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The Manual Muscle Examination for Rotator Cuff Strength

An Electromyographic Investigation*

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ABSTRACT

The electromyographic activity of eight muscles of the rotator cuff and shoulder girdle (supraspinatus, infraspinatus, subscapularis, pectoralis, latissimus dorsi, and the anterior, middle, and posterior deltoid) was measured from the nondominant shoulders of 11 subjects during a series of 29 isometric contractions. The contractions simulated different positions used for strength testing of the rotator cuff and involved elevation, external rotation, and internal rotation at three degrees of initial humeral rotation (−45° of internal rotation, 0°, +45° of external rotation) and scapular elevation (0°, 45°, 90°). Isolation of the supraspinatus muscle was best achieved with the test position of elevation at 90° of scapular elevation and +45° (external rotation) of humeral rotation. Isolation of the infraspinatus muscle was best achieved with external rotation at 0° of scapular elevation and −45° (internal rotation) of humeral rotation. Isolation of the subscapularis muscle was best achieved with the Gerber push-off test. This study used four criteria for identifying the optimal manual muscle test for each rotator cuff muscle: 1) maximal activation of the cuff muscle, 2) minimal contribution from involved shoulder synergists, 3) minimal provocation of pain, and 4) good test-retest reliability. Based on the results of this study and known painful arcs of motion, an objective identification of the optimal tests for the manual muscle testing of the cuff was elucidated.

Manual muscle testing is an integral part of the physical examination of the shoulder.[5,8,14,17,19,32,39,42] When performed appropriately, this examination technique provides useful information about a muscle's capability to function in movement and its ability to provide stability and support.[26] However, if careful attention to detail and standardization of technique is not exercised, the results may correlate poorly with accurate functional assessment.[31,41] As seemingly minor changes in the positioning of the body can substantially affect the results of strength testing,[41] significant efforts have been made to standardize the manual muscle testing positions used for the assessment of the rotator cuff muscles. Recommendations for traditional testing positions for the shoulder have been based on biomechanical studies examining the effects of joint position on force production,[9,16,31] cadaveric dissections of the involved musculature,[27] and clinical experience.[11,21,22] Unfortunately, the manual muscle examination of the rotator cuff has continued to challenge clinicians because of such factors as positional pain provocation in the injured shoulder and the complex interactions of shoulder synergists with cuff physiology.[38,41,44]

Electromyography offers an enticing opportunity to establish standardization criteria for manual muscle examination technique. The EMG analysis of the shoulder has gained widespread acceptance since the pioneering work of Inman et al. in 1944.[18] Since that time, numerous questions regarding shoulder physiology have been addressed through the use of this research modality. The EMG research on the shoulder has ranged from the analysis of normal function[6,15,20,30,35] to the examination of muscle activation during shoulder rehabilitation protocols.[2,33,43] In addition, EMG has been used to compare the muscle activation of normal shoulders with that of abnormal shoulders,[29] as well as to analyze shoulder muscle activation and coordination during sports activity.[7,12,13,34,37]

Although some EMG studies have examined the neural activation of the supraspinatus muscle during different

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isometric testing positions,[22,45] a complete EMG examination of rotator cuff muscle activation during manual muscle testing positions has not been performed. Given the complexities of shoulder muscle physiology, and the subsequent challenge associated with isolated strength testing of the rotator cuff, EMG is a useful experimental tool for the refinement of this important clinical examination skill. The purpose of this study was to determine the optimal manual muscle testing maneuvers for the assessment of rotator cuff strength based on the neural activation of three cuff muscles (supraspinatus, infraspinatus, and subscapularis) and five shoulder muscle synergists. Optimal tests resulted in maximal activation of the desired cuff muscle, minimal activation from involved muscle synergists, minimal positional pain provocation, and good test-retest reliability. The results from this study provide a quantitative, objective measurement of rotator cuff activation during manual muscle testing and suggest standardized test positions for the reliable, accurate, and comfortable assessment of rotator cuff strength and integrity.

MATERIALS AND METHODS

Subjects

The left shoulders (nondominant side) of 11 male subjects who had given informed consent were investigated. Institutional Review Board approval was obtained before subject involvement. The mean age was 28.2 years, ranging from 21 to 45. None of the subjects had a history of previous shoulder surgery or had shoulder symptoms at the time of the study.

Electrodes

Intramuscular indwelling wire electrodes and surface adhesive electrodes were used. The fine-wire electrodes were made based on the technique described by Basmajian and De Luca.[3,4] Modifications of the Basmajian technique were made in accordance with the recommendations of Kelly et al.[25] Single 0.025-mm diameter, Teflon-coated wires (California Fine Wire Co., Grover City, California) were threaded through 3.5-inch, 25-gauge hypodermic needles. A bipolar electrode arrangement was attained through the independent insertion of two separate needles spaced 1 cm apart.[25] Silver/silver chloride (Ag/AgCl) surface electrodes (Medtronic Andover Medical Inc., Haverhill, Massachusetts) were used for surface placement. An Ag/AgCl surface adhesive ground electrode (3M Health Care, St. Paul, Minnesota) was placed on the dorsum of the hand.

Placement of the Electrodes. Fine-wire intramuscular electrodes were inserted using a sterile technique into the supraspinatus, infraspinatus, and subscapularis muscles using the hypodermic needles as guides. For needle insertion into the supraspinatus and infraspinatus muscles, the subjects were placed in the prone position with the arm abducted to 90° and the elbow flexed over the edge of the table. The spine of the scapula was palpated and outlined. Electrodes were inserted into the supraspinatus and infraspinatus muscles approximately 1.5 cm above the midpoint of the spine of the scapula (supraspinatus) and approximately 2.5 cm below the midpoint of the spine of the scapula (infraspinatus).[36] For needle insertion into the subscapularis muscle, the subject's arm was placed into full internal rotation with the wrist placed on the back. This caused scapular winging and allowed access to the anteriorly located subscapularis muscle. The insertion point was approximately 5 cm below the spine of the scapula and anterior to the lateral border.[23] After insertion, the needles were removed, leaving the wire tips in the bellies of the muscles. The protruding wires were taped to the skin and the uninsulated proximal ends were attached to the spring cables of a telemetry transmitter.

The Ag/AgCl surface adhesive electrodes were placed on the pectoralis major, latissimus dorsi, and the anterior, middle, and posterior deltoid muscles, centered about the ideal needle electrode points recommended by Perotto.[36] The skin sites were prepared by shaving the hair, gently abrading the skin, and cleaning the area with alcohol pads. The electrodes were placed 1 cm apart according to Basmajian and De Luca.[4] The electrode center point for the pectoralis major muscle was 3.5 cm medial to the anterior axillary line in parallel with the muscle fibers. The center point of the latissimus dorsi muscle was 4.5 cm caudal to the posterior axillary line. Three surface electrodes were used to record deltoid muscle activity. The electrodes were placed 3.5 cm below the anterior angle of the acromion (anterior deltoid muscle), 2 cm below the posterior angle of the acromion (posterior deltoid muscle), and at the intersection of the midpoint between the anterior and posterior deltoid muscles and the midpoint between the acromion and deltoid tuberosity (middle deltoid muscle).

Electrode placement was confirmed by testing maneuvers for appropriate neural activation and adequate EMG signal processing. The test maneuvers included elevation (supraspinatus, anterior deltoid, middle deltoid muscles), external rotation (infraspinatus, posterior deltoid muscles), and internal rotation (subscapularis, pectoralis major, latissimus dorsi muscles).[24]

Apparatus and Recording

Each set of bipolar recording electrodes from each of the eight muscles was connected to a Noraxon Telemyo electromyograph transmitter (Noraxon U.S.A., Inc., Scottsdale, Arizona). The transmitter consisted of a crystal-locked, ultrahigh-frequency dielectric oscillator module, a microprocessor, and an 8-channel, 12-bit analog-to-digital converter. The raw EMG signal was sent from the transmitter to a Noraxon Telemyo electromyograph receiver. Eight integrated channels were used for signal filtering and rectification. The data were subsequently transferred to a computer for analysis and integration using Myosoft EMG software (Noraxon U.S.A., Inc.). The sampling rate was 1000 Hz.[40]

Isometric contractions were performed by subjects with a wrist attachment to an Isobex Strength Analyzer (Cursor AG, Bern, Switzerland). The Isobex Strength Analyzer is a force dynamometer and measures the force generated from isometric contractions in different planes of upper extremity movement. The force of contraction was measured for a total of 4 seconds at a sampling rate of 10 Hz. The Isobex Strength Analyzer provided data points for the force of contraction at the 2nd and 4th seconds, and the average over this 3-second period. These data points provided a measure of the constancy of the isometric contraction.

Procedure

Once the electrodes were placed and tested for adequate signal processing, the subjects were asked to perform a total of 29 different isometric contractions (Table 1). There were 27 core test positions that included the basic exercises of elevation, external rotation, and internal rotation at varying degrees of initial humeral rotation (−45°, 0°, +45°) and elevation (0°, 45°, and 90°). The two additional tests were the Gerber push-off test and the Gerber push with force test (full combined internal rotation with resistance).[11] The test order was randomized such that the same basic exercise (elevation, external rotation, internal rotation) was never performed consecutively. All maneuvers with the same initial starting elevation were performed as a group. The order of initial starting elevation was randomized between subjects. The degree of humeral rotation for each basic exercise was randomized between subjects. The Gerber push-off test and the Gerber push with force test were performed at random times throughout the test series.

TABLE 1
Twenty-nine Exercise Positions Used in Study[a]

Exercise	Scapular elevation (deg)	Humeral rotation (deg)
Elevation	0	0 (NR)
		+45 (ER)
		−45 (IR)
	45	0 (NR)
		+45 (ER)
		−45 (IR)
	90	0 (NR)
		+45 (ER)
		−45 (IR)
External rotation	0	0 (NR)
		+45 (ER)
		−45 (IR)
	45	0 (NR)
		+45 (ER)
		−45 (IR)
	90	0 (NR)
		+45 (ER)
		−45 (IR)
Internal rotation	0	0 (NR)
		+45 (ER)
		−45 (IR)
	45	0 (NR)
		+45 (ER)
		−45 (IR)
	90	0 (NR)
		+45 (ER)
		−45 (IR)
Gerber push with force		
Gerber push-off test		

[a] NR, neutral rotation; ER, external rotation; IR, internal rotation.

Subjects performed each of the 27 core test positions against the Isobex Strength Analyzer for a total of 4 seconds. The Isobex Strength Analyzer was activated with the initiation of force generation by the subject. The isometric contraction was correlated with the EMG signal obtained on the computer through the use of the EMG software. If the subject's isometric contraction was not constant for the 3-second testing period (as demonstrated by the three Isobex data points), the subject was asked to repeat the test. The subject was allowed approximately 90 seconds of rest between tests. Five subjects were asked to perform the 29 exercises a second time after approximately 30 minutes of rest.

Data Analysis

Integrated EMG (IEMG) values for each muscle were determined for the 29 test positions examined. The EMG signals were synchronized with the 4-second isometric contractions by identifying the initial EMG signal burst on the Myosoft EMG readout. This initial signal corresponded to the initiation of the isometric contraction. For all tests except the Gerber push-off test, the 1st second of the 4-second isometric contraction was discarded (to allow time to reach maximal voluntary contraction) and an IEMG value was derived from the final 3 seconds of the isometric contraction. Since the EMG readout from the Gerber push-off test consisted of a short signal burst, the IEMG value was derived from the 1 second corresponding to the time of movement.

Mean IEMG values for each test were determined for all 8 muscles for a total of 232 IEMG data points. Each mean IEMG measurement was transformed to a natural logarithm because an exponential distribution was implied by means that were approximately proportional to their standard deviations across a range of values. This transformation produced a homogeneous estimate of variance.

A blocked, mixed-model analysis of variance (ANOVA) was applied to the 11 single trials of the 27 core test positions for the 3 rotator cuff muscles. Three different main effects (interactions) were analyzed. Each main effect (Table 2) compared three different terms. The three main effects with their respective terms were the type of exercise (elevation, external rotation, internal rotation), the degree of initial elevation, 0°, 45°, 90° and the degree of initial humeral rotation (−45°—internal rotation, 0°—neutral rotation, +45°—external rotation). The optimal test positions from the 27 core movements were identified for each cuff muscle by determining which terms within each main effect were significant. Terms were considered significant at a level of $P < 0.05$.

In addition to using the blocked, mixed-model ANOVA to analyze the 27 core test positions for maximal signal generation, the IEMG areas generated by all 29 tests (the 27 core tests plus the two Gerber tests) were rank ordered for each of the cuff muscles. The rank order allowed for an

TABLE 2
Blocked, Mixed-Model ANOVA with Means, SDs, and P values for the Three Main Effects by Muscle[a]

Muscle[b]	First main effect (N = 11)				Second main effect (N = 11)				Third main effect (N = 11)			
	Type of exercise	Mean	SD	P	Degree of elevation	Mean	SD	P	Degree of rotation	Mean	SD	P
Supraspinatus	Elevation	8.35	0.48		0	6.69	2.96		Neutral rotation	6.95	2.87	
Ex > El > (HR)	External rotation	8.39	0.42	0.0001	45	7.31	2.25	0.0007	45 ER	7.54	1.82	0.1253
323 > 19 > (7)	Internal rotation	4.91	2.88		90	7.65	1.58		45 IR	7.16	2.26	
Infraspinatus	Elevation	7.62	0.53		0	6.45	2.72		Neutral rotation	6.87	2.09	
Ex > HR > (El)	External rotation	8.16	0.42	0.0001	45	6.81	2.14	0.1929	45 ER	6.1	2.94	0.0006
357 > 22 > (4)	Internal rotation	4.29	2.75		90	6.81	2.21		45 IR	7.09	1.84	
Subscapularis	Elevation	7.68	0.74		0	7.19	1.35		Neutral rotation	7.6	0.94	
Ex > El > HR	External rotation	6.59	1.21	0.0002	45	7.49	0.99	0.0123	45 ER	7.26	1.18	0.0002
50 > 6 > 3	Internal rotation	8.13	0.81		90	7.72	0.99		45 IR	7.6	1.25	

[a] Significant terms are underlined ($P < 0.05$). Ex, external; El, elevation; HR, humeral rotation; ER, external rotation; IR, internal rotation.

[b] Mean square values for each main effect are listed below the muscle name. The larger mean square value corresponds with the main effect that had the greatest effect on the resultant IEMG value. Mean square values in parentheses were not significant ($P > 0.05$).

assessment of the two Gerber tests (which did not fit the format of the blocked, mixed-model ANOVA) as well as a more complete assessment of the relative contribution of the remaining muscles during the best rotator cuff test positions. This information was used to determine which tests resulted in the greatest isolation of each cuff muscle.

Five subjects performed the test series two times on the same day with approximately 30 minutes of rest between trials. Test-retest reliability coefficients were calculated for the IEMG areas generated by each muscle for all exercises. Reliability coefficients were considered significant at a level of $P < 0.05$.

RESULTS

Supraspinatus Muscle

There were six test positions that produced significantly greater IEMG values based on the blocked, mixed-model ANOVA: external rotation at 90° of elevation and 0° (neutral rotation), +45° (external rotation), and −45° (internal rotation) of humeral rotation, and elevation at 90° of initial elevation and 0° (neutral rotation), +45° (external rotation), and −45° (internal rotation) of humeral rotation (Tables 2 and 3 [first column]). There were no significant differences between these six tests. The rank order of the top seven test positions (Table 4, top section) (consisting of variations on the exercises of external rotation and elevation) was used for the determination of the optimal supraspinatus muscle isolation test by minimizing the infraspinatus muscle contraction (Table 5, top section). Five of the top seven tests had good test-retest reliability (Table 4, top section). Of these, elevation at 90° with +45° of humeral rotation ("full can") resulted in the greatest supraspinatus muscle activation with the least activation from the infraspinatus (Table 5, top section; Fig. 1).

Infraspinatus Muscle

There were three test positions that produced significantly greater IEMG values based on the blocked, mixed-model ANOVA: external rotation with −45° of humeral rotation at 0°, 45°, and 90° of initial scapular elevation (Tables 2 and 3 [middle column]). There were no significant differences between these three tests. The rank order of the top seven test positions (consisting of variations of external rotation) was used for the determination of the optimal infraspinatus muscle isolation test (Tables 4 and

TABLE 3
Test Positions Resulting in Maximal Neural Activation of the Cuff Muscles, Based on the Blocked, Mixed-Model ANOVA[a]

Optimal Supraspinatus Exercises	Optimal Infraspinatus Exercises	Optimal Subscapularis Exercises
ER @ 90°, 0°	ER@ 0°,−45°	IR@90°, 0°
Elev. @ 90°, 0°	ER@90°,−45°	IR@90°,−45°
ER @ 90°, +45°	ER@45°,−45°	
Elev. @ 90°, +45°		
ER @ 90°, −45°		
Elev. @ 90°, −45°		

[a] Tests with significant test-retest reliability are underlined ($P < 0.05$). ER, external rotation; Elev, elevation; IR, internal rotation; @ ° initial scapular elevation, and ° humeral rotation.

TABLE 4
Mean Values and Reliability Coefficients of Top Seven Tests by Muscle[a]

Exercise	Ln Mean	Reliability	Significance
	Supraspinatus		
ER @ 90°, 0°	8.71	0.76	0.048
Elev @ 90°, +45°,	8.66	0.87	0.015
ER @ 45°, +45°	8.57	0.12	0.43
Elev @ 90°, −45°	8.55	0.84	0.015
ER @ 90°, +45°	8.54	0.65	0.014
ER @ 45°, 0°	8.54	0.62	0.11
Elev @ 90°, 0°	8.51	0.90	0.006
	Infraspinatus		
ER @ 0°, 0°	8.42	0.77	0.023
ER @ 0°, −45°	8.38	0.71	0.011
ER @ 0°, +45°	8.38	0.43	0.077
ER @ 90°, +45°	8.36	0.83	0.019
ER @ 45°, 0°	8.20	0.62	0.12
ER @ 90°, 0°	8.20	0.95	0.003
ER @ 45°, +45°	8.15	0.41	0.25
	Subscapularis		
IR @ 90°, −45°	8.65	0.49	0.15
IR @ 45°, −45°	8.55	0.53	0.17
Gerber force	8.55	0.94	0.004
IR @ 90°, 0°,	8.54	0.84	0.022
IR @ 45°, 0°,	8.53	0.78	0.022
IR @ 0°, −45°	8.52	0.63	0.06
IR @ 0°, 0°	8.28	0.83	0.01

[a] Tests with significant test-retest reliability are underlined ($P < 0.05$). ER, external rotation; Elev, elevation; IR, internal rotation; @ ° initial scapular elevation, and ° humeral rotation; Ln, natural log.

5 [middle section]). From the four tests with good test-retest reliability, external rotation at 0° with −45° (internal rotation) of humeral rotation resulted in the greatest activation of the infraspinatus muscle with the least activation from the supraspinatus muscle. Minimal activation from the posterior deltoid muscle was achieved during external rotation at 0° with −45° *and* 0° of humeral rotation. Thus, the single best test for isolating the infraspinatus muscle from both the supraspinatus and the posterior deltoid muscles was external rotation at 0° with −45° of humeral rotation (Table 5; Fig. 2).

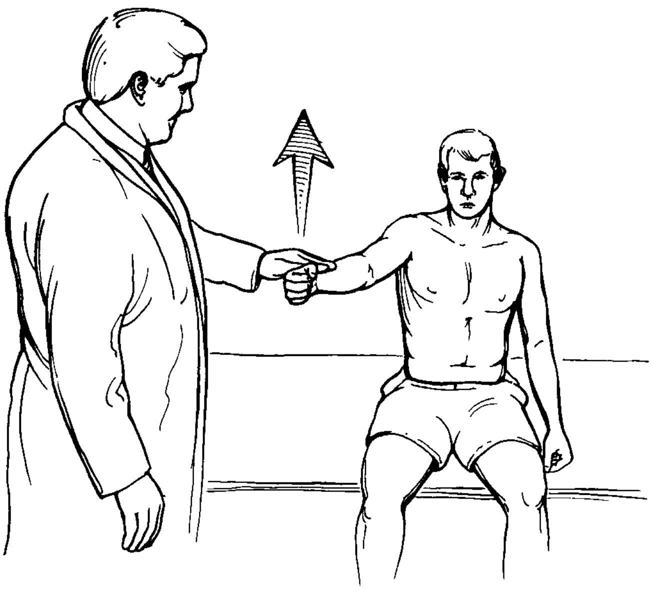

Figure 1. Optimal manual muscle testing position for the isolation of the supraspinatus muscle: elevation at 90° of scapular elevation and +45° of humeral rotation ("full can" position).

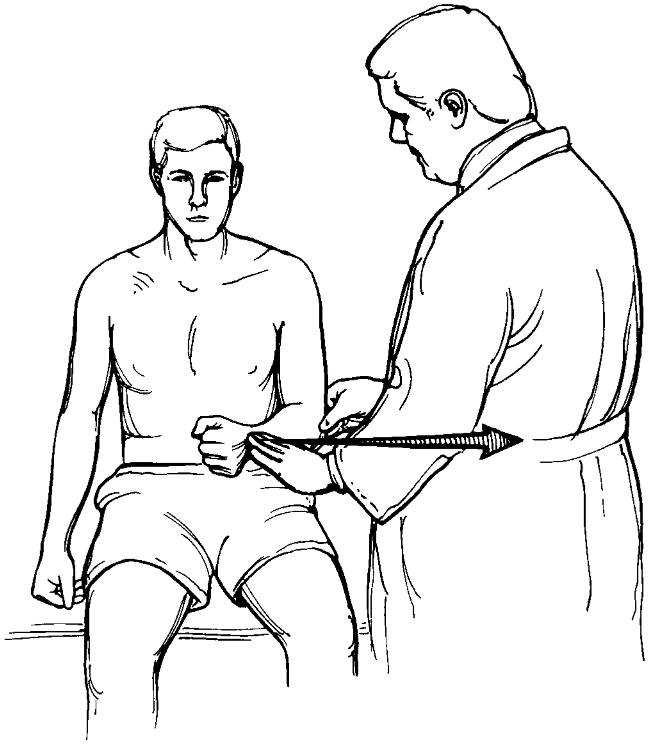

Figure 2. Optimal manual muscle testing position for the isolation of the infraspinatus muscle: external rotation at 0° of scapular elevation and −45° of humeral rotation.

Subscapularis Muscle

There were two test positions that produced significantly greater IEMG values based on the blocked, mixed-model ANOVA (which did not look at the two Gerber tests): internal rotation at 90° with 0° and −45° humeral rotation (Tables 2 and 3 [last column]). The rank order of the top seven test positions (consisting of variations of internal

TABLE 5
Top Seven Test Positions for Cuff Isolation by Muscle and Test[a]

Optimal Supraspinatus Isolation Tests

Exercise	Supraspinatus-Infraspinatus
Elev @ 90°, +45°	0.80
Elev @ 90°, 0°	0.79
Elev @ 90°, −45°	0.79
ER @ 90°, 0°	0.51
ER @ 45°, +45°	0.41
ER @ 45°, 0°	0.34
ER @ 90°, +45°	0.18

Optimal Infraspinatus Isolation Tests

Exercise	Infraspinatus-Supraspinatus	Exercise	Infraspinatus-Posterior Deltoid
ER @ 0°, −45°	0.09	ER @ 45°, +45°	1.10
ER @ 0°, 0°	0.03	ER @ 45°, 0°	1.03
ER @ 0°, +45°	0.01	ER @ 0°, −45°	0.84
ER @ 90°, +45°	−0.18	ER @ 0°, 0°	0.84
ER @ 45°, 0°	−0.34	ER @ 90°, +45°	0.69
ER @ 45°, +45°	−0.41	ER @ 0°, +45°	0.65
ER @ 90°, 0°	−0.51	ER @ 90°, 0°	0.53

Optimal Subscapularis Isolation Tests

Exercise	Subscapularis-Pectoralis Major	Exercise	Subscapularis-Latissimus Dorsi
IR @ 90°, −45°	3.75	Gerber Force	2.54
Gerber Force	3.15	IR @ 0°, 0°	2.03
IR @ 45°, −45°	3.12	IR @ 0°, −45°	1.89
IR @ 90°, 0°	2.12	IR @ 90°, −45°	1.78
IR @ 45°, 0°	1.79	IR @ 45°, 0°	1.74
IR @ 0°, −45°	1.48	IR @ 90°, 0°	1.68
IR @ 0°, 0°	1.20	IR @ 45°, −45°	1.53

[a] Tests with significant test-retest reliability are underlined ($P < 0.05$). See footnote at Table 4 for abbreviations.

rotation and including the Gerber push with force test) was used for the determination of the optimal subscapularis muscle isolation test (Tables 4 and 5 [bottom section]). From the four tests with good test-retest reliability, the Gerber push with force test resulted in the greatest activation of the subscapularis muscle with minimal activation from the pectoralis and the latissimus muscles (Table 5; Fig. 3). The absolute value of the IEMG generated during the Gerber push-off test could not be compared with the other 28 test positions (because the test lasted for only 1 second). However, it was noted that this test resulted in IEMG values approximately one-third the size of the values produced during the Gerber push with force test, corresponding to the decreased time allotted for EMG analysis.

DISCUSSION

Manual muscle testing has become a clinical standard for the assessment of muscular strength.[1,10,26] Studies looking at the utility of this examination technique report a range of outcomes. Some studies indicate that manual

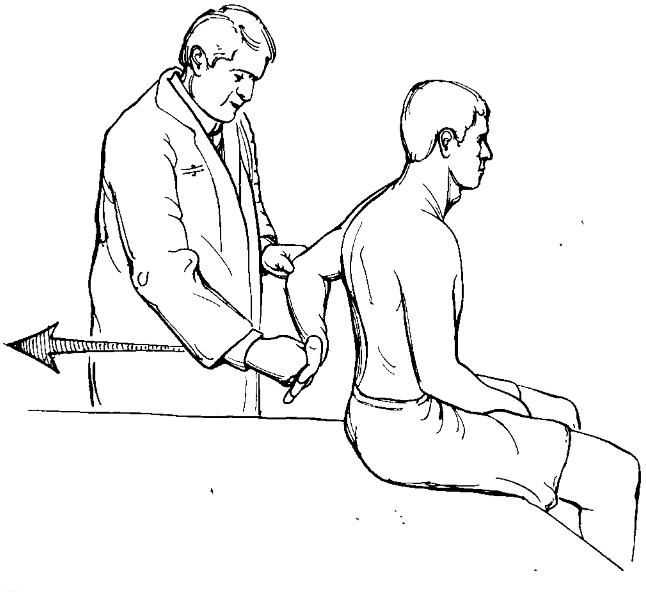

Figure 3. Optimal manual muscle testing position for the isolation of the subscapularis muscle: the Gerber push with force test.

muscle testing is a reliable examination method that can be used as an objective criterion,[1,28] while others report large interobserver variability and bias.[31,38] Despite these varying outcome reports, there is widespread agreement that considerable examiner experience is needed for an accurate assessment of isolated muscle strength.[10,26] Consistent testing procedures and strict quality control are required for the elimination of confounding factors such as muscle substitution, variation in joint angle, and submaximal effort secondary to positional pain provocation.[1,41] This EMG analysis of the manual muscle examination of the rotator cuff has used four criteria for the identification of "optimal" testing positions. To most accurately assess the strength of a specific rotator cuff muscle, the test should 1) maximize the neural activation of the desired cuff muscle, 2) simultaneously minimize the activation from involved synergist muscles, 3) have good test-retest reliability, and 4) minimize positional pain so that maximal effort can be exerted. By identifying test positions that fulfill these four criteria, we have addressed some of the confounding factors mentioned above and have suggested positions that may result in improved clinical examination methods.

Figures 1 and 2 illustrate the optimal testing positions for each of the cuff muscles based on these four criteria. The optimal test for the supraspinatus muscle was elevation at 90° of scapular elevation with +45° of humeral rotation ("full can") (Fig. 1). This test position differs from the traditional test position identified by Jobe and Moynes[22]: elevation at 90° of scapular elevation with −45° of humeral rotation ("empty can"). Our findings indicate that there is no significant difference in supraspinatus muscle activation with variation in humeral rotation (Table 3, first column). Furthermore, when the humerus is rotated externally (the "full can" position) there is slightly less relative activation from the infraspinatus muscle, thus indicating better isolation of the supraspinatus muscle (Table 5, top section). Perhaps most importantly, however, is the decreased positional pain provocation associated with an externally rotated humerus. Internal rotation of the humerus at 90° of elevation results in the classic "impingement position," where the greater tuberosity is rotated under the acromial arch.[39] Such positional pain may decrease the reliability and accuracy of the manual muscle test of the supraspinatus muscle.

The optimal test for the infraspinatus muscle was external rotation at 0° elevation with −45° of humeral rotation (Fig. 2). This position resulted in maximal activation of the infraspinatus and minimal activation of the supraspinatus and posterior deltoid muscles (Table 5, middle section). There is minimal pain provocation associated with this position. Kuhlman et al.[31] looked at the effect of joint angles on isometric and isokinetic strength measurements associated with external rotation. Their findings suggest that isometric strength of external rotation should be measured at 45° of scapular elevation with the shoulder in 45° of internal rotation. However, isometric testing after block of the suprascapular nerve suggested that the contribution of the supraspinatus and infraspinatus muscles was greatest at 0° to 30° of external rotation.[31] Iannotti[17] reported that external rotation strength is most reliably tested with the arm in 0° of abduction and slight external rotation. Our EMG analysis indicates that isolation of the infraspinatus muscle is best performed at −45° (45° of internal rotation). Furthermore, our study demonstrated poor test-retest reliability of infraspinatus muscle EMG activity when external rotation was performed at 45° of external rotation (Table 4, middle section).

The optimal test for the subscapularis muscle was the Gerber push with force test[11] (Fig. 3). This test maximizes subscapularis muscle activation and minimizes the activation from the pectoralis and the latissimus muscles (Table 5, bottom section). Although the Gerber push with force test could not be analyzed using the blocked, mixed-model ANOVA (it did not fit into the model of the three main effects), of the tests with significant reliability coefficients, it resulted in the largest IEMG value for the subscapularis muscle (Table 4, bottom section). In addition, this test avoids the impingement position associated with internal rotation at 90° of scapular elevation. The results from this EMG analysis corroborate the clinical findings observed by Gerber and Krushell[11] during their examination of patients with isolated rupture of the tendon of the subscapularis muscle.

CONCLUSIONS AND SUMMARY

This study provides a methodologic analysis of the manual muscle examination of the rotator cuff. By applying strict criteria for the identification of optimal manual muscle testing positions, we have addressed some of the confounding elements of this important clinical examination skill. By systematically identifying test positions that result in maximal activation of each of the three cuff muscles, minimal activation of involved shoulder synergists, good test-retest reliability, and decreased positional pain provocation, we have attempted to provide guidelines for a more accurate and reliable assessment of the strength and integrity of the rotator cuff.

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