0363-5465/92/2002-0128$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 20, No. 2

EMG analysis of the scapular muscles during a shoulder rehabilitation program

J. BRUCE MOSELEY, JR,* MD, FRANK W. JOBE,† MD, MARILYN PINK‡§, MS, PT, JACQUELIN PERRY,‡ MD, AND JAMES TIBONE,† MD

*From the *Division of Orthopaedic Surgery, Baylor College of Medicine, Houston, Texas, the †Kerlan-Jobe Orthopaedic Clinic, and the ‡Centinela Hospital Medical Center, Biomechanics Laboratory, Inglewood, California*

ABSTRACT

The purpose of this study was to determine which exercises most effectively use the scapular muscles. Eight muscles in 9 healthy subjects were studied with indwelling electromyographic electrodes and cinematography while performing 16 exercises. The 8 muscles studied were the upper, middle, and lower trapezius; levator scapula; rhomboids; pectoralis minor; and the middle and lower serratus anterior. Each exercise was divided into arcs of motion and the electromyographic activity was quantified as a percentage of the maximal manual muscle test. The optimal exercises for each muscle were identified based on intensity (greater than 50% maximal manual muscle test) and duration (over at least 3 consecutive arcs of motion) of the muscle activity. Twelve of the exercises qualified as top exercises for all of the muscles. On further analysis, a group of 4 exercises was shown to make up the core of a scapular muscle strengthening program. Those 4 exercises include scaption (scapular plane elevation), rowing, push-up with a plus, and press-up.

The glenohumeral joint is highly mobile resulting in over 16,000 positions for the arm, which can be differentiated by 1° in the normal person.[7] The mobility is particularly evident in overhand athletes who repeatedly place their arm in positions of extreme range of motion. This mobility requires a stable base. The stable base, and therefore the mobility, is largely dependent on the relationship of the scapula and the humerus. This relationship is a shifting one, since the center of rotation changes when the arm moves and the mechanical advantages of the muscles change. The humerus and scapula must accommodate the shifts in order to maintain stability. This delicate, shifting, yet requisite precise relationship was defined by Codman[4] in 1934 as scapulohumeral rhythm.

Inman and Saunders[5] did the initial work to define the scapulohumeral rotation using radiographs of living subjects with pins inserted in the bones. They concluded that during the first 30° of abduction or 60° of flexion, the scapula and humerus were seeking a stable relationship, and different people did this in one of several ways. Thus, at this point, the scapulohumeral rotation was irregular. Once the stable relationship was found, the humerus to scapula ratio was 2:1, and quite predictably so. Toward the end of elevation, the ratio once again changed. Stookey[10] showed the relationship between the first and last phases as 12:1, and the middle phase as 5.5:4. Poppen and Walker[8] agreed with the middle phase as a ratio of 5:4 in abduction. In addition, they noted that in the scapular plane there was a great deal of conformity, and concluded that as long as there were compressive forces (which were evident in this plane of motion), the glenohumeral joint was stable and the humeral head rotated on a fixed base with little if any excursion.

With this as ground work for the importance and ever-changing nature of scapulohumeral motion, the next question is related to the muscles responsible for the motion of the scapula. Areas that need to be explored are the muscles responsible for the different motions, the range of motion where they are most active, and how those muscles are best strengthened. MacKenzie[6] wrote of the singular functions of a muscle based on the anatomic position. However, others strongly disagreed. Brunnstrom[3] noted that by merely looking at the muscles' origin and insertion, one can only speculate on function. She further stated that a muscle may be in a perfectly good anatomic position for a specific movement, but remains inactive when that motion is performed.

Most of the information available on how to exercise specific shoulder girdle muscles is based on anatomic knowledge rather than quantifiable data such as electromyography

§ Address correspondence and reprint requests to: Marilyn Pink, MS, PT, Centinela Hospital Medical Center, Biomechanics Laboratory, 555 East Hardy Street, Inglewood, CA 90301.

(EMG). This is particularly true of the scapular muscles. There are no studies that have quantifiably determined which exercises generate the greatest muscle activity for the vital and individualistic scapular muscles. The overhand athlete is an example of the population most at risk if there is inadequate strength or synchrony of scapular motion because of the excessive and repetitive range of required shoulder motion in these sports.

The purpose of this study was to determine how the muscles responsible for scapular motion could best be exercised in a shoulder rehabilitation program.

MATERIALS AND METHODS

Nine subjects, seven male and two female, volunteered for this study. They were all healthy young adults, aged 22 to 34 years, with no previous shoulder problems. All considered themselves to be recreational athletes.

Eight muscles, or portions of muscles, responsible for scapular motion were studied: three parts of the trapezius (upper, middle, and lower), the levator scapula, the rhomboid major, middle serratus anterior (at the level of the 5th and 6th rib), lower serratus anterior (at the insertion of the muscle into the lateral, inferior border of the scapula that are the most inferior muscle fibers), and the pectoralis minor.

The subjects were asked to perform 16 exercises based on those used in a shoulder rehabilitation program at the Kerlan-Jobe Orthopaedic Clinic and by the Los Angeles Dodgers and the California Angels baseball clubs. The exercises were done concentrically with the subject holding at the top of the range, then eccentrically to bring the arm back to the starting position. All of the exercises in the programs were included whether they were thought to exercise the scapular muscles or not. The exercises described were done in a consistent manner, emphasizing low intensity, and using light-weight dumbbells (range, 3 to 30 pounds). The weight of the dumbbell was individually selected by the subject for each exercise. The subjects were asked to select a weight with which they could do 10 repetitions of the exercise without using a muscle substitution pattern. The exercises were done at a slow, controlled speed, similar to the speed used in a clinical rehabilitation setting. The 16 exercises used were as follows:

1) elevation of the arm in the sagittal plane (shoulder flexion) (Figures of exercises appear in a previously published article by Townsend et al., *Am J Sports Med 19:* 264–272, 1991. The figure and page number are given for each repeated figure.)(Fig. 1, p 265),

2) elevation of the arm in the scapular plane with humeral external rotation (shoulder scaption)(Fig. 3, p 266),

3) elevation of the arm in the coronal plane (shoulder abduction) (Fig. 4, p 266),

4) rowing (Fig. 5, p 266),

5) horizontal shoulder abduction (Fig. 6, p 267),

6) horizontal abduction with humeral external rotation (Fig. 7, p 267),

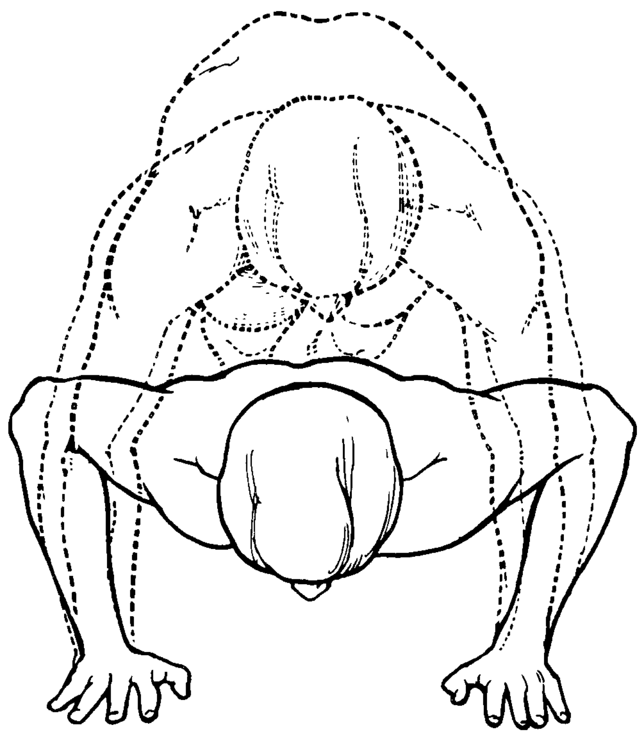

Figure 1. Push-up with a plus: normal push-up adding maximum shoulder and scapular protraction with elbows fully extended.

7) push-up with hands apart (Fig. 10, p 267),

8) push-up with a plus—normal push-up adding maximum shoulder and scapular protraction with elbows fully extended (Fig. 1),

9) dumbbell bench press (Fig. 11, p 268),

10) dumbbell military press (Fig. 12, p 268),

11) shoulder shrug (Fig. 2),

12) deceleration exercise—simulating the pitching follow-through (Fig. 14, p 269),

13) shoulder extension prone (Fig. 15, p 269),

14) shoulder internal rotation (Fig. 16, p 269),

15) shoulder external rotation (Fig. 17, p 269), and

16) press-up (Fig. 13, p 269).

The solid-line drawing of the arm in the figure notes the starting position of the exercise, as well as the ending position. The dotted line notes the top of the range. These exercises were initially tested with multiple trials per exercise. The pilot tests indicated reproducible results, thus only one trial per exercise was considered necessary for each muscle.

Consent forms were obtained for each subject and precautions were taken to prevent complications from the invasive procedure. Wire electrodes were used to measure muscle activity for each muscle during the exercises. After proper skin preparation and isolation of the desired muscle, dual 50 micron insulated wires with 2 to 3 mm bared tips were inserted into the muscle using a 25 gauge hypodermic needle as a cannula, as described by Basmajian.[2] The wires from each muscle were attached to insulated leads and taped to

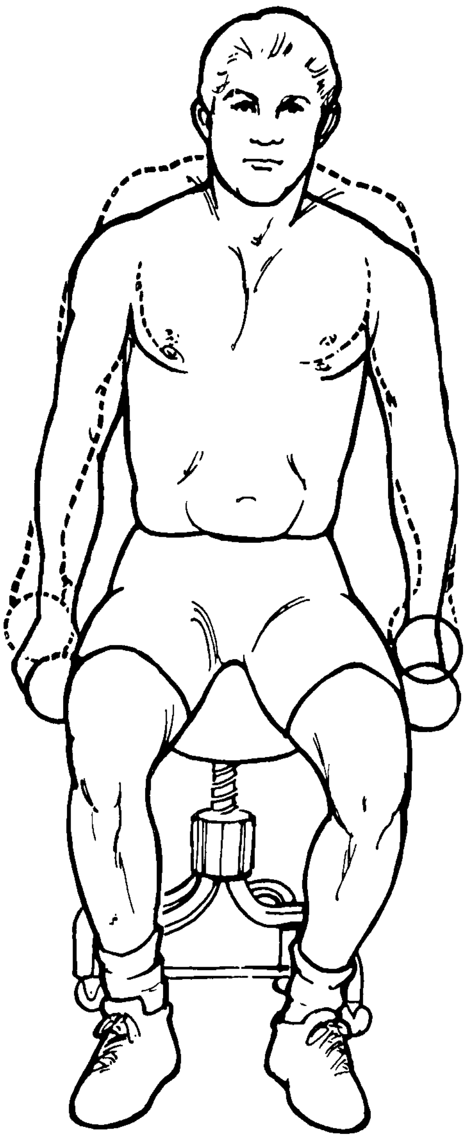

Figure 2. Shoulder shrug.

the subject's body. The signals from the leads were transmitted using an FM-FM telemetry system capable of transmitting up to four muscles simultaneously. Correct wire-electrode placement was confirmed either by electrical stimulation of the muscle through the inserted wires, or by a manual muscle test specific to the inserted muscle, with the telemetry signal monitored on an oscilloscope. Each subject wore the battery pack in such a way that it did not restrict bodily movements.

We began by recording the resting level of the electrical activity for each muscle. Next, a maximum manual muscle test was done for each muscle (this would later be used to normalize and quantify the electrical activity in the exercises). Then the subject performed each of the exercises twice: once for transmission of each group of four muscles. The EMG information was filtered at a center frequency of 300 Hz and recorded on a multichannel instrumentation recorder for later retrieval and review.

The EMG data were converted from analog to digital signals by computer at a sampling rate of 2500 Hz and quantitated by computer integration. After excluding the noise identified by the resting recording, the peak 1-second EMG signal during a maximum manual muscle strength test (MMT) was selected as the normalizing value (100%). Activity patterns were assessed every 20 ms and expressed as a percent of the normalization base (percent MMT).

The muscle activity generated was synchronized to the subject's motion using a 16-mm high-speed motion picture camera operating at 50 frames/sec to record the subject's motion. Marks were electronically placed on the film and EMG data to allow for synchronization. All of the exercises except four were divided into 30° arcs of concentric and eccentric motion with an isometric contraction at the top of the range. The exceptions were the push-up (with a plus and hands apart), the shoulder shrug, and the press-up. The push-ups were divided based on the amount of elbow flexion: from elbows fully extended to 30° of flexion, 30° to 60° of flexion, 60° to 90° of flexion, and returning to the fully-extended position of the elbows (divided into the same arcs as the downward motion), with exaggerated scapular protraction for the plus maneuver. The shrug and press-up were divided into seven arcs reflecting the two halves of the upward motion, the 3 seconds of holding the motion, and the two halves of the downward motion. The EMG activity was averaged for each arc and expressed as percent MMT. Thus, each subject generated a number representing the average muscle activity for each muscle, during each arc of each exercise.

Once the data were collected, any outlier data were evaluated to determine the validity of the signal (i.e., noise, interference, poor signal). If it was an invalid signal, the data were deleted. The data from all nine subjects were used to calculate means and standard deviations for muscle activity generated by each muscle during each arc of each exercise.

It was then determined, for each muscle, which exercises were optimal. For an exercise to qualify as optimal, it had to meet the criteria for both intensity and duration: the muscle activity had to be greater than or equal to 50% MMT over at least three consecutive arcs of motion. This criteria was selected after an analysis of the data, determining the consistent natural breaking points. If a muscle had less than three qualifying exercises, then the criteria was altered to three consecutive arcs of 40% MMT or greater muscle activity. The amount of time the exercise met the qualifying criteria or altered criteria (i.e., the number of arcs) was called the duration, and was expressed as a percent of the exercise. The data from the one arc with the greatest muscle activity was called the peak arc. The optimal exercises for each muscle were then ranked by percent MMT of the peak arc.

RESULTS

The upper trapezius had two exercises that qualified as optimal and four additional exercises under the altered criteria. Rowing was active above 50% MMT for 75% of the exercise with a peak arc of 112% MMT during the isometric contraction at the top of the maneuver. The military press met the qualifying criteria with a duration of 27% of the exercise and a peak arc of 64% MMT during the last concentric arc. Horizontal abduction in both the neutral position and with the humerus in external rotation, scaption, and abduction all met the altered criteria for at least 23% of the exercise with peak arcs of 62%, 75%, 54%, and 52% MMT, respectively, during arcs near the end of the concentric contractions (Table 1).

The middle trapezius had four exercises that qualified as optimal. Horizontal abduction in neutral and with the humerus in external rotation, had durations of 78% and 67% of the exercise with peak arcs of 108% MMT and 96% MMT during the last concentric and the first eccentric arcs, respectively. Extension qualified for this muscle with a duration of 27%, and a peak arc of 77% MMT between neutral and 30° of hyperextension. Rowing was the fourth exercise to qualify, with a duration of 33% and a peak arc from 90° to 120° of 59% MMT (Table 1).

The lower trapezius had five exercises that qualified: abduction, rowing, horizontal abduction with external rotation, flexion, and horizontal abduction in neutral. The peak arcs ranged from 68% to 56% MMT with durations of 50%, 50%, 33%, 23%, and 33%, respectively. The peak arcs for abduction all began at 90°, and for rowing and flexion at 120°. In addition, scaption is worth mentioning: the third consecutive arc was only 49% MMT and, like flexion, the peak arc was 60% MMT during the 120° to 150° arc for a duration of 23% (Table 1).

The levator scapulae had six qualifying exercises, and the top five all had peak arcs during the isometric arc. Rowing, horizontal abduction in neutral, shrug, horizontal abduction with external rotation, and extension had peak arcs of 114%, 96%, 88%, 87%, and 81% MMT with durations of 78%, 67%, 63%, 33%, and 36%, respectively. Scaption was the sixth ranked exercise with a duration of 46% and a peak arc of 69% MMT between 120° and 150° of elevation (Table 1).

Four exercises qualified for the rhomboids. Horizontal abduction in neutral, scaption, abduction, and rowing demonstrated peak arcs of 66%, 65%, 64%, and 56% MMT and durations of 33%, 25%, 31%, and 30%. The peak arcs were all near the top of the exercise (Table 1).

The middle serratus anterior had six exercises that qualified. Flexion, abduction, and scaption were the top three, with peak arcs of 96%, 96%, and 91% MMT between 120° and 150° of elevation, and with durations of 69%, 54%, and 58%. The military press had a duration of 64%, and a peak arc of 82% MMT during the last concentric arc. Both of the push-ups qualified with durations of 28% and 21% and peak arcs of 80% and 57% MMT during the plus maneuver and the last arc of the push-up, respectively (Table 1).

The lower serratus anterior had the same qualifying exercises as the middle serratus anterior, but with different rankings. Scaption, abduction, and flexion were the top three with peak arcs of 84%, 74%, and 72% MMT during the 120° to 150° arc, and with durations of 50%, 54%, and 31%. The push-up with a plus, push-up with hands apart, and military press also qualified with peak arcs of 72%, 69%, and 60% MMT. The push-up with a plus had a duration of 67% and the peak arc was as the chest moved away from the floor. The push-up with hands apart had a duration of 21% and the peak was during the isometric contraction when the chest was near the floor. The military press had a duration of 36% and the peak was present from 120° to 150° of elbow extension (Table 1).

The pectoralis minor had one qualifying exercise: the press-up, with a peak arc of 89% MMT during the isometric phase and a duration of 75%. The two push-up exercises qualified under the altered criteria. The push-up with a plus had a peak arc during the plus maneuver of 58% MMT and a duration of 34%. When done in the hands-apart position, the peak arc was 55% MMT during the second to last arc of the push-up, and the duration was 50% of the exercise (Table 1).

DISCUSSION

Muscle function

The upper trapezius had six optimal exercises. During rowing and the two horizontal abduction exercises, it was functioning as a scapular retractor. The peak activity for these exercises was at the end of the concentric contraction and the isometric hold for maximal scapular retraction. During the military press, scaption, and abduction, the upper trapezius functioned for upward rotation of the scapula, and the peak activity was between 90° of elevation and the end of the concentric contraction (Tables 1 and 2). Saha and Chakravarty[9] tested the upper trapezius electromyographically during abduction and found it fired maximally at 120°, then decreased. Bagg and Forrest[1] tested it during scaption, and found that it increased until about 45°, then leveled off, and after about 110° it began to increase once again. They suggested the plateau may be caused by the changing function of the muscle from scapular supporter to scapular rotator. The observations of both these authors was confirmed in this study during abduction and scaption.

The middle trapezius was functioning as a scapular retractor during all of the qualifying exercises (Table 2), and the peak arcs were near the position of maximal scapular adduction (Table 1).

The lower trapezius, like the upper trapezius, had three qualifying exercises where it functioned as a retractor, and three where it upwardly rotated the scapula. It retracted the scapula during the same three exercises as seen in the upper trapezius. Similarly, it upwardly rotated the scapula during scaption and abduction, and flexion (rather than the military press) (Table 2). Bagg and Forrest[1] found the lower trapezius to be most active during scaption at the 90° to 120° arc. This is only a slight alteration to this study, which showed the peak arc to be between 120° and 150°. Saha and Chakravarty[9] reported it to be most active between 90° and 120° in abduction, then it demonstrated decreasing activity.

TABLE 1
Qualifying exercises for each muscle (ranked by intensity of peak arc)

Muscle	Exercise	Duration qualified (% of exercise)	Peak arc (% MMT ± SD)	Peak arc range
Upper trapezius	Rowing	75	112 ± 84	Isometric[a]
	Military press	27	64 ± 26	150-peak
	Horiz abd w/ER[b]	33	75 ± 27	Isometric[a]
	Horiz. abd (neutral)[b]	33	62 ± 53	90-peak
	Scaption[b]	23	54 ± 16	120–150
	Abduction[b]	31	52 ± 30	90–120
Middle trapezius	Horiz. abd (neutral)	78	108 ± 63	90-peak
	Horiz. abd w/ER	67	96 ± 73	Peak-90
	Extension (prone)	27	77 ± 49	Neutral-30
	Rowing	33	59 ± 51	90–120
Lower trapezius	Abduction	50	68 ± 53	90–150[c]
	Rowing	50	67 ± 50	120–150
	Horiz. abd w/ER	33	63 ± 41	90-peak
	Flexion	23	60 ± 18	120–150
	Horiz. abd (neutral)	33	56 ± 24	90-peak
	Scaption[d]	23	60 ± 22	120–150
Levator scapulae	Rowing	78	114 ± 69	Isometric[a]
	Horiz. abd (neutral)	67	96 ± 57	Isometric[a]
	Shrug	63	88 ± 32	Isometric[a]
	Horiz. abd w/ER	33	87 ± 66	Isometric[a]
	Extension (prone)	36	81 ± 76	Isometric[a]
	Scaption	46	69 ± 46	120–150
Rhomboids	Horiz. abd (neutral)	33	66 ± 38	90-peak
	Scaption	25	65 ± 79	120–150[c]
	Abduction	31	64 ± 53	90–150
	Rowing	30	56 ± 46	Isometric[a]
Middle serratus anterior	Flexion[e]	69	96 ± 45	120–150
	Abduction[e]	54	96 ± 53	120–150
	Scaption	58	91 ± 52	120–150
	Military press	64	82 ± 36	150-peak
	Push up w/a plus	28	80 ± 38	Plus maneuver
	Push up hands apart	21	57 ± 36	Last arc of push up
Lower serratus anterior	Scaption	50	84 ± 20	120–150
	Abduction	54	74 ± 65	120–150
	Flexion[e]	31	72 ± 46	120–150
	Push up w/a plus[e]	67	72 ± 3	Chest moving away from floor
	Push up hands apart	21	69 ± 31	Isometric as the chest was near the floor
	Military press	36	60 ± 42	120–150
Pectoralis minor	Press up	75	89 ± 62	Isometric[a]
	Push up w/a plus	34	58 ± 45	Plus maneuver
	Push up w/hands apart	50	55 ± 34	Second to last arc of push up

[a] Isometric contractions were at the extreme of the range of motion.
[b] One or two of the consecutive arcs was between 40% and 50% MMT.
[c] Identical % MMT over two consecutive arcs for peak activity.
[d] One of the consecutive arcs was 49% MMT.
[e] Two exercises tied for the same ranking position.

Again, the slight difference between this study and theirs was that this study demonstrated the peak from 90° to 150°.

The levator scapulae functioned as a scapular retractor in four of the six qualifying exercises. In the other two exercises it elevated the scapula (Table 2). Also, in five of the six qualifying exercises, it was most active during the isometric contraction at the end of the range (Table 1). Previous investigators have not looked at the levator scapulae during the exercises that demonstrated optimal activity.

The rhomboids functioned only for scapular retraction during the four qualifying exercises (Table 2). Saha and Chakravarty[9] found the rhomboids to have a steady rise in activity during abduction from 30° to 120° of elevation, and then a maintenance of activity until 180°. This was also the case in this study, as the peak activity was seen between 90° and 150°.

The middle and lower serratus anterior were active during the same six exercises for upward rotation and protraction

TABLE 2
Muscle function for the qualifying exercises

Muscle	Exercise	Function
Upper trapezius	Rowing	Retraction
	Military press	Upward rotation
	Horiz. abd w/ER	Retraction
	Horiz. abd (neutral)	Retraction
	Scaption	Upward rotation
	Abduction	Upward rotation
Middle trapezius	Horiz. abd (neutral)	
	Horiz. abd w/ER	Retraction
	Extension (prone)	
	Rowing	
Lower trapezius	Abduction	Upward rotation
	Rowing	Retraction
	Horiz. abd w/ER	Retraction
	Flexion	Upward rotation
	Horiz. abd (neutral)	Retraction
	Scaption	Upward rotation
Levator scapulae	Rowing	Retraction
	Horiz. abd (neutral)	Retraction
	Shrug	Elevation
	Horiz. abd w/ER	Retraction
	Extension (prone)	Elevation
	Scaption	Retraction
Rhomboids	Horiz. abd (neutral)	
	Scaption	Retraction
	Abduction	
	Rowing	
Middle serratus anterior	Flexion	Upward rot. & protraction
	Abduction	
	Scaption	
	Military press	
	Push up w/a plus	
	Push up w/hands apart	
Lower serratus anterior	Scaption	Upward rot. & protraction
	Abduction	
	Flexion	
	Push up w/a plus	
	Push up w/hands apart	
	Military press	
Pectoralis minor	Press up	Depression
	Push up w/a plus	Protraction
	Push up w/hands apart	Protraction

of the scapula (Table 2). The three top exercises were for humeral elevation in the three planes (flexion, scaption, and abduction). The peak arcs for both parts of the muscle in all three planes were between 120° and 150° with nearly the same intensities (Table 1). Saha and Chakravarty[9] found increasing activity in this muscle from 60° to 180° during abduction, and reported little activity during flexion. Bagg and Forrest[1] saw a gradual increase in muscle activity throughout scaption. Both of these reports are slightly different from this data. However, the amazing consistency in this study between flexion, scaption, and abduction reinforces the role of the serratus anterior. The other three qualifiers included the two push-ups and the military press. It is interesting to note that during the two push-ups, the middle serratus anterior exhibited the peak arc at the top of the range of motion, whereas the lower serratus anterior exhibited the peak arc at the bottom of the range of motion (Table 1). Thus, the two parts of the muscle demonstrated a subtle difference in function.

The pectoralis minor was the only muscle that demonstrated optimal activity during the press-up, as it depressed the scapula. Under the altered criteria, it also revealed activity during the two types of push-ups to protract the scapula. Saha and Chakravarty[9] reported relative inactivity during planar elevation in this muscle. The pectoralis minor is a small muscle, and it has been suggested that it is active for fine motor control rather than strength.[7]

Inman et al.[5] developed the concept of the force couple about the scapula for rotation. They noted three complementary forces: upward rotation, medial contraction, and anterolateral force from the inferior angle. The upper trapezius, upper three digitations of the serratus anterior, and levator scapulae worked together to supply the upper part of the force couple. The lower trapezius and last four digitations of the serratus anterior functioned in synchrony to supply the lower part of the force couple. Their results agree with those in this study. In addition, the middle trapezius and rhomboids obviously supplied the medial force. The pectoralis minor appeared to be more of an accessory for scapular depression and protraction rather than a major part of the force couple.

Exercise program

Twelve of the 16 exercises tested qualified as an optimal exercise for at least one of the muscles.

Flexion, scaption, and abduction were the exercises to elevate the arm up to 180°. During flexion, three muscles were optimally recruited, while scaption recruited six muscles and abduction used five muscles (Table 3). The peak arcs for all muscles during both flexion and scaption were between 120° and 150°. Because of the similarities of these two exercises, only one needed to be included in the core program. Scaption with humeral external rotation was used as an optimal exercise in twice as many muscles than was flexion, thus scaption was the exercise chosen for the core program. Also, because of the added stability of the humeral head in the glenoid during this plane of motion,[8] scaption is thought to be even more favorable. When scaption with humeral external rotation is done beyond 90° of elevation, there is no impingement of the rotator cuff under the coracoacromial arch. However, that is not the case with abduction. In an injured shoulder, abduction should be done to 90° to avoid impinging the rotator cuff muscles under the arch. This study revealed that all of the qualifying arcs were above 90° of elevation. If abduction were done to just 90°, it would not be considered as an optimal exercise. For that reason, abduction was not recommended as a core exercise for the scapular muscles.

Rowing, horizontal abduction in neutral, and abduction with the humerus in external rotation were the three exercises that focused on scapular retraction. Both rowing and horizontal abduction in neutral optimally exercised five of the same muscles, and horizontal abduction with humeral external rotation used four of these muscles. Because of the

TABLE 3
Order of exercises qualifying for a given muscle

Exercise	Upper trap.[a]	Middle trap.	Lower trap.[b]	Lev. scap.	Rhomb.	Middle SA	Lower SA	Pec. minor[c]
Flexion			4			1	3	
Scaption	5		6	6	2	3	1	
Abduction	6		1		3	1	2	
Rowing	1	4	2	1	4			
Hor. abd	4	1	5	2	1			
Hor. abd w/ER	3	2	3	4				
Push-up w/plus						5	3	2
Push-up apart						6	5	3
Bench press								
Military press	2					4	6	
Shrug				3				
Decel.								
Ext. (prone)		3		5				
Int. rotation								
Ext. rotation								
Press up								1

[a] Exercises ranked 3 to 6 had only 2 arcs >50%; 3rd arc >40%.
[b] During scaption the 3rd consecutive arc was 49% MMT.
[c] During push up with plus the 3rd arc was 48%; during push up with hands apart the 2nd and 3rd arcs were 48%.

similarities in these three exercises, only one of them needed to be in the core exercise program. Rowing allowed for a greater range of scapular retraction than did the two horizontal abduction exercises and had a greater intensity of muscle activity as noted in the peak arcs. Thus, rowing was selected as the exercise of choice.

Both the push-up with a plus and with hands apart qualified for the same three muscles. Again, because of the similarities of the two exercises, only one needed to be in the core program. Push-up with a plus was selected because of the higher rankings of the peak arc.

The military press qualified for three muscles, the shoulder shrug for one muscle, and extension in the prone position for two muscles. All of the muscles facilitated by these exercises were optimally used during another exercise already included in the core program. Thus, none of these three exercises were included.

The press-up qualified only for the pectoralis minor. In that it was the only exercise that met the original (more stringent) qualifying criteria for the pectoralis minor, it was included in the core exercise recommendations.

Thus, four exercises make up the core program for the scapular rotator muscles: scaption, rowing, push-up with a plus, and press-up. This combination uses all eight of the scapular rotators at least once with the stringent qualifying criteria; and with the altered criteria, seven of the muscles were included twice.

SUMMARY

Twelve of the exercises tested generated electrical activity in at least one of the scapular muscles. A combination of four exercises was scientifically shown to be a solid core to be included in a shoulder rehabilitation program to assure that the scapular muscles are not neglected. Those key exercises were scaption, rowing, push-up with a plus, and press-up.

The role of scapular motion as a stable base for glenohumeral mobility is apparent. The motion is necessary to position the arm throughout daily activities and becomes of paramount importance to the overhead athlete. Based on this study, health care professionals can now be advised in the selection of effective exercises for scapular motion. The core program for scapular motion is recommended as a beginning point, and additional exercises can be selected to develop the total program once the specific patient problem is evident.

REFERENCES

1. Bagg SD, Forrest WJ: Electromyography study of the scapular rotators during arm abduction in the scapular plane. *Am J Phys Med 65:* 111–124, 1986
2. Basmajian JV: *Muscles Alive.* 5th edition. Baltimore, William & Wilkins Co, 1985
3. Brunnstrom S: Muscle testing around the shoulder girdle. *J Bone Joint Surg 23:* 263–272, 1941
4. Codman EA: *The Shoulder.* New York, Medical Publishers, 1934
5. Inman VT, Saunders M, Abbott LC: Observations on the function of the shoulder joints. *J Bone Joint Surg 26:* 1–30, 1944
6. MacKenzie WC: *The Action of Muscles, Including Muscle Rest and Muscle Re-Education.* Second edition. New York, Paul B. Hoeber, 1930, pp 44–45
7. Perry J: Normal upper extremity kinesiology. *Phys Ther 58:* 265–278, 1978
8. Poppen NK, Walker PS: Normal and abnormal motion of the shoulder. *J Bone Joint Surg 58A:* 195–201, 1976
9. Saha AK, Chakravarty BG: Studies on electromyographic changes of muscles acting on the shoulder joint complex. *Calcutta Med J 53:* 409–413, 1956
10. Stookey B: The motofacient and non-motofacient cycle in elevation of the humerus. *AMA Arch Neurol Physiat 4:* 323–330, 1920