

Effect of hand position on EMG activity of the posterior shoulder musculature during a horizontal abduction exercise

Brad Schoenfeld, PhD, CSCS, CSPS, FNSCA¹

R. Gul Tiryaki Sonmez, PhD¹

Morey J. Kolber, PT, PhD, CSCS³

Bret Contreras, MA, CSCS²

Robert Harris, MSc¹

Serife Ozen⁴

1. Lehman College, Bronx, NY
2. AUT University, Auckland, NZ
3. Nova Southeastern University, Ft. Lauderdale Florida
4. Abant Izzet Baysal University, Bolu, Turkey

Introduction

The posterior deltoid is an important muscle for maintaining dynamic stability of the shoulder joint (2, 12). It is the primary glenohumeral horizontal abductor (10) and also serves as an external rotator, although its moment arm for this action does not appear to be as great as that of the infraspinatus and teres minor (11). Moreover, the posterior deltoid has been shown to be active in frontal plane glenohumeral adduction and abduction, but its role in these movements appears to be as a stabilizer against the tendency of the prime movers to produce unwanted internal rotation or horizontal flexion (15).

Strengthening the posterior head of the deltoid is desirable for ensuring shoulder joint integrity (6) as well as enhancing athletic performance and reducing injury potential (13). This can be accomplished with a variety of modalities including free weights, cables, and machines. However, given the posterior deltoid's limited role in the sagittal and frontal planes, traditional overhead pressing movements will tend to favor the anterior and middle deltoids at the expense of the posterior head. Hence, the posterior deltoid may become underdeveloped vis-a-vis the other deltoid heads unless direct transverse plane exercise such as horizontal shoulder abduction is performed.

From an exercise performance standpoint, the activity of the deltoid muscles are affected not only by the direction of humeral movement in a given plane, but also may be influenced by whether the joint is placed in internal or external rotation. Using fine wire electromyography (EMG), Reinold et al. (14) showed that the prone full-can exercise, where the subject lies face down and performs horizontal abduction at approximately 100 degrees of glenohumeral abduction and full external rotation, produced significantly greater EMG activity in the posterior deltoid compared to the standing full-can or empty can exercises that elevate the arm in the

scapular plane. Similar results were found by Boettcher et al. (4), who used a combination of surface EMG and intramuscular fine wire electrodes to evaluate muscle activity during these same exercises. Moreover, Anderson et al. (3) found that the reverse fly (horizontal abduction in the transverse plane) performed with partial external rotation produced the highest level of posterior deltoid muscle activation when compared to the one-arm dumbbell row, shrug, upright row, and lateral raise. It is clear from these studies that horizontal shoulder abduction exercise maximizes muscle recruitment of the posterior deltoid. Unfortunately, the impact of varying degrees of shoulder rotation during horizontal abduction exercise has not been well studied despite the fact that exercise equipment such as the reverse fly machine (seated horizontal shoulder abduction in the transverse plane) is often designed with alternate hand positioning options.

A number of studies have examined the effect of performing glenohumeral elevation in external versus internal rotation on the various deltoid heads during scapular plane movement. Reinold et al. (14) found significantly greater muscle activity in the middle and posterior heads in the empty can exercise (shoulder abduction 30-degrees anterior to the frontal plane with internal rotation) compared to the full can exercise (shoulder abduction 30-degrees anterior to the frontal plane with external rotation). Similarly, Boettcher et al. (4) displayed that the empty can exercise produced greater EMG activation of all three deltoid muscles compared to the full can exercise, but results did not reach statistical significance.

A search of the PUBMED-MEDLINE and EBSCO databases revealed only one study that examined the effects of using internal versus external rotation during horizontal abduction. In this study (16), 15 male subjects performed 17 different dumbbell exercises for the glenohumeral joint, including horizontal shoulder abduction carried out in both internal and

external rotation. Fine wire EMG was used to assess peak activity in the glenohumeral muscles. Results in the aforementioned study showed that shoulder rotation had a minimal effect on muscle activation of the posterior deltoid. Statistical significance between exercises was not reported, however, so results can only be interpreted on an absolute basis.

In summary, there is a paucity of evidence-based research that has investigated the effect of shoulder rotation during horizontal abduction on muscle activation of the posterior deltoids. Moreover, no research that we are aware of has investigated the effect of shoulder internal rotation versus neutral rotation on posterior deltoid activation when using the reverse fly machine. Thus, the purpose of this study was to assess the impact of varying one's hand position, and consequently altering shoulder joint rotation, on muscle activity in the posterior deltoid during exercise on the reverse fly machine. Given that internally rotating the shoulder increases stiffness of the posterior deltoid (8), it was hypothesized that horizontal abduction combined with internal rotation would produce greater muscular activity compared to a performance of the movement in neutral rotation. A secondary purpose of the study was to evaluate the effect of these exercise variations on the middle deltoid and infraspinatus muscles.

Materials and Methods

Experimental Approach to the Problem

The reverse fly machine is a popular exercise for strengthening the horizontal shoulder abductors, namely the posterior deltoid. With correct body alignment, this machine helps to facilitate proper form by restricting degrees of freedom so that movement takes place purely in the transverse plane. Moreover, the machine may allow for greater force development in the target shoulder musculature since the need for core stabilization is minimized. Exercise performance can be carried out either with the hands in a pronated position, which places the

shoulder joint in internal rotation, or a neutral position, which places the shoulder joint in neutral rotation. There seems to be little consensus as to which hand position most effectively targets the posterior deltoid despite this option on most machines. This study was designed to investigate whether significant differences in muscle activity are seen in the posterior deltoid when performing the reverse fly with either a neutral grip (NEU) or a pronated (PRO) grip as determined by surface EMG. A repeated measures counterbalanced design was used to answer the question: During horizontal abduction of the glenohumeral joint (reverse fly), will varying hand position significantly affect muscle activation of the posterior deltoid?

Subjects

Nineteen men (mean age = 23.2 ± 4.3 years; height = 176.9 ± 7.1 centimeters; body mass = 81.3 ± 10.5 kilograms; body mass index = 25.9 ± 2.6) were recruited from a university population to participate in this study. All subjects were experienced with resistance training, defined as lifting weights for a minimum of 2 days a week (mean = 4.1 ± 1.3 days/week) for 1 year or more (mean = 5.2 ± 2.7 years).

Inclusion criteria required subjects to read and speak English as well as pass a physical activity readiness questionnaire (PAR-Q). Those receiving care for any shoulder or neck pathology at the time of the study or those with an amputation of an upper extremity limb were excluded from participation. A post-hoc power analysis showed that this sample size was sufficient to detect an absolute mean difference in EMG activity of 10%—normalized to the MVIC—between conditions with a statistical power of 0.80 at $\alpha = 0.05$. Each subject gave written informed consent prior to participation. The research protocol was approved by the institutional review board at Lehman College, Bronx, NY.

Procedure

Following consent, subjects were prepared for testing by wiping the skin in the desired areas of electrode attachment with an alcohol swab to ensure stable electrode contact and low skin impedance. After preparation, self-adhesive disposable silver/silver chloride pre-gelled dual snap surface bipolar electrodes (Noraxon Product #272, Noraxon USA Inc, Scottsdale, AZ) with a diameter of 1 cm. and an inter-electrode distance of 2 cm. were attached parallel to the fiber direction of the posterior deltoid, middle deltoid, and infraspinatus muscles. All subjects had very little if any body hair in the shoulder region, thus rendering it unnecessary to shave the area. Electrode placement was made on the right side of each subject to minimize potential ECG artifact. The posterior deltoid electrode was centered approximately 2 fingerbreaths behind the angle of the acromion. The middle deltoid electrode was placed along the line from the acromion to the lateral epicondyle of the elbow, corresponding to the greatest bulge of the muscle. The infraspinatus electrode was placed parallel to and approximately 4 cm below the spine of the scapula, on the lateral aspect, over the infraspinous fossa. A neutral reference electrode was placed over the bony process at the base of the neck. These methods are consistent with the recommendations of Criswell (5) and the SENIAM (Surface EMG for Non Invasive Assessment of Muscles) project (1). After all electrodes were secured, a quality check was performed to ensure EMG signal validity.

Instrumentation

Raw EMG signals were collected at 2000 Hz by a Myotrace 400 EMG unit (Noraxon USA Inc, Scottsdale, AZ), and filtered by an eighth order Butterworth bandpass filter with cutoffs of 20-500 Hz. Data were sent in real time to a computer via Bluetooth and recorded and analyzed by MyoResearch XP Clinical Applications software (Noraxon USA, Inc., Scottsdale, AZ). Signals were rectified (by root mean square [RMS] algorithm) and smoothed in real time.

Maximal Voluntary Isometric Contraction

Maximal voluntary isometric contraction (MVIC) data were obtained for each muscle tested by performing a series of resisted isometric contractions as outlined by Hislop and Montgomery (7). Table 1 describes the specific manual muscle testing exercises employed. Tests were carried out as follows: After an initial warm up consisting of 5 minutes of light cardiovascular exercise and slow dynamic stretching in all three cardinal planes, subjects were asked to slowly increase the force of the contraction so as to reach a maximum effort after approximately 3 seconds. Subjects then held the maximal contraction for 3 seconds before slowly reducing force over a final period of 3 seconds. This procedure was repeated once for each muscle following a 60 second rest interval and the highest MVIC value was used for comparison.

Exercise Description

Five minutes after MVIC testing, subjects were positioned to sit face forward in a reverse fly machine (Model #MD 504, Body Masters Corporation, Rayne, LA) so that the chest was flush against the restraint pad. Seat height was adjusted so that the hand grips of the unit were aligned with the shoulder joint axes of rotation. Subjects grasped the hand bars on the machine with either a PRO (performed with palm down, see Figure 1) or NEU (performed with thumb up, see Figure 2) grip. The order of performance of the hand positions was counterbalanced between participants so that approximately half of the subjects performed PRO first and the other half performed NEU first. The starting position of the exercise was at 90 degrees of humeral elevation in the sagittal plane and the finish position was when subjects reached the point where the humerus was parallel to the torso. Subjects completed as many repetitions as possible to

muscular fatigue for each hand position with a resistance corresponding to ~75% of body mass, which ultimately corresponded to an intersubject variance of 4 to 12 total repetitions. From a within-subject standpoint there was virtually no difference in the number of repetitions between variations. The vast majority of subjects performed equal numbers of reps for each of the hand positions and no subject had a variance of more than 1 repetition between hand positions, therefore indicating that fatigue was not a confounding issue in results. Concentric actions were performed as forcefully as possible (velocity of ~1 second) and eccentric actions were performed at a 2 count (velocity of ~2 seconds). Technique instruction and verbal inducements were given to each subject before and during performance by the primary investigator who is a certified trainer to ensure that exercise was carried out in the prescribed manner. The exercise bout was stopped when the subject could no longer perform a concentric repetition in proper form throughout a complete range of motion.

Statistical Analysis

Statistical analysis was carried out using SPSS statistical software (version 20.0; IBM Corporation, New York, NY). The normalized EMG differences between the 2 trials for each of the muscles studied were tested for statistical significance using a paired t-test. The entire set of repetitions was analyzed for each variation in every subject. Both mean (the average amplitude across each set) and peak (the highest value found in each set) EMG values were assessed. Effect size (d) was calculated using formula $M_1 - M_2 / SD$, whereas means from each group (hand position) were subtracted and divided by the standard deviation. Statistical significance was considered at $\alpha \leq 0.05$.

Power analysis was performed a priori to determine the number of subjects required to produce a power of 0.80 at an α level of 0.05. It was assumed that 10% differences between hand

positions in posterior deltoid muscle activity would be clinically relevant. A sample of at least 18 subjects was determined to be a reasonable number to achieve adequate statistical power.

Results

Results showed that mean normalized EMG activity for the posterior deltoid was significantly greater in NEU compared to PRO ($p = 0.046$; 95% CI = 0.1 to 7.4% MVIC). Similarly, mean normalized EMG activity of the infraspinatus also was significantly greater in NEU compared to PRO ($p = 0.002$; 95% CI = 3.7 to 13.6% MVIC). There was a trend for greater mean normalized EMG activity in the middle deltoid during NEU compared to PRO ($p = 0.087$) but this did not reach statistical significance. No significant differences were seen in peak normalized EMG activity between hand positions in any of the muscles studied, although there was a trend for greater peak activity in the infraspinatus during NEU compared to PRO ($p = 0.076$). Effect sizes for differences between shoulder positioning were small for both mean and peak EMG for all muscles ($d \leq 0.3$) with the exception of mean infraspinatus activity where a moderate effect was identified ($d = 0.5$). Figure 3 and Table 2 provide descriptive data and paired sample test results, respectively, for all of the muscles studied.

Discussion

This was the first study to investigate the effects of shoulder joint rotation on various glenohumeral muscles during performance exercise on the reverse fly machine. The study produced several interesting findings. First, contrary to our original hypothesis, mean normalized EMG activity of the posterior deltoid was significantly greater with a neutral hand position compared to a pronated hand position (90.3 ± 28.3 versus $86.5 \pm 31.4\%$ MVIC, respectively), although the magnitude of this difference was small ($d \sim 0.2$). While it is uncertain as to the exact mechanism for this finding one might postulate that maintaining the internally rotated

position prevents the posterior deltoid from achieving its secondary function of external rotation. Furthermore, the internally rotated and horizontally adducted start position of this exercise has the potential to place a considerable stretch on the posterior deltoid (8, 9) thus this position may prevent the musculature from developing adequate force due to the length tension relationship of the actinomyosin complex. These hypotheses require further study.

When comparing our findings to that of Townsend et al. (16), it is important to point out several important differences between the two studies. First, the Townsend et al. (16) study was designed to determine muscle recruitment during a shoulder rehabilitation program, and thus exercises were performed slowly with very light weights. Conversely, our study sought to evaluate horizontal abduction exercise performed in a manner that is more common to strength and conditioning, where intensity is relatively high and there is intent to move the weight quickly on concentric actions. Furthermore, subjects in the Townsend et al. (16) study used dumbbells whereas exercise in our study was carried out on a reverse fly machine. Finally, the hand position for internal rotation in Townsend et al. (16) was consistent with the NEU position in our study, while full external rotation in Townsend et al. (16) was performed with hands in a supinated position. Considering these differences, it is difficult to make a comparison between studies.

Another intriguing finding was that the infraspinatus showed a clear advantage to using a neutral versus a pronated grip with respect to mean normalized EMG activity (70.4 ± 19.9 versus $61.7 \pm 13.7\%$ MVIC, respectively) and a strong trend for significance in peak normalized EMG activity (158.7 ± 63.1 versus $143.1 \pm 46.5\%$ MVIC, respectively). Similar to the posterior deltoid, plausible explanations for these results lie in both the action of the infraspinatus and the length tension relationship of the muscle. Given the infraspinatus is an external rotator the neutral position more closely represents the muscles action and thus it would not be unreasonable to

assume it would be advantageous from a muscle activity perspective. Additionally, the internally rotated and horizontally abducted start position has the potential to place a considerable stretch on the posterior deltoid (8, 9) thus this position may prevent the musculature from developing adequate force due to the length tension relationship of the actinomyosin complex. It is also interesting to note the large inter-individual variability between subjects with respect to muscle activation patterns at the glenohumeral joint. Despite the relative homogeneity in subject age and training status, subjects nevertheless showed substantial variation in both normalized mean and peak EMG, with some displaying greater activity during internal rotation and others during neutral rotation. In some cases, the magnitudes of these results were stark. For example, one subject had a peak normalized EMG reading that was 33% greater for NEU compared to PRO (200% MVIC versus 150% MVIC, respectively) while another subject had 53% greater peak activity for PRO compared to NEU (150% MVIC versus 98% MVIC, respectively). While these findings may seem aberrant, it is not unreasonable to consider the possibility that some individuals may have experience and/or a preference toward a particular grip position, and thus demonstrate greater muscle activity in one grip position versus another. Unfortunately, data was not collected that required subjects to document whether they routinely performed this exercise and, if so, what specific grip position they use during performance. It also should be noted that the results obtained are context specific, and thus only applicable to situations in which individuals train with a load corresponding to ~75% of their body mass. Further study is warranted to determine if these results can be generalized to other levels of intensity.

Practical Applications

The reverse fly machine is a popular piece of gym equipment for strengthening and hypertrophying muscles at the glenohumeral joint. The results of this study show that performing

the exercise with a neutral hand position significantly increases activity of the posterior deltoid as well as the infraspinatus compared to a pronated hand position. Given that the magnitude of difference in mean normalized EMG activity between hand positions for the posterior deltoid was fairly small ($d \sim 0.2$), it is questionable whether altering hand position will translate into a meaningful difference in muscle adaptations for this muscle in the recreational weight-training participant. Thus, a case can be made that if the sole objective is to target the posterior deltoid for maximum muscular development in this population, an individual can self-select hand position based on whichever position feels most comfortable. Among the athletic or competitive population, however, this small difference may in fact be of value and these individuals therefore may be best served by using a neutral hand position. On the other hand, the magnitude of the effect for normalized mean EMG activity for the infraspinatus was moderately greater for NEU compared to PRO ($d = 0.05$), which would conceivably translate into meaningful differences in muscle recruitment. Hence, if the training objective is to target the infraspinatus, a neutral hand position appears to be the preferred choice in this exercise irrespective of competitive status.

References

1. SENIAM Project: Recommendations for sensor locations on individual muscles. 2005. Retrieved from: http://seniam.org/sensor_location.htm.
2. Ackland, DC, and Pandy, MG. Lines of action and stabilizing potential of the shoulder musculature. *J. Anat.* 215: 184-197, 2009.
3. Andersen, JL, Kjaer, M, Andersen, CH, Hansen, PB, Zebis, MK, Hansen, K, and Sjogaard, G. Muscle activation during selected strength exercises in women with chronic neck muscle pain. *Phys. Ther.* 88: 703-711, 2008.
4. Boettcher, CE, Ginn, KA, and Cathers, I. Which is the optimal exercise to strengthen supraspinatus? *Med. Sci. Sports Exerc.* 41: 1979-1983, 2009.
5. Criswell, E. Cram's Introduction to Surface Electromyography. Sudbury, MA; Jones and Bartlett Publishers, Inc., 2010.

6. Halder, AM, Halder, CG, Zhao, KD, O'Driscoll, SW, Morrey, BF, and An, KN. Dynamic inferior stabilizers of the shoulder joint. *Clin. Biomech. (Bristol, Avon)* 16: 138-143, 2001.
7. Hislop, H, and Montgomery, J. Daniels and Worthingham's Muscle Testing: Techniques of Manual Examination. Philadelphia, PA; WB Saunders, 2002.
8. Hung, CJ, Hsieh, CL, Yang, PL, and Lin, JJ. Relationships between posterior shoulder muscle stiffness and rotation in patients with stiff shoulder. *J. Rehabil. Med.* 42: 216-220, 2010.
9. Kolber, MJ, and Hanney, WJ. The reliability, minimal detectable change and construct validity of a clinical measurement for identifying posterior shoulder tightness. *Am. J. Sports Phys. Ther.* 5: 208-219, 2010.
10. Kuechle, DK, Newman, SR, Itoi, E, Morrey, BF, and An, KN. Shoulder muscle moment arms during horizontal flexion and elevation. *J. Shoulder Elbow Surg.* 6: 429-439, 1997.
11. Kuechle, DK, Newman, SR, Itoi, E, Niebur, GL, Morrey, BF, and An, KN. The relevance of the moment arm of shoulder muscles with respect to axial rotation of the glenohumeral joint in four positions. *Clin. Biomech. (Bristol, Avon)* 15: 322-329, 2000.
12. Lee, SB, and An, KN. Dynamic glenohumeral stability provided by three heads of the deltoid muscle. *Clin. Orthop. Relat. Res.* (400): 40-47, 2002.
13. Mallon, W, Hawkins, R. Shoulder injuries. In: *Clinical Practice of Sports Injury Prevention and Care*. Renstrom, P, ed. Oxford: Blackwell Scientific Publications, 1994. pp. 39.
14. Reinold, MM, Macrina, LC, Wilk, KE, Fleisig, GS, Dun, S, Barrentine, SW, Ellerbusch, MT, and Andrews, JR. Electromyographic analysis of the supraspinatus and deltoid muscles during 3 common rehabilitation exercises. *J. Athl Train.* 42: 464-469, 2007.
15. Shevlin, MG, Lehmann, JF, and Lucci, JA. Electromyographic study of the function of some muscles crossing the glenohumeral joint. *Arch. Phys. Med. Rehabil.* 50: 264-270, 1969.
16. Townsend, H, Jobe, FW, Pink, M, and Perry, J. Electromyographic analysis of the glenohumeral muscles during a baseball rehabilitation program. *Am. J. Sports Med.* 19: 264-272, 1991.