GLUTEAL AND HIP MUSCLE STRENGTH OF PHYSICALLY ACTIVE COLLEGIATE STUDENTS FOLLOWING A SIX WEEK EXERCISE PROGRAM

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Kinesiology – Master of Science

2013

ABSTRACT

GLUTEAL AND HIP MUSCLE STRENGTH OF PHYSICALLY ACTIVE COLLEGIATE STUDENTS FOLLOWING A SIX WEEK EXERCISE PROGRAM

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Background: Research has linked weakness in the hip abduction muscles with emphasis on the gluteus medius muscle to injuries in the lower extremities. Studies completed have shown performing strengthening exercise programs with hip abduction exercises helped with increasing hip abduction strength. However, few studies have been performed that have actually measured the amount of strength gain after performing a program.

Purpose: The purpose of this study was to determine if a 6 week exercise program (clam shells, side lying hip abduction, side lying hip abduction with external rotation) created strength gains in torque values of side lying hip abduction and side lying hip abduction measured with external rotation with a BioDex System 3.

Methods: Three side lying exercises were performed over a 6 week period by 60 physically active subjects between the ages of 18-35. Pre and post program peak torque was measured using a Biodex dynamometer.

Results: The findings from the current study revealed that even with a significant statistical value ($p = .000$) for all hypotheses tested, no clinically significant strength gains were noted following the six week program.

Conclusion: There were no significant findings to suggest that performing a 6 week program of side lying hip abduction, side lying hip abduction with external rotation, and clam shell exercises would lead to strength gains for the gluteus medius muscle.

ACKNOWLEDGEMENTS

I would like to acknowledge the efforts of my thesis committee Dr. Tracey Covassin, Dr. Sally Nogle and Dr. Thomas Mackowiak for their help and guidance throughout the process of this thesis.

To Dr. Tracey Covassin, thank you for all of your positive encouragement and guidance throughout this entire process. Without you, there is no possibility this would have been accomplished. You helped me keep my head on my shoulders during this whole process. Thank you for all of the long hours and all of your hard work. The memories made during this time will be remembered forever.

To Dr. Sally Nogle, there are not enough words (or allowed space) to express the gratitude I have for everything you have done for me the past two years. Thank you for being on my committee. Thank you for being my guidance in the athletic training room. The amount of growth I have gained this year is of credit to you. I am so grateful to have had the opportunity to work under your supervision and wish we had more time together. Because of you, I have become a more confident and knowledgeable athletic trainer. Even more so, you have deepened my passion and love for this profession.

To Dr. Thomas "T-mack" Mackowiak, you are the reason I decided to write this thesis in the first place. Thank you for always challenging me to achieve to be greater than average. Thank you for all the time you have given me mentoring me to grow both as a professional and as a person. The opportunities that I have achieved under your guidance are some that I will never forget. The lessons and "tools" I have learned from you are some I will use forever.

To Mom and Dad, you are my rock. Thank you for always believing in me. Even when I had my doubts of brighter times, you always believed I was meant for greater things. Thank you for never giving up on me. I hope this thesis can be an example to everyone that there can be light that comes out of darkness. I love you both so much.

To my sister Chrissy; thank you for always having positive things completely unrelated to school, thesis or work when I needed it the most. You are far beyond your years and I cannot wait to see what the future has in store for you. Wherever you end up, I promise you success will find its way to you. I hope Chicago is ready for us.

To Jeff Monroe, Brian Bratta, Lianna Hadden, Destiny Teachnor-Hauk, LouAnne Jefferson, Dave Carrier, Quinton Sawyer, Dr. John Powell, Mike Straus, Katie Kelly, Rick Atkinson, Seth Kesler, Mike Vorkapich, Sue Halsey, Darlene Howe, Carol Smith, and Salina Halliday; whether it was your words of encouragement, motivation to stay positive, advice on fixing my computer, gifts of caffeine, borrowing of equipment, or simply lending your ear, you all have had an integral part of me completing this thesis. Thank you so much for your support; I am forever grateful to have met and worked with all of you.

To Helen Knull, Molly Maloney, Shawn Hindy and the entire Field Hockey team; thank you for your support, encouragement and understanding throughout this process. It was am honor to work with you all this year. You have made me a better athletic trainer, and for that, I am grateful.

Finally, to all of my participants, thank you for your great efforts and for volunteering for this study. Without you, this would not have been possible.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW OF THE PROBLEM

Sport participation can often result in injury. The majority of injuries should entail some type of rehabilitation to help the injured athlete heal. However, with athletic injuries, there is usually no black and white rehabilitation protocol outline as to how to best rehabilitate the injury. Certified athletic trainers best design their practices based upon their clinical experience and published research. This challenge is even greater when the injury has no known mechanism. Some injuries, specifically overuse, can be caused by previous or existing conditions that create tightness or weakness within the musculoskeletal system. Gluteus medius weakness is one type of condition that has been identified as a predisposing factor for lower extremity injuries (Cichanowski, Schmitt, Johnson & Niemuth, 2007; Earl, Hertel & Denegar, 2005; Fredericson et al., 2000; Niemuth, Johnson, Myers & Thieman, 2005). Gluteus medius weakness has been targeted in the rehabilitation process to help with injuries related to the low back, hip, knee, and ankle. Numerous researchers have examined exercises used to target the gluteus medius to determine if an increase of activation occurs during the various exercises (Earl et al., 2005; Earl, 2004; Distefano, Blackburn, Marshall & Padua, 2009; Schmitz, Riemann & Thompson, 2002). However, few studies have investigated the actual strength gains in torque after a six week exercise program targeted at strengthening the gluteus medius.

The gluteus medius' primary function is hip abduction, although it's anterior fibers also has secondary function in flexion and internal rotation and it's posterior fibers in external rotation and extension. Gluteus maximus and tensor fascia latae (TFL) are also contributors to hip abduction. Recent studies have shown that there have been links to gluteus medius weakness and other lower extremity injuries such as patellofemoral pain (Cichanowski et al., 2007; Earl et al., 2005; Ferber, Kendall & Farr, 2011; Ireland, Willson, Ballantyne & Davis, 2003). While these studies have stated gluteus medius weakness could be the main cause, the question remains if this is the sole muscle contributing to the cause of injury or if the entire muscular structure for hip abduction is responsible.

Prior research has linked a variety of therapeutic exercises for the hip abductors to an increase in gluteus medius firing (Distefano et al., 2009; Earl, 2004) Distefano and associates investigated quantifying and comparing gluteal muscle activation via EMG surface electrodes over 12 strengthening exercises. The study concluded that while there was an ability to show the differences in muscle activation among the different exercises, further research needs to be performed to determine if the high levels of activity actually resulted in muscle strength gains over time (Distefano et al., 2009). A previous graduate student from Michigan State University examined an increase in EMG activation measures of the gluteus and other hip muscles during non weight bearing exercises. Results revealed that using side-lying abduction, side-lying abduction with external rotation, and clamshell exercises would create an increase in muscle activation for the gluteus medius and TFL muscles. Furthermore, the study concluded that of the three exercises tested, the side-lying abduction produced the greatest amount of activation for the gluteus medius muscle (Sieve, 2007). However, this study did not include any strength training program to be completed over a set period of time.

As previously stated, there have been several studies examining the activation measures of the gluteus medius muscle as well as the other hip muscles; however, very little research has been performed on the measurement of the strength value in torque after a hip strengthening program. Fredericson and colleagues (2000) investigated the correlation between strength deficits in hip abduction through a rehabilitation program aimed to successful return the participants back to running. Following the 6 week protocol, females exhibited an increase in hip abduction torque values by 34.9% in the injured limb, while males increased hip abduction torque values by 51.4% (Fredericson et al., 2000). Another study by Mascal, Landel and Powers (2003) discussed two case reports on females with patellofemoral pain. Following the rehabilitative protocol, both subjects reported a significantly reduced pain level, improved function, and gluteus medius torque values were increased by 50% in subject A and 90% in subject B (Mascal, Landel, & Powers, 2003). While these studies have been able to show a positive effect of strength gains and improvement of injury by returning to activity, further research is needed to examine the strength torque gains to further support these results.

1.2 SIGNIFICANCE OF THE PROBLEM

When gluteus medius weakness has reached a significant point, it will create what is known as a Trendelenburg’s gait (Presswood, 2008; Starkey & Ryan, 2002). This gait may already be structurally present within a person’s body. Due to an increase in weakness of the hip abductors, this gait may be exacerbated. A Trendelenburg’s gait is noted when there is a drop in the opposite hip of the affected side during a single leg stance (Presswood, 2008). This drop creates a different angle of force throughout the entire lower extremity chain, thus changing one’s gait (Cichanowski et al., 2007; Fredericson et al., 2000). This is easily seen in severe cases, although changes and injury can still occur in less noticeable cases. Many studies have linked weakness in gluteus medius to injuries in the lower extremity such as patellofemoral pain, IT Band Syndrome, anterior shin pain, ankle instability, ankle sprains, stress fractures, and even an increase in risk of ACL injury. (Cichanowski et al., 2007; Ferber et al., 2011; Fredericson et al., 2000). While there have been different treatment options tried to all of these injuries, one consistent rehabilitation exercise has been to strength the gluteus medius/hip abduction muscle group. Multiple research studies have noted that exercises such as the clamshell, side lying hip abduction, and side lying hip abduction with external rotation have been the best at strengthening the gluteus medius (Distefano et al., 2009; Earl, 2004). Most of these previous research methods have investigated EMG activity that the muscles produce during a particular exercise. Few articles have examined the actual gain in strength following a strengthening program.

By combining the results from previous research and measurements in torque of the strength gains in the gluteus medius, it will be possible to determine if performing side lying exercises will produce strength gains in the gluteus medius. Working in athletics, it is important that not only the athlete receives the highest degree of care, but also that the care is provided in an efficient manner. By providing the athlete with an exercise program that is efficient in creating strength gains, it may also increase the potential the athlete will return from injury quicker and maintain the athlete's health throughout the season with little risk of secondary injury due to the weakness presented.

There is significant amount of knowledge within the field linking an increase of hip abduction activation to strengthening exercises through measurements with EMG (Distefano et al., 2009; Earl, 2004; Sieve, 2007). However, little research has been performed on the measurement of strength in torque values by testing the strength gains through a Biodex (Fredericson et al., 2000). Studies have even mentioned the need for future research to collect strength gain values (Distefano et al., 2009). By examining increases in muscle strength, it can help determine rehabilitation protocols to promote hip abduction strengthening.

1.3 PURPOSE OF THE STUDY

The purpose of this study is to determine if an exercise program (clam shells, side lying hip abduction, side lying hip abduction with external rotation) will create strength gains in torque values (during measurement) of side lying hip abduction and side lying hip abduction with external rotation with a BioDex System 3 over a period of six weeks.

1.4 HYPOTHESES

1. There will be increases in hip abduction strength in torque values of the dominant leg following the 6 week exercise program.

2. There will be increases in hip abduction strength in torque values of the non dominant leg following the 6 week exercise program.

3. There will be an increase in hip abduction with external rotation strength in torque values of the dominant leg following the 6 week exercise program.

4. There will be an increase in hip abduction with external rotation strength in torque values of the non dominant leg following the 6 week exercise program.

5. There will be greater increases in strength gain in the non dominant leg verses the dominant leg following the 6 week exercise program.

1.5 OPERATIONAL DEFIINTIONS OF TERMS

<u>Ball and Socket Joint:</u> The name of the type of joint given to the hip joint. The ball and socket joint of the hip is made up of the femoral head and acetabular fossa. The acetabular fossa is bordered by the glenoid labrum. (Starkey & Ryan, 2002)

<u>BioDex System 3:</u> The isokinetic dynamometer that measures net muscle torque for the ankle, knee, hip, wrist, elbow and shoulder. The modes of operation for exercise and testing include isokinetic, passive, isometric, isotonic and reactive eccentric (Drouin, Valovich-mcLeod,

Shultz, Gansneder & Perrin, 2004; Feiring, Ellenbecker, & Derscheid, 1990; Zawadzki, Bober & Siemienski, 2010).

Clam Shell Exercise: A side-lying hip strengthening exercise in which the patient will start and end with 60 degrees of hip flexion and 90 degrees of knee flexion. Patient will then abduct their hip (at the knee) while keeping their heels together, and return to starting position in a slow and controlled manner (Distefano et al., 2009)

Electromyography (EMG): Measurement device used to record the amount of electrical impulses of a muscle to determine contraction (Distefano et al., 2009; Earl, 2004).

Physically Active: Someone who accumulates at least 150 minutes of moderate-intensity exercise per week. Exercise recommendations can be met through 30-60 minutes of moderate-intensity exercise (five days per week) or 20-60 minutes of vigorous-intensity exercise (three days per week). (Garber et al., 2011)

Q Angle: The relationship between the line of pull of the quadriceps and the patellar tendon. With extended knee, normal Q Angle for men is 13 degrees and 18 degrees for women. With flexed knee to 90 degrees, Q Angle is normal at 9 degrees for both genders (Starkey & Ryan, 2002).

Side Lying Hip Abduction Exercise: A hip strengthening exercise that has the patient side-lying on the floor with a starting position of full knee extension and neutral hip position. The patient will abduct the hip of the top limb while keeping the knee locked out in extension. The patient will stop at 30 degrees of hip abduction and then return to the starting position in a slow, controlled manner (Distefano et al., 2009; Earl, 2004).

Side Lying Hip Abduction with External Rotation Exercise: A hip strengthening exercise that has the patient side-lying on the floor with a starting position of full knee extension and neutral hip position. The patient will abduct and externally rotation the hip of the top limb while keeping the knee locked out in extension. The patient will stop at 30 degrees of hip abduction with about 10-15 degrees of external rotation and then return to the starting position in a slow, controlled manner (Distefano et al., 2009; Earl, 2004).

Trendelenburg's Gait: Occurs when one leg swings forward during gait and the gluteus medius cannot stabilize the pelvis, resulting in a downward tilt when the swing leg is in the air. (Presswood, 2008)

CHAPTER 2

REVIEW OF LITERATURE

2.1 INTRODUCTION

The review of literature is divided into five sections. First, an overview of hip and pelvis anatomy including bony anatomy, bony and hip abduction muscular articulations, and function of the hip abduction muscles are discussed. Second, there is a discussion of hip abduction weakness and its relationship to injury. Third, there is a discussion on research of the correlation between gluteus medius strength and exercise. Fourth, an overview is provided on rehabilitation techniques used to prevent and/or correct gluteus medius weakness. Finally, this review of literature discusses research that has utilized the Biodex system on hip abduction testing.

2.2 HIP ANATOMY

2.2.1 Bony Anatomy

The anterior and lateral portion of the pelvis consists of two innominate bones. Each innominate is made up by the ilium, ischium, and pubis. The lateral portion of the pelvis also articulates with the femoral head via the acetabulum. On the proximal portion of the femoral shaft, the greater trochanter and lesser trochanter are two attachment sites for many pelvic and hip muscles. The posterior portion of the pelvis is formed by an articulation with the sacrum (Starkey & Ryan, 2002). The hip is a ball and socket joint. The musculature of the hip can be placed into the six directional categories (DeStefano, 2011) including flexion-extension, abduction-adduction, and internal-external rotation. This next section examines the abductor musculature and its function.

2,2,2 **Hip Abduction Muscles/Attachments/Function**

The four hip muscles that contribute to hip abduction are gluteus medius, tensor fasciae latae, gluteus minimus and sartorius. The gluteus medius originates on the outer surface of the iliac crest and inserts on the greater trochanter of the femur (Earl, 2004; Starkey & Ryan, 2002). There are 3 different areas of the gluteus medius that are distinct through their function. Although the primary function in the medial fibers of the gluteus medius is abduction, the anterior fibers contribute to hip flexion and hip internal rotation, and the posterior fibers assist in hip extension, hip external rotation and contribute to the stabilization of the hip joint (Earl et al., 2005; Presswood, Cronin, Keogh, Whatman, 2008; Starkey & Ryan, 2002). According to Earl et al. (2005) and Presswood et al. (2008), the gluteus medius has dual purposes; a pelvic stabilizer during stationary activities and a pelvic rotator during movement activities. Therefore, it is important to note that the gluteus medius is important for both stabilization and movement.

The tensor fasciae latae (TFL) originates on the anterior superior iliac spine (ASIS) and external lip of the iliac crest and inserts on the iliotibial tract in the middle third of the thigh (IT band) (Starkey & Ryan, 2002). Similar to the gluteus medius, the TFL's primary action is hip abduction, however the TFL also assists in hip flexion and internal rotation (Starkey & Ryan, 2002). It is important to note that when one favors the TFL in hip abduction over the gluteus medius, weakness and atrophy occurs in the gluteus medius (Bewyer & Bewyer, 2003).

Gluteus minimus originates off the lower portion of the ilium and greater sciatic notch and inserts on the greater trochanter of the femur (Starkey & Ryan, 2002). The gluteus minimus' primary action is hip abduction, but also contributes to hip internal rotation and hip flexion (Starkey & Ryan, 2002). The sartorius originates on the ASIS and inserts on the proximal portion of the anterior medial tibia (Starkey & Ryan, 2002). The sartorius contributes to abduction, flexion, and internal rotation of the hip (Starkey & Ryan, 2002).

2.3 **HIP ABDUCTION WEAKNESS**

Since one of the gluteus medius' functions is to act as a pelvic stabilizer, when it is weak, it creates what is known as a Trendelenburg's gait pattern (Presswood et al., 2008; Starkey & Ryan, 2002). When one leg swings forward during gait, the opposite gluteus medius (non swinging leg) contracts to prevent the pelvis from laterally tilting. During a Trendelenburg gait, the gluteus medius cannot stabilize the pelvis, resulting in a downward tilt when the swing leg is in the air (Presswood et al., 2008). In other words, when there is insufficient hip abduction strength, it is believed there is excessive femoral internal rotation and hip adduction. Looking further down the kinetic chain, this increase in hip movement affects the valgus motion of the knee, resulting in an increase in the Q-angle (Cichanowski et al., 2007; Fredericson et al., 2000). It is believed that this increase in Q-angle creates repetitive abnormal forces to the various areas of the lower extremity, ultimately resulting in injury (Cichanowski et al., 2007; Ferber et al., 2011; Fredericson et al., 2000).

Willson and Davis (2008) conducted a study that looked into the kinematic changes of the lower extremities when comparing females with and without patellofemoral pain syndrome. In this study, 20 females with patellofemoral pain and 20 female controls performed single leg squats, running, and repeat sets of single leg jumps. As these exercises were performed, three dimensional biomechanics were recorded. Transverse and frontal hip plane measurements were compared between the two groups. Results showed that subjects who experienced patellofemoral pain syndrome (PFPS) had greater hip adduction which was attributed to abnormal frontal plane mechanics due to weak hip abductors when compared to a control group. The authors also reported that the biomechanical changes in the various hip planes were consistently different throughout the three exercises (Willson & Davis, 2008). Although this specific study didn't actually measure hip abductor strength, other studies have included hip abductor strength measures.

In a study by Ireland, Willson, Ballantyne, and Davis (2003), the purpose of the study was to examine hip strength in women diagnosed with patellofemoral joint pain (PFP). The authors hypothesized that the women diagnosed with PFP would demonstrate lower strength values in hip abduction and external rotation compared to the control group. Using side-lying hip abduction isometric strength testing, 15 female subjects with PFP and 15 control group subjects were tested. Results indicated that subjects with PFP demonstrated a 26% decrease in hip abduction strength and 36% weaker hip external rotation strength then their control group counterparts (Ireland et al., 2003).

Another study conducted by Niemuth, Johnson, Myers and Thieman (2005) tested the strength of the six muscle groups (hip flexors/extensors, hip abductors/adductors, internal/external rotators) in the involved leg of injured versus non injured recreational runners to see if a difference in strength was prevalent. Of the 30 injured runners tested, 10 were diagnosed with Achilles tendonitis, 9 with iliotibial band friction syndrome, 6 had anterior knee pain, 2 had tibial or fibula stress fractures, 2 were diagnosed with medial tibial stress syndrome, and 1 experienced plantar fasciitis. Using a hand held dynamometer to measure maximal isometric contraction strength; the study suggested that there was a relationship between hip muscle imbalances and injury patterns in runners suffering from overuse injuries that didn't exist in healthy runners. The study went further to discuss the biomechanics of the running gate, emphasizing the stabilizing factor of the gluteus medius (Niemuth et al., 2005).

Another study performed by Boling, Padua and Creighton, (2009) used a Biodex isokinetic dynamometer system to measure strength differences in subjects with and without patellofemoral pain. Forty volunteers between the ages of 18 and 40 years old were included in the study. Twenty of those subjects were diagnosed with patellofemoral pain. Concentric and eccentric torque of the hip extensors, external rotators, and abductors were assessed. All strength testing was performed at 60 degrees range of motion. This degree was chosen because as stated in the article, a muscle produces greatest concentric force at a slower isokinetic testing velocity. Furthermore, there is a positive correlation between eccentric contraction velocity and force production. Each participant was given two minutes of rest between strength test trials. Results showed that the subjects with patellofemoral pain had weaker peak eccentric hip abduction torque as well as average concentric and eccentric hip external rotation torque (Boling, Padua, & Creighton, 2009).

Researchers have also examined the relationship of gender and hip biomechanical differences. Ferber, Davis and Williams III (2003) conducted a study comparing the hip and knee three dimensional joint angles and negative work during the stance phases of the running gate. In his study, the gait of 20 men and 20 women were analyzed using retro-reflective markers. The study found that female recreational runners demonstrated greater hip adduction, hip internal rotation, and knee abduction. Females also demonstrated greater hip front and transverse plane negative work when compared to males (Ferber, Davis & Williams, 2003).

Cichanowski, Schmitt, Johnson and Niemuth (2007) examined potential reasons behind collegiate female athletes with PFPS. Once again in this study, the six aforementioned muscle groups were tested using maximal isometric strength testing with a handheld dynamometer. They hypothesized that women with PFPS would have weaker hip strength, specifically in the hip abductor and external rotators versus their uninjured leg and the leg of the uninjured control group. Twenty-six athletes were subjects for the study; 13 athletes diagnosed with patellofemoral pain and 13 controls. Results found that the force produced by the injured leg's hip abductors and external rotators were significantly weaker than the uninjured leg. Furthermore, the study also showed that there were no significant differences in strength of the hip flexors, extensors, adductors or internal rotators. When compared to the uninjured control group, the injured athletes legs had overall weaker hip strength values. The only muscle group that wasn't unequal was the hip adductors. The authors determined that future research was needed to determine if adding exercises to address these weaknesses would promote recovery and allow for faster return to full activity (Cichanowski et al., 2007).

2.4 HIP ABDUCTION STRENGTH AND EXERCISE

Some researchers have shown a positive correlation between hip abduction strength and exercise programs. One of these studies by Fredericson and colleagues (2000) investigated the correlation between corrections of strength deficits in hip abduction through a rehabilitation program to successful return to running. In this study, 24 runners with diagnosed iliotibial band syndrome (ITBS) were measured for hip abduction torque using the Nicholas Manual Muscle Tester for both pre and post testing. During pre testing, it was found that hip abduction torque values were decreased for the injured limb of both genders [7.82% body weight times height (BWh) for females, 6.86% BWh for males] when compared to the uninjured limb [9.82% BWh for females, 8.62% BWh for males] and the control group [10.19% BWh for females, 9.73% BWh for males]. These runners were then administered a 6 week standardized rehabilitation protocol that focused on the strengthening of the gluteus medius. During the 6 weeks, the subjects were treated by the same physical therapist once a week. Exercises chosen for this protocol included side-lying hip abduction and pelvic drops performed at 1 set of 15 repetitions and increased over the next several weeks with a goal of 3 sets of 30 repetitions. The subjects were instructed that as long as there was no significant post workout soreness the following day, repetitions could be increased by 5 per day. Besides the physical rehabilitation protocol, subjects were also administered non-steroidal anti-inflammatory drugs, application of ultrasound with a corticosteroid gel, stretching protocol, and were told to discontinued running or any other activity that continued to cause pain. However, cross training was allowed as long as it didn't recreate any pain. Following the 6 week protocol, females exhibited an increase in hip abduction torque values by 34.9% in the injured limb, while males increased hip abduction torque values by 51.4%. Following 6 weeks of this protocol, 22 of the 24 runners returned to running pain free with no recurrent complications following a 6 month follow up. The authors suggest that the strength gains in hip abduction allowed greater control of hip adduction and internal rotation, thus, creating less valgus force at the knee (Fredericson et al., 2000).

Another study by Mascal, Landel and Powers (2003) discussed two case reports on females with patellofemoral pain. Both subjects experienced hip abductor, extensor, and external rotational weakness and displayed excessive hip adduction, internal rotation and knee valgus forces. Both subjects were then placed on rehabilitation protocols that occurred over a 14 week period and focused in stages on the training of the hip, pelvis, and truck musculature. The subjects were scheduled to attend physical therapy sessions once to twice a week over the 3 month period. During weeks 0-6, non weight bearing exercises were performed. Weeks 6-10 incorporated weight bearing exercises, and weeks 10-14 incorporated functional training. Following the protocol, both subjects reported a significantly reduced pain level, improved function, and gluteus medius torque values were increased by 50% in subject A and 90% in subject B. It was suggested that the prescribed exercises in this study should be considered in the treatment of patients with PFP and that further research needed to be conducted to define the relationship between proximal hip weakness and PFP (Mascal et al., 2003).

Ferber, Kendall and Farr (2011) examined a 3-week protocol consisting of 2 exercises targeting hip abductors to see if there would be changes in strength, pain, and biomechanics in 15 runners diagnosed with patellofemoral pain syndrome. The protocol consisted of 2 theraband exercises, the first in hip abduction and the second in hip extension with 45 degrees of hip abduction. The subjects were instructed to perform 3 sets of 10 repetitions for each exercise daily over the course of the 3 weeks. All subjects returned after 7-10 days to follow up on logging exercise protocol compliance and to have their technique evaluated. For this study, the subjects continued to run on a regular basis. Pain was measured using a 0 to 10 scale with 0 indicating no pain and 10 indicating the most pain imaginable. Results of the study showed that the subjects were compliant with the protocol, completing the exercises on average 6.2 days per week over the 3 week period. Furthermore, post test results demonstrated an increase in isometric strength testing by 32.69% and a 43.10% decrease in the pain scale compared to baseline values. It was concluded that the 3 week program was effective in increasing hip abduction strength and decreasing pain (Ferber et al., 2011).

Snyder and colleagues (2009) performed a study on 15 healthy females that included measuring hip abduction with a hand held dynamometer and administering a 6 week strengthening program using closed chain hip rotation exercises. Inclusionary study criteria included physical activity level that met the American College of Sports Medicine requirements for moderately active people (30 minutes of moderately intense activity on most days of the week). The authors hypothesized that after 6 weeks; there would be an increase in isometric hip abduction and external rotation strength. The three closed chain hip rotation exercises that provided resistance to hip abduction and rotation were chosen because of previous literature that described this position to produce a high amount of gluteus medius activity via electromyography testing. The exercises were also chosen because of the ability to perform the exercises at home. These three exercises were named toward, away, and hip hike. Strength testing was repeated at the midpoint (week 3) and end of the protocol. Following the 6 week program, hip abduction and external rotation strength increased by 13% and 23% respectively. The authors interpreted the results as positive and believed that with the alteration in joint loading due to increased strength, injury risk could be reduced (Snyder, Earl, O'Connor & Ebersole, 2009).

It is important to note that not all studies have supported the idea of targeting hip abductors. Tyler, Nicholas, Mullaney and McHugh (2006) conducted a study using 35 subjects diagnosed with patellofemoral pain syndrome and placed them on a 6 week rehabilitation program to see if a positive outcome (pain decrease) could be achieved. Even though there were 35 subjects in the study, some of the subjects had bilateral PFP diagnoses, which allowed for 43 knees to be studied. Prior to the start of the protocol, the subjects were measured for hip flexion, abduction and adduction strength via a hand held dynamometer. These measurements indicated weakness on the involved limb in hip flexion by 14% and hip abduction by 14% when compared to the uninjured side. The therapeutic intervention consisted of a multi phased guideline that incorporated open and closed kinetic chain exercises. The exercises were performed initially in a non weight bearing format and progressively moved to a weight bearing format. Home programs were given to each subject and progression of the program was allowed when the subject could successfully perform the exercises during the clinic evaluations without verbal corrections. Following the 6 week protocol, the study found that although there were improvements in the different areas of strength (flexion 35%, abduction 18-28%, adduction 24-40%) there was a significant difference in the positive outcomes based upon which hip motion was strengthened. When hip flexion was increased by more than 20%, 17 of 19 lower extremities had a positive outcome. When hip abduction was improved by more than 20%, only 14 of 22 lower extremities had a positive outcome. The authors suggest that hip abduction and adduction exercises were not pertinent to the treatment of patellofemoral pain syndrome (Tyler, Nicholas, Mullaney & McHugh, 2006). Ferber et al. (2011) addressed this finding, indicating that other muscles in addition to the hip abductors could be important in the treatment of injury; however, further studies involving comprehensive hip muscle strengthening protocols would be necessary to support the results found (Ferber et al., 2011).

2.5 REHABILITATION TECHNIQUES TO CORRECT WEAKNESS

While the previous research was able to show a relationship between gluteus medius strength and exercises, there were different protocols and exercises chosen. This review of literature examined to see if there was a reason specific exercises were chosen and to see if there were some exercises that were more beneficial than others.

Schmitz and colleagues (2002) examined isometric closed chain external hip rotation exercises to see if there was an increase in gluteus medius (GM) activity via surface EMG recordings. Twenty college age subjects that were free from lower extremity injury were recruited. Once the EMG electrodes were placed, subjects performed a five second stance on the dominant limb in three different positions. These positions were 0° knee flexion with 0° hip flexion, 0° knee flexion with 20° hip flexion, and knee flexed 20° to 30° with 20° hip flexion. While these positions were being held, a posterior force of 8.9 Newtons (N), 17.8 N, and 26.7 N, respectively were placed using a pulley belt system. These forces were chosen from results during a pilot study done. Results showed that GM activity increased in response to isometric, closed-chain, external hip-rotation forces (Schmitz, Riemann & Thompson, 2002). While this study did show inference for creating a rehabilitation program designed to stabilize the pelvis and trunk, it did not look into the abduction action of the muscle.

Another study that took the groundwork of Schmitz et al.'s was conducted by Earl (2004). In the article, she stated that while frontal plane exercises such as side-lying straight leg raises and standing hip hikes were good for early stages of improvements of neuromuscular control, they weren't a good representation of functional action in the gluteus medius. She suggested that a program aimed towards functional strengthening would be one that incorporates both abduction and internal rotation. Her study investigated which combination of hip rotation and abduction loads caused the greatest activity of the gluteus medius and to determine if the gluteus medius responded to the increased loads in these exercises. In this study, 20 healthy subjects 23 ± 5 years (10 men, 10 women) were recruited. EMG data was collected using surface electrodes on the dominant leg. Three variations of single leg stance isometric exercises were performed with the force coming from a pulley belt system. The exercises used were abduction only (ABD), abduction-internal-rotation exercise (ABD-IR), and abduction-external-rotation (ABD-ER). The subjects were asked to hold this position for five seconds while measurements were taken. Results showed that the ABD-IR produced the most activity in the anterior and middle sections of the gluteus medius muscle. It also showed that the 4.53 kg load produced greater activity than the 2.26 kg load. Based on these results, it was concluded that the gluteus medius was more active when performing abduction and internal rotation of the hip (Earl, 2004).

Another study by Distefano and colleagues (2009) looked into quantifying and comparing gluteal muscle activation via EMG surface electrodes over 12 strengthening exercises. The exercises were side lying hip abduction, clam shell with 30 degrees of hip flexion, clam shell with 60 degrees of hip flexion, single limb squat, single limb deadlift, lateral band walk, forward lunge, sideways lunge, transverse lunge, forward hop, sideways hop, and transverse hop. The exercises were chosen based upon feedback given on which exercises would be used to strengthen gluteal muscles. Twenty-one uninjured subjects (nine males, 12 females) who participated in physical activity for at least 60 minutes, three days per week participated in the study. The subjects completed eight repetitions of each of the exercises. EMG data was collected and revealed that there was a significant difference among the exercises for muscle activity for the gluteus medius. The side lying hip abduction exercise was found to produce the greatest amount of activation. In fact, this exercise produced almost 16% more activation than the other 4 top tier measured exercises and 30% more activation then the lower tier exercises. The study concluded that while there was an ability to show the differences in muscle activation among the different exercises, further research needs to be performed to determine if the high levels of activity actually result in muscle strength gains over time (Distefano et al., 2009).

2.6 RELIABILTY AND VALIDITY OF THE BIODEX ISOKINETIC DYNAMOMETER

Finally, this overview of literature investigated previous research done on the reliability and validity of the Biodex Isokinetic Dynamometer. There have been several studies performed on the test-retest reliability of the Biodex unit, however, this review focused solely on the lower extremity measurements.

The first study performed by Feiring, Ellenbecker and Derscheid (1990) examined the test-retest reliability for isokinetic concentric forces of healthy active populations measuring peak torque of knee extension and flexion. Nineteen healthy active males and females between the ages of 20-35 with no history of knee injury were pre and post tested concentrically bilaterally at 60, 180, 240, and 300 degrees of knee extension and flexion. There were seven days between pre and post tests. Analysis of the data showed that the intra-class coefficients (ICC) for all measurements taken were between r = 0.95-0.97. All ICCs were significant at the 0.05 level. Therefore, it was concluded that the isokinetic concentric mode for the BioDex dynamometer were reliable for the test-retest measures of peak torque, and single repetition work (Feiring et al., 1990).

Another study in 2004 assessed the mechanical reliability and validity of angular position, isometric torque and concentric velocity measures of the BioDex System 3 isokinetic dynamometer (Drouin et al., 2004). Position was measured at five degree increments throughout the entire ability of the machine's range of motion. Torque measurements were assessed isometrically using six different hanging calibrated weights that were placed off the lever arm of the machine. Velocity was measured from a range of 30 degrees per second to 500 degrees per second across a 70 degree arc of motion by the administrators manually accelerating the weighted lever arm. All measurements were compared to a criterion of data. Within the limitations of the study, it was found that the Biodex unit provided mechanically reliable measures of torque, position and velocity on repeated trials performed both same day and different days (Drouin et al., 2004).

Finally, a study in 2010 examined the analysis of static measurements of torque and angular position of the lever arm of the dynamometer. Two separate dynamometers were used in this study. To measure torque, weights were hung on the lever arm to produce a constant force during measurement. The angular position of the lever arm was tested by measuring the torque produced by the weight attached to the lever at the distance from the axis of rotation. The results of the measurements were determined by comparing them to previous results reported by the Biodex report and the raw data collected from the measuring computer of the second isokinetic machine. The results showed that the Biodex System 3 dynamometer was within the error range specified by the manufacturer, and therefore results could be considered valid (Zawadzki et al., 2010).

2.7 CONCLUSION

Many researchers have studied the increases in muscle activation in the gluteus medius after performing a rehabilitation program. This research has concluded that increases in activation have occurred in the gluteus medius muscle (Distefano et al., 2009; Earl, 2004; Schmitz et al., 2002). Other studies have also shown that after performing rehabilitation exercises aimed at increasing strength at the gluteus medius, lower extremity injuries have decreased or resolved (Bewyer & Bewyer, 2003; Cichanowski et al., 2007; Ferber et al., 2011; Mascal et al., 2003). However, very few studies have actually measured the strength gains in torque values (Boling et al., 2009). Therefore, the purpose of this study is to determine if rehabilitation exercises (clam shells, side lying hip abduction, side lying hip abduction with external rotation) will create strength gains in torque values for both the dominant and non dominant leg in healthy individuals over a period of six weeks.

CHAPTER 3

METHODS

3.1 RESEARCH DESIGN

A randomized, counterbalanced, within-subject experimental design was used to determine if the 6 week exercise program would produce strength gains. The independent variable was time (strength prior to 6 week program, strength post 6 week program) and the dependent variable was peak torque.

3.2 SAMPLE POPULATION AND PARTICIPANT SELECTION

Sixty subjects from a large mid-western university between the ages of 18-35 were asked to volunteer for the study. All participants fell into the category of physically active; defined by the ACSM as someone who accumulated at least 150 minutes of moderate-intensity exercise per week. Exercise recommendations can be met through 30-60 minutes of moderate-intensity exercise (five days per week) or 20-60 minutes of vigorous-intensity exercise (three days per week) (Garber et al., 2011). Participants were excluded from the study if they had a lower extremity injury within the past 6 months. Participants were excluded from the study if they had surgery on their lower extremity within the last 6 months. Participants were excluded from the study if they have ever had hip surgery.

3.3 INSTRUMENTATION

3.3.1 BioDex System 3 Dynamometer

The BioDex system 3 dynamometer was used to collect peak torque values for the hip during this study. Hip abduction and hip abduction with external rotation was measured. This system is reliable and valid, used specifically for isolated muscle testing and rehabilitation. A study performed in 2004 measured the mechanical reliability and validity of angular position, isometric torque and concentric velocity measures of the BioDex System 3 Isokinetic dynamometer. Position was measured at five degree increments throughout the entire ability of the machine's range of motion. Torque measurements were assessed isometrically using six different hanging calibrated weights that were placed off the lever arm of the machine. Velocity was measured from a range of 30 degrees per second to 500 degrees per second across a 70 degree arc of motion by the administrators manually accelerating the weighted lever arm. All measurements were compared to a criterion of data. Within the limitations of the study, it was found that the BioDex unit provided mechanically reliable measures of torque, position and velocity on repeated trials performed both same day and different days (Drouin et al., 2004).

3.4 STRENGTHENING INTERVENTION

There were three exercises that were demonstrated during the first session and used throughout the six week program. The first exercise was the clamshell exercise. For this exercise, the participant was side-lying with the knees flexed to 90 degrees, the hips flexed to 60 degrees. The hips and shoulders were perpendicular to the table with their feet together. Participants abducted the hip by moving the top knee off the bottom knee while keeping their heels together and their spine remaining in a neutral position. They returned to the starting position in a slow and controlled manner (Distefano et al., 2009; Earl, 2004). This exercise was performed in 3 sets of 10 repetitions (Bewyer & Bewyer, 2003; Ferber et al., 2011; Mascal et al., 2003). The therband was placed just above the knees. The arm and hand on the top side rested on the table in front of the body while the arm of the bottom side was bent resting underneath the participants head. (See Figure 3.1)

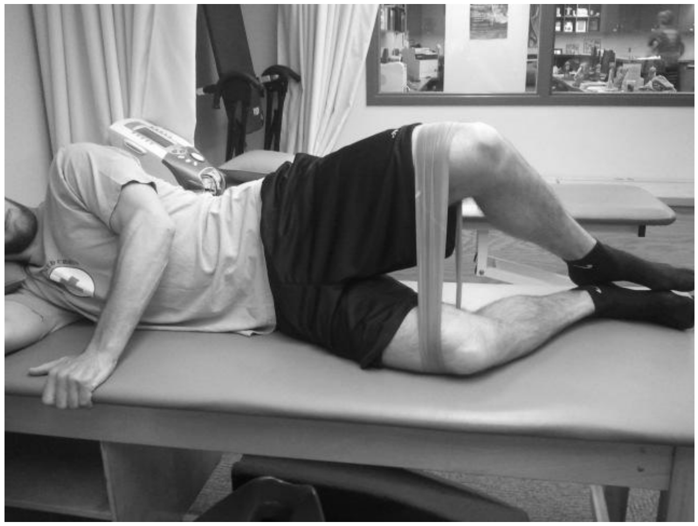

Figure 3.1: The Clamshell Exercise

The second exercise was the side-lying hip abduction exercise. This exercise was performed with the participant in a side-lying position with full knee extension and a neutral hip position. The arm and hand on the top side rested on the table in front of the body while the arm of the bottom side was bent resting underneath the participants head. The participant slowly abducted the top leg while keeping the knee in extension, making sure the tibia and femur remained in a neutral position. The bottom legremained stationary. The participant stopped at 30 degrees of hip abduction, and slowly returned to the starting position (Distefano et al., 2009; Earl, 2004). This exercise was performed in 3 sets of 10 repetitions (Bewyer & Bewyer, 2003; Ferber et al., 2011; Mascal et al., 2003). The therband was placed around the ankles. (See Figure 3.2)

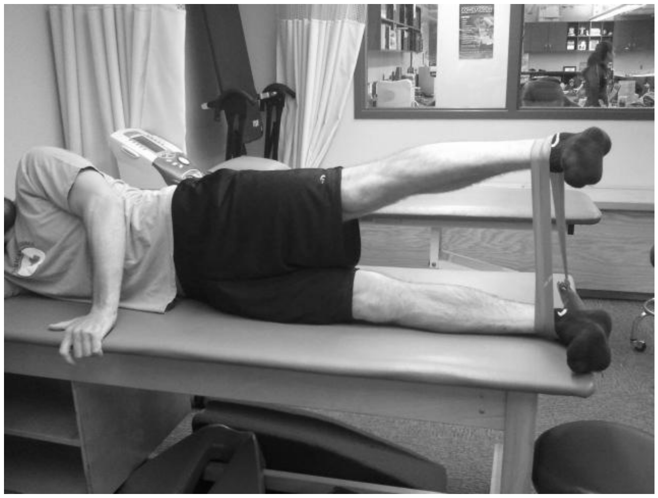

Figure 3.2: Side Lying Hip Abduction Exercise

The third and final exercise was the side-lying hip abduction with external rotation. This exercise was very similar to the side-lying hip abduction exercise in terms of patient positioning with the exception that during this technique, the top leg had about 10-15 degrees of external rotation added to it. Once the participant reached 30 degrees of hip abduction, they slowly returned to the starting position in a slow, controlled manner (Earl, 2004; Distefano et al., 2009). This exercise was performed in 3 sets of 10 repetitions (Bewyer & Bewyer, 2003; Ferber et al., 2011; Mascal et al., 2003). The therband was placed around the ankles. (See Figure 3.3)

All three exercises included a therband for overload. There were three different resistances that were used; yellow, red, and green. Therband resistance was determined during the exercise educational component of Session 1 by completing 10 repetitions of the exercises with the red therband. Participants self reported if the exercises were of moderate intensity. If intensity was too easy, the higher therband color was chosen. If exercise intensity was determined too high, or if exercise technique was compromised, the lower therband color was chosen. During each check in session, research assistants asked if the resistance changed, and made modifications using the same protocol if needed.

Figure 3.3: Side Lying Hip Abduction with External Rotation Exercise

3.5 PROCEDURES

Prior to data collection, this study was approved by the Institutional Review Board (IRB) at Michigan State University. Each participant completed an informed consent (see Appendix A) and healthy history questionnaire prior to participating in this study (see Appendix B). Participants wore comfortable athletic clothing that allowed the participant to perform the necessary exercises and the investigator to access the testing area. Only the participant, investigator, and research assistants were present in the testing area. Data collection took place in the Exercise Physiology Lab of IM Circle at Michigan State University. Participants were required to attend two testing sessions (60 minutes, 30 minutes) with the investigator and attended a check in meeting during week 2, 3, and 5 (15 minutes) with the research assistant who reviewed the exercise program and exercise technique.

3.5.1 Session 1

The participants' name, age, and side of their dominant leg were recorded. The dominant leg was determined by asking the participants what leg they would kick a ball with. Session 1 was set for baseline testing. Baseline testing was done for hip abduction and hip abduction with external rotation peak torques using the BioDex, respectively. Both the dominant and non dominant leg was tested.

To test hip abduction, participants were side-lying facing away from the dynamometer force sensor with the tested leg superior to the non tested leg. The knee of the tested leg was in extension and the opposite knee was bent at 90 degrees. The axis of the dynamometer was aligned perpendicular to the hip frontal plane of motion at the level of the greater trochanter. The tested hip was positioned at 30 degrees of hip abduction in a neutral rotated position. The pad of the dynamometer was placed just above the lateral knee joint line proximal to the lateral epicondyle. The participants' torso was stabilized with securing straps.

To test hip abduction with external rotation, participants were side-lying facing away from the dynamometer force sensor with the tested leg superior to the non tested leg. The knee of the tested leg was in extension and the opposite knee was bent at 90 degrees. The axis of the dynamometer was aligned perpendicular to the hip frontal plane of motion at the level of the greater trochanter. The tested hip was positioned at 30 degrees of hip abduction and 10-15 degrees externally rotated position. The pad of the dynamometer was placed just above the lateral knee joint line proximal to the lateral epicondyle. The participants' torso was stabilized with securing straps.

All muscular testing was done isometrically. Participants performed three warm up contractions with the muscular group being tested at 50%, 75%, and 100% of their maximum perceived effort. After a ten second rest period, the participants were asked to produce maximal voluntary isometric contraction. There were three trials performed for each motion tested, with a ten second rest period between each trial. (Piva et al., 2011) (See Figures 3.5 and 3.6).

Following the peak torque measurements, participants in the exercise program group were instructed and evaluated on the home program with the investigator. This included the exercise protocols as well as the home management and contact procedures between the participant and research assistants. An initial pain reading off a Likert scale with 0 representing no pain and 10 representing excruciating pain was taken.

3.5.2 Home Program Check-Ins

The home program was kept on a exercise program card that allowed the participants to keep track of the exercises performed and number of times per week they were performed (See Appendix C). During week 2, 3, and 4, as scheduled by the investigator, the research assistants checked in with the participants. The research assistants asked how many times per week the participants were able to perform the exercises, and also asked for the pain rating on the Likert scale with 0 being no pain and 10 being excruciating pain. They also had the participant perform 5 reps of each exercise to evaluate for proper technique.

3.5.3 Session 2

Baseline testing was performed for peak torque of hip abduction and hip abduction with external rotation in Session 1. Following the 6 week rehabilitation program, post-testing measurements were acquired using the same techniques for peak torque of hip abduction and hip abduction with external rotation. At this time, the final pain measurement on the Likert scale was taken.

3.6 STATISTICAL ANALYSIS/DATA MANAGEMENT

Means and standard deviations were calculated for descriptive statistics. Each dependent variable (i.e., peak torque hip abduction, peak torque hip external rotation) in this study was analyzed separately. Data was analyzed using paired sample t-tests. The level of significance was set at $p \leq .05$ and all analyses will be conducted using SPSS version 19.1 for Windows (SPSS Inc., Chicago, IL). In order to correct for multiple t tests, a Bonferroni comparison was performed to set the new p value at $p=.0125$.

H1. There would be increases in hip abduction strength in torque values for the dominant leg after a six week exercise program. A paired sample t-test was performed on peak torque of hip abduction.

H2. There would be increases in hip abduction strength in torque values for the non-dominant leg after a six week exercise program. A paired sample t-test was performed on peak torque of hip abduction.

H3. There would be increases in hip abduction with external rotation strength in torque values for the dominant leg after a six week exercise program. A paired sample t-test was performed on peak torque of hip abduction with external rotation.

H4. There would be increases in hip abduction with external rotation strength in torque values for the non-dominant leg after a six week exercise program. A paired sample t-test was performed on peak torque of hip abduction with external rotation.

H5. There would be a greater increase in hip abduction strength in torque values for the non-dominant leg versus the dominant leg after a six week exercise program. The results from both paired sample t-tests would be compared to determine.

CHAPTER 4

RESULTS

4.1 OVERVIEW

The purpose of this study was to determine if an exercise program (clam shells, side lying hip abduction, side lying hip abduction with external rotation) would create strength gains in torque values during measurement of side lying hip abduction and side lying hip abduction with external rotation with a BioDex System 3 over a period of six weeks. For clarity, the results section is separated into subject demographics, pre and post hip abduction strength of the non dominant leg, pre and post hip abduction of the dominant leg, pre and post hip abduction with external rotation strength of the non dominant leg, and pre and post hip abduction with external rotation strength of the dominant leg.

4.2 SUBJECT DEMOGRAPHICS

A total of 60 physically active college students from a large mid-western university between the ages of 18-35 volunteered to participate in the study (see Table 4.1). Thirteen subjects were unable to complete the study (three due to injury, 10 due to incompletion of second session); therefore, 47 subjects were used in the data set. There were 17 male subjects (36.2%) and 30 female subjects (63.8%) (age = 19.87 ± 1.87 years, 67.53 ± 3.65 inches, 151.85 ± 28.97 lbs). All were healthy individuals with no self-reported lower extremity injuries or surgery within the last six months, or hip surgery. All participants met the ACSM category of physically active, achieving at least 150 minutes of moderate intense activity per week. Of the subjects, none were self reported as left leg dominant, thus 47 (100%) were self reported as right leg dominant. The subjects completed the exercise program an average of 5.72 ± .949 days per week.

Table 4-1: Descriptive Statistics for Subject Demographics

	N	Minimum	Maximum	Mean	Std. Deviation
Years	47	18	26	19.87	± 1.87
Pounds	47	105	240	151.85	± 28.97
Inches	47	60	74	67.53	± 3.65
Days	47	4	7	5.72	± .95

4.3 RESULTS FOR SIDE LYING HIP ABDUCTION PEAK TORQUE

Subjects participated in a pre and post testing session. During the pre testing session, subjects were also educated on the exercise program that was to be performed for six weeks. Baseline peak torque testing at 30 degrees abduction was performed using a Biodex System 3 Dynamometer which included measurements for both the dominant and non dominant leg. In the case of this study, all subjects' dominant leg was the right and the non dominant leg was the left.

4.3.1 Side Lying Hip Abduction Peak Torque for the Dominant Leg

Subjects performed a Biodex test to measure side lying hip abduction. Consistent with other data analysis performed for hip strength, paired sample t-tests were conducted to determine side lying hip abduction peak torque (average peak torque/body weight) and testing occasions (pre vs post). In order to correct for multiple t tests, a bonferroni comparison was performed with the new p value set at $p=.0125$. Significant differences were noted within the testing occasions (mean RPreABD = 174.17 N/bW, mean RPostABD = 174.67 N/bW, $t = -3.996$, $p= .000$). However, it is noted that these differences do not make clinically significant gains (see Tables 4-3, 4-4). It is also noted that when compared to the non dominant side, the dominant side recorded a lower pre-test peak torque/body weight; however, made slightly larger gains when compared pre vs. post testing to the non dominant side (RPreABD = 174.17 N/bW, LPreABD = 174.22 N/bW RPostABD = 174.67 N/bW, LPostABD = 174.63 N/bW) (See Figures 4-2, 4-3, 4-4, 4-5).

Table 4-2: Descriptive Statistics for Side Lying Hip Abduction for the Dominant Leg

	N	Mean	Std. Deviation
RPreABD	47	174.17	± 31.97
RPostABD	47	174.67	± 32.03

***(measurements recorded as peak torque (N)/body weight (bW))**

Table 4-3: Paired Sample Statistics for Side Lying Hip Abduction of the Dominant Leg

	Paired Differences		T	Sig. (2-tailed)
	95% Confidence Interval of the Difference			
	Lower	Upper		
RPreABD- RPostABD	-.749	-.247	-3.996	.000

4.3.2 Side Lying Hip Abduction Peak Torque for the Non Dominant Leg

Subjects performed a Biodex test to measure side lying hip abduction for the non-dominant leg. Paired sample t-tests with bonferroni correction (p=.0125) were conducted to determine side lying hip abduction peak torque (average peak torque/body weight) and testing occasions (pre vs post) for the non-dominant leg. Results revealed significant differences within the testing occasions (mean LPreABD = 174.22 N/bW, mean LPostABD N/bW = 174.63, t = -3.952, p= .000). Again these differences do not represent clinically significant gains (see Tables 4-4, 4-5).

Table 4-4: Descriptive Statistics for Side Lying Hip Abduction for the Non-Dominant Leg

	N	Mean	Std. Deviation
LPreABD	47	174.22	± 31.93
LPostABD	47	174.63	± 32.20

***(measurements recorded as peak torque (N)/body weight (bW))**

Table 4-5: Paired Sample Statistics for Side Lying Hip Abduction of the Non-Dominant Leg

	Paired Differences: 95% Confidence Interval of the Difference		T	Sig. (2-tailed)
	Lower	Upper		
LPreABD-LPostABD	-.610	-.198	-3.952	.000

4.4 RESULTS FOR SIDE LYING HIP ABDUCTION WITH EXTERNAL ROTATION

4.4.1 Side Lying Hip Abduction with External Rotation Peak Torque for the Dominant Leg

Subjects performed a Biodex test to measure side lying hip abduction with external rotation. Paired sample t-tests (bonferroni corrected p=.0125) were conducted to determine side lying hip abduction with external rotation peak torque and testing occasions. Results indicated that there were significant differences within the testing occasions (mean RPreABDER = 174.23 N/bW, mean RPostABDER = 174.62 N/bW, t = -4.032, p= .000) although no clinically significant gains (see Tables 4-6, 4-7). It is also noted that when compared to the non dominant side, the dominant side recorded a higher pre-test peak torque/body weight; however, made slightly smaller gains when compared pre vs. post testing to the non dominant side (RPreABDER = 174.23 N/bW, LPreABDER = 174.06 N/bW, RPostABDER = 174.62 N/bW, LPostABDER = 174.65 N/bW) (See Figures 4-6, 4-7, 4-8, 4-9).

Table 4-6: Descriptive Statistics for Side Lying Hip Abduction with External Rotation for the Dominant Leg

	N	Mean	Std. Deviation
RPreABDER	47	174.23	± 31.97
RPostABDER	47	174.62	± 32.09

***(measurements recorded as peak torque (N)/body weight (bW))**

Table 4-7: Paired Sample Statistics for Side Lying Hip Abduction with External Rotation of the Dominant Leg

	Paired Differences		T	Sig. (2-tailed)
	95% Confidence Interval of the Difference			
	Lower	Upper		
RPreABDER-RPostABDER	-.590	-.197	-4.032	.000

4.4.2 Side Lying Hip Abduction with External Rotation Peak Torque for the Non Dominant Leg

Similar analyses as mentioned above were performed on the non dominant leg for side lying hip abduction with external rotation. Healthy participants exhibited significant differences within the testing occasions (mean LPreABDER = 174.06 N/bW, mean LPostABDER = 174.65 N/bW, t = -5.100, p= .000) but did not demonstrate clinically significant gains (see Tables 4-8, 4-9).

Table 4-8: Descriptive Statistics for Side Lying Hip Abduction with External Rotation for the Non-Dominant Leg

	N	Mean	Std. Deviation
LPreABDER	47	174.06	± 31.96
LPostABDER	47	174.65	± 32.16

***(measurements recorded as peak torque (N)/body weight (bW))**

Table 4-9: Paired Sample Statistics for Side Lying Hip Abduction with External Rotation of the Non-Dominant Leg

	Paired Differences – 95% Confidence Interval of the Difference		T	Sig. (2-tailed)
	Lower	Upper		
LPreABDER-LPostABDER	-.834	-.362	-5.100	.000

4.5 RESULTS FOR MEASUREMENTS OF PAIN PRE AND POST EXERCISE PROGRAM

For both sessions, subjects were asked to rate their current pain levels on a Likert scale (0 = no pain, 10 = extreme pain). A paired sample t-test was conducted to determine if there was a significant difference in pain levels pre and post program. Results indicated there was not a significant difference with pain levels pre and post program (t = -1.615, p = .113) (see figure 4-10).

Table 4-10: Paired Sample Statistics for Likert Scale Rating Pain

	N	Mean	Std. Deviation	Paired Differences – 95% Confidence Interval of the Difference		t	Sig. (2-tailed)
				Lower	Upper		
Pre Pain	47	.30	± .78	-.621	.068	-1.62	.11
Post Pain	47	.57	± 1.19				

CHAPTER 5

DISCUSSION

5.1 OVERVIEW

The purpose for the study was to determine if an exercise program performed over a six week period (clam shells, side lying hip abduction, side lying hip abduction with external rotation) would create strength gains in torque values during measurement of side lying hip abduction and side lying hip abduction with external rotation with a BioDex System 3. It was hypothesized that there would be an increase in torque measurements for both the dominant and non dominant legs. It was also hypothesized that after a period of six weeks, the non dominant leg would have larger increases in torque measurements than the dominant leg. The discussion section is organized into subsections. These include: a) hip abduction and hip abduction with external rotation peak torque measurements of the dominant and non dominant legs, b) utilization and clinical implications for an exercise program to create strength gains in hip abduction and hip abduction with external rotation, c) limitations of current study, d) future research implications, and e) conclusions.

5.2 ASSESSMENT OF HYPOTHESIS

There were five hypotheses for the current study. These were a) there would be increases in hip abduction strength in torque values for the dominant leg after a six week exercise program, b) there would be increases in hip abduction strength in torque values for the non-dominant leg after a six week exercise program, c) there would be increases in hip abduction with external rotation strength in torque values for the dominant leg after a six week exercise program, d) there would be increases in hip abduction with external rotation strength in torque values for the non-dominant leg after a six week exercise program, and e) there would be a greater increase in hip abduction strength in torque values for the non-dominant leg versus the dominant leg after a six week exercise program. Even though all p-values for the five hypotheses were p =.000, the hypothesis were rejected due to the insignificant clinical gains in peak torque. Specifically, college students only demonstrated a change of 1% increase in strength gains. Furthermore, when comparing the dominant to the non dominant leg, even with the small gains noted, the dominant leg measured with a greater increase than the non dominant leg.

5.3 PEAK TORQUE OF HIP ABDUCTION AND HIP ABDUCTION WITH EXTERNAL ROTATION FOR THE DOMINANT AND NON DOMINANT LEG FOLLOWING A SIX WEEK EXERCISE PROGRAM

While the current study's findings revealed a statistical significant difference in peak torque measurements of hip abduction for both the dominant and non dominant leg, clinically, there was not a large enough increase in the measurements to suggest a significant difference. In other words, there were minimal gains made in the strength of the hip abductors for both legs following the six week exercise program. When the dominant and non dominant legs were compared for differences in peak torque measurements for both pre and post program, it was revealed that the non dominant side tested pre program had a higher peak torque measurement than the dominant side. However, after the six week program was completed, the dominant side had a higher peak torque measurement compared to the non dominant leg. Therefore, the dominant leg had a larger increase in strength versus the non dominant leg.

Although the current study did not reveal clinically significant differences in strength gains following the six week program, the findings are similar to a previous research. In 2000, Fredericson and colleagues (2000) investigated strength gains produced after a rehabilitation program. There were 24 subjects all diagnosed with iliotibial band syndrome (ITBS). They were measured pre and post rehabilitation program by using the Nicholas Manual Muscle Tester. The runners were taken through a 6 week rehabilitation program with the focus on the gluteus medius. They were also administered NSAIDS, modalities, and discontinued all training. Following the 6 week protocol, results revealed that females increased their hip abduction torque values by 34.9% in the injured limb and males increased their hip abduction torque values by 51.4% in their injured limb. Furthermore, following the program, 22 out of the 24 runners returned to their running programs pain free and remained that way after a six month follow-up (Fredericson et al., 2000).

Similarly, Ferber, Kendall and Farr (2011) examined a three week protocol with two therband exercises on 15 runners diagnosed with patellofemoral pain syndrome (PFPS). The subjects were directed to perform 3 sets of 10 reps daily over a three week period. All subjects returned in 7-10 days for follow up on exercise technique. The subjects were allowed to continue to run on a regular basis. Results of the study revealed that there was a program completion rate of 6.2 days per week. Furthermore, isometric strength testing revealed a 32.69% increase, and a 43.10% decrease in pain when compared to baseline values (Ferber et al., 2011). However, there was not a significant difference in comparison to the control group which is more indicative of our study participants. The greater significant gains in the aforementioned studies could be due to their subjects being injured, therefore, one would assume that they would make considerable gains following a rehabilitation program. Our study used healthy active college students which possibly resulted in minor gains. Moreover, researchers have correlated gluteus medius weakness to injury (Boling et al., 2009, Fredericson et al., 2000, Ireland et al., 2003, Niemuth et al., 2005). Specifically, previous research has shown greater differences in baseline strength of the gluteus medius when comparing the injured to non injured leg.

Another possible explanation between the current study and other studies could be due to the type of overload/exercises selected. For the current study, rehabilitative therbands and side lying exercises were used. Side lying exercises were chosen to stay consistent with the way the subjects were being tested with the BioDex unit. In addition, these exercises were chosen based upon results of Distefano and colleagues who reported that side lying hip abduction and clam shells produced the most EMG feedback (Distefano et al., 2009). Previous researchers used single leg stance exercise and exercises with abduction/internal rotation which may have produced greater strength gains (Earl, 2004)

The current study also examined differences in strength gains between hip abduction and hip abduction with external rotation. Based upon the results, (Difference RABD = + .50 Difference LABD = + .41 Difference RABDER = +.39 Difference LABDER = +.59) It was found that during hip abduction, the dominant side made greater strength gains than the non dominant side. However, during hip abduction with external rotation, the non dominant side made greater strength gains than the dominant side. When comparing if hip abduction or hip abduction with external rotation made more significant strength gains, no significance was found. Furthermore, the three exercises selected for this study (clam shells, side lying hip abduction, side lying hip abduction with external rotation) did not suggest that these exercises resulted in more strength gains for either hip abduction or hip abduction with external rotation. Therefore, the current study suggested that between the 3 exercises of clam shells, side lying hip abduction, and side lying hip abduction with external rotation, none would make a significant difference in strength gains between hip abduction or hip abduction with external rotation.

5.4 UTILIZATION AND CLINICAL IMPLICATIONS FOR AN EXERCISE PROGRAM TO CREATE STRENGTH GAINS IN HIP ABDUCTION AND HIP ABDUCTION WITH EXTERNAL ROTATION

Although the current study does not have clinically significant results for increases in hip strength, it still provides athletic trainers, physical therapists, strength and conditioning specialists and coaches important information regarding strengthening protocols for hip abduction. The protocol of the current study could potentially help injured athletes through a rehabilitative process as well as non injured athletes with sports performance.

In essence, the current study suggests that while the protocol did not produced clinical strength gains in healthy collegiate individuals, one could imply that with the statistical gains and previous research demonstrating more significant baseline strength deficits in injured athletes that the protocol could be of value to them. Furthermore, a clinician could ideally use the current study's protocol as a starting point in their rehabilitative prescription as the loads are small, and as the pain from injury decreases and minimal strength gains are noticed, the clinician could increase the load and change the exercises to a more weight bearing method. However, further research is warranted to determine if this protocol helps injured athletes gain hip strength.

5.5 LIMITATIONS OF STUDY

There are several limitations of the current study. First, the timing of the six week program went into spring break for Michigan State. All subjects who participated were students of MSU, therefore, program home check in sessions were unable to be completed this week. In addition, the exercises were documented by writing down the date performed on a workout card. While it is hoped that the subjects recorded and actually performed the exercises, it cannot be guaranteed. Although there was a good number of subject participants (N=47) there was an unequal number of males to females (36.2% to 63.8%, respectively). As a result, sex was not equally represented and therefore, results may apply more to females than males. Another limitation was peak torque was measured in a side lying position; however, this is not a functional position to running or other sport specific activities. This is not a direct representation of the sport specific skills used in activity, but rather a tool to represent the demands placed on the body during these activities. Finally, only collegiate subjects at MSU were used for this study. Thereby limiting the specificity of the current findings to other geographical locations.

5.6 FUTURE RESEARCH

As previously mentioned, the current study has led to the possibility of several future studies. One potential future study could examine sex differences in hip strength gains. A study by Ferber et al. (2003) examined sex differences in lower extremity and found that females exhibit a greater peak hip adduction, internal rotation and knee abduction compared to men. Other studies have also indicated that females exhibit a greater Q angle, which could lead to a higher chance of injury (Cichanowski et al., 2007; Ferber et al., 2011; Fredericson et al., 2000). This may determine if males or females require different protocols of various exercises to achieve strength gains. Another study could potentially take the data presented in the current study and compare it to a study examining strength gains over a six week period with a BioDex only using single leg stance exercises with a pulley weight machine as overload. This would allow one to compare different types of overload principals to levels of strength gain. Further studies could investigate injured athletes compared to a control group using both side lying and single leg stance protocols over a greater period of time (14 weeks). This study would allow researchers to examine an entire progression of rehabilitation and potentially greater increases in strength with the allowance for more muscular facilitation over time to occur.

5.7 CONCLUSIONS

Overall, this study illustrated there were no clinically significant differences in strength gains of hip abduction and hip abduction with external rotation after a six week side lying exercise program. Results of this study and other studies will allow clinicians to determine different types of exercise protocols and overload to place on the client for the objective goal of strength gain over time. It will also allow them to consider potentially trying other types of gluteus medius exercises (single leg stance, abduction with internal rotation) for aims of increasing strength in hip abduction and hip stabilization.

APPENDICES

APPENDIX A

Health History Questionnaire

GLUTEAL AND HIP MUSCLE STRENGTH OF PHYSICALLY ACTIVE COLLEGIATE STUDENTS FOLLOWING A SIX WEEK EXERCISE PROGRAM

MICHGAN STATE UNIVERSITY
38 IM SPORTS CIRCLE
HEALTH HISTORY QUESTIONNAIRE

Every participant must fill out this questionnaire and sign a release before he/she will be allowed to participate in an
exercise program or BioDex measures of muscular activity.

Name______________________________________ Phone_________________________
Date____________________

Address____
Date of Birth__________________ Age_______

Email______________________________________ Ht______________ Wt_____________

1. Has your doctor ever said you have heart trouble?
Yes No

2. Have you ever had chest pain or heavy pressure in your chest as a result of exercise, walking, or other physical activity, such as climbing a flight of stairs? (Note: This does not include the normal out-of-breath feeling that results from vigorous exercise)
Yes No

3. Do you often feel faint or experience severe dizziness?
Yes No

4. Has a doctor ever told you that you have high blood pressure or diabetes?
Yes No

5. Have you ever had a real or suspected heart attack or stroke?
Yes No

6. Do you have any physical condition, impairment or disability, including any joint or muscle problem that should
be considered before you undertake an exercise program?
Yes No

7. Have you ever taken medication to reduce your blood pressure or cholesterol levels?
Yes No

8. Are you excessively overweight?
Yes No

9. Is there any good physical reason not mentioned here why you should not follow an exercise program even if you wanted to?
Yes No

If you answered YES to one or more questions, and if you have not recently done so, consult with your physician BEFORE entering an exercise program or participating in an exercise test. After medical evaluation or consultation, have your physician sign this form indicating your suitability for the following activity:

____
____
____
____
_______________________ _______
____

Signature of Physician **Date** **Phone Number**

Exclusion Criteria Questionnaire

Please answer the following questions regarding your health history.

Have you: (circle your response)

Had a lower extremity injury in the last six months? Y N

Had a lower extremity surgery in the last six months? Y N

Ever had a hip surgery? Y N

Do you obtain at least 150 minutes of moderately intense activity per week? Y N

Is there any reason that you can identify that you would not be able to complete the exercises related to this study? Y N

Thank you for your participation. Answers to this questionnaire will remain confidential. If you are not selected for this study, or choose not to participate, your questionnaire will be shredded.

Signature: ____________________________________

Date:______________________

APPENDIX B

Informed Consent Form

GLUTEAL AND HIP MUSCLE STRENGTH OF PHYSICALLY ACTIVE COLLEGIATE STUDENTS FOLLOWING A SIX WEEK EXERCISE PROGRAM

Informed Consent

For questions regarding this study, Please contact:
Tracey Covassin, Ph.D., ATC
Department of Kinesiology
Michigan State University
Phone: (527) 353-2010
E-mail: covassin@msu.edu

OR

Kathleen Scott, ATC
Department of Kinesiology
Michigan State University
Phone: (847) 529-1633
E-mail: scottk19@msu.edu

For questions regarding your rights as a research participant, please contact:
Michigan State University's Human Research Protection Program
408 West Circle Drive #207
Michigan State University
East Lansing, MI 48824
E-mail: irb@msu.edu
Phone: (527) 355-2180
Fax: (517) 432-4503

Purpose:

The purpose of this study is to determine if an exercise program (clam shells, side lying hip abduction, side lying hip abduction with external rotation) will create strength gains in torque values during measurement with a BioDex System 3 over a period of six weeks. This study will use the BioDex System 3 Dynamometer to determine hip strength.

Consent:

You have been selected to be a participant in this study because you are a physically active individual who accumulates at least 150 minutes of moderate-intensity exercise per week. Your participation in the research study is voluntary. You have the right to say no. You may discontinue participation in the study at any time without penalty. You may change your mind at any time and withdraw from the study. You may choose not to answer specific questions or to stop participating at any time.

General Experimental Procedures:

Your participation in this research study will consist of one 60 minute session, one 30 minute session and three 15 minute sessions. You will not be compensated for your participation in this study. During the 60 minute session the therband exercises will be demonstrated for you and you will have a chance to practice these exercises. You will also be measured for baseline strength via the BioDex Dynamometer. An athletic trainer will then prepare you for measurement of strength on the BioDex Dynamometer. You will be side-lying on the machine. You will do 3 sets of 10 exercises for three different therband exercises (clam shells, side lying hip abduction, side lying hip abduction with external rotation) for 6 weeks. During the three 15 minute sessions (2, 3, and 4 weeks into program) you will be evaluated on progress and verify your exercise form. After six weeks, you will come back and do a 30 minute session where you will be re-evaluated for strength gains via the BioDex Dynamometer.

Possible Risks:

It is impossible to completely eliminate the risk of injury during physical activity. However due to the nature of the study the risks are minimal. There is potential for minimal muscular soreness during or after the study as a result of completing the exercises and having strength tested. A certified athletic trainer will be present during all sessions. There will be a phone easily accessible during the study to contact emergency medical services if the need arises. Please be assured that you may choose not to answer certain questions and still continue to participate in this study. **All answers are strictly confidential and will not be released to anyone.**

Benefits:

You will directly benefit from participation in this study. You will learn and perform exercises to increase gluteus and hip strength. This study will contribute to understanding the benefits of various exercises for the gluteus and hip muscles.

Confidentiality/Anonymity:

Your participation in this study is completely voluntary. The only people who have access to your answers are the researchers and Institutional Review Board. Your identity and information recorded during the study will remain confidential. Confidentiality will be protected by; (a) results of this study may be published or presented at professional meetings, but the identities of all research participants will remain anonymous; and (b) all data will be stored in a computer that is password protected, as well as all surveys will remain in the researchers office under double lock and key for 3 years. Your privacy will be protected to the maximum extent allowable by law. You may also discontinue participation at any time without penalty. Your participation in this research project will not involve any additional costs to you or your health care insurer.

Disclaimer/Withdrawal:

If you are injured as a result of participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. You may contact *Dr. Tracey Covassin at 517-353-2010* with any questions or to report an injury.

Institutional Contacts:

If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher *Kathleen Scott at 847-529-1633 or e-mail scottk19@msu.edu or regular mail at Department of Kinesiology, Michigan State University, East Lansing, MI 48824.*

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at Olds Hall, 408 West Circle Drive #207, MSU, East Lansing, MI 48824.

Your signature below indicates your voluntary agreement to participate in this study.

I, ____________________, have read and agree to participate in this study as described above.
(Please Print Your Name)

___________________________________ ________/_________/_________

APPENDIX C

Take Home Program

MICHIGAN STATE UNIVERSITY
6 WEEK EXERCISE PROGRAM CARD

EXERCISE: CLAM SHELL W/ THERBAND (3 SETS 10 REPS)									
WEEK 1									
WEEK 2									
WEEK 3									
WEEK 4									
WEEK 5									
WEEK 6									
EXERCISE: SIDE LYING HIP ABDUCTION W/ THERBAND (3 SETS 10 REPS)									
WEEK 1									
WEEK 2									
WEEK 3									
WEEK 4									
WEEK 5									
WEEK 6									
EXERCISE: SIDE LYING HIP ABDUCTION WITH EXTERNAL ROTATION W/ THERBAND (3 SETS 10 REPS)									
WEEK 1									
WEEK 2									
WEEK 3									
WEEK 4									
WEEK 5									
WEEK 6									

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