al., 2003).

Sagittal Plane. In addition to hip adduction and knee valgus in injury prevention, hip and knee flexion also contribute. Biomechanical concerns during functional movement in the sagittal plane have included decreased hip and knee flexion during jump landings (Chappell, Creighton, Giuliani, Yu, & Garrett, 2007). If one makes an athletic move without having adequate hip and knee flexion, then they are in an upright position that is ineffective in absorbing the forces experienced (Landry et al., 2007). Decreased hip and knee flexion during functional tasks is speculated to be the point of the ACL rupture (Ireland, 1999). Following the initial injury, the body weight is transferred over the injured leg resulting in an increase in both hip and knee flexion (Ireland, 1999).

Female soccer players are classified as high-risk because they exhibit decreased hip and knee flexion when performing unexpected athletic movements (Landry et al., 2007). It is necessary to perform with efficient hip and knee range of motion (ROM) in order to properly dissipate the forces and decrease injury risk. Having a greater degree of hip flexion upon landing is beneficial for absorbing the force of the landing and transmitting the force through the body. However, excessive hip flexion causes the pelvis to anteriorly tilt, thus creating a quad dominant position (Hertel et al., 2004).

Furthermore, Yu et al (2006) found neither flexion nor extension of the hip to dictate the absorption of the forces as much as the angular velocity. The findings by Yu et al. (2006) support the belief that female athletes tend to land from a jump with decreased hip and knee flexion, thus causing increased forces imparted upon the body. However, it has also been documented that if female athletes land with a greater angular velocity at both the hip and the knee, the forces experienced are decreased (Yu et al., 2006). These results suggest that landing with decreased hip and knee flexion is a risk factor; however, the risk may not be based upon the forces experienced through the body upon landing (Yu et al., 2006).

The position of the knee is extremely important because different positions change the mechanical properties of the ACL as discussed previously. Specifically, when the knee is in an extended position, the ACL is taut which increases the risk of injury (Blackburn & Pauda, 2008). The increase risk is also due to the large elevation angle associated with the ACL (Blackburn & Pauda, 2008). Once in full extension, the shear force elicited by the quadriceps muscle through the patellar tendon becomes greater (Blackburn & Pauda, 2008). If the athlete is able to maintain a position of active knee flexion, the ACL elevation angle will decrease; thus the shear force exhibited on the tibia will be reduced decreasing the chance of injury (Blackburn & Pauda, 2008).

Transverse Plane. Some hip abductors also function as external rotators. The movement of external and internal rotation of a joint occurs in the transverse plane. Rotation is significant because when speaking of ACL injuries, rotation occurs at the hip, and tibia (Ireland, 1999). The position of no return is when the hip is internally rotated while the tibia is externally rotated (Ireland, 1999).

Females have been shown to demonstrate both frontal and sagittal plane motion during functional tasks; specifically during a stop-jump task females land with less external hip rotation than males (Chappell et al. 2007). Similarly, during a side stepping task, females compared to males land with less hip internal rotation (McLean, Huang, & Van de Bogert, 2005). Concerning running, females land with a greater degree of hip internal rotation at the point of heel strike (Ferber et al., 2003). In all the above circumstances, the risk for injury is elevated.

Soccer is a sport that requires vast amount of running; thus a biomechical alternation while running places female soccer players at a high risk. By landing in hip internal rotation and adduction, one is at greater risk for knee valgus (Hewett et al., 2005). To combat this increased risk, it has been advised that the neuromuscular control of the lower extremity, specifically hip strength, be a point of focus to decrease the risk of an ACL injury (McLean et al., 2005).

Concerning tibial rotation, Olsen et al (2004) supported Ireland's results that tibial rotation is a main component of an ACL injury. The images captured of handball athletes sustaining ACL tears displayed athletes landing with a planted foot followed by tibial rotation (Olsen et al., 2004). During running females have been shown to have tibial rotation with running, landing with external rotation of the tibia (Ferber et al., 2003). Furthermore, when athletes perform unanticipated movements the amount of rotation experienced at the knee was double the rotation that was experienced when the movement was planned (Besier, Lloyd, Ackland, & Cochrane, 2000). Imwalle et al (2009) reported that females specifically experienced a larger degree of knee internal rotation during an unanticipated 45-degree cutting angle. Besier et al. (2000) hypothesized that the reason such a greater degree of internal rotation was experienced during unanticipated movements was attributed to improper muscle firing in the short reaction time.

Lumbo-Pelvic Hip Complex

The lumbo-pelvic complex is commonly referred to as the core and has been shown to be a key component of pelvic stability (Leetun et al., 2004). This complex includes all the muscles from the spine, hip, pelvis, lower limb, and abdominal region going from the diaphragm to the pelvic floor (Kibler et al., 2006). However, the foundation that supports all of these listed structures are dependent upon the hip and pelvis (Kibler et al., 2006). The core is centrally located in the body; this position allows it to be active in every functional task (Kibler et al., 2006). Additionally, the musculature of the core has been documented as the first to become activated during functional activity (Oliver & Adams-Blair, 2010). If the proper strength is not present, pelvic stability can be compromised (Kibler et al., 2006), thus demonstrating the importance of proper core strength in injury prevention. The concern with female athletes, however, is if the female athletes possess proper strength to perform the functional tasks required of their sports.

Strength. An athlete is able control motions in the transverse, frontal, and sagittal plane by possessing ample strength in the lumbo-pelvic complex (Leetun et al., 2004). By achieving ample strength in the lumbo-pelvic complex, the athlete is then able to efficiently transfer energy and force production throughout the body (Oliver & Adams-Blair, 2010). However female athletes, specifically collegiate soccer athletes, possess weak abdominal strength (Brophy et al., 2009). If a weakness is present in the core a change in the position of the hip and/or the trunk can occur (Kibler et al., 2006). A strength decrease has been shown to decrease the dynamic stability of the knee resulting in an increased risk of injury at the knee (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007). By improving core strength, the dynamic stability of the knee would improve (Zazulak, Hewett, Reeves, Goldberg, & Cholewicki, 2007).

Hip abductor and external rotator strength play a crucial role in injury prevention. In one athletic season, injury risk could be predicted by the strength of the hip external rotators (Leetun et al., 2004). Adequate strength in the hip abductors and external rotators was found to be a main characteristic in injury-free athletes (Leetun et al., 2004). There is cross-over in the action of the hip abductors with some also acting as external rotators (Zazulak et al., 2005). The gluteus maximus' primary action is hip extention; however, it also aids in abduction of the hip (Zazulak et al., 2005). Secondly, the gluteus medius specifically acts as both a hip abductor and an external rotator. If the gluteus medius is not strong enough, the hip will adduct and the tensor fascia late will force the hip into internal rotation coupled with knee valgus (Fredericson et al., 2000). This type of collapse becomes increasingly prevalent in functional activities similar to landing, cutting and changing direction (Shultz et al., 2007). Female soccer players perform these types of maneuvers frequently. Functional tasks, such as squatting and landing, are affected by hip muscle weakness resulting in hip adduction, hip flexion, and knee valgus (Kibler et al., 2006). The inability for an athlete to safely perform a functional task increases the risk of injury (Cicanowski, Schmitt, Johnson, & Niemuth, 2007; Fredericson et al., 2000).

Muscle activation must be considered when examining strength due to the different activation pattern experienced when the core is firing (Kibler et al., 2006). It has been shown that muscles in the core may not be activated for their primary function when the core is activated but instead their secondary function (Kibler et al., 2006). This change in primary to secondary function activation can create a problem if the athlete already possesses a strength deficit, or is not skilled in activating the secondary function. Muscles of concern are the glute medius and glute maximus since they have two actions, which hold great importance in correct biomechanics. Implementing neuromuscular training to improve the activation of the core may help that athlete to use the appropriate musucle correctly (Zazulak et al., 2007). In order to decrease the prevalence of the high-risk position, an implementation of neuromuscular training specific to the trunk is warranted (Myer, Chu, Brent, & Hewett, 2008).

Pelvis Position. The pelvis is comprised to two innominate bones that join with the sacrum. Possessing ample strength leads to pelvic stability and prevents the pelvis from tilting unilaterally (Leetun et al., 2004). However, if ample muscular strength is not present the innominate bones may rotate resulting in a unilateral tilt to the pelvis. Unilateral tilt of the pelvis can lead to a leg length discrepancy that can force the shorter leg into pronation predisposing injury (Hertel et al., 2004; Shultz et al., 2007).

Secondly, anterior pelvic tilt has been demonstrated to lead to femoral internal rotation and hip adduction, which alters the biomechanics of the lower extremity and muscle function (Ireland, 2002 & Leetun et al., 2004). The hamstrings become elongated with an anterior tilt preventing this muscle group from contracting properly to resist anterior translation of the tibia (Hertel et al., 2004). Secondly, hamstring elongation will also elicit dynamic genu recuvatum in the athlete since the hamstrings are not there to stop the posterior motion (Alentorn-Geli et al., 2009). With the hamstrings in an elongated position, the opportunity for quadriceps dominance becomes a risk (Hertel et al., 2004).

Another biomechanical alteration is femoral torsion. Brophy et al (2009) stated that in conjunction with weak hip abductors, female soccer players demonstrated femoral anteversion. This anteversion of the femoral head creates a decrease in the function of the gluteus medius (Shultz et al., 2007). The decrease in the function of the gluteus medius is attributes to increase in the external rotation moment arm (Delp et al., 1999). Increased external rotational moment arm is also seen with tight hip flexors for the hip is brought into flexion. Female soccer players have also been shown to have a dominance of tight hip flexors (Brophy et al., 2009).

Methodology

Strength. In order to test for the strength of the hip musculature several previous techniques have been implemented. One study performed by Cichanowski et al (2007) divided the hip musculature into six groups: the hip flexors and extensors, the hip abductors and adductors, and the hip internal and external rotators. The athletes were isometrically tested twice and were required to hold each contraction for two seconds with a three to five minute rest in between. The researchers then used a handheld dynamometer during a manual muscle test to record the force and time of musculature contraction. The highest force output from the two contractions was recorded. The manual muscle test positions that this study utilized were from *Techniques of Manual Muscle Testing: Lower Extremity* by Reese (2005). Hip flexion was tested with the athlete seating in a 90/90 position with the handheld dynamometer 2cm above the femoral condyles. Hip extension was tested with the knee in full extension while the athlete was in the prone position with the handheld dynamometer located 2cm above the popliteal crease. Hip abduction and adduction were both tested with the patient in the side-lying position. For hip abduction, the handheld dynamometer was located 2cm above the femoral condyles while for adduction it was located 3 cm above the femoral condyles. For both hip internal and external rotation, the athlete was again placed in a seated 90/90 position with the arms crossed over the chest. The handheld dynamometer was positioned 2cm above the appropriate malleolus. All of the strength values from the handheld dynamometer were normalized against the athletes' body weight.

A study done by Fredericson et al (2000) examined hip abductor strength and its effect on the iliotibial band. However, contrary to the manual muscle testing done by Cichanowski et al (2007), when testing the hip abductors, Fredericson et al (2000) referenced *Muscles: Testing and Function by* Kendall et al (1993). No verbal encouragement was given to the athletes while they were being manual muscle tested. To test the hip abductors, the athletes were concurrently positioned in the side-lying position. However, the untested leg was in a flexed position while the athlete held the opposite end of the table to stabilize the trunk. The tested leg was in a knee extended position. Then the patient actively abducted the tested leg toward the ceiling and held an isometric contraction at 30 degrees. The patient was verbally advised to avoid any hip rotation or flexion. Here five trials were completed with a rest time of 15 seconds. The examiners utilized a hand-held dynamometer (Nicholas Manual Muscle Tester by Lafayette Instruments) to record the strength output, which again was normalized to the athletes' body weight. The equation utilized was % (BW x h) = Torque (N x m) x 100/BW(N) x h(m). In the equation, N represented Newtons, which were calculated by multiplying the kilograms from the dynamometer to 9.81. The m in the equation was to represent the action length or the leg length.

In addition, Jacobs et al. (2007) examined the differences between male and female hip abductor function when performing a functional task. To test hip abductor strength, Jacob et al.

(2007) utilized a Primus dynamometer. The athletes were positioned in pelvic neutral side-lying position as previously described. The resistance arm of the Primus dynamometer was placed above the lateral femoral condyle. The athletes were tested three times with a thirty-second rest in between. The athletes were to create a maximal contraction and hold that contraction for five-seconds. Again the examiners normalized the force output to height weight utilizing the equation reported by Fredericson et al. (2000). In Addition, to strength testing, Jacobs et al. (2007) also implemented the use of electromagnetic sensors through the Flock of Birds (Ascension Technology Corp., Burlington, VT) and MotionMonitor™ software (Innovative Sports Training Inc, Chicago, IL). The sensors were placed at both the lateral thigh, proximal and distal, and the sacrum. Electromyography was also utilized to determine muscular fatigue.

Functional Testing. A study done by Yu et al. (2006) utilized a stop-jump functional task. The athletes again were outfitted with reflective markers to collect three-dimensional video. The reflectors were positioned on the anterior superior illiace spine, lateral malleolus, proximal and distal anterior tibia, L4 and L5. The system used to record three-dimensional image was Peak Performance Montus video and analog data acquisition system (Peak Performance Technology, Inc., Englewood, CO). The athletes completed a ten-minute warm-up prior to performing the functional task. The stop-jump task consisted of an approach run, done at the maximal speed the athletes felt comfortable with, consisting of no more than five steps. The athletes then performed a double leg vertical jump performed at maximal height. This type of functional task was chosen to imitate a basketball or volleyball move.

Previously, Blackburn and Padua (2008) implemented a controlled drop landing as the functional task. Athletes were outfitted with electromagnetic sensors prior to performing the tasks (Flock of Birds, Ascension Technology Corp., Burlington, VT, USA) along with a motion monitoring software (MotionMonitor™ software, Innovative Sports Training Inc, Chicago, IL). The sensors were located on the sacrum, thigh, shank, and thorax. Athletes performed two vertical drop landings off a 60cm platform. The first drop landing simulated the athletes preferred landing. The athletes were asked to step off the platform with the right knee extended landing on both feet with the right one on a force plate. The second drop landing simulated a flexed trunk landing. The athletes again performed the same maneuver as previously stated except they were asked to additionally flex their trunks.

Similarly, Hewett et al (2005) also executed a drop landing however the athletes had to additionally perform a vertical jump. Reflective markers were placed upon the athletes before performing the functional task. Motion movement software was also implemented to create a three dimensional image (EvaRT software, version 3.21, Motion Analysis Corp, Sanata Rosa, California). Additionally two force plates were positioned on the landing platform from the vertical jump. The athletes were to drop down off of a 31cm tall box with their feet 35cm apart landing with each foot on a separate force plate. Once the athletes completed the double-leg landing they were to immediately perform a vertical jump raising their hands above their head landing on both feet. This functional task was completed three successful times with no rest time reported. This testing protocol was determined to be both specific and sensitive in identifying knee adduction motion and identifiying ACL risk (Myer et al., 2010).

An additional functional task is the tuck jump assessment. This functional assessment was reported by Myer, Ford, and Hewett (2008) to be a clinician-friendly method for determining lower extremity landing mechanisms. This is a plyometric activity where the athlete must exhibit a large amount of effort to complete (Hewett et al., 2010). The athlete is asked to complete as many tuck jumps as possible in a ten second time frame. Two cameras are placed in both the sagittal plane and the frontal plane to capture the athlete's performance of the tuck jumps. The tuck jump is described as an athletic jump that is initiated during a loading phase where the athlete goes into a downward crouch with the arms extended past the torso. The athlete then flexes the arms forward while jumping straight in the air. While the athlete is jumping up, he/she is to flex the hips so that the knees are pulled up and the thighs are parallel to the ground at the peak of the jump. When the athlete lands, he/she is to continue performing the tuck jump until time expires. While the athlete is performing the tuck jump, the examiners are looking for flaws during pre, middle, and post jump. There is a total of ten flaws; these flaws are valgus landing, thighs not parallel or not equal, foot placement not shoulder width apart or not parallel or not equal contact time, noise when landing, pause between jumps, do not land in same place as take off, and technique deteriorates before ten seconds have expired. The examiner is to record each flaw and then add up the amount of flaws at the end of the assessment to achieve a final score. If the athlete demonstrates six or more flaws he/she may be at risk and should be exposed to technique training. This type of technique is beneficial for targeting high-risk mechanisms that can predispose an athlete to an ACL injury.

CHAPTER 3

METHOD

Participants

A total of 32 (20±2yrs, 64.5±16.5kg, 166±14cm) females were recruited to participate in this research study. All participants were members of a Division I soccer team. The participants were injury free upon participation in this study.

Testing Location, Ethics, Consent, and History

Testing location was the University of Arkansas Health, Physical Education, and Recreation Building. All testing procedures were approved by the University of Arkansas Institutional Review Board (Appendix A). The participants in the research study were informed of all approved testing procedures and risk associated with these prior to beginning the approved testing. Additionally, every participant completed an informed consent form prior to beginning the approved testing (Appendix B).

Variables

The independent variable in this study was hip abductor strength. This is specific to the following musculature: gluteus maximus (upper to middle fibers), gluteus medius, gluteus minimus, and tensor fasciae latae. The second independent variable was time through the course of the soccer season. The dependent variable was lower extremity kinematics of the participant. The lower extremity kinematics was evaluated through the tuck jump functional task.

Patient Set-up

To maintain unity the participants wore Women's Nike Shox Junior tennis shoes. The participants were allowed to wear orthotics if they wore them for competition. A hand held dynamometer (Grip Dynamometer, Takei, Japan) was utilized to record the hip abductor isometric strength. One off-the-shelf standard two-dimensional video camera (Cannon, USA) was utilized to record images of the participant while performing the functional task.

Testing Protocol

Strength

To obtain the isometric hip abductor strength, participants were tested in the side-lying position (see figure 1 & figure 2). Testing was done on both lower extremity limbs. The side-lying position was found to be both reliable and valid in assessing the hip abductor strength (Widler et al., 2009). The participants were positioned into the side-lying position in which the body was in line without a forward or backward lean. The participants' hips were positioned into neutral with both knees in extension. The participants folded their arm to support his/her head. The opposite arm was not allowed to supplement stability but was allowed to rest along the body in front of the participants. Additionally the participants were not allowed to supplement stability by pushing against the table with the opposing leg.

To obtain the maximal hip abductor strength the isometric method was implemented using a hand held dynamometer. The examiner placed the hand held dynamometer 2 centimeters above the lateral femoral condoyle. The participants were asked to elicit a maximal contraction for 5 seconds against the hand held dynamometer (Ireland, Wilson, Ballantyne, Davis, 2003). This procedure was completed twice with a 15 second rest in between. The participants were allowed one practice attempt followed by three attempts where the highest strength value was recorded. Then the participants were positioned onto the opposing side to test the hip abductors of the second side. Since the strength testing was not long enough to induce fatigue the participants progressed into the tuck jump functional testing.

Functional Testing

The tuck jump assessment reported by Myer et al (2008) was implemented to evaluate the kinematics of the participants. This functional task included one standard 2 dimensional cameras used to capture the participants' performance positioned in frontal plane (see figure 3). Participants were positioned in the view the camera 367.03cm away (see figure 4). Participants were instructed as to what constituted a tuck jump and were given instructions to complete as many jumps as possible in a 10 second period. Participants were instructed to perform each repetition with maximum effort. The examiners recorded time with a digital stopwatch. Participants were given a verbal cue to begin the exercise and a verbal cue when time expired. Upon completion of the exercise, the examiners went back through the video and recorded the flaws demonstrated by the participants. The assessment sheet supplemented by Myer et al. (2008) was utilized to record any flaws in the participants' performance during pre, middle, and post performance (see appendix D). There are a total of ten possible flaws for each section of the participants' performance.

Testing Points

Participants were tested three different times on days where the participant had engaged in soccer activity prior to testing. The first testing was conducted in August during preseason soccer training. The second testing was conducted before conference play started. The final testing was conducted upon completion of the season.

Data Analysis/ Reduction

The quantitative amount recorded by the hand held dynamometer was normalized for body weight using the equation utilized by Fredericson et al., (2000). A leg length measure was taken from anterior superior iliac spine to malleolus. The kilogram output from the hand held dynamometer was converted to Newtons by multiplying by 9.81. The Newtons were then converted to Torque by multiplying the newtons by the leg length measured. These units were converted into the following equation.

$$\% \text{ (BW x h)} = \text{Torque (N x m) x } 100/\text{BW(N) x h(m)}$$

To determine statistical significance a repeated measures ANOVA was utilized to compare the change in the strength over time. Similarly, a repeated measures ANOVA was utilized to compare the change in functional performance over time. To correlate strength with functional task, the change between the scores of the previous testing and the scores of the current testing was correlated. A Pearson correlation was used to make the comparison between the changes. All statistical analysis was run through statistical software SPSS 19.0 (Chicago, IL, USA).

CHAPTER 4

RESULTS

A total of 29 (19±2yrs, 64.5±16.5kg, 160±14cm) Division I female soccer athletes successfully completed this study. Descriptive and anthropological statistics from the 28 participants can be found in Table 1. During the course of the study, three of the participants were eliminated due to injury at the time of testing.

Hip strength was determined through the course of the study to change over the length of a season. Results, located in Table 2, found significance between the pre season testing and mid season testing (p = .000), the mid season and post season (p =.000), and finally the pre season and post season (p = .001). Participants' hip strength increased from preseason to midseason but strength then decreased in post season. However, the postseason strength was still greater than the preseason strength. These results support the hypothesis that a change would be found in the participants' hip strength over the course of the season.

In regards to the change of functional performance over the course of a season, results, found in Table 3, did not reach significance. During the course of the study, functional performance was found to increase between preseason to midseason. However, in post season functional performance decreased, with participants performing more errors than in preseason. Nonetheless, results of the functional performance between pre season and mid season (p = 1.000), mid season and post season (p = .110), and pre season and post season (p = .522) were not significant.

The relationship between the strength of the hip abductors and the functional performance of the participants was calculated through a Pearson product correlation. In regards to the change between pre season and mid season, a weak negative relationship (r = -.134) see

Table 4. Similarly, the results between midseason and post season, Table 5, found a stronger negative relationship (r = -.306) between strength and functional performance. Finally, when looking at postseason to preseason, Table 6, a weak negative relationship was also found (r = -.021). In sum these relationships suggested that as strength increased functional performance decreased.

CHAPTER 5

DISCUSSION

With the increase in female athletic participation, the number of injuries sustained while participating in athletics has correspondingly increased. Health professionals such as athletic trainers, coaches, strength and conditioning coaches and others are actively perusing methods to prevent this increase in injury. Based upon current literature, female soccer athletes sustain the most lower extremity injuries (Brophy et al., 2009). Females have been found to be at greater risk due to biomechanical factors (Ireland, 1999). Current literature has specifically evaluated the effect that hip abductor strength has on dynamic biomechanics (Kibler et al., 2006). It has been found that the hip abductor strength has a parallel relationship to lower extremity function (Jacobs et al., 2007). The relationship between hip abductor strength and lower extremity function suggests focus should be placed upon maintaining pelvic stability, specifically in females (Kibler et al., 2006). However, no data are available documenting the changes these athletes experience over the course of a season.

Therefore the purpose of this study was to examine athletes over the course of a season and the relationship between the athletes' hip abductor strength and performance. The results revealed three things over the season: (a) that there was a significant change in hip abductor strength (b) there was no significant change in functional performance (c) no significant relationship was exhibited between performance and strength.

Hip Abductor Strength

The first hypothesis stated the participants hip abductor strength would decrease over the course of the season. While the results found a significant change in hip abductor strength over the course of the season, a linear decrease in strength was not found. Over the course of the season the participants' strength was the strongest in the middle of the season while it was the weakest at the beginning of season. This could be attributed to lack of physical fitness during preseason due to absent team workouts over the summer. The participants were retested 6 weeks into the season, which could be the reason for the strength gain. Strength gains are seen 4-6 weeks into a strengthening program, which would place the participants retesting at the same time they were making strength gains (Abe, DeHoyos, Pollock & Garzarella, 1999; Myer, Ford, Palumbo & Hewett, 2005).

Additionally, participants were unfamiliar with the isometric hip abductor strength testing protocol at the time of testing preseason testing. Even though the participants were allowed a practice trial before the results were recorded, they appeared hesitant during the preseason testing in comparison to the postseason testing. This comfort in both the midseason and post season testing scores could also be attributed to a learning affect.

Furthermore, during the midseason testing unforeseeable changes in the soccer schedule occurred allowing the participants a weekend off prior to midseason testing. This allotted time off from physical activity decreases the predicted fatigue of the hip abductor strength. Fatigue is known to decrease both strength and functional performance in females (Rozzi, Lephart & Fu, 1999). Dynamic control of the knee can be compromised if musculature, specifically the hip abductors, is fatigued (Geiser, 2010). Therefore it is predicted that the participants would perform better being rested due to increase strength. This supports the midseason finding of increase strength.

Functional Performance

Functional performance did not decrease over the course of the season like the second hypothesis stated. Functional did change over the course of the season, however, this change was not statistically significant. Clinically, however, there is application to the functional performance change. The functional performance decreased from preseason to postseason suggesting that the athlete's performed the functional performance test with greater errors at the end of the season. The decrease in the athletes' ability to correctly complete the desired task suggests the athletes are at greater risk for injury at the end of the season followed closely by preseason.

The increase in functional performance during the midseason testing, however, could be attributed to the rest time the participants were provided since the rest time was in the days prior to testing. By allowing the participants two days of rest, the body was allowed to rest decreasing the current state of fatigue. As previously stated, this rest period has great improvements on both strength and functional performance. Therefore, it is logical that the participants' performance would improve after a period of rest.

In the current literature, neuromuscular control improved during a 5-7 week training program (Hewett, Lindenfeld, Riccobene & Noyes, 1999; Myer et al., 2005). This increase in control was evident in the increase in dynamic performance by the athletes (Hewett et al., 1999). Similarly, the participants in the current study performed the best at the 6-week mark of testing. The researchers did not implement a neuromuscular training program, however the participants trained both with the soccer coach and the strength and conditioning coach. Both of these settings included neuromuscular training, which could be attributed to the increase in control demonstrated in the midseason testing.

Furthermore, the participants' excitement and interest during participation in the study appeared to be the lowest during the postseason testing. Many of the participants were reluctant to finish the study at first; however, they did follow through with this testing. The decrease in the desire to participate in the study could have altered the effort the athlete's put forth during the testing protocol. However, the study did not take emotional ambition into account when recording data; therefore the researchers did not have a measure for the participants' effort.

The Relationship between Strength and Functional Performance

The third hypothesis stated that a positive correlation would be found between strength and functional performance, anticipating that when strength increased functional performance would also increase. A weak negative relationship was found between strength and functional performance. This correlation stated that as the scores for strength increased the scores for functional performance decreased. This decrease in functional performance scores demonstrates an increase in functional performance placing the athlete at a lower risk of injury. The largest correlation found was during the midseason testing; at this point in the season the participants' hip abductor strength scores were the highest with the functional performance scores the lowest, suggesting the lowest risk of injury.

The correlation is clinically significant concerning injury prevention. This relationship suggests that if the hip abductor strength is great, an athlete will perform with fewer errors decreasing the risk of injury. The hip abductor strength maintains pelvic stability, decreasing the valgus position of the knee during performance (Zazulak et al., 2007). The current literature supports the present results, that if hip abductor strength increases, functional performance will also increase. Athletes who participated without experiencing any injury possessed sufficient strength in the hip abductor musculature (Leetun et al,. 2004). It is important for health care providers to acknowledge this relationship and to take an active approach any athlete who presents with hip abductor strength deficit.

Limitations

During the course of the study, one limitation researchers faced was the size of the population. It is recommended for previous studies to utilize a larger number of participants in the same age group. Additionally, it is recommended to test the subjects prior to any physical activity to maintain consistency and decrease possible scheduling variables during the course of testing.

Conclusion

Based upon the results of this study no statistical significance was found in the relationship between hip abductor strength and functional performance. However in regards to athletic trainers, soccer coaches, and strength and conditioning coaches clinical significance can be seen in the relationship. During the season when the hip abductor strength was the highest, the functional performance of the athlete's was the best. Additionally the participants' hip abductor strength significantly changed during the course of the season. This is an important finding in regards to injury prevention and strength training. If it is possible to determine a point in the season where the strength is the weakest and design a program to address this weakness, injury risk could potentially decrease. Furthermore, while functional performance was not statistically significant, the athletes did present with the greatest amount of flaws at the end of the season and the beginning of the season. These findings highlight certain times in the season where the athletes are most vulnerable when performing a dynamic movement.

While this study was one of the first to examine changes in both strength and functional performance over a soccer season, further research is warranted. Specifically it is recommended to research the change in hip abductor strength over the course of the season eliminating any rest period prior to testing. This will allow the researcher to get a better idea of how the athletes' strength varies during the full season. Additionally, further research should examine functional performance of the athletes during the course of the season. It was suggested by this study that the beginning of season and end of season may be the times of greatest risk. However, further research is required before this suggestion can be supported.

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APPENDECIES

Appendix A: IRB Approval

July 29, 2011

MEMORANDUM

TO:	Caitlin Whale Gretchen Oliver
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	11-07-022
Protocol Title:	*The Relationship Between Hip Abductor Strength and Functional Performance in Division I Female Collegiate Soccer Athletes*
Review Type:	■ EXEMPT ■ EXPEDITED ■ FULL IRB
Approved Project Period:	Start Date: 07/29/2011 Expiration Date: 07/28/2012

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (http://vpred.uark.edu/210.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 40 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 210 Administration Building, 5-2208, or irb@uark.edu.

Appendix B: Informed Consent

UNIVERSITY OF ARKANSAS CONSENT TO
PARTICIPATE IN RESEARCH

Title: The Relationship Between Hip Abductor Strength and Functional Performance in Division I Female Collegiate Soccer Athletes

Investigators:

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Explanation and Purpose of the Research

You are being asked to participate in a research study for Caitlin Whale and Dr Oliver. The purpose of the research will be to determine the relationship between the hip abductor strength and functional performance.

Research Procedures

You must also be deemed free of injury at the time of participation

You will be required to dress in only a tee-shirt, a pair of shorts, socks, and tennis/turf shoes during testing.

You will have your isometric strength measured by in a side-lying posision with a hand-held dynamometer.

EMG activity will be recorded through bipolar surface electrodes will be placed over the following muscles on your dominant side: gluteus maximus, gluteus medius, quadriceps and hamstrings. **Surface** electrodes will be chosen because they are noninvasive and are able to reliably detect surface muscle activity. Prior to electrode placement your skin will be cleaned with alcohol. Skin must be cleaned in order to decrease any type of interference that could occur from dirt, sweat, or hair. Adhesive electrodes will be placed over the muscle bellies and parallel to the direction of the underlying muscle fibers. Each set of bipolar electrodes from each of the 8 muscle sites will be connected to a Noraxon 8 channel amplifier/encoder/fiber optic transmitter.

To assure proper electrode placement, manual muscle tests will be preformed through maximum contractions.

You will also perform a tuck jump assessment. You will be asked to jump and raise your knees as high as possible for consecutive jumps. You will be asked to perform as many tuck jumps as you can in 10 seconds.

Potential Risks

Potential risks related to your participation in the study are no more than what you would encounter during the course of your regular practice or conditioning session.

Confidentiality

Confidentiality will be protected to the extent that is allowed by law. A code number will be given to all of your data information. Only the investigators will have access to the data. All data will be stored in a locked filing cabinet in the investigator's office. The data will be erased and destroyed within fifteen years. It is anticipated that the results of this study will be published; however, no name or other identifying information will be included in any publication.
The researcher will try to prevent any problem that could happen because of this research. If at any time there is a problem you should let the researcher know and she will help you. However, the University of Arkansas does not provide medical services of financial assistance for injuries that might happen because you are taking part in this research.

Participation and Benefits

Your involvement in this research study is completely voluntary, and you may discontinue your participation in the study at any time without penalty.

Questions Regarding the Study

If you have any questions about the research study you may ask the researcher; the phone number is at the top of this form. If you have any questions about your rights as a participant in this research or the way this study has been conducted, you may contact the University of Arkansas Office of Research and Sponsored Programs at 479.575.2208 or via e-mail at irb@uark.edu. You will be given a copy of this signed and dated consent form to keep.

____ ________________
Signature of Participant Date

The above consent form was read, discussed, and signed in my presence. In my opinion, the person signing said consent form did so freely and with full knowledge of its contents.

____ ________________
Signature of Investigator Date

Appendix C

Participant	Long-Sit	Practice (L/R)	Trial 1 (L/R)	Trial 2 (L/R)	Trial 3 (L/R)
1		/	/	/	/
2		/	/	/	/
3		/	/	/	/
4		/	/	/	/
5		/	/	/	/
6		/	/	/	/
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33		/	/	/	/

Appendix D

Tuck Jump Assessment	Pre	Mid	Post	Comments
Knee and Thigh Motion				
1. Lower extremity valgus at landing	☐	☐	☐	
2. Thighs do not reach parallel (peak of jump)	☐	☐	☐	
3. Thighs not equal side-to-side (during flight)	☐	☐	☐	
Foot Position During Landing				
4. Foot placement not shoulder width apart	☐	☐	☐	
5. Foot placement not parallel (front to back)	☐	☐	☐	
6. Foot contact timing not equal	☐	☐	☐	
7. Excessive landing contact noise	☐	☐	☐	
Plyometric Technique				
8. Pause between jumps	☐	☐	☐	
9. Technique declines prior to 10 seconds	☐	☐	☐	
10. Does not land in same footprint (excessive in-flight motion)	☐	☐	☐	
	Total _____	Total _____	Total _____	

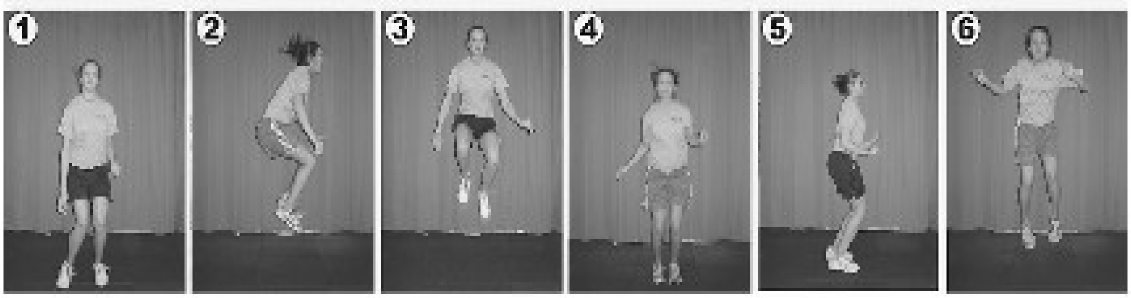

Figure 7 Tuck Jump Assessment: Six common mistakes that clinicians should aim to correct for their athletes while they perform the tuck jump exercise: (1) athletes display unwanted medial knee collapse, (2) athletes do not achieve the desired knees parallel position at top of flight, (3) athletes do not displayed synchronized lower limb positions during flight, (4) athletes land with their feet too close together, (5) athletes land in undesirable staggered position, and (6) athletes do not land with both feet at the same time.

Myer, G. D, Ford, K. R., & Hewett, T. E. (2008). Tuck jump assessment for reducing anterior cruciate ligament injury risk. *Athletic Therapy Today*, *13*(5), 39-44.

Appendix E

Figure 1: Isometric hip abductor strength testing patient set up

Figure 2: Isometric hip abductor strength testing patient set up

Figure 3: Tuck jump assessment set-up

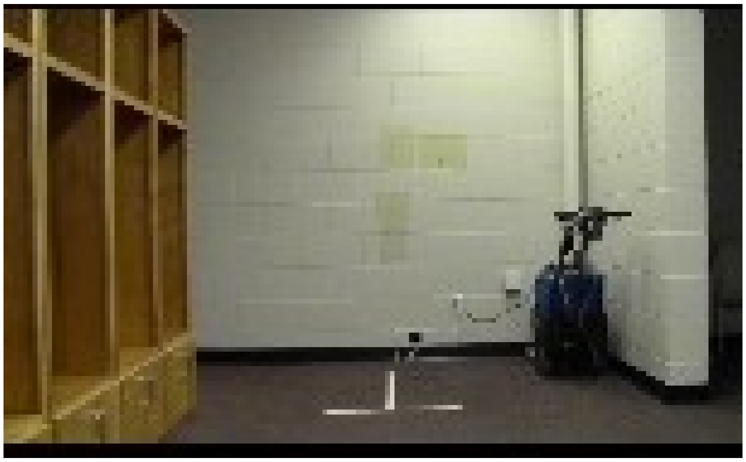

Figure 4: Tuck jump assessment patient initial set-up

Appendix F

Table 1: Descriptive and anthropological statistics

	Height (cm)	Weight (kg)	Age
1	167.64	60.33	19
2	170.18	58.51	21
3	160.02	51.71	19
4	167.64	58.06	20
5	160.02	53.07	20
6	157.48	55.34	18
7	160.02	57.15	20
8	167.64	65.97	19
9	167.64	76.20	20
10	165.10	62.14	20
11	170.18	72.57	20
12	162.56	68.04	20
13	170.18	65.77	21
14	167.64	58.06	18
15	165.10	65.77	19
16	180.34	77.11	18
17	170.18	66.22	19
18	160.02	58.97	18
19	162.56	54.43	21
20	157.48	52.16	18
21	170.18	66.68	20
22	162.56	80.29	18
23	167.64	66.68	18
24	177.80	66.22	18
25	172.72	72.57	18
26	167.64	65.77	20
27	165.10	65.77	18
28	152.40	48.99	22
29	180.34	63.50	18
30	154.94	48.99	19
31	162.56	58.97	22
32	167.64	65.32	19

Table 2: Strength repeated measures ANOVA

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	-8.070*	1.182	.000	-11.079	-5.060
	3	-3.728*	.923	.001	-6.078	-1.378
2	1	8.070*	1.182	.000	5.060	11.079
	3	4.341*	.802	.000	2.298	6.385
3	1	3.728*	.923	.001	1.378	6.078
	2	-4.341*	.802	.000	-6.385	-2.298

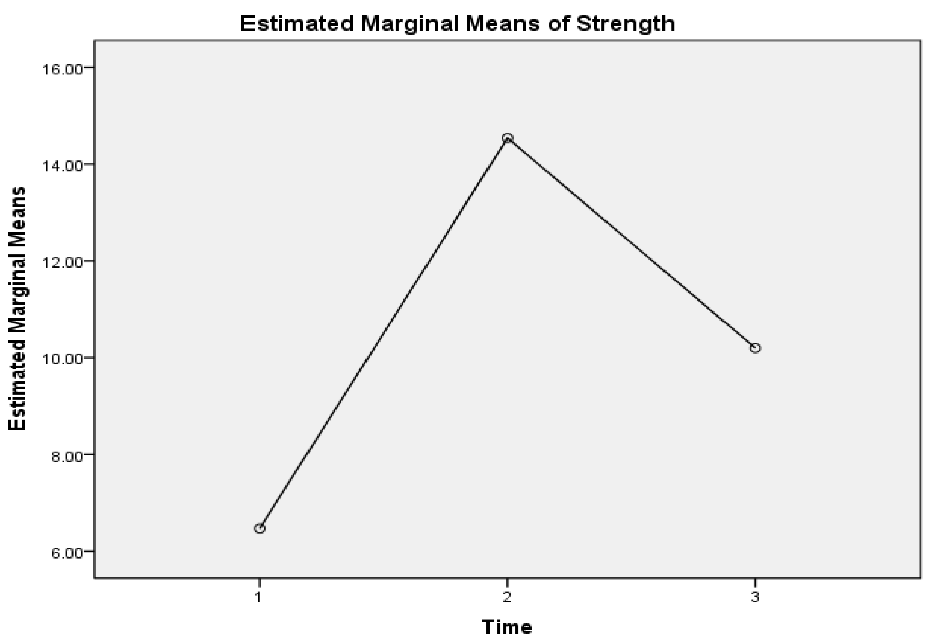

Table 3: Tuck jump assessment repeated measures ANOVA

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1	2	.172	.186	1.000	-.302	.646
	3	-.310	.223	.522	-.877	.256
2	1	-.172	.186	1.000	-.646	.302
	3	-.483	.220	.110	-1.043	.077
3	1	.310	.223	.522	-.256	.877
	2	.483	.220	.110	-.077	1.043

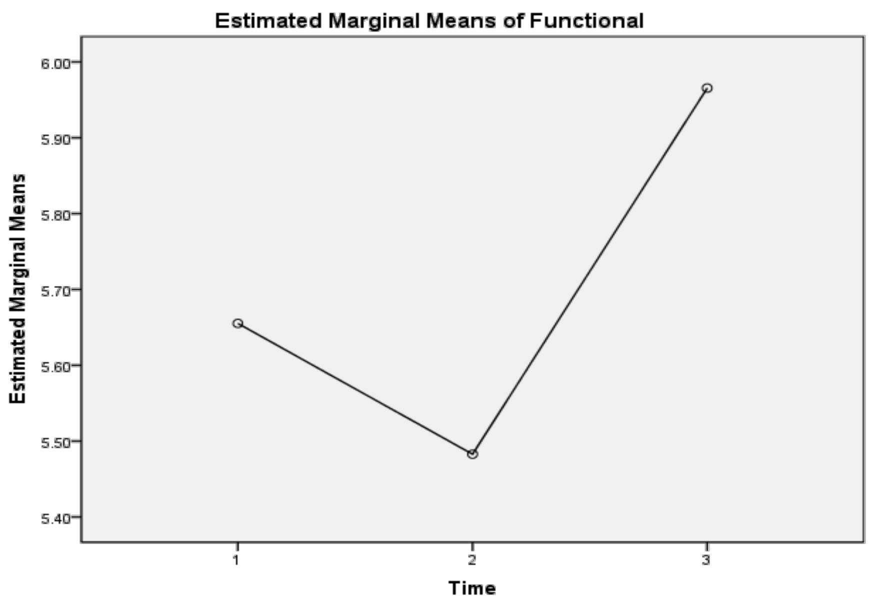

Table 4: Correlation between Preseason and Midseason

		Strength Average Difference	Functional Difference
Strength Average Difference	Pearson Correlation	1	-.134
	Sig. (2-tailed)		.490
	N	29	29
Functional Difference	Pearson Correlation	-.134	1
	Sig. (2-tailed)	.490	
	N	29	29

Table 5: Correlation between Midseason and Postseason

		Strength Average	Functional Performance
Strength Average	Pearson Correlation	1	-.306
	Sig. (2-tailed)		.106
	N	29	29
Functional Performance	Pearson Correlation	-.306	1
	Sig. (2-tailed)	.106	
	N	29	29

Table 6: Correlation between Preseason and Postseason

		Strength	Functional Performance
Strength	Pearson Correlation	1	-.021
	Sig. (2-tailed)		.913
	N	29	29
Functional Performance	Pearson Correlation	-.021	1
	Sig. (2-tailed)	.913	
	N	29	29