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Electromyography Activity of Gluteus Maximus and Gluteus Medius Muscles Using the Somax Power Hip Trainer in Collegiate Golfers

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The present study compared the electromyographic (EMG) activity of the gluteus medius and gluteus maximus muscles across three common golf training aids. EMG data were recorded using surface electrodes from the right- and left-sided gluteus medius and gluteus maximus muscles during hip rotation from three different exercises: (a) SPHT closed position, (b) medicine ball rotational throw, (c) and resisted elastic band downswing. A total of 11 golfers, six men and five women, performed two sets of 15 repetitions of each exercise. Peak EMG data for each muscle group and normalized EMG values by maximal isometric muscle contractions (%MVIC) were recorded during each of the training sessions. EMG data were analyzed with a repeated measure analysis of variance. Overall muscle activation was greatest for the medicine ball throw, which activated the gluteus medius and gluteus maximus muscles at 51% and 53% MVIC, respectively. Based upon the EMG data from the exercise conditions of the four muscles, the medicine ball rotational throw recruits significantly greater muscle activation for gluteus maximus in the trail leg compared with SPHT closed position and resisted elastic band during the concentric phase of hip rotational exercises. For the gluteus medius muscles, there was no statistical difference in muscle activation between the exercises.

Keywords: hip rotation, muscle activity, training aid

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Experienced golfers display proper proximal-to-distal sequencing of the pelvis before the trunk rotation during the golf swing (Gordon, Moir, Davis, Witmer, & Cummings, 2009; Neal, Lumsden, Holland, & Mason 2007; Tinmark, Hellstrom, Halvorsen, & Thorstensson, 2010). Callaway et al. (2012) reported that peak pelvis rotation, gluteus medius strength, and gluteus maximus strength are significantly correlated to a lower golf handicap score. It has been suggested that golfers with lower handicaps are able to use the strength in their hip musculature to a greater extent than are golfers with higher handicaps. This utilization of strength results in increased angular velocity and subsequently greater force transferred to the golf ball (Callaway et al., 2012). Studies have shown that greater flexibility is related to more separation between the upper torso and pelvis at the top and initiation of the backswing, which ultimately helps produce greater rotational velocity (Myers et al., 2008). This understanding changed the training goals of golf athletes and produced a new breed of golfers who were leaner, more muscular, and more flexible, which lends support to training paradigms that include balance, flexibility, core strength, and upper- and lower-body conditioning (Wells, Elmi, & Thomas, 2009).

The golf boom in the later part of the 20th century was the driving influence for golf researchers to understand the biomechanical and physiological factors that affect golf performance (Farrally et al., 2003). Most golfers train to develop sequential muscle activation that produces a fluid, reproducible golf swing that maximizes momentum and force (McHardy & Pollard, 2005). To achieve this goal, recreational golfers attempt to improve their golf performance (e.g., driving distance, club head speed, ball flight) by incorporating resistance exercises, weight training, and plyometric exercises that target hip and trunk musculature into their training protocols (Fletcher & Hartwell, 2004; Kim, 2010; Lephart, Smoliga, Myers, Sell & Tsai, 2007). Traditional exercises, such as step-ups (Simenz, Garceau, Lutsch, Suchomel & Ebben, 2012), hip abduction/adduction against resistance (Holcomb, Miller & Rubley, 2012), side planks, and single leg squats (Boren et al., 2011), are effective exercises for training the targeted gluteus muscles.

Commercially available training aids (Adler, 2007) and video analysis systems (Guadagnoli, Holcomb & Davis, 2002) have demonstrated some benefit to and improvement in golfing performance. One of these training aids, the Somax Power Hip Trainer (SPHT; Pritchard, 2013), purported to increase club head speed as well as hip strength and hip speed by resisting hip rotation against a spring-loaded variable resistance, has become available and is widely used. The SPHT consists of a padded hip cinch attached to a steel pole that is anchored to a high-tensile steel spring, which provides resistance to pelvic rotation. While the SPHT was developed to improve hip strength and flexibility for the sport of golf in healthy individuals, it may also be used to train individuals during rehabilitation in a clinical setting. The SPHT isolates the gluteus medius muscles required for hip internal/external rotation. Although more expensive (~$300) than traditional training aids, such as medicine balls and resistance tubing, the SPHT requires minimal space and can be performed at multiple locations (e.g., home, office, training facility).

Given the lack of empirical evidence that supports one training aid over another, the purpose of this study was to examine muscle activation of the gluteus maximus and gluteus medius during three different hip rotation exercises: (a) medicine ball rotational throws, (b) resisted downswing using an elastic band, and (c) use of the SPHT. We hypothesized that hip rotation exercises using the SPHT will produce significantly greater electromyographic (EMG) activation of the gluteus maximus and gluteus medius muscles than will either medicine ball rotation throws or resisted downswings using the elastic band. Data obtained from this study will provide information pertaining to the efficacy of common training methods at targeting hip musculature. This information can be used to develop strengthening programs that can be incorporated into golf-specific training exercises.

Experimental Approach to the Problem

In this study, we examined which exercise elicited the greatest EMG signal from the right and left gluteus medius and gluteus maximus muscles. The EMG signals were collected with surface electrodes and normalized to maximum voluntary isometric contraction (MVIC). A within-subject repeated measures design was used to test the null hypothesis that EMG activation in the right and left gluteus medius and gluteus maximus muscles would be equal when hip rotation was performed during each of the three exercise conditions. Testing order was randomized to reduce the potential of order effect to the study's internal validity. The independent variables included the three separate exercise training sessions (SPHT in closed position, medicine ball rotational throw, and resisted downswing with elastic band tubing). The dependent variable was the normalized EMG value of the left and right gluteus medius and left and right gluteus maximus muscles.

Methods

Primary Testing Procedures

Participants. A total of six males and five females, 19–24 years of age, volunteered to participate in this study. Ten of the participants were right-handed. All participants were healthy and were characterized as collegiate-level golfers for the Hofstra University varsity golf teams. Descriptive information for the participants is presented in Table 1. The risk of the investigation was explained to each participant, and each of them signed an informed consent before participation in this study. The procedures in this study were approved by the Hofstra University Institutional Review Board before initiation.

Procedures. All participants attended three sessions, which consisted of a maximum manual muscle-testing session, a training session that included two golf specific exercises, and a final training session using the SPHT. Each session was separated by one week. The first session measured the participants' anthropometry profile (i.e., height, weight, and age), followed by a series of maximal manual muscle tests. Manual muscle testing (Frost, 2002) was performed using the standard protocol and positions for the gluteus medius and gluteus maximus muscles on the right and left sides. For all muscle testing and exercise testing sessions, EMG was used to measure muscle activity for the selected muscles. EMG is a measurement of electrical activity generated in skeletal muscle and provides information about the neuromuscular impulses received in the muscle from the central nervous system (Basmajian & De Luca, 1985).

Manual Muscle Tests. One week before performing the training sessions, participants performed MVICs during right and left hip abduction and right and left

Table 1 Age, Height, Weight, and Handicap Score of the Sample

Subject	Age (yrs)	Height (cm)	Weight (kg)	Handicap
1	20	67	73.6	1.0
2	21	72	79.5	0
3	19	70	72.7	0
4	19	69	60.2	1
5	20	75	88.6	3
6	21	67	65.9	1.5
7	21	66	81.1	4
8	21	64	59.1	6
9	20	67	85.0	4
10	21	67	70.5	2
11	20	64	47.1	10
Mean ± *SD*	20.27 ± 0.78	68 ± 3.31	71.2 ± 12.46	2.95 ± 2.98

hip extension. Three MVIC tests were performed for each movement on both limbs. The highest MVIC recorded was used for the analysis. Participants were instructed to push as hard as possible against the investigator's hands, which was used to provide resistance to the leg movement. Participants were instructed to produce a maximum muscle contraction for five seconds before relaxing.

Gluteus Maximus

Position. The participant lay prone, bending his or her leg at least 90° and extending his or her hip (by lifting his or her leg from the table).

Stabilization. The examiner stabilized the opposite hip by applying downward pressure toward the table. The participant was not allowed to straighten the leg or rotate the pelvis during the test.

Muscle Test. With the participant's extending the hip with maximum force, the examiner resisted the leg down toward the table (toward flexion of the hip) while placing the hand near the posterior side of the ankle.

Gluteus Medius

Position. As the participant was side lying, the knee was fully extended and held in slight hip extension and abduction.

Stabilization. The examiner stabilized the pelvis to prevent tensor fascia lata activity.

Muscle Test. As the participant abducted the hip with maximum force, the examiner resisted the leg medially toward the other leg, while placing the hand near the lateral side of the ankle.

Training Sessions

The order of training sessions was randomized to reduce bias imposed by an order effect. Before the start of the training sessions, all participants were instructed on the correct exercise techniques. Training sessions were performed one time per week for two weeks and these training sessions were performed one week apart. A standardized warm-up and cool-down period was used in each training session (Fletcher & Hartwell, 2004) and consisted of 10 minutes of dynamic flexibility followed by low-level cycling. Participants performed a total body static stretch routine (one set of 12 seconds per muscle group) during the cool-down.

For one training session, all participants performed two different golf-specific exercises: (a) rotation medicine ball throw (Earp & Kraemer, 2010; Fletcher & Hartwell, 2004) and (b) resisted downswings using elastic tubing for resistance (Lephart et al., 2007). For all training sessions, participants performed hip rotational movements as fast as possible in an explosive manner, mimicking the golf swing as closely as possible. This allowed us to generalize our findings to how golfers would be performing these exercises during an actual strength and conditioning session or in a clinical setting. The weight used for medicine ball was 3kg. This is the weight of the medicine ball used in previous studies (Fletcher & Hartwell, 2004) and the medicine ball throw simulates the plane of movement (diagonal abduction) for the sport of golf regarding body positioning and swinging movements (Earp & Kraemer, 2010). This is also the proper medicine ball training weight for rotational sports that are nonreactive and stationary (Earp & Kraemer, 2010). The medicine ball was released at the end of each movement in an attempt to maximize the sequential acceleration of the movement (Figure 1).

Similar to the medicine ball throw, during the resisted downswing exercises, participants were instructed to rotate their hips as fast as possible, using a medium-resistance (orange) band (Power Systems; Knoxville, TN). Participants were instructed to increase the resistance of the exercise by moving farther away from the anchor point (Figure 2) of the elastic resistance tubing when they could comfortably complete the exercise (Lephart et al., 2007).

Figure 1 — Pictorial representation of the medicine ball throw exercise.

Figure 2 — Pictorial representation of the elastic band tubing exercise.

Participants performed two sets of 15 repetitions per exercise. Muscle activity was measured for each repetition for each of the two sets. The training sessions were aimed to incorporate the lower body muscles of the hip and trunk to enable optimal muscle activity of the gluteus medius and gluteus maximus muscles.

Somax Power Hip Trainer Sessions. Before the SPHT training sessions, all participants watched a brief video and were instructed on proper technique in the use of the Somax apparatus (Somax Performance Institute, Tiburon, CA). All participants performed two sets of 15 repetitions of hip rotations on the SPHT (Figure 3), during which time they were instructed to rotate their hips as fast as possible for each repetition. This ensured an equal amount of work for each exercise condition.

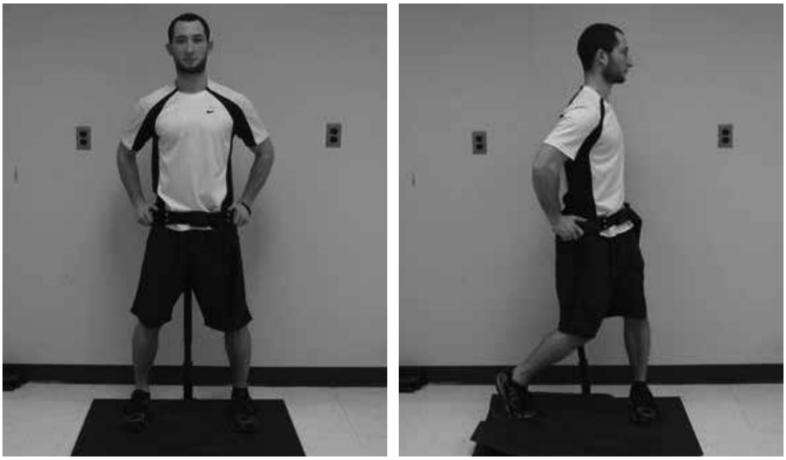

Figure 3 — Pictorial representation of the Somax Hip Power Trainer exercise.

Somax Power Hip Trainer (closed vs. open position). The SPHT has two different position settings, closed and open. The closed position is a resisted-loaded setting, while the open position is an assisted-loading setting. During data collection, minimal EMG activation was elicited in the open setting; therefore, only the closed-position data are being reported. In the closed-position setting, the participants faced forward (Figure 3) with their hands on the hip cinch. The hip cinch is a 2-inch wide nylon belt that allows for adjustment for different hip girths. In the closed position, the participants rotated their hips against the spring-loaded resistance.

EMG Recording and Processing

Muscle activity was recorded bilaterally from the upper and lower gluteus maximus muscles and bilaterally from the anterior fibers of the gluteus medius muscles. For the gluteus maximus, electrode placement varied between upper and lower placement for each individual, depending on muscle mass thickness and adipose tissue. Placement was confirmed by observing EMG signals while separately activating each muscle. This provided the best window to observe gluteal activity. Electrode placement on the lower gluteus maximus muscle was 2 cm apart and 2 cm above the gluteal fold (Chriswell, 2011). Placement on the upper gluteus maximus muscle was 2 cm apart and half the distance between the greater trochanter of the hip and the sacral vertebrae in the middle of the muscle (Chriswell, 2011). For the gluteus medius, electrode placement was 2 cm apart and parallel to the muscle fibers over the proximal third of the distance between the iliac crest and the greater trochanter.

Using 10 mm bipolar surface silver-silver chloride electrodes 1700 CLEARTRACE (Myotronics, Inc., Kent, WA), the investigator oriented the electrodes parallel to the muscle fibers with an interelectrode distance of approximately 40 mm. At each electrode site, the surface silver-silver chloride ground electrode was 10 mm in diameter. Before applying the self-adhesive electrodes, the investigator shaved the skin over each muscle with a disposable razor and cleaned with alcohol prep pads (70% isopropyl alcohol) to reduce impedance at the skin electrode interface. The electrode configuration was preamplified bipolar, grounded, surface electrodes (Mega Electronics Ltd., MESPEC 4000 system amplifiers, Kuopio, Finland).

Preamplified EMG (gain = 1000) cables were connected to electrodes at each muscle site and interfaced to the MESPEC 4000 system amplifiers (20–500 Hz (-3dB)). EMG signals were recorded using an analog-to-digital converter (12-bit resolution), interfaced to a computer with a sampling rate of 1000 Hz per channel. LabView software (National Instruments Corp., Austin, TX) was used for data acquisition and data processing. EMG signals were full-wave rectified, and a moving average smoothing algorithm (75-ms window) was used to generate a linear envelope for each muscle response during the MVIC tasks and for the two different exercises. For the MVIC tasks, raw EMG signals were partitioned into a five-second window of around the maximum absolute EMG value before applying the rectifying and smoothing algorithms. For the exercises, raw EMG signals were aligned and averaged for the entire two-minute time trial for each of the two sets before applying the rectifying and smoothing algorithms.

Maximum EMG amplitude for each exercise was defined as the peak of the linear envelope for each muscle during the task. The maximal EMG amplitude during each exercise was expressed as a percentage of the maximum EMG amplitude obtained during the MVIC (%MVIC).

Reliability of Electromyographic Measures

We determined the test-retest reliability for the normalized EMG data for the left and right gluteus medius and left and right gluteus maximus muscles during the maximal manual muscle-testing sessions. Intraclass correlations coefficients (ICC), examining reliability between the three maximum trials within each day, demonstrated excellent consistency for the normalized (ICC 0.92–0.98) values for the lower-limb muscles.

Statistical Methods, Data Analysis and Interpretation

Differences in %MVIC (dependent variable) for each muscle group were analyzed for each of the three exercises: (a) medicine ball rotational throw, (b) resisted downswing using elastic band tubing, and (c) SPHT in the closed position. Four one-way analyses of variance with repeated measures were used to determine significant differences in EMG values for each of the four muscles across the three exercise conditions. Post hoc effects with Bonferroni adjustments were used to compare EMG between exercise conditions when main effects were significant. If Mauchly's test of sphericity was violated, Greenhouse-Geisser adjustments were applied. All statistical analyses were conducted using the IBM Statistical Package for the Social Sciences software (Version 20.0; IBM Inc., Armonk, NY). Unless otherwise specified, $p < .05$ was used as an acceptable level of significance for all analyses.

Results

Left Gluteus Medius

There were no significant differences between the three exercises for the left gluteus medius muscle. Mean ± *SD* normalized EMG activity was 24.6 ± 11.4%, 30.3 ± 11.6%, and 27.4 ± 16.2 for the SPHT closed position, medicine ball throw, and elastic band tubing, respectively (Figure 4).

Right Gluteus Medius

There were no significant differences between the three exercises for the right gluteus medius muscle. Mean ± *SD* normalized EMG activity was 49.8 ± 24.1%, 50.5 ± 13.9%, and 33.1 ± 11.1% for the SPHT closed position, medicine ball throw, and elastic band tubing, respectively (Figure 5).

Left Gluteus Maximus

Significant main effects were observed in the left gluteus maximus muscle between the medicine ball and the SPHT closed position and medicine ball and elastic band tubing. Mean ± *SD* normalized EMG activity was 17.4 ± 11.1%, 31.6 ± 10.4%, and 22.7 ± 13.7% for the SPHT closed position, medicine ball throw, and elastic band tubing, respectively (Figure 6). Post hoc Bonferroni adjusted simple effects tests revealed significant pairwise differences in gluteus maximus muscle activation: (a) medicine ball throw greater than SPHT closed position (mean difference = 14.1%, $p = .006$, effect size = 1.1) and (b) medicine ball throw greater than elastic band tubing (mean difference = 8%, $p = .01$, effect size = 0.68).

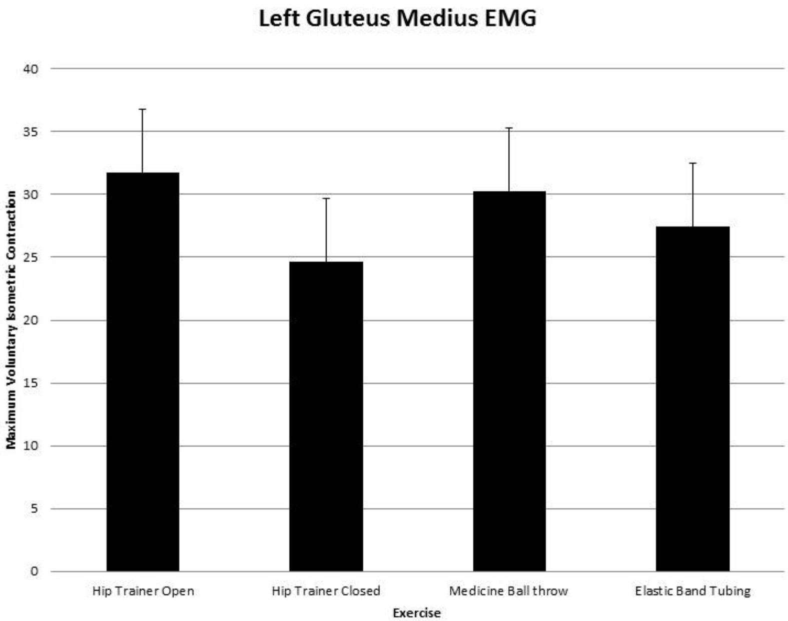

Figure 4 — Mean normalized EMG in the left gluteus medius muscle obtained during hip rotation exercise from the SPHT closed position, medicine ball throw, and resisted elastic band tubing. There was no difference between exercise conditions.

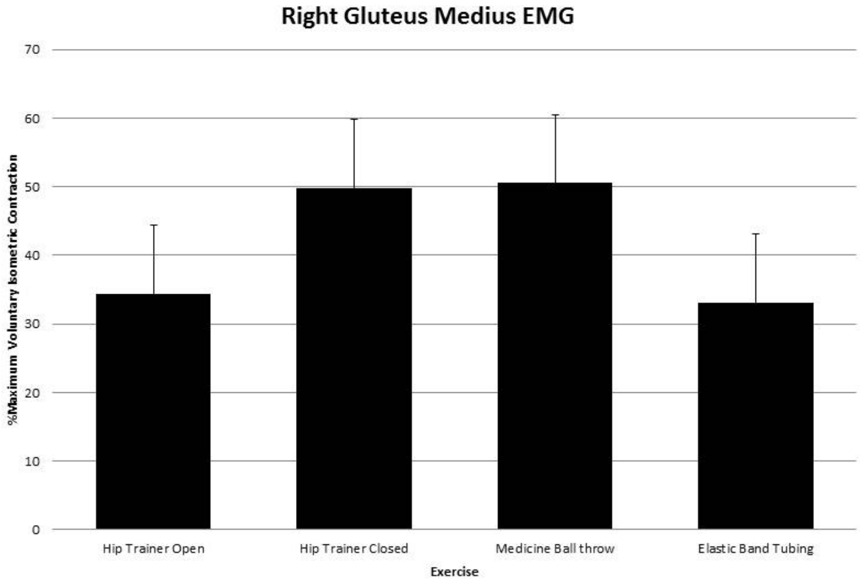

Figure 5 — Mean normalized EMG in the right gluteus medius muscle obtained during hip rotation exercise from the SPHT closed position, medicine ball throw, and resisted elastic band tubing. There was no difference between exercise conditions.

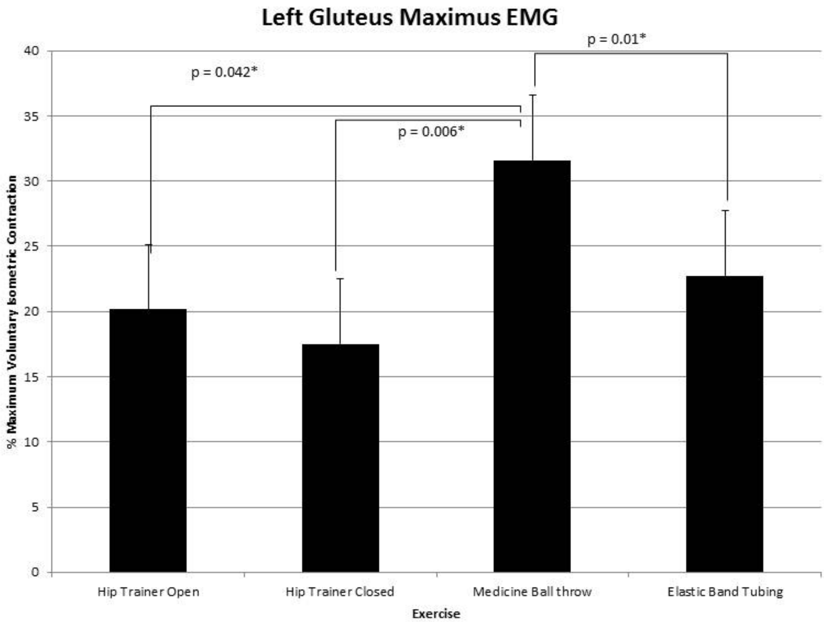

Figure 6 — Mean normalized EMG in the left gluteus maximus muscle obtained during hip rotation exercise from the SPHT closed position, medicine ball throw, and resisted elastic band tubing. The EMG activity is significantly greater in the medicine ball throw condition compared with the SHPT closed position ($p = .006$), and resisted elastic band tubing ($p = .01$).

Right Gluteus Maximus

Significant main effects were observed in the right gluteus maximus muscle between the medicine ball and the SPHT closed ($p = .01$), and medicine ball and elastic band tubing ($p = .001$). Mean ± *SD* normalized EMG activity was 36.4 ± 16.2%, 53.4 ± 20.5%, and 38.4 ± 14.3% for the SPHT closed position, medicine ball throw, and elastic band tubing, respectively (Figure 7). Significant differences were found for: (a) medicine ball throw greater than SPHT closed position (mean difference = 17%, $p = .01$, effect size = 0.79) and (b) medicine ball throw greater than elastic band tubing (mean difference = 15%, $p = .001$, effect size = 0.75).

Discussion

The aim of the current study was to compare the EMG activity of the gluteus medius and gluteus maximus muscles across three common golf training aids. Our primary hypothesis was not supported and the Somax exercise did not produce the largest muscle activation. The greatest EMG activity for the gluteus medius and gluteus maximus was found in the medicine ball throw exercise, which may be attributed to the greater range of motion during this exercise and the small differences in loading. In the golf swing, the muscles of the trail leg are the most active during the downswing phase (Bechler, Jobe, Pink, Perry, & Ruwe, 1995; McHardy & Pollard, 2012; Watkins et al., 1996). The EMG results from our study are consistent with

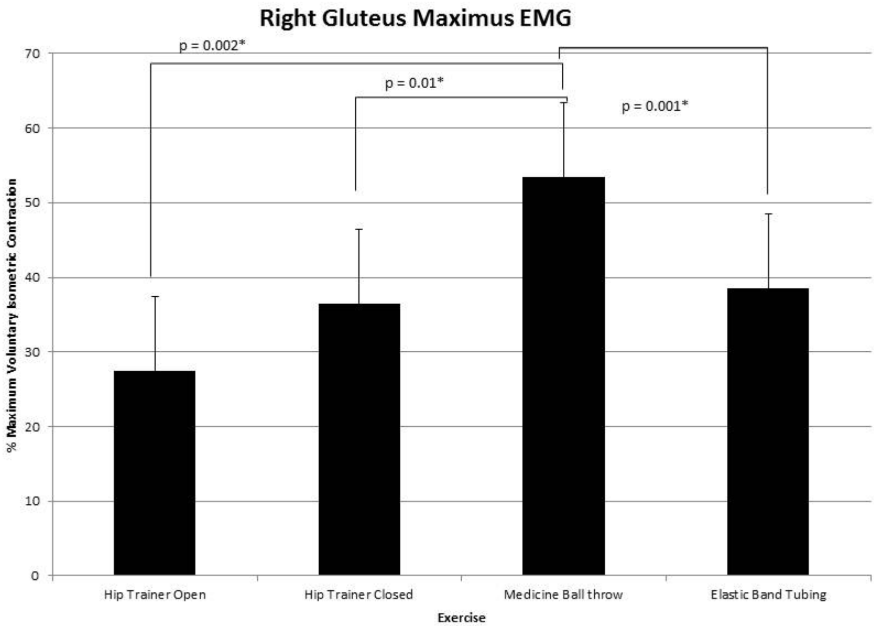

Figure 7 — Mean normalized EMG in the right gluteus maximus muscle obtained during hip rotation exercise from the SPHT closed position, medicine ball throw, and resisted elastic band tubing. The EMG activity is significantly greater in the medicine ball throw condition compared with the SHPT closed position ($p = .01$), and resisted elastic band tubing ($p = .001$).

these findings for the right gluteus medius and right gluteus maximus was the trail leg for ten participants. The primary movers with the highest amount of muscle activity during the acceleration phase of the downswing include the muscles of the trunk, shoulder, forearm, and lower limbs (Marta et al., 2012). The gluteus maximus and gluteus medius muscles transfer the great amount of power to the trunk during this time (Cole & Grimshaw, 2008; Tsai et al., 2004; Watkins, Uppal, Perry, Pink, & Dinsay, 1996). Not surprisingly, an inverse correlation exists between gluteus medius and gluteus maximus muscle strength and handicap score (Callaway et al., 2012). Callaway et al. concluded that low-handicap golfers had significantly more strength in the gluteus muscles compared with high-handicap golfers. Based on these findings, golf-specific training programs should include rotational exercises to increase rotational speed and power during the golf swing (Callaway et al., 2012).

EMG levels can be influenced by multiple factors, such as the direction of contraction (concentric vs. eccentric; Grabiner & Owings, 2002; Kay, St. Clair-Gibson, & Mitchell, 2000), velocity (Jakobsen, Sundstrup, Andersen, Aagaard, & Andersen, 2013; Jönhagen, Halvorsen, & Benoit, 2009), and “cross talk” from adjacent muscle groups (Chriswell, 2011). Concentric contractions produce greater EMG signals than do eccentric contractions (Grabiner & Owings, 2002; Kay et al., 2000); rapid or ballistic movements also can produce higher EMG amplitudes than can slower movements (Jönhagen et al., 2009; Sakamoto & Sinclair, 2012). Given these potential confounders, only the concentric phase of the downswing was analyzed in the current study. To control for contraction velocity, the investigator instructed each participant to rotate his or her hips as fast as possible to minimize the within-subject variability between trials. To account for the differences in electrical signals that may arise between individuals due to differences in body fat or skin impedance, the investigator normalized muscle activation to the MVIC during the manual muscle testing sessions. This allowed us to compare the percentage of EMG activity levels on an individual basis between the three different exercise conditions.

We examined the EMG activity of the right and left gluteus medius and gluteus maximus muscle required to perform the rotational hip turns that simulated the downswing phase of the golf swing. The gluteus medius is primarily a hip internal rotator and abductor but also plays an important role in pelvic stabilization. The gluteus maximus is acknowledged to be a hip extensor and hip external rotator (Frost, 2002) and is primarily activated when the hip starts to extend from a flexed position, as occurs during the address phase of the golf swing (Floyd, 2009). Pelvic stability and hip flexion are optimal characteristics in the address phase because this position allows for a more powerful and efficient swing (Smith, Roberts, Wallace, & Forrester, 2012).

The most important finding in this study is that performing medicine ball rotational throws as fast as possible will stimulate the most overall muscle activity for the gluteus medius and gluteus maximus muscles. However, statistical difference was only found in the gluteus maximus muscles. It is plausible that higher muscle activation was a function of the greater overall range of motion that occurs during the medicine ball throw exercise (Earp & Kraemer, 2010), although joint motion was not quantified during the testing sessions. The difference may have occurred due to the hip cinch connection of the hip trainer, which appears to restrict hip extension, and subsequently muscle activity of the gluteus maximus. However, it is also important to note that EMG activity of the gluteus medius during the SPHT (closed position) was comparable to the medicine ball throw. Therefore, the SPHT may be a clinically meaningful method of training the gluteus medius muscle group.

The practical application of the current study lies in the finding of different EMG activation between activities. For the gluteus maximus muscle, performing medicine ball rotational throws will activate the most muscle activation. For the gluteus medius muscle, the medicine ball throw and the SPHT in the closed position are comparable in muscle activation. The SPHT may be a viable alternative option if space and equipment is limited not allowing medicine ball throws to be performed. This may be helpful to golf instructors who prescribe exercises that target hip musculature. The primary limitation of the current study is that no kinematic data were recorded for the golfers during the training sessions, which is a viable subject for future studies and could provide valuable insight on whether the SPHT trains the golfer for the proper sequencing during the downswing phase of each of these exercises. Proper sequencing is reported to have proximal body segments (closer to the core) to reach peak speeds, followed by distal body segments (i.e., hands) to reach peak speed closest to impact (Neal et al., 2007). This is supported by later research that indicated that the downswing in elite golfers is initiated by reversal pelvic rotation, followed by reversal upper torso rotation (Meister et al., 2011). A second limitation is the inherent loading differences between the three exercise conditions, even though each exercise is a common training method for golf. Because there are different types of loads involved in each activity, it becomes impractical to create equal loading in the mechanical spring on the Somax device, the medicine ball, and the resistance band. Therefore, careful consideration of load-volume is needed when designing conditioning programs that use these modalities.

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