

## Electromyographic Analysis of Hip Rehabilitation Exercises in a Group of Healthy Subjects

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**Study Design:** Single-occasion, repeated-measures design.

**Objective:** To determine the magnitude of hip abductor muscle activation during 6 rehabilitation exercises.

**Background:** Many researchers have reported that hip strengthening, especially of the hip abductors, is an important component of a lower extremity rehabilitation program. Clinicians employ non-weight-bearing and weight-bearing exercise to strengthen the hip musculature; however, researchers have not examined relative differences in muscle activation during commonly used exercises. Information regarding these differences may provide clinicians with a scientific rationale needed for exercise prescription.

**Methods and Measures:** Sixteen healthy subjects (mean  $\pm$  SD age,  $27 \pm 5$  years; range, 18-42 years; mean  $\pm$  SD height,  $1.7 \pm 0.2$  m; mean  $\pm$  SD body mass,  $76 \pm 15$  kg) volunteered for this study. Bipolar surface electrodes were applied to the right gluteus medius muscle. We measured muscle activation as subjects performed 3 non-weight-bearing (sidelying right hip abduction and standing right hip abduction with the hip at  $0^\circ$  and  $20^\circ$  of flexion) and 3 weight-bearing (left-sided pelvic drop and weight-bearing left hip abduction with the hips at  $0^\circ$  and  $20^\circ$  of flexion) exercises. Data were expressed as a percent of maximum voluntary isometric contraction of the right gluteus medius. Differences in muscle activation across exercises were determined using a 1-way analysis of variance with repeated measures, followed by a sequentially rejective Bonferroni post hoc analysis to identify differences between exercises.

**Results:** The weight-bearing exercises demonstrated significantly greater EMG amplitudes ( $P < .001$ ) than all non-weight-bearing exercises except non-weight-bearing sidelying hip abduction.

**Conclusion:** The weight-bearing exercises and non-weight-bearing sidelying hip abduction exercise resulted in greater muscle activation because of the greater external torque applied to the hip abductor musculature. Although the non-weight-bearing standing hip abduction exercises required the least activation, they may benefit patients who cannot safely perform the weight-bearing or sidelying hip abduction exercises. Clinicians may use results from this study when designing hip rehabilitation programs. *J Orthop Sports Phys Ther* 2005;35:487-494.

**Key Words:** *gluteus medius, strengthening exercises, surface EMG*

**T**herapeutic exercise is one of the most important interventions used by rehabilitation professionals. Clinicians routinely prescribe hip abduction strengthening exercises for patients who have undergone a total hip arthroplasty or others who have sustained a hip injury. These exercises have important functional implications because they enable patients to regain the muscle strength needed for performing activities of daily living and sports. Additionally, clinical reports suggest that the hip abduction musculature can facilitate positive outcomes in the rehabilitation of knee dysfunction.<sup>11,17</sup> Together, these findings support the importance of strengthening the hip abduction musculature in rehabilitation programs.

Physical therapists and athletic trainers use many variations of hip abduction strengthening exercises in the rehabilitation process. Many clinicians use a standard sidelying hip abduction exercise.<sup>11,17,28</sup> An alternative form of exercise may involve single-leg stance activities, with these exercises requiring hip abduction activation to control pelvic orientation. Neumann and colleagues<sup>21-23</sup> reported that electromyographic (EMG) activity of the hip abductors during the stance phase of walking increases

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when carrying a load in the hand contralateral to the given hip abductors. Schmitz et al<sup>29</sup> also reported increased hip abduction demand during a single-leg stance activity with the hip placed in a slightly flexed (20°) position. Based on this information, hip abduction strengthening may occur using both non-weight-bearing (eg, sidelying hip abduction) and weight-bearing (eg, single-leg stance) exercise with the hip in varying amounts of flexion.

Researchers have used EMG to gain information regarding activation of various muscles during rehabilitation exercises.<sup>10,12,13,16</sup> To our knowledge, the relative activation of the hip abductors during various rehabilitation exercises has not been described. We believe that information about hip abduction muscle activation may help guide the decision-making process needed for appropriate exercise prescription. Therefore, the purpose of this study was to determine hip abduction activation during 3 non-weight-bearing and 3 weight-bearing exercises. We hypothesized that weight-bearing exercises would require greater muscle activation than non-weight-bearing exercises.

## METHODS

### Subjects

Sixteen healthy subjects (8 men, 8 women; mean  $\pm$  SD age, 27  $\pm$  5 years; mean  $\pm$  SD height, 1.7  $\pm$  0.2 m; mean  $\pm$  SD body mass, 76  $\pm$  15 kg) volunteered for this study. A sample of convenience was recruited from the local University community. Subjects participated in the study only if they had no lower extremity dysfunction and could safely perform a single-leg stance on each lower extremity. Subjects were excluded if they had a history of significant lower extremity injury or surgery in the preceding year. The primary investigator explained the testing procedures and associated risks and benefits specific to the study to all subjects, and they signified their voluntary decision to participate by signing a University-approved informed consent form. The University of Kentucky Institutional Review Board approved the protocol used in this study.

### Procedures

Subjects reported to the Musculoskeletal Laboratory for a single testing session. Prior to testing, subjects rode a stationary bike at a submaximal speed for 5 minutes. They also performed gentle hamstring-, calf-, and quadriceps-stretching exercises consisting of 5 repetitions with a 15-second hold. Next, subjects practiced each exercise to the beat of a metronome (60 beats per minute) to familiarize themselves with each task (Tables 1 and 2) until they demonstrated proficiency. Subjects generally required 8 to 10 practice repetitions for each task. Subsequent

**TABLE 1.** Description of the 3 non-weight-bearing (NWB) hip abduction exercises.

Exercise*	Description
NWB sidelying hip abduction <sup>11,17</sup>	Subjects lie on their left side with the right lower extremity parallel to the left one; they abduct the right lower extremity 25°; then return to the starting position
NWB standing hip abduction	Subjects stand with both lower extremities 10 cm apart; they abduct the right lower extremity 25°; then return to the starting position, while standing solely on the left lower extremity with the pelvis in a level position
NWB standing flexed hip abduction	Subjects stand with both lower extremities 10 cm apart with the hips and knees in 20° of flexion; they abduct the right lower extremity 25°; then return to the starting position, while standing solely on the left lower extremity with the pelvis in a level position

\* A cuff mass equal to 3% body mass was placed around the right ankle.

**TABLE 2.** Description of the 3 weight-bearing (WB) hip abduction exercises.

Exercise	Description
Pelvic drop <sup>11</sup>	Subjects stand on the right lower extremity on a 15-cm step; with both knees in a fully extended position, they lower the left pelvis toward the floor to adduct the right hip; subjects then return the pelvis to a level position
WB left hip abduction <sup>23*</sup>	Subjects stand with both lower extremities 10 cm apart; they then stand on the right lower extremity, keeping the pelvis in a level position, while abducting and adducting the left lower extremity 25°
WB with flexion left hip abduction*	Subjects stand with both lower extremities 10 cm apart with the hips and knees in 20° of flexion; they then stand on the right lower extremity, keeping the pelvis in a level position, while abducting and adducting the left lower extremity 25°

\* A cuff mass equal to 3% body mass was placed around the left ankle.

to the practice of the exercises, the subjects rested for 10 minutes prior to the start of testing to reduce the possible effect of fatigue. The principal investigator monitored all warm-up activities.

The principal investigator prepared the subject's skin for the surface EMG electrodes in a standard manner.<sup>3</sup> Bipolar surface electrodes (Medicotest, Roll-

ing Meadows, IL) were placed one-third the distance between the iliac crest and greater trochanter over the muscle belly of the right gluteus medius (GM).<sup>7</sup> Proper location was visually confirmed by examining the electrical signal on an oscilloscope through application of manual resistance, using the common manual muscle testing sidelying position for hip abductors.<sup>8</sup> Electrode tape was applied to prevent any slippage during testing and a ground electrode was positioned over the right acromion process. The principal investigator then secured a 2-dimensional electrogoniometer (Biometrics, Montreal, Canada), using double-sided tape over the lateral aspect of the right and left hips for the purpose of delineating repetitions during exercise, and visually confirmed correct electrogoniometer activity in response to hip movement prior to testing.

Surface EMG is subject to the sampling of crosstalk activity from adjacent musculature. To minimize crosstalk, we used Ag/AgCl electrodes that were 5 mm in diameter with an interelectrode distance of 20 mm. We placed the electrodes near the muscle's midsection one-third the distance from the iliac crest because placement in this location maximizes the recording of activity from the nearest motor unit action potential and minimizes musculature interference.<sup>3,7</sup>

Next, the subjects performed 3 maximum voluntary isometric contractions (MVICs) for the GM to normalize the raw EMG data. For this purpose, subjects assumed a left sidelying position with the right lower extremity in 25° of hip abduction by placing pillows between the lower extremities. In this position, resistance to movement was applied with a mobilization strap located over the lateral femoral condyle (Figure 1). We positioned subjects in this manner as to facilitate a best effort during testing<sup>15</sup> and chose 25° of hip abduction as our reference point because clinicians routinely use this position for manual muscle testing.<sup>8</sup> Subjects received strong verbal encouragement<sup>6</sup> as they performed three 5-second MVICs and rested 1 minute between each effort. A computer algorithm determined the maximum root-mean-square amplitude recorded over a moving 500-millisecond average window across the 3 MVICs. We then identified the window of activity having the greatest amplitude and expressed all GM activity as a percentage of this maximum value.<sup>2</sup> Normalization provided a standard reference of electrical activity for the GM and we expressed all EMG data as a percent MVIC for statistical analysis.

Because clinicians typically use both non-weight-bearing (NWB) and weight-bearing (WB) exercises in rehabilitation programs, we included 3 variations of each type of exercise. Pilot testing indicated that subjects required a slight amount of hand support to maintain balance and keep the pelvis level during the standing exercises. For the NWB standing hip abduc-

tion and the WB left hip abduction exercises, the subjects stood on 1 foot. To standardize each position and maintain balance, we instructed the subjects to keep their pelvis level and their trunk in a vertical alignment, while gently placing their fingertips on a table ledge.<sup>4</sup> For the pelvic drop exercise, the principal investigator stood to the left of each subject and provided light hand support to the subject's left hand, if needed. We implemented these forms of external support for all standing exercises because they represented techniques that clinicians might typically employ in clinical practice.

For the NWB exercises, we applied a cuff mass equal to 3% body mass (range, 1.8-3.6 kg; mean  $\pm$  SD, 2.0  $\pm$  0.9 kg) around the subject's right ankle. For the WB exercises (except the pelvic drop), we placed the same weight on the subject's left ankle. Although many clinicians employ these exercises using Thera-Band (The Hygenic Corporation, Akron, OH) resistance, we used an ankle weight to provide a known standardized mass throughout the entire range of motion for each exercise. For each exercise, we utilized wooden blocks to demarcate the appropriate range of motion and to ensure that subjects performed each exercise in a consistent manner. Tables 1 and 2 provide a full description of each exercise.

Subjects performed 15 repetitions of each exercise to a metronome set at 60 beats per minute and in a standardized manner to ensure similar rates of motion among subjects.<sup>30</sup> For all exercises except the pelvic drop, subjects raised the specific lower extremity on 1 beat, lowered it on the next, and rested 1 beat, a sequence they repeated for 15 repetitions. Selseth et al<sup>30</sup> incorporated a similar sequence to ensure similar rates of motion. We believe that this sequence may minimize the effects of momentum that could have occurred with performing the exercises in a continuous manner. For the pelvic drop exercise, subjects lowered the left lower extremity on



FIGURE 1. Subject position for obtaining maximum voluntary isometric contraction for the right hip abductor musculature.

1 beat and raised it on the next in a continuous manner. During pilot testing, subjects performed this exercise in a smoother manner using this sequence. Subjects rested 3 minutes between each exercise, and we randomized testing to reduce fatigue and ordering bias. After completion of the exercises, subjects repeated the MVIC procedures to ensure that the surface electrodes had not been displaced during testing.<sup>18,26</sup> Postexercise MVIC was determined in the same manner as during pretesting only to determine procedural reliability.

## EMG Analysis

We used a 16-channel EMG system (Run Technologies, Mission Viejo, CA) to record muscle activity. Subjects wore a Myopac transmitter belt unit (Run Technologies) that transmitted all raw EMG data at 1000 Hz via a fiber optic cable to its receiver unit. Unit specifications for the Myopac included a common mode rejection ratio (CMRR) of 90 dB, an amplifier gain of 2000 for the surface EMG electrode, and an amplifier gain of 1000 for the electrogoniometer. Raw EMG data were band pass filtered at 20 to 500 Hz using Datapac software (Run Technologies), stored on a personal computer, and analyzed using Datapac software.

Electrogoniometer signals were linear smoothed over a moving 15-millisecond window and used to demarcate hip motion for each repetition. For all exercises except the pelvic drop, the electrogoniometer showed an upward and downward deflection during movement, followed by a relatively flattened line during periods of no movement. We identified EMG signals associated with movement and excluded those signals generated during the 1-second rest period for purposes of statistical analysis. For the pelvic drop exercise, each combination of upward and downward electrogoniometer deflection represented an individual repetition. For each exercise, we then calculated the root-mean-square amplitude for each repetition and expressed these amounts as a percentage of the pretesting MVIC (% MVIC). Normalized data from the last 10 repetitions for each exercise were then averaged and used for statistical analysis.

## Reliability

We examined MVIC reliability to ensure that the electrode did not move during testing.<sup>18,26</sup> For this purpose, the maximal 500 ms of root-mean-square amplitude generated during the pretesting and the posttesting MVICs was identified, and reproducibility evaluated using an intraclass correlation coefficient (ICC<sub>3,1</sub>).<sup>31</sup> ICC<sub>3,1</sub> was 0.92, which would infer minimal electrode movement and consistent effort. We also examined intertrial reliability to determine the

**TABLE 3.** Means  $\pm$  SD for right gluteus medius (GM) electromyographic (EMG) amplitudes during each exercises expressed as a percent of maximum voluntary isometric contraction (% MVIC) for 6 hip abduction rehabilitation exercises. Intraclass correlation coefficients (ICC<sub>3,1</sub>) for intertrial reliability and standard errors of measurement (SEM) expressed as a % MVIC are also shown for each exercise.

Exercise*	% MVIC	ICC	SEM
1. Pelvic drop <sup>†</sup>	57 $\pm$ 32	0.95	4
2. Weight bearing (WB) with flexion left hip abduction <sup>§</sup>	46 $\pm$ 34	0.95	4
3. WB left hip abduction <sup>§</sup>	42 $\pm$ 27	0.96	4
4. Non-weight-bearing (NWB) sidelying hip abduction <sup>§</sup>	42 $\pm$ 23	0.88	3
5. NWB standing hip abduction	33 $\pm$ 23	0.82	5
6. NWB standing flexed hip abduction	28 $\pm$ 21	0.87	3

\* The 1-way analysis of variance with repeated measures revealed a significant main effect across exercise ( $F = 18.198, P < .001$ ).

<sup>†</sup> Exercise 1 significantly greater than exercises 3 through 6 ( $P < .003$ ).

<sup>§</sup> Exercises 2 through 4 significantly greater than exercises 5 through 6 ( $P < .008$ ).

consistency of muscle activation among subjects during each exercise.<sup>27</sup> For this purpose, we calculated ICC<sub>3,1</sub> for each exercise using the last 10 individual trial values. Table 3 summarizes ICCs and standard errors of measurement<sup>9</sup> for each exercise.

## Statistical Analysis

A 1-way ANOVA with repeated measures was used to determine differences in hip abduction activation amplitudes among exercise conditions. Statistical analysis was performed using SPSS Version 12.0 (SPSS Inc, Chicago, IL). Level of significance was set at 0.05.

Significant differences between exercises were determined using the sequentially rejective Bonferroni (Bonferroni-Holm) test.<sup>14</sup> Although some researchers have utilized the Bonferroni correction (performing pairwise comparisons applying the significance level  $\alpha = \alpha/\kappa$ , with  $\kappa$  equal to the number of pairwise comparisons), we did not choose this method because it may hold individual tests to an unreasonably high criteria.<sup>25</sup>

Holm<sup>14</sup> has demonstrated that the sequentially rejective Bonferroni test can adequately protect against a type I statistical error using less stringent criteria. A final important advantage is that this post hoc analysis is conservative but does not require any model or distribution-related assumptions.<sup>14</sup>

## RESULTS

Table 3 summarizes the descriptive statistics for normalized EMG activity under each exercise condi-

tion. The 1-way ANOVA with repeated measures indicated a significant main effect across exercise ( $P < .001$ ). Post hoc analysis revealed that the WB exercises and NWB sidelying hip abduction resulted in greater EMG amplitudes than the NWB standing hip abduction exercises.

## DISCUSSION

Throughout this study, the hip abductor muscles either moved (during NWB exercise) or stabilized (during WB exercise) the hip in the frontal plane by generating an internal torque. Nawoczenski and Neumann<sup>5</sup> have defined an internal torque as “the effect of a force tending to move a body segment about a joint’s axis of rotation,” with its magnitude dependent on the applied external torque. Based on this definition, we hypothesized that exercises that apply a greater external torque to the hip would require greater EMG amplitudes of the hip abductors to counterbalance this torque.

### Biomechanical Applications to Hip Exercises

During the NWB exercises, the hip abductors had to produce enough activity to overcome the external torque created by the mass of the right lower extremity. During these exercises, the external torque equaled the right lower extremity’s gravitational force (approximately 16% body mass plus the 3% body mass ankle cuff) times the external moment arm (perpendicular distance of each force from the joint center of rotation) as shown in Figures 2A and 2B. During the WB exercises, the hip abductors stabilized the pelvis in the frontal plane. With these exercises, the hip abductors had to generate sufficient internal torque to counterbalance the external torque produced by the mass of the head, arms, and trunk (HAT) and left lower extremity (approximately 84% body mass). As described by Neumann and colleagues,<sup>21,23</sup> the external torque at the hip would equal the gravitational force produced by the HAT and left lower extremity times the external moment arm (Figure 3).

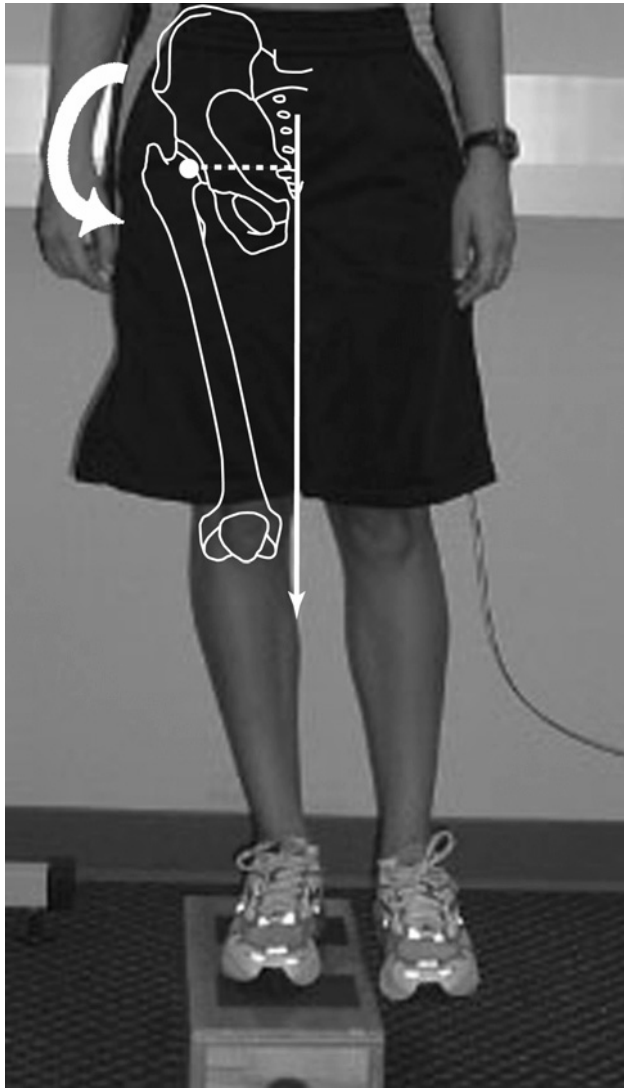
Based on these differences derived from a simplified static free body diagram, we expected greater hip abductor EMG activity during WB exercises, which was partially supported in this study. The WB exercises required greater EMG amplitudes than all NWB exercises except for sidelying hip abduction.

### NWB Exercises

The NWB standing hip and flexed-hip abduction exercises required less EMG activity than the NWB sidelying hip abduction. To perform NWB hip abduction, the hip abductors have to overcome an external torque equal to the mass of the right lower extremity



**FIGURE 2.** These figures illustrate the external torque applied to the right hip abductor musculature during non-weight-bearing (NWB) sidelying and NWB standing hip abduction. The vertical, solid line in each figure shows the force of gravity equal to approximately 19% body mass (16% for the right lower extremity and 3% from the ankle cuff). The horizontal, broken line represents the length of the external moment arm for each exercise. The arrows depict the rotary motion produced by the hip abductors to lift the right lower extremity. Because the right lower extremity represents a similar known mass for both exercises, differences in hip abductor EMG activity result from the difference in the length of the external moment arm between the 2 exercises.



**FIGURE 3.** Illustration showing the external torque applied to the right hip abductor musculature during weight-bearing left hip abduction. The vertical, solid line shows the force of gravity equal to approximately 84% body mass (mass of the head, trunk, arms, and left lower extremity). The horizontal, broken line represents the external moment arm for that mass. The arrow depicts the rotary motion produced by the hip abductors to maintain a level pelvis, which required greater EMG activity than non-weight-bearing exercises.

times the external moment arm of that mass.<sup>24</sup> Because the mass of the right lower extremity remained constant across the 3 exercises, the differences in external torque are attributed to changes in the external moment arm length, with the external moment arm being longer in the sidelying position (Figures 2A and 2B).

### WB Exercise

Our results indicate that both exercises performed with WB on the right lower extremity and left hip abduction resulted in similar EMG amplitudes as the NWB sidelying hip abduction exercise. To maintain balance during the WB exercises, the subjects needed

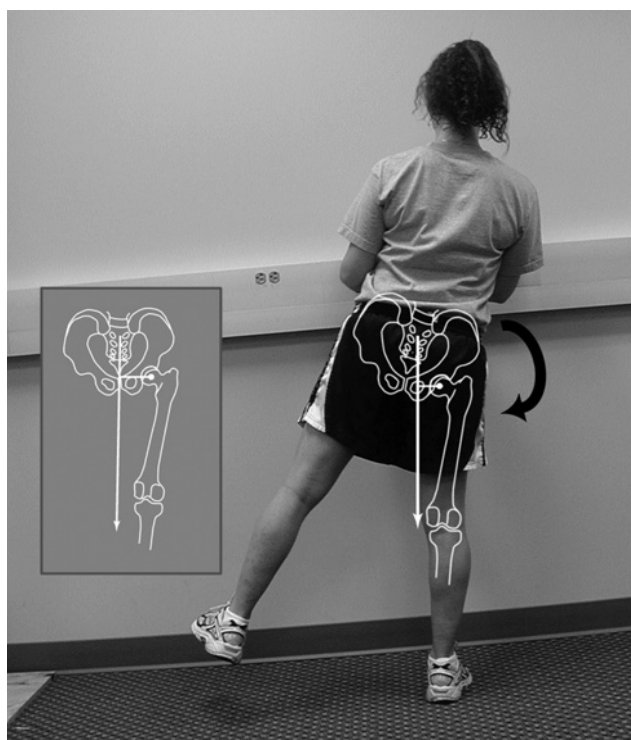
to shift their body mass over the right lower extremity while abducting the left leg. Although we attempted to minimize the amount of right trunk lean by standardizing body position (as described in the Methods section), subjects could have decreased the external torque applied to the hip abductors during the weight shift. Neumann and colleagues<sup>19-21</sup> have reported that right trunk lean would generate a torque in the same rotary direction ordinarily produced by the hip abductors (Figure 4). Consequently, right trunk lean might have diminished the amount of EMG activity required to maintain a level pelvic position<sup>20</sup> and may explain amplitude similarities between both WB left hip abduction exercises and NWB sidelying hip abduction.

We included 2 different hip positions during the WB left hip abduction exercises because people perform many activities of daily living with the hip in a neutral position and many sporting activities, like basketball and soccer, with the hip in a flexed position. Results from our study revealed similar EMG activation regardless of hip position, findings consistent with data from Schmitz et al.<sup>29</sup> These researchers investigated isometric gluteus medius activity during a single-leg stance in response to a posteriorly directed force applied to the contralateral hip with varying amounts of hip and knee flexion. They reported that subjects demonstrated similar gluteus medius activation with the stance hip and knee fully extended and in a position of 20° combined hip and knee flexion.

During the pelvic drop exercise, subjects first lowered (adducted) the pelvis by eccentrically activating the hip abductors and lifted (abducted) the pelvis to the original position using a concentric action. In performing this task, the hip abductors counterbalanced the external torque created from the HAT and left lower extremity. As discussed previously, this greater applied torque would account for differences in EMG amplitudes compared to NWB hip abduction exercises.

The pelvic drop exercise may have required greater EMG activity than the WB left hip abduction exercises for the following reasons. First, subjects performed the pelvic drop with a more vertical trunk alignment. Subjects could not perform WB left hip abduction exercise without some degree of right trunk lean; therefore, trunk lean would decrease the external torque applied to the right hip and require less hip abductor EMG activity compared to the pelvic drop.

Second, the pelvic drop exercise incorporated a greater amount of pelvic excursion and might have utilized more concentric and eccentric actions than WB left hip abduction. Researchers<sup>1,7,30</sup> have examined EMG activity during concentric, eccentric, and isometric muscle actions and reported greater EMG amplitudes during concentric actions. Therefore, a



**FIGURE 4.** This figure illustrates changes in the length of the external moment arm based on the magnitude of right trunk lean. Subjects must perform a limited amount of right trunk lean to maintain balance on the right lower extremity when abducting the left hip; however, excessive trunk lean may reduce the external torque applied to the right hip. The vertical lines represent the force of gravity; the horizontal lines represent the external moment arm. The inserted box shows the length of the external moment arm when the trunk is in vertical alignment. For purposes of this figure, the subject has exaggerated right trunk lean to illustrate the shortening of the external moment arm, which may result in decreased demands for the right hip abductors to maintain a level pelvis.

greater degree of concentric action during the pelvic drop exercise may have accounted for higher EMG amplitudes.

Third, the hip abductors exhibit changes in length-tension relationship during the pelvic drop exercise. Positions of less than optimal length-tension relationship (less cross-bridge overlap) during certain portions of the range of motion would require greater EMG activity to perform this exercise.

Finally, pelvic movement could have altered the hip abductor's internal moment arm (perpendicular distance from the muscle to the hip joint center of rotation) throughout the range of motion. A decrease in the internal moment arm, which most likely occurred at maximal right hip adduction, would require greater muscle force and likely greater EMG amplitudes when returning the pelvis toward a level position.<sup>19</sup>

### Clinical Implications

Our findings are clinically relevant when developing a rehabilitation protocol. The NWB standing hip

abduction exercises required the least amount of muscle activity. Therefore, weaker patients or patients who have recently sustained a hip injury or surgical intervention may be able to utilize these exercises early in the rehabilitation process. As patients become proficient with the NWB standing hip abduction exercises, they may progress to NWB sidelying hip abduction if they are unable to apply full weight bearing to the involved lower extremity. If patients can apply full weight, they can obtain a similar amount of resistance to the hip abductors by standing on the involved lower extremity and abducting the contralateral limb. These exercises may have the advantage of being more functional.

We recommend progression to the WB with flexion left hip abduction exercise because many sporting activities, like basketball and soccer, require movements in this flexed hip position. It is critical that clinicians monitor trunk position during WB left hip abduction exercises because excessive trunk lean to the right can decrease right hip abduction muscle activation.

The pelvic drop task differed from the other exercises because it required subjects to adduct and abduct the right hip in a WB position. It utilized a more dynamic motion compared to the other WB exercises and may require more muscular control. Therefore, the pelvic drop exercise would be more appropriate for patients needing a more challenging exercise.

### Limitations

The present study has limitations. Trunk position can significantly influence the demands placed on the hip abductor muscles during the WB exercises. Although we attempted to standardize the subjects' positions by instructing them to keep the pelvis level and the trunk in vertical alignment (verbal and physical cues typically used in a clinical setting), we did not objectively monitor trunk position. Therefore, varying postures might have affected our results.

A second limitation was the use of a young, asymptomatic subject cohort, which precludes direct extrapolation of results to patients with pain from degenerative changes, acute injury, or postoperative intervention. Although we believe that the above exercise progression may apply to patient populations, symptomatic subjects may demonstrate different motor recruitment patterns.

### CONCLUSION

This study indicated relative differences in hip abductor EMG activity during NWB and WB exercises. NWB exercises in standing applied smaller external torques on the hip and required less activation; therefore, these exercises may benefit patients

who cannot safely perform WB exercise. WB exercises applied greater external torques on the hip and required greater EMG activity. These exercises are more functional and appropriate for patients who can apply full weight on the involved extremity. Results from this study demonstrated a progression of hip abductor muscle activity among commonly used therapeutic exercises, and we believe that clinicians may use this information when developing and implementing hip rehabilitation protocols.

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