Outcomes of an Isolation Intervention Program To Increase Gluteus Medius Strength

by Leslie Taylor

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This thesis represents my own work in accordance with all applicable Department of Health and Human Performance and university guidelines and expectations for intellectual work.

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Abstract

Gluteus medius weakness is overlooked in many different cases, therefore an intervention program to increase the strength of this muscle should be implemented by healthcare professionals. In a six-week study, the goal was to discover if an intervention program for the gluteus medius would effectively increase the muscle's strength. Ten healthy subjects were asked to participate three times per week in an at-home exercise program that isolated the gluteus medius. Every other week the subjects were measured with a force dynamometer break test. At the end of the study, a group difference was visibly seen from the baseline results to the final results. This difference was analytically confirmed with p-values of .0001 for both the left and right GMED muscle groups. Consequently, this affirmed the main hypothesis that an at-home exercise program would produce GMED strength gains within six weeks. The results of this study point to the efficacy of an at-home exercise program, which could be implemented by healthcare professionals, and how it could possibly benefit sufferers of a weak GMED.

Chapter 1 – Introduction

Gluteus medius weakness is an issue that should be researched thoroughly as a medical issue. The reason that I found this study important was because of my personal clinical observation at Mountain Land Physical Therapy. Spending over 150 hours of observation under two respected physical therapists at this clinic has led me to witness a plethora of patients with joint replacements, physical pain, poor posture, deficient walking gaits, and various other problems that are remedied by therapeutic activities. Of all the patients that I have seen assessed in this clinic, only one had sufficiently strong gluteal muscles, and consequently was a very athletic teenager. A common reason for gluteus medius (GMED) weakness is that people overcompensate with the tensor fascia latae (TFL) femoris muscle, which is also a hip abductor. Therefore, this leads me to believe that if an easy, at-home program could be shown to strengthen the gluteal muscles, physical therapists, coaches, doctors, etc. should suggest that sufferers of joint problems, pain, and other lower extremity issues, to apply this program to activities of daily living (ADL's). In addition, I have observed many of my peers' poor performance with simple GMED strength tests. The simplest test that can assess gluteal strength is the single-legged squat, where one lowers the body to the lowest position possible, and raises the body up again, while maintaining balance. Very few people that I have observed performing this test have been able to demonstrate sufficient hip strength. Many studies support that weak hip musculature (gluteal muscles, in addition to the lateral rotator group, the adductor group, and the iliopsoas group) contributes to other problems. Due to a variety of previous studies and my personal clinical observations, I suspect that weak gluteal muscles may contribute to joint and pain issues.

It is my assumption that GMED weakness is overlooked in the diagnosis of hip and knee problems, as well as postural issues, therefore an intervention program to increase the strength of this muscle should be implemented by health professionals in their practices to help prevent and remedy GMED problems. Since strengthening the GMED may improve posture and walking gait, reduce pain, and help to prevent future injury, I strongly feel that conclusive research needs to be performed to demonstrate that the GMED needs to be strong to prevent injury and remedy overcompensation of the TFL.

The main goal of this study was to discover if an intervention program for the GMED would increase the muscle's strength. Over a six-week period, subjects participated in an at-home program that isolated strengthening the GMED as much as possible. One expectation I had for this study was that an improvement in the GMED strength would be seen at least by the conclusion of the fourth week. After that point, I expected the subjects to continue to increase more slowly in strength gain by the completion of the study. I was not confident that the subjects would increase in strength by the end of the second week of the study, but I assumed increases would definitely be seen at the end of weeks four and six. In addition, the efficacy of the at-home exercise program would be assessed if the subjects increased in GMED strength. Therefore, this would indicate whether a GMED intervention program would be profitable for physical therapists, coaches and doctors to implement in their patients' ADL's. Due to my inferences and questions on this issue, many research questions and hypotheses became plausible variables to be considered for this study.

The research questions that were posed for this six-week study were:

1. Will a gluteus medius strength intervention program increase the strength of the muscle?

2. Is there a significant difference of strength gained between the legs?
3. Is there a significant difference in the strength gains at each of the 2 week marks within the 6-week at-home exercise program?

The hypotheses for this study were the following statements:

1. If subjects complete the prescribed 6-week at-home exercise program, then an increase in GMED strength should be observed.
2. By the end of the 4th week, strength gains in the GMED should be observable.
3. Strength gains for the GMED should be bilateral.

For purposes of clarifying the information in this study, several operational definitions are provided below:

Gluteus Medius (GMED) – Refers to a broad, thick, fan-shaped muscle that is situated on the outer surface of the pelvis. The GMED is covered by the gluteus maximus and gluteal aponeurosis, separating it from the superficial fascia and integument. The GMED is involved in abduction and external rotation of the hip.

Gluteus Maximus (GMAX) – This muscle is a thick, fan-shaped muscle, located near the pelvis that acts to extend the upper leg and externally rotate the hip.

Gluteus Minimus (GMIN) – The smallest muscle in the gluteal group whose action abducts the thigh.

Tensor Fascia Latae (TFL) – Refers to a muscle of the thigh that starts at the anterior, outer iliac crest, and the outer surface of the anterior superior iliac spine. The TFL is situated between the gluteus medius and, inserted between two layers of the iliotibial band. The TFL is involved in abduction and medial rotation of the hip.

Muscle Strength – Refers to the amount of force a muscle can produce with a single maximal effort. To increase muscle strength, the muscles contract, which causes minor injuries to occur in the muscle fibers, and the muscle consequently heals stronger than it was before.

At-Home Exercise Program – The activity program that subjects will follow in the study as described in detail in Chapter 3. After the first two weeks, the at-home exercise program will increase in intensity and type, as the researcher will provide and demonstrate the exercises to the subjects.

Force Dynamometer – This is a portable measurement device used to measure force, torque or power up to 250 pounds. A force dynamometer can be used to evaluate physical status, performance, and task demands by applying a force to a lever on the arm, leg, hand or back, through which a cable measures and converts the moment of force by multiplying the perpendicular distance from the force to the axis of the level. It is used in various therapies for client assessment, where maximum muscle strength quantification is required.

Break Test – "A test of a person's muscle strength by application of resistance after the person has reached the end of a range of motion. Resistance is applied gradually in a direction opposite to the line of pull of the muscle or muscle group being tested. The resistance is released immediately if there is any sign of pain or discomfort" (25).

Healthy subject – A subject that is pain-free, meaning that pain related to injury or chronic pain has not been reported in the last year.

Chapter 2 – Theoretical Background

. With the medical world constantly changing and discovering innovative, improved methods of providing health care, I find it my place to be a part of this research and to help implement better treatment. By participating in clinical observation and research, my study in conjunction with others, will hopefully "provide physical therapists and other health care professionals with information critical to guiding therapeutic exercise interventions for people seeking to regain or retain" (12) functions.

Through clinical observation as an undergraduate student seeking a Health and Human Performance degree, I have discovered an interest in the GMED muscle, the role it has in human function, and the interventions to strengthen this particular muscle. Through this study and future research, the ultimate goal will be to discover a standardized intervention protocol for patients to follow in order to improve functional ability and reduce disability compared to the current physical therapy interventions (26).

As a basis for this study, it is crucial to understand the GMED muscle and to compare it to the surrounding hip musculature as it relates to the complete function of this muscle. The fan-shaped GMED lies deep to the gluteus maximus (GMAX) and superficial to the gluteus minimus (GMIN). The muscle is comprised of three distinct parts, the anterior, posterior, and middle portions, each with their own independent nerve supply (15). It attaches proximally to the external surface of the ilium between the anterior and posterior gluteal lines, and attaches distally to the lateral surface of the femur's greater trochanter (20). The GMED works to stabilize the hip in the frontal and transverse planes, as well as prevent the sagging of the pelvis on the unsupported side in the stance phase of the walking gait (17, 19).

In addition the GMED has been shown to play an important role in pelvic stability during weight bearing exercises (16). One study suggests “Of all the hip muscles, the GMED may have the largest impact on lateral as well as frontal mobility and stability of the hip” (23). The functional actions of the GMED are primarily to abduct the hip and medially rotate the thigh. Between sexes, it is important to note that a study found that females have less hip external rotation and abduction strength than men (4). Traditionally the GMED is labeled primarily as a hip abductor, aiding in the prevention of hip adduction, as it is two times larger than the GMIN and three times larger than the TFL. These three hip muscles comprise 15.3% of the entire muscle mass of the hip joint. The best position for hip abduction, utilizing the GMED, is between 0 and 40 degrees of flexion. Moving beyond 40 degrees of flexion to 90 degrees, the three-heads of the GMED become less efficient and the small external rotators of the hip take over this abduction movement (23, 24). In relation to the entire stabilizing musculature, the GMED works with the upper and lower trapezius and hip rotators to stabilize the core. Muscle size and symmetry are important in stabilizing the core for efficient function (15). “The core is important to provide local strength and balance and to decrease back injury. In addition, since the core is central to almost all kinetic chains of activities, control of core strength, balance and motion will maximize all kinetic chains of upper and lower extremity function” (21). In summary, the GMED is an abductor of the hip and a medial rotator of the thigh that functions in stabilization of the hip, balance, proper maintenance of the gait, pelvic stability and proper posture, and core stabilization.

Since the GMED and TFL are both involved in hip abduction, with the GMED being three times larger than the TFL, it would be assumed that the GMED takes on most of the action. However, the TFL overcompensates for the GMED in the abduction task, thus creating a weak

GMED. Due to the anatomical position of the TFL and its superiority in abduction, this muscle easily overcompensates for the GMED. A weak GMED muscle has been associated to a plethora of injuries, pains, diseases, and other maladies. The largest sign of a weak GMED can be observed by the Trendelenburg gait, which is an abnormal walking gait caused by the weakness of abductor muscles (21). This gait is observed in the stance phase, when the weakened abductors muscles allow the pelvis to tilt down on the opposite side and the trunk consequently lurches to the weakened side to attempt to maintain a level pelvis throughout the gait cycle. This weak hip musculature creates a kinetic chain throughout the body that triggers reduced joint stability and mechanical shock absorption, which may predispose joints to osteoarthritis. Weak muscles "cannot produce enough strength to stabilize the knee and to prevent overload during the amortization of the mechanical impact during gait" (1).

Studies have linked abnormal hip musculature activity and hip osteoarthritis as the GMED provides joint and postural stability when challenged in the mediolateral direction. Osteoarthritis of the hip is a degenerative joint disease that leads to a loss of cartilage and subsequent subchondral bone stress. Due to this loss, a muscle imbalance is created in the GMED as a result of hip osteoarthritis (10, 15, 25).

An additional condition that has been related to a weak GMED is low back pain. "Myofascial trigger points in the gluteus medius are a commonly overlooked source of low back pain" (20). These often misdiagnosed myofascial trigger points are painful, overly-agitated areas in muscles that cause pain, stiffness, and limit one's range of motion. Pain is often deferred to other parts of the body, and may appear far from the original location, thus low back pain emerging as a result of GMED myofascial trigger points. Low back pain is a very common musculoskeletal problem that many studies have linked to hip strength (5, 26). Poor motor

control or inefficient active stabilization of the GMED and other core stabilizing muscles may cause a kinetic chain effect to the central nervous system, hence leading to low back pain. Therefore, “muscle activation patterns at the hip may be a useful addition for screening individuals to identify those at risk of developing low back pain” (13).

The next phenomenon that has been linked to a weak GMED is patellofemoral pain syndrome (PFPS). PFPS is one of the most common causes of knee pain in the United States and covers a range of vague symptoms of anterior kneecap pain that is in, under or behind the patella. The pain typically occurs with activity and often worsens when descending steps or hills, or after sitting for long periods of time. It is assumed that the patella tracks incorrectly in this syndrome due to weak hip musculature (9). “Inability of the GMED to eccentrically control femoral internal rotation and vastus medialis oblique inhibition may both lead to excessive lateral tracking of the patella within the trochlea of the femur” (16). Aside from the primary Trendlenburg gait, GMED weakness is attributed largely to PFPS.

As discussed above, a kinetic chain occurs from muscle weakness at the core to more distal injuries in the body. Ankle injury appears to not be restricted to the ankle itself, but has been seen to proximally change postural sway and hip abductor muscle strength. Studies have found diminished values of generating-torque in lower limb muscles when testing ipsilateral hip abduction. “This weakness noted with isokinetic testing suggests that inversion ankle injury may encompass more than an isolated, singular joint pathology” (6). Especially in females, anterior cruciate ligament (ACL) injuries are a common incident that has led to preventative programs, as well as surgery and rehabilitation after an injury has occurred. The activation muscles, the quadriceps, the hamstrings, GMED, and GMAX, associated with ACL loading, are important factors for ACL injury. Studies have demonstrated that the insufficient muscle activation patterns

may put individuals at a greater risk for ACL injury (8, 17). As discussed above, several issues point to how a weak GMED may contribute to hip, knee, and ankle problems, postural and walking gait troubles, and low back pain.

Many problems seem to be related to a weak GMED, therefore interventions to strengthen and decrease this muscle imbalance seem warranted. Programs that integrate balance, stretching, and strengthening exercise affect pain, function, and muscle activation patterns the best. In addition, weight-bearing rehabilitation programs are more functional than non-weight bearing exercises, as multi-joint movement is required, simulating proprioceptors and aiding a functional pattern of muscle recruitment (9). “Weight-bearing exercises are frequently used to train and strengthen muscles of the hip. These exercises have been advocated in the rehabilitation of a variety of hip and knee dysfunctions” (17). Therefore, the broad spectrum of exercises suggested to strengthen the GMED include walking, elliptical training, lateral step-ups, strength-training, dynamic exercises, and core stabilization exercises. Walking simulates gait and elliptical trainers emulate gait, both of which have provided data to guide therapeutic use of these exercises (12). Lateral step-ups have been shown to provide greater activation of the GMED compared to forward step-ups, which is why I will use them as a weekly exercise in this study (22, 26). Other exercises, such as strength training, have shown that exercised muscles will experience adaptive changes. Highly specific training effects have led to the widely accepted physiological principle, the specificity of training, as increases in myokinase activity and fast-twitch fiber area have been observed (2). Dynamic exercises, which can be described as performing exercises on an unstable surface, have also been shown to increase the challenge on the GMED, thus increasing strength gains. Balance cushions, dyna disks, and Airex cushions all provide a variety of dynamic surfaces that single limb exercises can be performed on. In

addition, single limb exercises require greater GMED activity than a double limb stance does (17). These last exercises focus on core stabilization, concentrating on the intrinsic needs for flexibility, strength, balance, and the function of the core in relation to its role to the GMED and other muscles. “Progression for lower extremity rehabilitation includes forward and side lunges, integrated trunk rotation/hip rotations, and knee flexion/extensions with trunk rotations” (21). Therefore, in my study, I should essentially progress subjects from static exercises to dynamic exercises, building a base of stability and force generation. Since this study is limited to a six-week time frame, not all of the above exercises can be implemented, suggesting further research in this area.

A few different ways to measure GMED strength are available. The most common way to measure the activity of the GMED muscle is to use surface electromyography (EMG). Electromyography detects the electrical potential generated by muscle cells when electrically or neurologically activated. An EMG is used to quantify muscle activation and the signals can be analyzed to identify medical abnormalities, activation level, recruitment order, or the biomechanics of human movement (16). This is the optimal way to measure GMED strength and activation, but since access to an EMG is not available for this study, another type of measurement, called the break test, will be used. This manual muscle test can be used by assessing with personal strength or using a mechanical device to measure pounds of force generated. The subject is placed in the optimal range of motion for the muscle being measured (11). In many therapy settings, a mechanical device is not needed to measure the strength, as it is simply a functional test of the patient that the therapist can assess by using personal strength. The break test is “a test of a person's muscle strength by application of resistance after the person has reached the end of a range of motion” (24).

For this study, I expect to see GMED strength gains at least by the fourth week, and certainly by the completion of the six-week study. Many muscle strength programs utilize a training length of four weeks for research projects. The four week point has demonstrated significant strength improvements across many studies (18). Many authors over the years have indicated that neural adaptations are the primary mechanisms that influence muscle strength change over the first four weeks of training. “Neural adaptations that occur with training have been described as increased motor unit recruitment, increased motor unit synchronization, and enhanced inter- and intramuscular coordination, which are adaptations due in part to lowering of neural inhibitory reflexes” (14). As discussed earlier, these neural adaptations likely occur as a result of the ability of the central nervous system to respond to changes in functional demands. However, beyond four weeks of training it is presumed that peripheral and structural changes are responsible for any additional strength gains (3).

As I set out to study the outcomes of an isolation intervention program to increase GMED strength, it is important to know what will be expected as far as compliance with subjects. In general, one would assume that there will always be subjects who are not available for various reasons on the data collection days, and subjects who will be non-compliant with the study if not under constant supervision. A study showed that 47% of active participants were fully compliant with an at-home exercise program (7). Consequently, since I will only observe the subjects perform the exercise program once every two weeks, it is presumed that only half of the participants will be fully obedient to completing the at-home exercise program three times per week.

Chapter 3 – Methods and Procedures

This six-week study will be designed to discover the outcomes of an isolation intervention program for the GMED (It is important to note that the exercises cannot completely isolate the GMED muscle). The goal during the 6-week period is for 10 subjects to participate in an at-home exercise program that will strengthen and increase mass (not observable for purposes of this study) in their GMED muscles. During the initial meeting, the baseline strength for the GMED was determined in both legs with a break test utilizing the force dynamometer (procedure described later in this chapter). In addition, the subjects signed the Informed Consent Form at the initial meeting (See Appendix 1).

The mean age of the subjects, 5 males and 5 females, was 23.2 ± 2.7 years. The subjects were picked out of convenience, as friends or acquaintances of the researcher. However, to be a part of the study the subjects had to report no pain or injury currently or in the past year. Exclusion criteria for the subjects included a past history of back pain, knee injury, or hip injury.

Throughout the six weeks, the subjects performed exercises that the researcher generated under the guidance of a physical therapist. The subjects were instructed to complete the at-home exercise program three times a week for approximately 10 minutes in order to strengthen their gluteal muscles. At the end of the second, fourth, and sixth week, each subject's strength was measured again in both legs as a result of performing the at-home exercise program. The format for the at-home exercise program and bi-weekly measurements was as follows:

Week 1: Meet with subjects for the initial meeting. Researcher discussed the project with the subjects and answered any questions. The subjects signed the Informed Consent Form. The researcher situated the subjects in the correct position to isolate the GMED group, informing the subject as to what should be felt and assisting in positioning the body. Baseline measurements

were taken using a force dynamometer break test three separate times on each leg. The at-home exercise program requirements and procedures were discussed between the subjects and researcher, as well as demonstrated by the researcher. The subject was given an illustrative and narrative sheet with the at-home exercise program. The at-home exercise program was conducted once through with subject. At the end of the meeting any questions or concerns were discussed between the subject and researcher. (See Appendix 2)

End of Week 2: Meet with subject and perform measurement with force dynamometer break test to measure the strength of the GMED on both sides of the body three separate times. The researcher discussed an increase in intensity and type of the at-home exercise program, as well as providing a new exercise sheet. Once again, the new at-home exercise program was demonstrated by the researcher. The new at-home exercise program was performed once through with subject. Any questions or concerns regarding the study were discussed between the subject and researcher. (See Appendix 3)

End of Week 4: This third meeting with the subject was very similar to the second meeting. The subject performed three individual tests per leg to measure the strength of the GMED. No differences were made in the at-home exercise program. The subject and researcher performed the at-home exercise program once-through during this meeting to revisit the exercises. At the end of the meeting any questions or concerns were discussed between the subject and researcher.

End of Week 6: This was the final meeting with the subjects. The researcher measured the subject's GMED strength with a force dynamometer break test on both sides of the body three separate times. Any outstanding questions or concerns that the subject had were answered by the

researcher. Researcher discussed information with client on how to maintain and continue strength gains of the GMED muscles.

Throughout the study, the strength of the subjects' legs was measured by using a force dynamometer. The researcher instructed the subject to lie on a flat, firm surface on their side, with the body in alignment and the pelvis tilted slightly forward. The leg closest to the ground is bent at a 90 degree angle, while the other leg is kept in a straight line with the body. By keeping this alignment and tilting the pelvis forward, the subject is forced to utilize the GMED and not overcompensate with the TFL muscle. A force-dynamometer break test measures strength from the subjects' optimal range of motion, where resistance is then applied in a direction opposite to the line of pull of the muscle group. Consequently, this isolated position allows for fairly accurate measurement of a person's GMED muscle strength. The procedure that was followed for each individual test of GMED strength was conducted strictly by the researcher to reduce other measurement error. The researcher placed the force dynamometer in the middle of the subject's calf at the optimal range of motion for the limb, and proceeded to push down on the force dynamometer as the subject resisted this resistance. This attempt to not "break" against the resistance was digitally read as pounds on the force dynamometer. Three separate tests for each leg were used each time, with at least 15 seconds rest between the next break test. The average of the three tests was then used as the result for the GMED muscle strength for that measurement time. It is important to note that this position isolates mostly the gluteus medius strength; however other muscles of the gluteal group are incorporated, indicating the inclusion of the GMAX and GMIN in the strength measurement. See the following pictures that give an example of both the force dynamometer and the break test.

Chapter 4 – Results

At the beginning of the study, I established the baseline data for the strength of the GMED in each leg. In general, the subjects progressed each week in GMED muscle strength with significant increases seen at the end of weeks four and six. At the conclusion of the study, all of the subjects increased in strength bilaterally for the GMED. These results demonstrate that a difference was seen in GMED strength from the baseline data to the final results. In the following paragraphs, each subject's results will be presented, as it is important to note that in physical therapy, and the medical world, that every person is a case by case study. In the end, an overall summary of the group data will be discussed that exhibits two paired t-tests and general group information.

The first subject exemplified consistent strength gains bilaterally in the GMED during the six week study. Subject 1's largest strength gains were seen at the end of week 2 and week 6, where a 7-11 pound increase in force generated was seen. At the end of week 2, the subject gained 8.5 pounds of strength in the left GMED muscle, and 10.3 pounds in the right GMED muscle, demonstrating a large increase from the baseline data. At the next measurement, the client gained 3.6 and 3.3 pounds of increased muscle strength in the left and right GMED muscle, respectively. At the end of six weeks, Subject 1 gained 9.7 pounds in the left GMED

muscle and 6.5 pounds of strength in right GMED muscle from the previous week. The subject demonstrated an overall left GMED strength gain of 21.8 pounds for the six-week timeframe. For the right GMED muscle, Subject 1 displayed an overall strength gain of 20.1 pounds for the duration of the study. These final results demonstrate that Subject 1 doubled their GMED strength over the six-week study. Subject 1's results can be seen in Appendix 5, and in the graph in Table 1 on page 21.

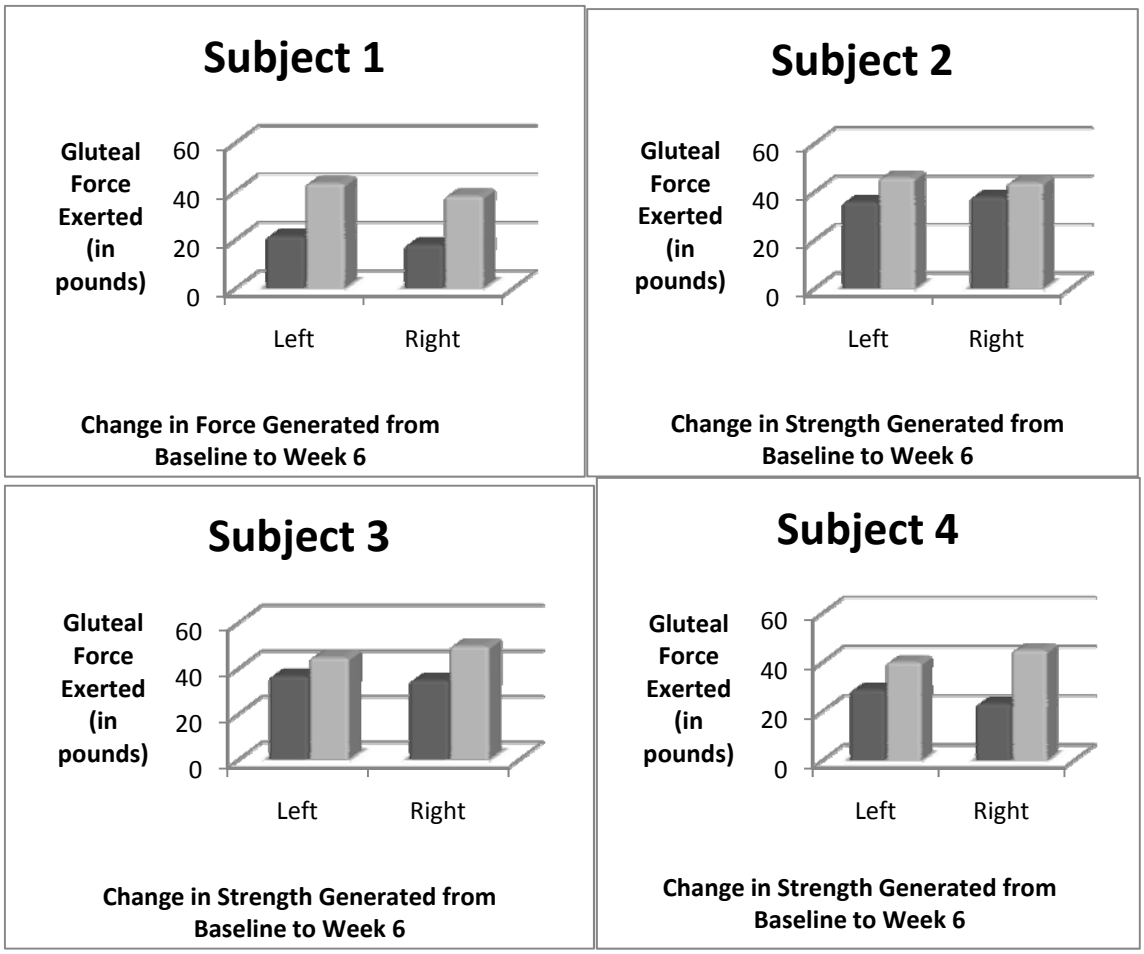
Subject 2 illustrated much smaller gains than Subject 1 did. However, this subject's strength gains were consistent over the six-week period as well. Subject 2 did not demonstrate large jumps in force generated throughout the study. The subject gained 4.5 pounds in the left GMED muscle and 0.7 pounds in the right GMED muscle at the end of week 2 from the baseline data. At the end of the fourth week, Subject 2 demonstrated a gain from the fourth week of 2 pounds and 2.8 pounds in the left and right GMED muscle, correspondingly. Subject 2 increased the left GMED strength by 3.6 pounds and the right GMED strength by 2.4 pounds at the end of the sixth week. In the end, this Subject demonstrated an improvement in GMED strength by 10.1 pounds on the left and 5.9 pounds on the right. Just as Subject 1's results showed, Subject 2 demonstrated strength gains in the six-week study. This subject's results can be seen in Appendix 6 and in Table 1 on page 21.

The next subject exemplified a similar strength gain pattern to that of Subject 2. However, this subject was not available to be measured at the end of week 4, which eliminated the measurements for that week. The subject was not in town at the end of week four, therefore large gains were not assessed in Subject 3 as the week four measurements were not available. This subject demonstrated strength gains bilaterally in the GMED muscle, but with a larger gain seen in the right GMED muscle. At the end of week 2, Subject 3 improved by 7.5 pounds and 5.4

pounds in the left and right GMED muscle respectively. Moving to the final week, Subject 3 showed a gain of 0.7 pounds from the previous 2nd week measurement. Subject 3 illustrated a 7.8 pound strength gain in the right GMED muscle from the preceding measurement. Accordingly, Subject 3 also demonstrated strength gains by the end of the six-week study. This subject generated 8.2 pounds, of additional force, in the left GMED and 13.2 pounds in the right GMED from the baseline data to the week 6 results. Subject 3's results can be found in Appendix 7 and on page 21 in Table 1.

The fourth subject demonstrated different results from what was seen for Subjects 1-3. Consequently, this subject showed no strength gains for one measurement in the study, and negative gains in another week of the study. Despite this irregularity, the subject did improve in overall GMED strength bilaterally by the end of the six-week study. At the end of week 2, Subject 4 did not improve in strength for the left GMED muscle. Unexpectedly, the subject gained 13.9 pounds in the right GMED muscle from the baseline to the end of week 2. The next measurement at the end of week 4 showed an 8.3 pound increase in the left GMED muscle for Subject 4. Again, Subject 4 presented an inconsistent measurement in the right GMED muscle for week 4 as a 0.7 pounds decrease was seen on this side. At the end of week six, this Subject finally bilaterally gained in both the left and right GMED muscles as an increase of 3 and 8.5 pounds, accordingly, was seen. Overall, this subject did exemplify an overall strength gain in the GMED muscle as an 11.3 pounds increase was seen for the left GMED and a 21.9 pounds increase was seen for the right GMED at the end of the six weeks. The results for Subject 4 can be located in Appendix 8 and in Table 1 on page 22.

<u>Table 1:</u> Subject 1- 4; Baseline Results Versus Final Results in the Right and Left Legs



Just as Subject 4 demonstrated irregular data, Subject 5 showed inconsistency from measurement to measurement over the six-week study. From the baseline results to the end of week 2 figures, Subject 5 showed no increase in the left GMED muscle and a decrease of 1.9 pounds in the right GMED muscle. This strange anomaly was repeated at the end of week four in the left GMED muscle measurement. Although Subject 5 had gained no strength from the baseline measurement to the end of week 2, a 3.5 pound decrease was demonstrated at the end of week 4. Oddly, Subject 5 illustrated an 8.4 pound increase at the end of week four in the right GMED muscle strength. As all the subjects have demonstrated to this point, strength gains were observed bilaterally at the end of week six. Subject 5 exhibited a 7.2 additional pounds of left

GMED muscle strength, and a 15.6 pounds increase in the right GMED muscle strength in the final week of the study. On the whole, the subject gained 7.2 pounds in the left GMED and 15.6 pounds in the right GMED at the conclusion of the project. Subject 5's results are situated in Appendix 9 and in Table 2 on page 25.

Over the six-week study, Subject 6 was only able to be measured twice. At the end of week 2, the subject was not available to be measured despite the attempts to make contact with the subject at school, work and home. In addition, the week six measurements were not able to be calculated as the force dynamometer was not working when Subject 6 was available. The baseline measurements and end of week four measurements consequently do not provide much information to add to the results of this study. From the baseline data to the end of week four, the Subject gained 3.9 pounds of strength in the left GMED. Conversely, the subject decreased in strength by 2.3 pounds in the right GMED from the baseline to the end of week 4 results. Therefore, no information can be gathered from this subject as the program was likely not adhered to, and the two measurements available do not show considerable results. The results for Subject 6 can be seen in Appendix 10 and on page 21 in the Table 2 graph.

The seventh subject exemplified consistent strength gains bilaterally in the GMED during the six week study. Subject 7's largest strength gains were seen at the end of week 4, where a 10 pound increase in force generated was seen for both the right and left GMED muscle. At the end of week 2, the subject gained 2.6 pounds of strength in the left GMED muscle, and 3 pounds in the right GMED muscle. At the next measurement, the client gained 10.4 and 10.3 pounds of increased muscle strength in the left and right GMED muscle, respectively. These measurements exemplified a large increase in muscle strength from the second week's results. At the end of six weeks, Subject 7 gained 3.1 pounds in the left GMED muscle and 1 pound of strength in the

right GMED muscle from the previous week. The subject demonstrated an overall left GMED strength gain of 16.1 pounds for the six-week timeframe. For the right GMED muscle, Subject 7 displayed an overall strength gain of 14.3 pounds for the duration of the study. These final results demonstrate that Subject 7 consistently increased their GMED strength over the six-week study. Subject 7's results can be seen in Appendix 11, and in Table 2 on page 25.

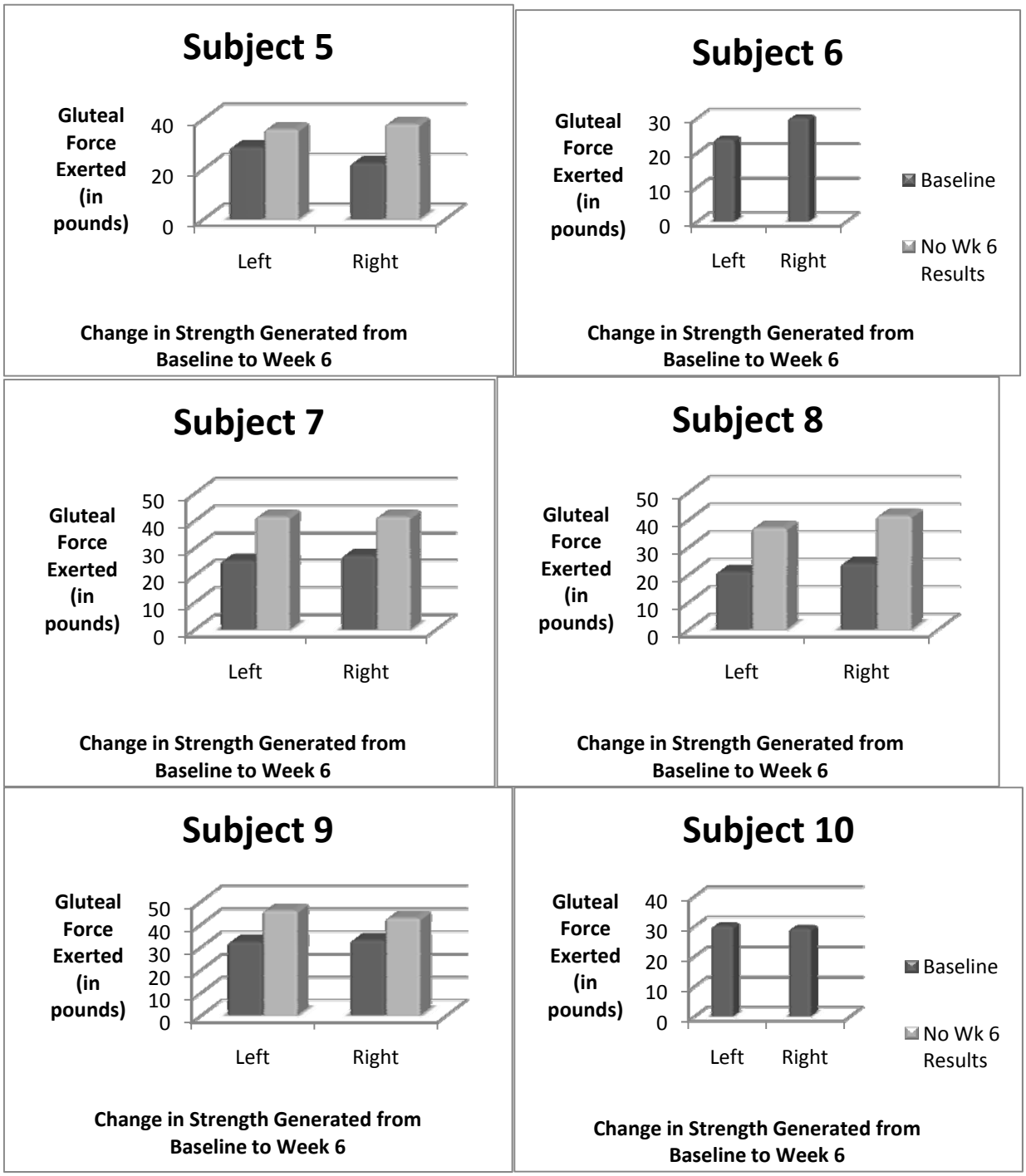
Subject 8 illustrated similar results to Subject 7. However, this subject's largest strength gains were seen at the end of the second week. The subject gained 10 pounds in the left GMED muscle and 9.5 pounds in the right GMED muscle at the end of week 2 from the baseline data. This data shows an impressive, large increase in strength from the baseline data to end of the second week. At the end of the fourth week, Subject 8 demonstrated a gain from the fourth week of 5.7 pounds and 5.9 pounds in the left and right GMED muscle, correspondingly. Subject 2 increased the left GMED strength by 0.3 pounds and the right GMED strength by 2 pounds at the end of the sixth week. In the end, this Subject demonstrated a consistent improvement in GMED strength during the study by adding 16 pounds generated on the left and 17.4 pounds generated on the right. This subject's results can be seen in Appendix 12 and in Table 2 on page 25. Similar to Subjects 4 and 5, Subject 5 demonstrated incongruent measurements during the six-week study.

Subject 9 showed an odd decrease in strength bilaterally at the end of the six-week study. From the baseline results to the end of week 2 figures, Subject 9 showed an increase of 3.7 pounds in the left GMED muscle and 5.4 pounds in the right GMED muscle. At the end of week four, Subject 9 exemplified a large jump in strength gains by a respective left GMED muscle strength addition of 12.8 pounds and a right GMED muscle strength addition of 10.8 pounds. This strange anomaly of decreasing in strength was seen at the end of week 6. The subject lost

2.7 pounds of force in the left GMED and 6.5 pounds of force in the right GMED at this measurement. Nonetheless, the subject still illustrated bilateral strength gains at the full conclusion of the study. Subject 9 exhibited 13.8 additional pounds of left GMED muscle strength, and a 9.7 pounds increase in the right GMED muscle strength by the end of the study. Subject 9's results are positioned in Appendix 13 and in Table 2 on page 25.

Information that is pertinent to the study is not available with Subject 10's results. Although the subject was enthusiastic to participate at the beginning of the study, Subject 10 did not show up for any of the subsequent measuring. Therefore, all that is available with Subject 10 is the baseline data, which cannot truly be associated with the other subjects' results. Nevertheless, no other information can be gathered from Subject 10. The baseline data for Subject 10 is available in Appendix 14 and can be seen in Table 2 on page 26.

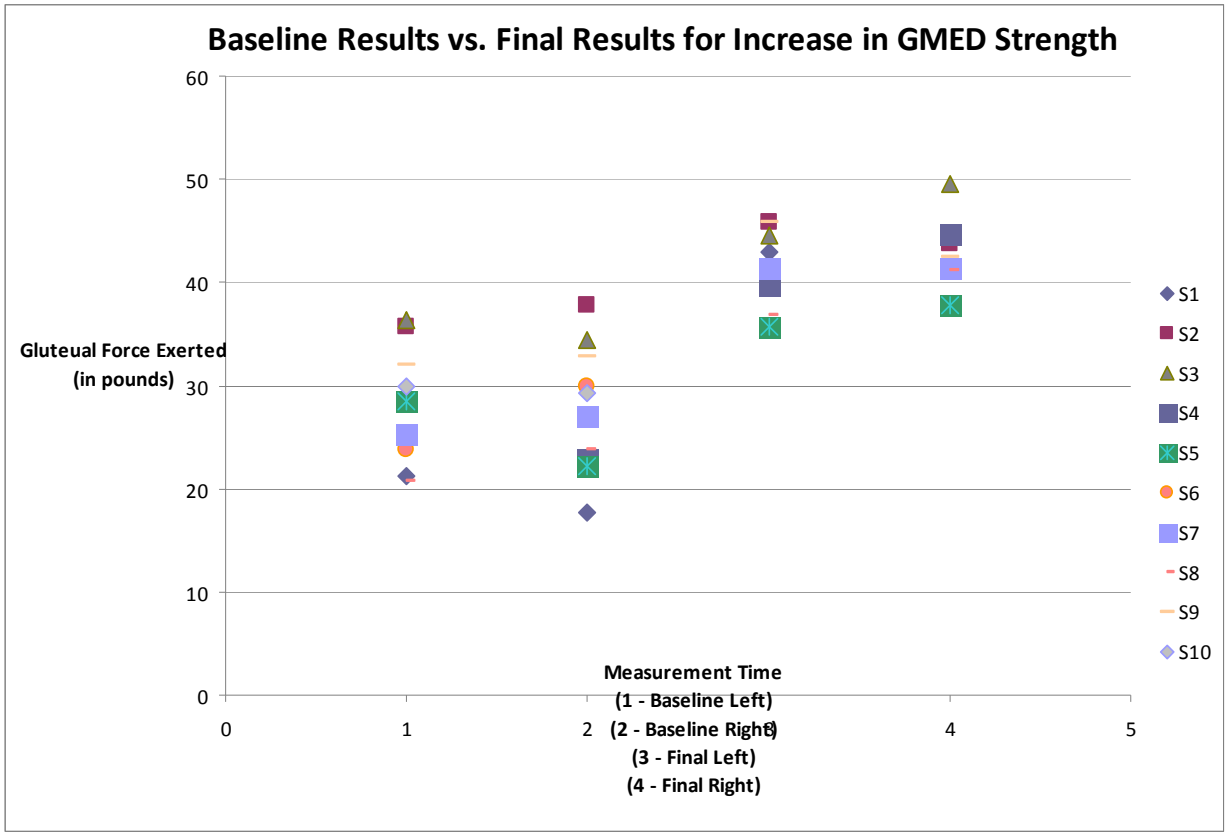
<u>Table 2:</u> Subject 5 - 10; Baseline Results Versus Final Results in the Right and Left Legs



Just as discussed for each of the compliant subjects, the results demonstrate strength gains were seen bilaterally in the GMED by the conclusion of the six-week study. Strength gains were seen in the subsequent weeks of the study by different subjects, with the largest jumps

observed at the ends of week two, four or six. Although decreases, zero change, and increases were seen among different subjects at the different measurement points, each compliant subject did demonstrate overall GMED muscle strength gains by the project end. The overall results comparing baseline results to final results for this study can be found in Appendix 15 and in Table 3 below.

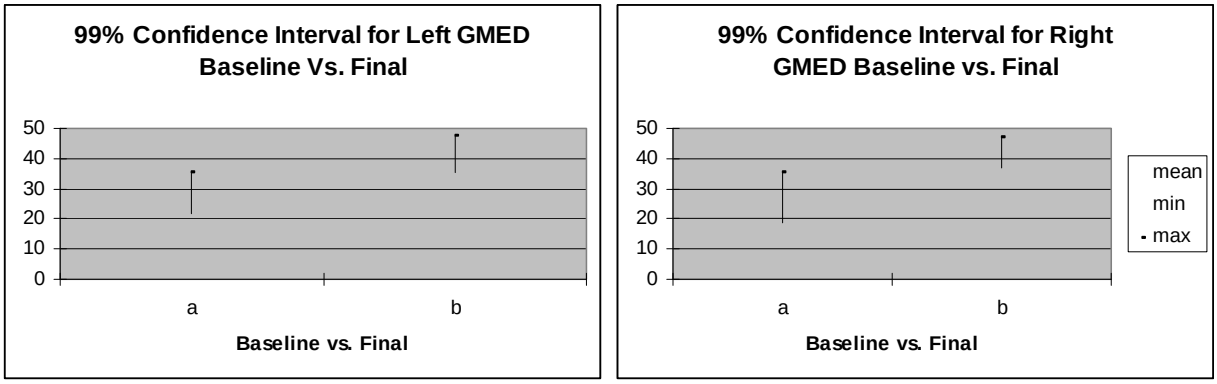
<u>Table 3:</u> Overall Results; Baseline Results Versus Final Results for Increase in GMED Strength



In order to statistically analyze the results from the study, the VassarStats online statistical package was used to run a correlated t-test. Two separate comparisons were made for each the right and left legs, with baseline data being weighed against the final data. Therefore, the correlated t-test is an indication of a difference present between the baseline data and the results of the sixth week, demonstrating the positive efficacy of the at-home exercise program. Due to the small sample size in this study, a valid p-value could be set at .05 and below in order

to indicate a difference. However, a considerably smaller p-value was shown in both the right and left legs, affirming the hypothesis that strength gains would be seen by the end of the sixth week. For the left GMED, the two-tailed p-value for the correlated t-test was 0.0001. Just as the left side did, the right GMED presents a two-tailed p-value of 0.0001 for the correlated t-test. These results are highly indicative that a difference was clearly observed from the baseline information to the final results, pointing in affirmation to the efficacy of the at-home exercise program. With a 99% confidence interval, the baseline results to not overlap with the finals results. The difference is clearly shown in Table 4.

Table 4: **99% Confidence Interval with Mean, Max, Min to Indicate Difference in Baseline vs. Final**



Chapter 5 – Discussion, Interpretations, and Recommendations

My results lead me to affirm that this six-week isolation intervention program of the GMED, bilaterally increased muscle strength. The first hypothesis, which stated "If subjects complete a 6-week at-home exercise program, then an increase in GMED strength should be observed", can be accepted with confirmation from the t-test and the line graph. As said above, the bilateral strength gains were seen, affirming the hypothesis asserting "If subjects complete the exercises for each leg, then the strength gains for the GMED should be bilateral." However the second hypothesis of "By the end of the 4th week, strength gains in the GMED should be

observable" could not be confirmed, as increases, decreases and zero changes were all seen at this week in the study. Therefore, I am forced to reject this hypothesis.

As two of the hypotheses were affirmed by the study, it is important to explore the research questions posed in the beginning as well. The main question was "Will a gluteus medius strength intervention program increase the strength of the muscle?". As seen by the difference in the t-tests for both the left and right GMED, it can be said with a 99% confidence interval that the at-home exercise program did produce a difference from the baseline to final results. There was not a significant difference of strength gained between the legs as both were equally strengthened throughout the duration of the study. In addition, as seen in the Appendices for each subject, there was not a significant difference in strength gains at each of the two week marks within the six-week at home exercise program. This leads to the conclusion that steady gains in were strength were seen over the six weeks rather than large jumps between weeks.

In the future, it would be beneficial to have an EMG to assess GMED activation in a study. Only a few studies that I could find used the break test to evaluate GMED strength (11). The remaining studies I explored utilized surface electromyography to quantify the muscle activation (16). As this is the current standard measurement protocol, in the future it would be constructive to utilize this equipment. Although the force dynamometer worked well for the purposes of this study, inconsistencies were presented with each subjects' break test. However, it is important to point out that it can be just as effective in a therapy setting to do a manual muscle test when quantitative data is not required. Due to where I had to measure my subjects, I performed measurements in seven different places throughout the study. Since I did not have a therapy bed in each setting, measurements were taken on hard floors, mats, tables, etc., providing inconsistent data in both where I measured from and how the subjects were positioned. In

addition, the force dynamometer that I used was at least 15 years old and may not produce accurate results each time. For the last measurement, the battery was completely dead, despite being plugged in, and therefore did not allow me to take Subject 6's final results. Therefore, in the future, it would be advantageous to have consistency in equipment.

An error that I did not control for in this study was the subjects' other exercise activities. Although the subjects were required to be healthy, I did not set limitations on the other exercise regimens they may have participated in over the six weeks. It was interesting to see decreases in some of the subjects, as they performed better in the weeks previous. However, it is likely that most of the exercises that they did perform did not isolate the GMED, which does not account for the decreases. For one subject, I know that the individual was participating in a P90X program that ended in the middle of this study. P90X is a home exercise system which aims for an improved physique in 90 days through rigorous interval training, consisting of cardiovascular, strength training, and stretching exercises divided into three 30-day phases.. Decreases were seen in this subject's results after this intense exercise program ended. However, losses in muscle strength should not have been seen that quickly. Therefore, I once again attribute this anomaly to possible equipment measurement error.

Although the main focus of this study was GMED strength, it would have been interesting to incorporate GMED hypertrophy. For the scope of this study, measuring hypertrophy, which is an increase in the size of muscle cells, was not possible. Ultimately this would be a difficult detail to measure as one must take into account fat loss, as well as the increase in muscle size. If one measured the circumference of the gluteal region, there are many possibilities for error with incorrect positioning, loss or gain of muscle, loss or gain of fat, etc. The timeframe of the study would also need to be expanded, as current research supports that

strength gains can be seen after four weeks, but does not support a solid stage for hypertrophy (18). From the conclusions drawn from this study, I would infer that hypertrophy did occur at the end of six weeks, as each compliant subject demonstrated bilateral strength gains in the GMED muscle.

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For the electronic copy, only Appendices 2 & 3 will be attached with the submission.