EMG analysis of shoulder positioning in testing and strengthening the supraspinatus

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ABSTRACT

MALANGA, G. A., Y.-N. JENP, E. S. GROWNEY, and K.-N. AN. EMG analysis of shoulder positioning in testing and strengthening the supraspinatus. *Med. Sci. Sports Exerc.*, Vol. 28, No. 6, pp. 661-664, 1996. We examined the electromyographic (EMG) activity of the supraspinatus and other rotator cuff muscles, the three portions of the deltoid muscle, and the pectoralis major muscle in two previously suggested positions for isolating the supraspinatus. The position suggested by Jobe and colleagues is with the elbow extended, the shoulder in full internal rotation, and the arm in the scapular plane. Blackburn and colleagues recommended the prone position, with the elbow extended and the arm abducted to 100° and externally rotated. Fine-wire EMG activity was obtained from the rotator cuff muscles and surface EMG from the other muscles in 17 subjects tested in these two positions. Both positions resulted in significant activity of the supraspinatus, but the difference between these two positions was not statistically significant. The Jobe position produced greater activation of the anterior deltoid and pectoralis major, whereas the Blackburn position caused greater activation of the posterior deltoid. Both positions produced significant activation of the middle deltoid. We conclude that either position can be used to strengthen the supraspinatus; however, neither position selectively isolates the supraspinatus during manual muscle testing.

SUPRASPINATUS, STRENGTH TESTING, STRENGTHENING EXERCISES

The supraspinatus muscle is important in maintaining dynamic stability of the shoulder (5,14). It is commonly injured in both young and old athletes. Strengthening exercises are an important aspect of the nonoperative and postoperative treatment of rotator cuff injuries; however, there is controversy about the optimal shoulder position for isolating the supraspinatus for strengthening and for strength testing (2,11,13,15). Jobe and Moynes (6) suggested that the best position for isolating the supraspinatus is with the elbow extended, the shoulder in full internal rotation, and the arm in the scapular plane. However, Blackburn et al. (2) recommended the prone position, with the elbow extended and the shoulder abducted to 100° and externally rotated with the subject lifting in abduction.

The purpose of our study was to evaluate these two commonly accepted supraspinatus strengthening and strength-testing positions by electromyographic (EMG) analysis to determine which position produced greater or more isolated (or both) activation of the supraspinatus.

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MATERIALS AND METHODS

Seventeen healthy volunteers (8 males and 9 females) younger than 40 yr and without a history of shoulder problems were evaluated. Because the rotator cuff muscles are inaccessible to surface electrodes, fine-wire electrodes were used to evaluate them electromyographically. These electrodes were also used to reduce cross-talk from other muscles. Surface electrodes were used for the other muscles tested. Teflon-coated EMG fine wires were inserted into the supraspinatus and other rotator cuff muscles according to techniques described by Basmajian and De Luca (1) and Kadaba et al. (7). Surface electrodes were placed according to a standard EMG text on the following muscles: anterior, middle, and posterior deltoid; serratus anterior; pectoralis major; and biceps (3). The dominant extremity was tested in all subjects. Resistive manual muscle testing was performed for each muscle group. The EMG activity of the supraspinatus was tested in two positions: 1) the Jobe position: the elbow extended, with the shoulder in full internal rotation and the arm in the scapular plane and with the subject lifting the arm into abduction (Fig. 1); and 2) the Blackburn position: the prone position, with the elbow extended and the shoulder abducted to 100° and externally rotated (Fig. 2). The order of testing was randomized. All subjects performed a single contraction of each test position.

EMG activity was recorded simultaneously from the supraspinatus and the nine other muscles. Each muscle was maximally tested with standard manual muscle-testing positions (11) to obtain a maximal contraction. There was a 1-min rest between testing each muscle. The raw EMG signal was high-pass filtered at 20 Hz and rectified and low-pass filtered at 40 Hz with an MA-100B EMG system (Motion Lab System, Inc., Tampa, FL). This provided a linear envelope representation of the EMG signal, which was sampled at 100 Hz for 4 s by using a DAS-16 analog-to-digital conversion board (Metrabyte Corp., Taunton, MA) on an IBM PS/2 Model 30 personal computer. The average of the period of 1-s maximal EMG activity of each muscle was analyzed. We normalized the data for each muscle to the maximal EMG output

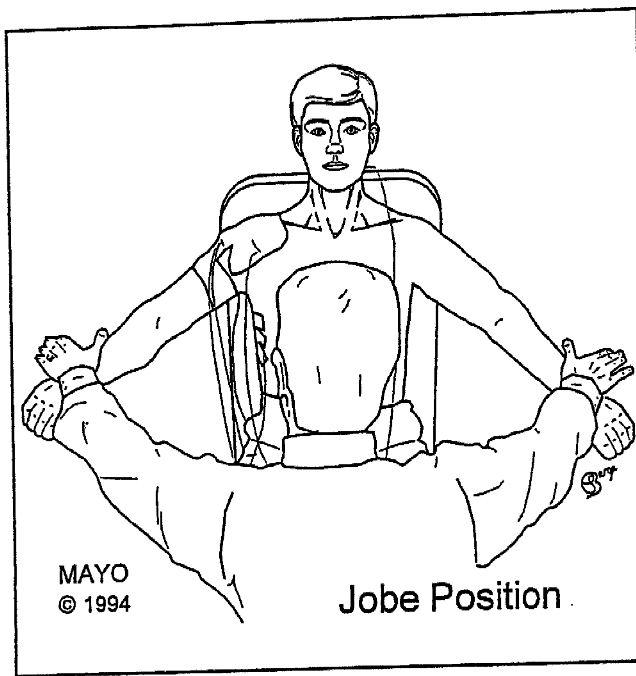

Figure 1—Jobe position: the elbow is extended, with the shoulder in full internal rotation ("thumbs down"), the arm in the scapular plane, and the subject lifting the arm in abduction. (By permission of the Mayo Foundation.)

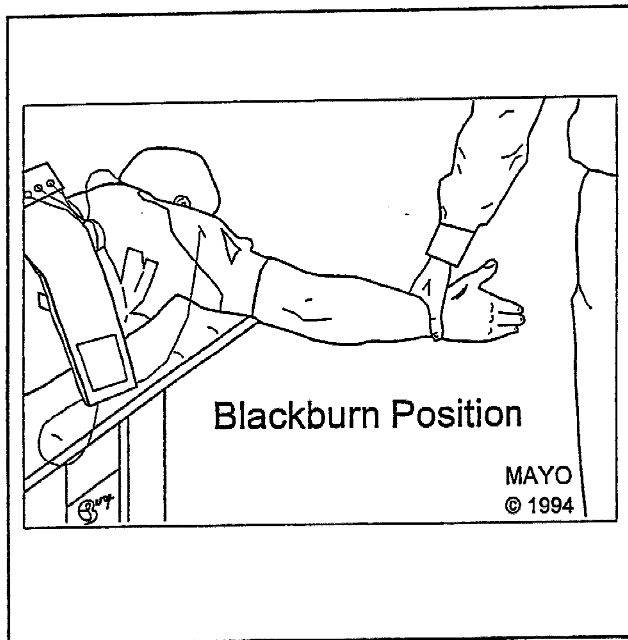

Figure 2—Blackburn position: prone position, with the elbow extended, the shoulder abducted to 100°, and the arm externally rotated ("thumbs up") and the subject lifting the arm in abduction. (By permission of the Mayo Foundation.)

using standard manual muscle testing positioning, e.g., for the middle deltoid, the EMG activity found in the Jobe and Blackburn position test was normalized to the EMG activity found during resisted abduction of the arm in 90° of abduction and with the elbow flexed. For the supraspinatus, the EMG activity produced by the Jobe and the Blackburn positions was normalized by dividing the average EMG activity of each recommended position by the opposing position; that is, for the Jobe position, the normalization was performed by dividing the average EMG activity obtained in the Jobe test position by the average EMG activity found in the Blackburn test position, and vice versa.

Statistical Methods

The mean values for the normalized activity of each muscle were found for both positions and then normalized to the Jobe and the Blackburn test positions (Table 1). Paired t-tests were used to determine statistical differences in the maximal EMG activity between muscles in the two test positions. Because multiple comparisons were performed, the Bonferroni correction was used to adjust for any possible increase of a Type I error. With the use of Bonferroni correction, P values of less than 0.005 (0.05 divided by 10) were considered significant.

RESULTS

The results of the normalized EMG for the Jobe and Blackburn positions are summarized in Table 1. The difference in the peak EMG activity of the supraspinatus in the Jobe position compared to the Blackburn position was not significant ($P = 0.142$). However, statistically significant differences were found in the EMG activity of other shoulder muscles. The Blackburn position was associated with greater activity in the posterior deltoid ($P = 0.00001$). In contrast, the Jobe position produced greater activity in the anterior deltoid ($P = 0.001$) and pectoralis major ($P = 0.001$). Both positions produced significant activation of the middle deltoid, but the difference between the two positions was not significant. In fact, both positions produced greater than 100% activation when normalized to the standard manual muscle-testing posi-

TABLE 1. Normalized EMG for the Jobe and Blackburn positions.

Muscle	Normalized EMG* (Mean ± SD) Jobe Position	Normalized EMG* (Mean ± SD) Blackburn Position	Difference	P
Anterior deltoid	96 ± 16†	65 ± 25	31 ± 30	0.001
Middle deltoid	104 ± 11	111 ± 26	−7 ± 22	0.211
Posterior deltoid	76 ± 19	96 ± 12†	−20 ± 14	0.00001
Pectoralis major	44 ± 24†	17 ± 8	27 ± 20	0.0001
Subscapularis	29 ± 26	30 ± 32	−1 ± 30	0.900
Teres minor	49 ± 30	66 ± 21	−17 ± 29	0.030
Infraspinatus	76 ± 14	72 ± 22	4 ± 23	0.510
Supraspinatus	107 ± 38	94 ± 25	13 ± 33	0.142
Biceps	45 ± 24	63 ± 28	−18 ± 26	0.010
Serratus anterior	77 ± 27	61 ± 31	16 ± 38	0.122

* EMG activity was normalized to the maximal muscle tested activity for each muscle. For the supraspinatus, the Jobe and Blackburn positions were normalized to each other.
† Significant ($P < 0.001$).

tion of the middle deltoid, i.e., arms abducted to 90° in the frontal plane, with the elbows flexed.

DISCUSSION

The importance of strengthening the supraspinatus in the nonoperative and postoperative treatment of rotator cuff injuries is well recognized (4,6,12). Jobe and Moynes (6) suggested that the optimal position for strengthening and manual muscle testing of the supraspinatus is with the elbow extended, the shoulder in full internal rotation, and the arm in the scapular plane and with the subject lifting the arm into abduction. Blackburn et al. (2) found that the prone position, with the elbow extended and the shoulder abducted to 100° and externally rotated, produced the greatest EMG activity in the supraspinatus. Worrell et al. (15) concurred that the Blackburn position produced greater EMG activity than the Jobe position but found that greater abduction torque was generated by the Jobe position. They hypothesized that the prone position placed the deltoid in a less than optimal length-tension relationship, which allowed for better isolation of the supraspinatus. Worrell et al. (15) further postulated that the greater force production in the Jobe position resulted from increased activity of the anterior and middle deltoid muscles. They recommended that future research to resolve this issue should include the three divisions of the deltoid.

We examined the rectified EMG activity of the supraspinatus in the Jobe and Blackburn positions. In addition, we examined nine other muscles of the shoulder girdle, including the three divisions of the deltoid, as suggested by Worrell et al. (15). Our data are based on the single maximal contraction. Repeated contractions would have allowed for interclass correlation coefficients and provided a measure of reliability. However, previous studies have demonstrated the reliability of surface EMG. Lippold (10) reported that the inter-day reliability coefficients of muscles with surface electrode recordings ranged from 0.93 to 0.99, whereas Komi and Buskirk (8) reported values of 0.88-0.91 between contractions within a test period and 0.64-0.73 between tests. Using fine-wire EMG, Komi and Buskirk found that the within-day reliability coefficient was 0.62, and between days, the reliability ranged from −0.05 to a maximum of 0.55. These studies illustrate some of the advantages and disadvantages of surface and fine-wire recording. Surface electrodes detect electrical activity over a greater area of muscle and the data are more reproducible; however, there is also a greater risk of contaminating the EMG signal with cross talk from other muscles. Fine-wire EMG recording allows more specific electrode placement and is needed for muscles that cannot be recorded by surface electrodes, but the recorded data are less reproducible because even small variations in the placement of the fine-wire electrodes produce recordings from a different area of muscle.

In our study, fine-wire EMG was necessary for recording activity from the subscapularis and teres minor because these muscles cannot be assessed with surface EMG. Also, by using fine-wire electrodes to record from the supraspinatus, the cross-talk from the upper trapezius was decreased. For consistency, the infraspinatus was also studied using a fine-wire electrode. The other muscles examined could be accessed with surface electrodes. We attempted to reduce cross-talk by isolating each muscle on manual muscle testing by selecting points that produced the best activation of the selected muscle and elicited as little activity as possible from surrounding muscles. The two positions produced no significant difference in the EMG activity of the supraspinatus. The Blackburn position caused greater activity in the posterior deltoid and the Jobe position produced greater activity in the anterior deltoid and pectoralis major, although the mean normalized EMG of the pectoralis major was still less than 50% of its maximal voluntary contraction. The increased activity in the anterior deltoid confirms the hypothesis of Worrell et al. (15). However, the Jobe and Blackburn positions both produced marked activity in the middle deltoid, although the difference in the activity produced by the two positions was not significant. Therefore, both positions generate a significant amount of EMG activity, but neither selectively isolates the supraspinatus.

The relationship between the EMG signal amplitude and force was reviewed by Basmajian and De Luca (1). The relationship between EMG signal and force output has been recorded by Lawrence and De Luca (9), who found that for small muscles, such as the first dorsal interosseous, the EMG signal-to-force relationship is linear. However, for larger muscles such as the deltoid, this relationship is nonlinear, with the signal amplitude increasing more than the force. Basmajian and De Luca noted that the amplitude of the EMG signal can reflect the force of the muscle but that other technical details in the detection procedure may also influence the amplitude of the signal. They warned against relying on the amplitude of the signal as an indication of force output, especially in nonisometric contractions.

Although both positions activate the supraspinatus, each one has certain benefits and limitations. The Jobe position places the arm in internal rotation and decreases the subacromial space, which may cause pain in patients with impingement. The Blackburn position requires patients to lie on a plinth or table, which may not be readily available, and requires them to be in a prone position, as compared with sitting used in the Jobe position. Strengthening is not recommended during the acute and inflammatory phase when the tendon is more likely to be

impinged; therefore, the issue of possible impingement with the Jobe position may not be a problem after pain and inflammation have resolved.

CONCLUSION

There is no statistically significant difference in the EMG activity of the supraspinatus when testing in the Jobe or the Blackburn position. Although both positions activate the supraspinatus, neither position truly isolates this muscle for testing or strengthening, because othe shoulder muscles are active in both positions. Therefore either the Jobe or the Blackburn position (or both) can b used in strengthening the supraspinatus but neither on isolates it for manual muscle testing or for selectiv strengthening.

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