How Different Exercise Programs Affect Hip Abduction Joint Moment Over a Strength Curve: A Pilot Study

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Abstract

Background and Purpose: The gluteus medius has significant implications on lower extremity injury prevention. A paucity of information exists regarding the outcomes of common exercises. In this pilot study, the clamshell exercise and isometrics were compared based on strength changes over an 8-week training period.

Methods: Hip abduction joint moment was assessed on twenty-four participants at four different hip abduction angles. Participants were randomized into three different therapeutic exercise programs (isometric, resistance band, and control), and were re-tested after eight weeks.

Findings: The isometric group demonstrated increased joint moment at each angle upon program completion. The clamshell group demonstrated a linear relationship between increased joint moment production and hip abduction angles.

Clinical Relevance: Although the isometric and clamshell groups both demonstrated gains in hip abduction strength, the gains observed with the isometric group match the functional demands placed on the gluteus medius.

Conclusion: While further research is indicated, rehabilitation specialists may want to consider hip abduction isometrics to effectively rehabilitate patients.

Keywords: hip biomechanics, isometric strengthening, resistive band strengthening

Introduction

The basis of rehabilitation is to provide individuals with results in improved quality of life. While there are different approaches to accomplishing this, the prescription of exercise is a foundational component for nearly all diagnoses. Contrary to common perceptions, an increase in muscular strength secondary to exercise does not automatically translate to improvements in the muscle’s capabilities during functional activities such as walking, running, dressing, bathing, kicking a soccer ball, etc. [1]. Consequently, increasing a manual muscle test grade does not necessarily mean that a patient will no longer present with functional impairments such as Trendelenburg gait. Numerous biomechanical factors must work together to make functional gains, and all factors should be considered
when prescribing exercise. These factors are not only specific to the person, but also to the targeted muscle and its architecture. For those with Trendelenburg gait, the gluteus medius and hip abductor muscles need to contract during the stance phase of gait. Some exercises commonly prescribed for patients may not consider the factors required for functional gains. These factors include strength in the desired functional range, or activation of the muscle at the appropriate time of the activity. Patients deficient in any one of these areas may demonstrate pathomechanics, which in turn can lead to injury. While the personal factors that surround a patient’s case are constantly changing, the muscles that are targeted by rehabilitation specialists are not.

Hip and pelvic musculature have become more of a focus in injury prevention and rehabilitation due to their role in the regional interdependence of the lower extremity. Of these proximal muscles, the gluteus medius has been identified as a primary contributor to controlling the lower extremity [2]. The gluteus medius stabilizes the pelvis and assists in controlling the position of the lower extremity during ambulation among other dynamic lower extremity weight bearing activities. Therefore, deficiencies of the gluteus medius, the chief hip abductor, will affect gait and other functional activities [3]. The architecture of this muscle aligns with the demands that are placed on it during daily activities. The gluteus medius has a large physiological cross-sectional area (PCSA) and relatively short fibers, which allow it to generate large forces over its narrow range of excursion [3]. Therefore, the gluteus medius functions to stabilize the hip-pelvic complex. The orientation and the architecture of the gluteus medius muscle provide it the potential to assist in preventing pathomechanics down the kinematic chain not only because it can stabilize, but also because it functions to prevent valgus collapse of the lower extremity, especially when working in conjunction with the gluteus maximus [2]. Numerous studies have looked at the implications of these pathomechanics stating that they can lead to injuries such as iliotibial band syndrome, anterior cruciate ligament injuries, patellofemoral syndrome, and ankle injuries [4-6]. Because the gluteus medius functions optimally in a narrow range, the motion of hip abduction, which shortens the gluteus medius, compromises force production [7]. Therefore, the integration of muscle activation and strength in the functional range must occur for the gluteus medius to assist in preventing these pathologies. Integration is possible during the predominant functional demand on the gluteus medius, which arises during the single leg stance portion of gait. Fortunately, the moments of resistance match the peak moments of the joint during gait; the gluteus medius produces the greatest joint moment in lesser degrees of hip abduction (closer to neutral), which is the approximate position of the hip during single leg stance [7]. From a biomechanical perspective, matching these two variables, the moment of resistance and the joint’s peak moment, can result in more effective strengthening [8].

Some exercises prescribed in rehabilitation settings do not take into consideration all the factors that can affect a muscle’s ability to meet the demands that the patient is placing on it while commuting to work, cleaning their home, or participating in a sporting event. In fact, there are some exercises, specific to the gluteus medius, that may lack compatibility with its architecture, correlated force-length relationship, and the functional demands placed upon it [8]. Consequently, while a muscle may gain strength during the episode of care, the individual may still present with the original functional deficit or complaint. In other words, the lack of knowledge regarding the effects of exercise on muscles and muscle architecture prevents rehabilitation specialists from accurately applying the specificity principle of training in the development of their exercise programs for their patients.

Rehabilitation specialists prescribe isometric and isotonic exercises, and gluteus medius specific exercises are no exception. Strengthening of a localized region in the muscle’s range of motion theoretically occurs with isometric exercises [9]. However, current literature does not provide information on how these exercises affect the strength curve of the gluteus medius muscle throughout its excursion. A strength curve shows the amount of joint moment a muscle produces throughout a range of motion, which is specific to the joint the muscle is acting on. The gluteus medius strength curve demonstrates an inverse relationship between joint moment and hip abduction, which means that the
gluteus medius produces the greatest amount of joint moment at lesser degrees of hip abduction when the muscle is at a relatively long length [3,7]. Thus, it appears there is a case for strengthening the gluteus medius in this position (neutral to slight hip adduction) because of its position of optimal function [7]. However, not all gluteus medius specific exercises occur in this ideal range. For example, the clamshell exercise, which occurs by placing a resistance band around the knees and pushing outward, works the muscle most at end range abduction. Yet, it is commonly prescribed by clinicians [10]. The gluteus medius produces the least amount of joint moment at its end range of approximately 40° abduction [7]. In addition, resistance bands used when performing clamshells challenge the muscle the most at the end of the excursion suggesting that this exercise does not work the muscle as significantly within its typical functional range. Even though this exercise does not match the architecture of the targeted muscle, symptom relief has been reported; [10] however, there is no literature explaining why that occurs. One speculation is that clamshells promote activation of the muscle. Perhaps, a combination of range specific isometric strengthening with the addition of an activation-specific exercise, potentially the clamshell, would provide the proper environment for the gluteus medius to function optimally. Ultimately, ideal functioning for any muscle would include strength in the architecturally determined functional range, activation at the appropriate time, and an intact neuromuscular system to connect the two.

The goal of this pilot study was to determine the effect that common gluteus medius strengthening exercises have on the hip abduction strength curve to effectively prescribe exercises. Investigators hypothesize that subjects in the isometric group will demonstrate greater strength gains at 0° abduction than the clamshell and control groups. Secondly, both the isometric group and the clamshell group will demonstrate increased joint moment at all hip positions when compared to the control group. However, the isometric group’s gains will be more specific to the targeted exercise range of 0° while the clamshell group’s greatest gains will be seen at the 30° hip abducted position.

Methods
Study design
This is a pilot study designed to determine if an exercise program of hip abduction isometrics or one of clamshells have a greater effect on the joint moment of the gluteus medius, most specifically within its functional range of 0° abduction. This study was approved by the Institutional Review Board of Saint Francis University.

Setting
Data was collected from members of the Saint Francis University community in Loretto, Pennsylvania. Participants who met the inclusion/exclusion criteria (see Participants section) were recruited and received an exercise program to perform for 8 weeks. All data was collected and analysed by the investigators at Saint Francis University.

Participants
Following a recruitment email that was sent, 30 eligible participants (22 female, 8 male) met the following inclusion criteria: 1) between the ages of 18-30 years; 2) free of any hip, knee, or ankle pain or pathology; 3) the ability to provide informed consent; 4) hip abduction PROM of at least 30 degrees. However, due to attrition and circumstances beyond the researchers’ control, only 24 subjects returned for post-test data collection.

Table 1: Subject Demographics, mean (SD)

<table>
<thead>
<tr>
<th>Subject Demographics</th>
<th>Gender</th>
<th>Age (years)</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamshell (n=7)</td>
<td>M=2, F=5</td>
<td>24.1 ± 1.4</td>
<td>25.2 ± 3.9</td>
</tr>
<tr>
<td>Isometric (n=8)</td>
<td>M=2, F=6</td>
<td>20.9 ± 1.2</td>
<td>23.8 ± 4.7</td>
</tr>
<tr>
<td>Control (n=9)</td>
<td>M=2, F=7</td>
<td>21.7 ± 3.0</td>
<td>28.7 ± 4.8</td>
</tr>
</tbody>
</table>
Procedures

Upon entering the lab, height, weight, body mass index, age, orthopaedic issues, screening of hip abduction range of motion, and current activity level were all included in the initial intake form. Participants that agreed to the terms of informed consent performed a five-minute warm-up on a stationary recumbent exercise bike at a self-selected speed. Participants were then placed in a side-lying position facing a Biodex® dynamometer (Biodex 4 Systems Pro, Biodex Medical Systems, Shirley, NY). The participant’s top (right) leg was tested. The fulcrum of the dynamometer was lined up with the participant’s acetabulum. The dynamometer arm was placed 5 cm proximal to the lateral epicondyle of the femur and a Velcro strap was used to secure the top leg. The non-tested (left) hip was flexed to 45° and the left knee was flexed to 60° for comfort and stabilization (Figure 1) [11]. Participants performed maximal isometric tests at positions of 15° of hip abduction, 0° (neutral), and 15° and 30° of hip abduction. Joint positions were randomized into four different sequences to account for factors such as fatigue. Participants performed three sustained maximal voluntary isometric contractions (MVIC) of 5 seconds at each angle (-15°, 0°, 15°, 30°) of hip abduction (Figure 1). The average of the three peak joint moments was recorded. Participants were given a 30-second rest period in between each trial and a 1-minute rest period between each joint position. Verbal encouragement was given throughout the test to ensure maximal effort was provided from each subject. An examiner was always present to ensure the subject kept the pelvis in proper position and did not compensate with other substitutions.

Following initial testing, participants were randomized, divided, and began an eight-week training regimen as per Buress et al. in either the isometric, Thera-Band®, or control group [12,13]. Randomization was achieved by instructing participants to blindly choose a slip of paper, each labelled with one of the three exercise groups. Once an exercise group was prescribed, it was removed from the pile until each of the three exercises were assigned to participants. The three exercise programs were then returned to the pile, allowing the fourth participant to blindly choose from the isometric, Thera-Band®, or control group. As displayed in Table 1, equal numbers of men and women were randomized to each of the three groups, by chance, rather than the randomization being stratified by sex. Following the selection process, each participant was educated in their respective home exercise program by one of the researchers regarding proper positioning of materials, correct technique, sets, repetitions, and hold times. A home exercise program consisting of hip isometrics was given to one-third of participants. The isometric exercise was performed in a supine position with the hip in a neutral abduction position (0°) to target the most functional position of the hip [14]. A standard gait belt of 60” x 2” was provided for all isometric participants [15]. During the pre-test, gait belt size was determined for each based on neutral hip position. Once the size was adjusted to fit the participant, duct tape was used to position the belt and prevent further alterations. The participant was educated on the placement of the gait belt, 5 cm proximal to the lateral epicondyle of the femur, resembling the position of the Biodex® dynamometer arm during the test [11]. The hip isometric exercise was completed on both legs at 0° of hip abduction consisting of a 10 second hold time for 15 repetitions [15]. A home exercise program consisting of the clamshell exercise was given to a third of participants. The clamshell exercise was performed side-lying, with the pelvis in neutral, hip 60°, and knees 90° [16]. A Thera-Band® was provided to the patient and tied to a standard tension 5 cm proximal to the lateral epicondyle of the femur, resembling the position of the Biodex® dynamometer arm during testing [11]. Standard tension was determined as tied around the leg with knees together and no elongation of the band [17]. Subjects were instructed to pull the knees as far apart as possible. Clamshells were performed by participants at home on both sides for three sets of 10 repetitions [13]. Both the isometric exercise and clamshell exercise group were instructed to perform training sessions on two successive days followed by a day of rest, then two more successive days followed by two days off (Monday-Tuesday, Thursday-Friday) [13]. A one-minute rest break was permitted between sets [13]. The control
group, consisting of a third of participants, were instructed to not perform any exercises nor change their activity level during the eight-week trial.

After eight-weeks, participants returned for retesting. Initial intake information was taken again and set up and testing procedures were identical to initial evaluation procedures described above. Due to attrition and unforeseen circumstances, final post-test data was gathered on seven subjects from the Theraband® group, eight subjects from the isometric group, and nine subjects from the control group.

**Statistical Analysis**

For each subject the moment data were normalized with respect to each subject’s body mass [17]. Data was organized on a Microsoft Excel spreadsheet and analyzed using Minitab [17]. Descriptive statistics were performed. A fixed-effect model of analysis of variance (ANOVA) was used to determine any differences in joint moment between the isometric exercise group, the clamshell exercise group, and control group. The effect sizes, ds, were quantified where the numerator is the differences between means of the intervention group and the control group and the denominator the pooled standard deviation of the differences [18,19]. A p-value less than 0.05 was used to assess statistical significance.

**Results**

The average normalized peak joint moment difference and standard deviation for each group from pre-test to post-test at each position of hip abduction (-15°, 0°, 15°, 30°) was: for the Thera-Band® group -0.94 ± 18.85, 1.17 ± 11.29, 2.70 ± 7.67, and 5.07 ± 8.09 Nm/kg, respectively; for the isometric group 4.16 ± 17.11, 3.14 ± 14.14, 4.68 ± 8.89, and 7.54 ± 11.86 Nm/kg, respectively; and for the control group -9.92 ± 22.11, 1.52 ± 12.93, -4.24 ± 7.35, and -0.66 ± 5.65 Nm/kg, respectively (See Table 2 and Figure 1). After performing the statistical analysis of the three groups comparing pre-test to post-test joint moment differences, it was determined that none of the results demonstrated a significant difference (p<0.05). However, effect sizes (ds) for clamshells and isometrics were medium (0.4 ≤ ds ≤ 0.6) at the 15° and 30° abducted position, and even high (ds ≥ 0.8) for isometrics at the 30° position.

![Figure 1: Joint moment differences at four hip abduction angles following an 8-week intervention.](image)
### Table 2: Joint Moment Differences from Pre-Test to Post-Test

<table>
<thead>
<tr>
<th>Average Normalized Peak Joint Moment Differences from Pre-Test to Post-Test (Nm/kg)</th>
<th>-15° Abduction</th>
<th>0° Abduction</th>
<th>15° Abduction</th>
<th>30° Abduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clamshell</td>
<td>-0.94 ± 18.85 (d = 0.42)</td>
<td>1.17 ± 11.29 (d = 0.027)</td>
<td>2.70 ± 7.67 (d = 0.72)</td>
<td>5.07 ± 8.09 (d = 0.76)</td>
</tr>
<tr>
<td>Isometric</td>
<td>4.16 ± 17.11 (d = 0.67)</td>
<td>3.14 ± 14.14 (d = 0.11)</td>
<td>4.68 ± 8.89 (d = 0.67)</td>
<td>7.54 ± 11.86 (d = 0.83)</td>
</tr>
<tr>
<td>Control</td>
<td>-9.92 ± 22.11</td>
<td>1.52 ± 12.93</td>
<td>-4.24 ± 7.35</td>
<td>-0.66 ± 5.05</td>
</tr>
<tr>
<td>p-values</td>
<td>0.376</td>
<td>0.957</td>
<td>0.100</td>
<td>0.208</td>
</tr>
</tbody>
</table>

### Discussion

The main objective in this study was to investigate common gluteus medius exercises by determining the efficacy of each exercise program based on joint moment assessment across a continuum of positions. Following the eight-week exercise program, it was found that participants in the isometric group achieved an increase in joint moment production across all four test positions (Figure 2). The clamshell group demonstrated a direct linear relationship between moment production increases and increased hip abduction angles. The clamshell group increased in joint moment at higher abduction angles (Figure 3). No increases were seen in the control group; in fact, joint moment decreased in three of the four tested positions.

![Figure 2: Joint moment-angle line of best fit of isometric group at initial testing and follow-up eight weeks later. Subjects tended to get stronger at all angles of hip abduction.](image-url)
These results match predictions made by current and previous researchers as they largely follow the specificity principle of training. The results from the clamshell group support the specificity principle of training because the resistance offered by the Thera-Band® and the increases in joint moment both demonstrate a direct linear relationship. In the Thera-Band® group, the greatest increase in joint moment production occurred where the greatest resistance occurred (30° of hip abduction). This was also the position of the largest effect size for the Thera-Band® group. The isometric group also demonstrated an increase in moment production at the angle where resistance was offered (0°); however, there was carry over at every hip position tested despite a lack of resistance moment at those positions. This is contrary to what other researchers have found [9]. The gains made by the isometric group were relatively consistent across the entire range analyzed, as can be seen through the joint moment-angle curve (Figure 2). Meanwhile, the control group only increased slightly at one position and decreased at the others.

The difference in response to the exercise programs could be due to the differences in muscle contraction required by both exercises. The sustained muscle contraction that occurred with the isometric exercise possibly resulted in better motor unit recruitment training than the more variable resisted contraction of the clamshell exercise. Previous literature identified the strength curve of the gluteus medius and made speculations about the implications of certain exercises based on extrapolations of principles; however, no data was available to substantiate those speculations [8]. In this pilot study, the isometric group demonstrated more consistent peak moment gains throughout the range in comparison to the clamshell group, which could be due to the isometric versus isotonic contraction taking place. It could also be due to the isometric exercise more precisely matching the architecture and functional demands of the gluteus medius. In addition to the aforementioned factors, the isometric exercise required little excursion from the short fibers of the gluteus medius, whereas the clamshell required a large excursion from anatomically short fibers [3].
Because of the disparity between the makeup of the gluteus medius and the demands of the clamshell exercise, it is not surprising that strength gains may not translate functionally [1]. The strength curve of the gluteus medius demonstrates an inverse relationship where hip abduction joint moment production decreases with greater hip abduction angles. The gluteus medius inherently produces the greatest joint moment at -10˚ of hip abduction [7]. During the gait cycle the stance limb hip is in approximately -10˚ of hip abduction. Yet, the clamshell group demonstrated the greatest strength gains at 30˚ of abduction. Because the gluteus medius is inherently strongest at lower hip abduction angles and is constantly being challenged in that position due to functional demands, it is likely that the clamshell exercise underwhelms the muscle at these lower hip abduction angles because the band’s tension is low, with the exact opposite occurring at greater hip abduction angles. Overload only took place as the hip abduction angle increased, which is why there were greater strength gains seen in those positions. Interestingly, the greatest increases in moment production occurred at 30° of hip abduction for both the clamshell and isometric groups. This could be secondary to that inherently being the weakest position of the muscle, [7-8] and therefore having the most potential for strength increase.

The control group was largely unremarkable regarding moment production improvement. A slight increase (1.52Nm/kg) was found at 0°, but all other positions decreased. This minimal strength gain is thought to be a result from functional activities such as gait due to constant demand at this hip angle during ambulation. The other three test positions demonstrated a loss of joint moment output which is what was expected due to an abstinence of muscle training.

Based upon the results from this pilot study, the joint moment gains made by the isometric group are theoretically more likely to equip the gluteus medius with the ability to prevent lower extremity injuries due to its role in the regional interdependence of the lower extremity [4,5]. Isometric exercises are not better than elastic resistance-based exercises in all circumstances. However, the functional position in which strength is desired should be considered when prescribing exercise. It is a matter of considering architecture, functional demands, and personal factors when developing an exercise program.

Numerous limitations exist in this study. The subjects were healthy young adults, primarily females, which limits the ability for extrapolation to other populations, including those suffering from pathomechanics secondary to hip abduction weakness. Additionally, there was no statistical significance among the results, although effect sizes were intriguing, which is likely due to the complications of an intervention-based study including lack of compliance and/or retention of the participants. Larger group numbers would be ideal to account for outliers, especially for the variability which occurs during an 8-week intervention program. Finally, the method of testing (isometrically) may have biased the increases seen across the range of hip positions for the isometric group compared to the other groups.

Specifically, two hypotheses were investigated: (1) the isometric group will demonstrate greater peak joint moment differences at 0° than the clamshell and control groups, (2) the isometric group and the clamshell group will demonstrate increased peak joint moment differences at all positions compared to the control group. Because statistical significance was not achieved, both hypotheses could not be accepted. However, this pilot study and positive effect sizes do provide possibilities for future research.

**Clinical applications**

The isometric exercise program yielded better and more consistent joint moment results than the clamshell group not only where the resistance occurred, but across the entire range of motion examined. Most importantly these gains correlate with the functional demands placed on the gluteus medius, while any gains made by the clamshell group do not. Thus, the isometric exercise appears to be a more effective exercise. If these results can be substantiated by a large randomized controlled trial, rehabilitation specialists may choose to consider utilizing hip
abduction isometrics when rehabilitating the gluteus medius. Determining the effects that certain exercises have on joint moment over a curve can be beneficial for exercise prescription in the rehabilitation setting because therapists will be able to prescribe exercises that address the deficits specific to that patient, with an understanding of how the exercise will affect their musculoskeletal system.

**Conflict of Interest**

The authors declare that there are no conflicting interests with respect to the research, authorship, and/or publication of this article.

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**References**


