[ Sports Physical Therapy ]

# An Electromyographic Evaluation of Subdividing Active-Assistive Shoulder Elevation Exercises

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**Background:** Active-assistive range of motion exercises to gain shoulder elevation have been subdivided into gravity-minimized and upright-assisted exercises, yet no study has evaluated differences in muscular demands.

**Hypothesis:** Compared with gravity-minimized exercises, upright-assisted exercises will generate larger electromyographic (EMG) activity. Compared with all active-assistive exercises, upright active forward elevation will generate more EMG activity.

**Study design:** Controlled laboratory study.

**Methods:** Fifteen healthy individuals participated in this study. The supraspinatus, infraspinatus, and anterior deltoid were evaluated. The independent variables were 11 exercises performed in random order. The dependent variable was the maximum EMG amplitude of each muscle that was normalized to a maximal voluntary isometric contraction (MVIC).

**Results:** Each muscle demonstrated significant differences between exercises ($P < .001$), with upright active forward elevation producing the greatest EMG for all muscles (95% confidence interval [CI], 12% to 50% MVIC). The orders of exercise varied by muscle, but the 5 gravity-minimized exercises always generated the lowest EMG activity. The upright-assisted exercises (95% CI, 23% to 42% MVIC) for the anterior deltoid generated more EMG activity than did the gravity-minimized exercises (95% CI, 9% to 21% MVIC) ($P < .05$). The infraspinatus and supraspinatus demonstrated increasing trends in EMG activity from gravity minimized to upright assisted ($P > .05$).

**Conclusion:** The results suggest a clear distinction between gravity-minimized exercises and upright-assisted exercises for the anterior deltoid but not for the supraspinatus and infraspinatus. Between the 2 types of assisted exercises, the results also suggest a clear distinction in terms of active elevation of the arm for the supraspinatus and anterior deltoid but not for the infraspinatus.

**Clinical Relevance:** Muscle activation levels increase as support is removed, but subdivision of active-assistive range of motion to protect the supraspinatus and infraspinatus may not be necessary.

**Keywords:** physical therapy; rehabilitation; rotator cuff; therapeutic exercise

Improving active elevation commonly constitutes a large part of the rehabilitation associated with many shoulder conditions[6,12,21] and is typically achieved with a combination of active-assistive and active exercise.[12,19,20] However, objective evidence to guide exercise selection and progression for this level or exercise is limited.[23,28]

Active-assistive range of motion (AAROM) exercise programs to regain active elevation have been described as starting with gravity-minimized exercises and progressing to inclined- and upright-assisted elevation exercises.[6,19,21,22] For patients with rotator cuff repairs, Levy et al[21] initiated exercises with supine gravity-eliminated activities, which advanced to semisitting

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exercises and then, finally, standing elevation against gravity. Krupp et al[19] recommended a progression from side-lying active shoulder flexion to supine active reaching to progressive upright reaching as a way to achieve upright active elevation following a biceps tenodesis or tenotomy. Bohmer et al[6] used a sling suspended overhead to support the arm during gravity-eliminated active elevation exercises, progressing to upright-assisted exercises to reestablish active elevation for patients with impingement. It appears that these studies logically assumed that gravity-minimized elevation exercises should be less demanding than upright-assisted elevation exercises on the shoulder girdle muscles. No study has measured muscular activity with electromyography (EMG) to evaluate this effect of subdividing AAROM elevation exercises into gravity-minimized and assisted elevation. There is an assumption of increased muscular demand based on a biomechanical rationale but no empirical data to document the magnitude of change during this exercise progression.

Therefore, the purpose of this study was to evaluate the EMG activity of the supraspinatus, infraspinatus, and anterior deltoid during active-assistive forward elevation exercises to determine if subdivisions of active-assistive exercise exist. We hypothesize that upright-assisted exercises will generate more EMG activity in the supraspinatus, infraspinatus, and anterior deltoid than that of gravity-minimized exercises. Secondarily, compared with all the AAROM exercises, upright active forward elevation will generate more EMG activity in these same muscles.

## MATERIALS AND METHODS

### Participants

Fifteen participants volunteered for the study: 7 women and 8 men (mean age, 23.9 years; range, 22 to 28; height, 173.4 ± 10.6 cm; weight, 74.4 ± 15.9 kg). Before participation, all had the study explained to them, and all read and signed a consent form approved by the university's institutional review board. The criteria necessary to be included in the study was an age of 18 to 40 years, no previous shoulder injury to the dominant arm (fracture, dislocation, chronic pain, or surgery), no current shoulder girdle pain, and the ability to demonstrate full active range of motion.

### Rehabilitation Exercises

The 11 exercises that we studied represent AAROM exercises typically used in our clinical practice to regain patients' active forward elevation. The exercises are described as they were demonstrated to the participants (Table 1). Participants randomly picked exercises from an envelope to minimize the effects of fatigue and order biasing. The patient was given a visual demonstration of each exercise and the opportunity to practice no more than 6 repetitions before data collection started. The patient then performed 5 repetitions of the exercise, controlling arm speed by following an electronic metronome (Seiko, Bloomfield, Connecticut) adjusted to keep a consistent 30 degrees per second for the 11 exercises.

Elevation exercises were divided into 3 types: gravity minimized, upright assisted, and upright active. For this study, we defined gravity-minimized elevation exercise as any exercise in which (1) gravity provides assistance to the participant to complete the concentric portion of the exercise or (2) the primary movement is perpendicular to gravity with the weight of the arm supported. In this study, gravity-minimized exercises included dusting center (Figure 1), dusting medial and lateral, side-lying elevation (Figure 2), and supine forward elevation with elastic resistance from 90° (Figure 3). The second type of elevation exercise, upright assisted, is any exercise performed in the upright position that elevates the arm against gravity during the concentric phase of motion with assistance. In this study, assistance was provided (1) by the hand being supported by an object during movement or (2) by the hand moving on an object. Upright-assisted elevation exercises included the rope and pulley, wall walk, ball roll, standing T-bar active-assistive forward elevation (Figure 4), and standing T-bar assistive elevation with active lowering. The third type of elevation exercise, upright active forward elevation, was performed unsupported against gravity to serve as a comparison with the active-assistive exercises.

### Procedures

Surface and fine wire EMG data were collected from 3 muscles: anterior deltoid (surface), supraspinatus (fine wire), and infraspinatus (fine wire). The rationale for using surface on the anterior deltoid is that surface electrodes have a larger pickup area and are more representative of the muscle's activity.[3,7] The supraspinatus is deep to the upper trapezius, so fine wire is necessary. The fine wire instrumentation was used to reduce cross-talk from other musculature for the infraspinatus.[3,8] The dominant arm, designated as the throwing arm, was instrumented for the study. Before surface electrode placement, the participants' skin was prepared by abrasion with fine sandpaper and vigorously cleansed with isopropyl alcohol wipes to decrease electrical impedance.[3] Bipolar Ag/AgCl disposable surface electrodes (Medicotest, Olstykke, Denmark) with a 2-cm interelectrode distance were applied to the anterior deltoid one-third the measured distance from anterior acromion to the deltoid tuberosity.[29] Electrodes were aligned parallel to the underlying muscle fiber orientation with the ground electrode placed on opposite acromion.[13]

Two muscles, supraspinatus and infraspinatus, were instrumented with indwelling fine wire electrodes (California Fine Wire, Grover City, California). The fine wire electrodes, sterilized in a 27-gauge needle, were inserted into the respective muscle bellies using a 2-needle technique with the interelectrode distance of 1 cm.[14] Electrode placement was visually confirmed to ensure placement and minimal cross-talk during active motions. An electronic goniometer (Biometrics Ltd, Ladysmith, Virginia) was adhered to the spine of the scapula and the midline of the humerus with the arm abducted to 90°. The middle of the electronic goniometer was aligned with the center of

Table 1. Exercise descriptions and categorization by type of elevation exercise.

| Type of Exercise | Description |
|---|---|
| Gravity minimized | |
| Dusting center | Participant positioned sitting in front of an adjustable table with table at elbow height and elbow at midline of body. Participant placed hand on a towel and then slid towel directly forward and backward in sagittal plane until elbow was fully extended while keeping body still. (See Figure 1.) |
| Dusting lateral | Dusting exercise repeated 45° lateral to first exercise along plane of the scapula. |
| Dusting medial | Dusting exercise repeated 45° medial to first exercise. Glenohumeral joint moved through an arc of approximately 0° to 45° for each of first 3 exercises. |
| Side-lying elevation | Lying on nondominant side, dominant hand rested on ironing board top that was adjusted to height that dominant arm positioned near plane of the scapula with hand at chest level, elbow flexed humerus near the trunk. Participant instructed to slide towel on board with weight of hand resting on board, effectively elevating arm overhead to approximately 140° and then lowering hand to starting position. (See Figure 2.) |
| Supine forward elevation with elastic resistance from 90° (supine band) | Participant supine, feet resting flat on plinth, nondominant hand holding red Theraband at waist level. Exercise started with dominant shoulder flexed 90° and elbow extended. Participant actively moved arm into forward elevation of approximately 160°, thereby lengthening band. Dominant arm then lowered slowly back to starting position. No slack and only minimal tension allowed in band at starting position. Dominate arm maintained in external rotation throughout exercise. (See Figure 3.) |
| Upright assisted | |
| Rope and pulley | Starting with dominant arm resting at side, participant raised dominant hand by allowing nondominant hand to primarily assist arm elevation in plane of the scapula. Participant then lowered dominant arm back to original position primarily using nondominant arm. Arm traveled an arc of approximately 0° to 160° during exercise. |
| Wall walk | Participant stood 20 cm to 40 cm from wall with dominant hand resting at shoulder level on wall. Participant instructed to walk hand up and down wall using index and middle fingers into forward elevation within an arc of approximately 30° to 160°. Performed taking 4 beats to walk up and down at a rate of 40 beats per minute. |
| Ball roll | Participant stood 1 arm length from wall with a tennis ball against wall at shoulder height. Participant asked to roll ball up and down wall 1-hand length (approximately a 20° arc) while keeping elbow extended. |
| Standing T-bar active-assistive forward elevation | In standing, participant instructed to primarily use nondominant arm to raise and lower dominant arm into elevation. Dominant arm grasped 1-in. PVC bar with thumb pointing up and moved through an approximately 160° arc. (See Figure 4.) |
| Standing T-bar assistive elevation with active lowering | Exercise performed exactly as standing T-bar active-assistive forward elevation except upon lowering dominant arm, participant released bar and under volitional control, actively eccentrically lowered dominant arm to starting position keeping elbow extended. |
| Upright active | |
| Active forward elevation | While standing, participant asked to actively raise and lower dominant arm from side to full overhead motion through approximately a 160° arc. Movement performed in the plane of scapula, elbow extended, thumb pointed up. |

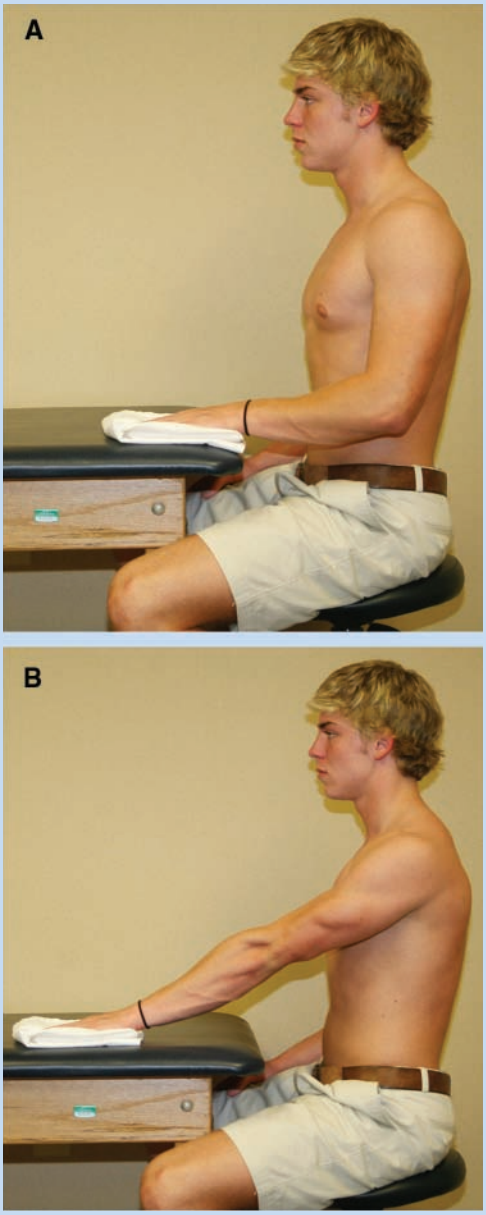

Figure 1. A, starting position for dusting center; B, ending position.

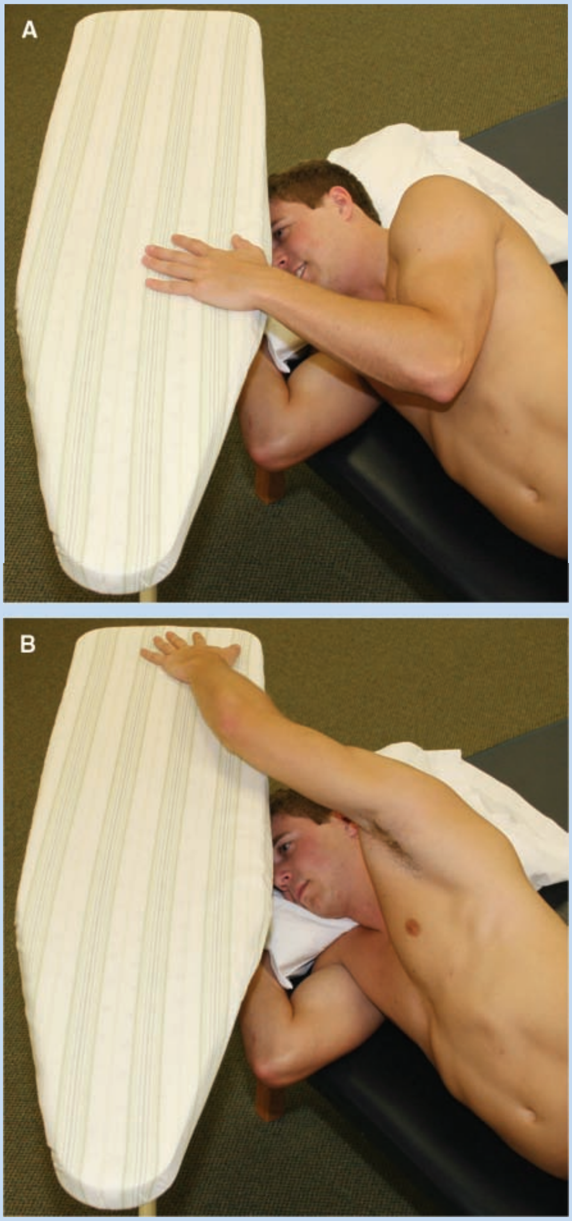

Figure 2. A, starting position for side-lying elevation; B, ending position.

the posterior glenohumeral joint. The electronic goniometer was monitored during data collection to ensure that it stayed securely affixed during all exercises (Figure 5). The electrical signal from the goniometer indicated the initiation and completion of the exercise and was used during EMG data reduction to define a trial.

Two trials of 5-second maximal voluntary isometric contractions (MVICs) were performed for each muscle using manual muscle-testing techniques previously described.[15,16] Anterior deltoid and supraspinatus were tested with the humerus in plane of the scapula, flexed to 90° in neutral rotation. The infraspinatus was tested with the humerus abducted and elbow flexed to 90° and with the shoulder internally rotated 30°.[15] The highest 500-ms root mean square amplitude recorded over the two 5-second trials represented 100% EMG activity for each muscle.[2] A 5-second resting baseline was recorded for each participant while standing with one's hands at the side, given that the majority of the exercises were performed in an upright position. The root mean square amplitude for 1 second of this resting data was calculated to subtract out electrocardiographic and background noise signal from the amplitude data recorded during the

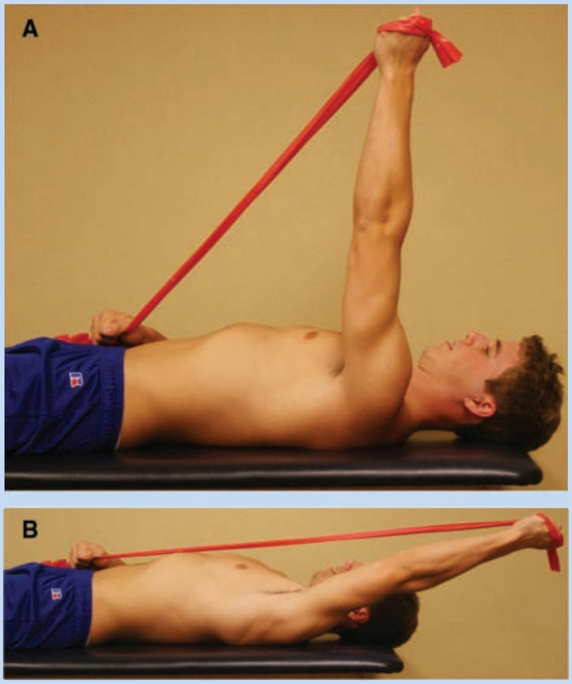

Figure 3. A, starting position for supine forward elevation with elastic resistance from 90°; B, ending position.

exercises.[25] The maximal electrical activity collected during the exercises is represented as a percentage of the MVIC, for statistical comparison. The rationale for evaluating only maximal activity was to estimate the greatest muscle activity likely to be generated during an exercise. These exercises are typically used during rehabilitation when healing tissues are relatively weak. The greatest demand was important to identify to protect healing tissues.

## EMG Data Reduction

The electrodes and electric goniometer were connected to a Myopac amplifier belt unit (Run Technologies, Mission Viejo, California). The kinematic data gain and sampling were set at 1000 Hz. The amplifier has a common mode rejection ratio of 90 dB at 60 Hz. The raw indwelling EMG data were collected with 1000 gain at a rate of 2000 Hz and band pass filtered at 10 to 1000 Hz, whereas the surface EMG data were collected with 2000 gain at rate of 1000 Hz and band pass filtered at 20 to 500 Hz. A 30-ms root mean square centering algorithm was applied to all EMG data.[26] The amplified signals were transmitted to a PC-type computer through a 12-bit A/D board (Measurement Computing, Norton, Massachusetts). Datapac software (Run Technologies, Mission Viejo, California) was used to process, analyze, and store all analog data.

Five exercise trials were identified for each exercise with the electric goniometer. The maximal amplitude for each trial was determined as a percentage of the respective muscles' MVIC. The average of the 5 maximal amplitudes recorded from each muscle and each exercise was used for statistical analysis.

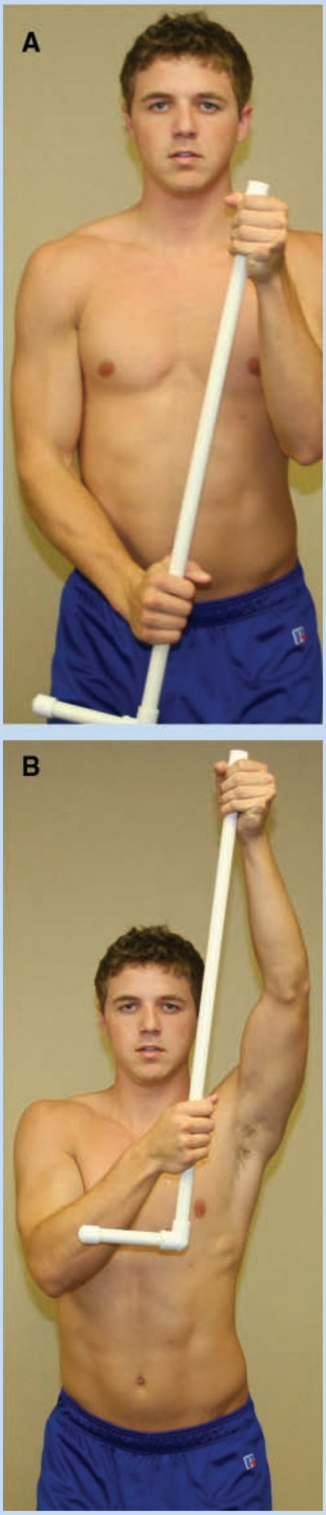

Figure 4. A, starting position for standing T-bar active-assistive forward elevation; B, ending position.

Figure 5. Demonstration of the electronic goniometer and electrode placement during the supine forward elevation exercise with elastic resistance from 90°.

### Statistical Analysis

Each maximal muscle activity was analyzed separately because of the differing electrode pickup area between surface and indwelling electrodes. Three separate repeated measure analyses of variance were used to determine if differences between exercises existed to determine an exercise progression. The level for significance was set at $P < .05$, and if found, a Bonferroni post hoc analysis was used to control for family-wise error rate and to minimize for a type I error due to the multiple comparisons (adjusted significance, $P < .00091$). A Greenhouse-Geiser correction was applied to all analyses of variance to correct for assumption of compound symmetry. The intratrial reliability of the EMG data (based on an intraclass correlation model; $\text{ICC}_{2,3}$) and the standard error of measurement were determined.[9] All statistical analysis was performed with SPSS (version 16).

## RESULTS

Tables 2 to 4 present the descriptive data of the average maximal EMG activity for the 3 muscles studied. The analysis of variance with Greenhouse-Geiser correction demonstrated significant differences between exercises for the supraspinatus, $F_{(3.3,\,46.7)} = 19.5$, infraspinatus, $F_{(3.2,\,42.1)} = 7.8$, and the anterior deltoid, $F_{(4.3,\,60.4)} = 34.5$, muscles ($P < .001$). Bonferroni post hoc analysis for the supraspinatus revealed that upright active forward elevation (29% ± 13% MVIC) was significantly greater than all other exercises (Table 2). All gravity-minimized exercises were not significantly different from one another, and all upright elevation exercises were significantly larger than side-lying elevation (7% ± 5% MVIC). Wall walk (21% ± 10% MVIC) was the only upright-assisted elevation exercise that was significantly greater than all gravity-minimized exercises for the supraspinatus muscle.

Post hoc analysis for the infraspinatus revealed that upright active forward elevation (21% ± 15% MVIC) generated the most EMG activity but was significantly greater than only the dusting medial exercise (7% ± 5% MVIC), which generated the least EMG activity ($P = .00089$) (Table 3). Only 2 gravity-minimized exercises, dusting medial and center, resulted in significantly lower EMG activity than 4 of the upright-assisted elevation exercises, rope and pulley, ball roll, and both T-bar exercises (Table 3).

Bonferroni post hoc analysis for the anterior deltoid activity revealed that active forward elevation (45% ± 9% MVIC) was significantly greater than all other exercises (Table 4). Upright-assisted elevation exercises were found to generate significantly more anterior deltoid activity than that of all gravity-minimized exercises (Table 4); one exception to this result was the rope and pulley exercise (30% ± 12% MVIC), which was not different from side-lying elevation exercise (16% ± 7% MVIC) but approached significance ($P = .00092$).

## DISCUSSION

Relative muscular demand classifies EMG activity into 4 categories: low (< 20%), moderate (20% to 40%), high (41% to 60%), and very high (> 60%).[10] According to the present results, all gravity-minimized exercises are low and would thus be used in the earliest stage of a rehabilitation continuum to regain active motion. The EMG levels for these exercises have not been previously reported, making comparisons difficult. Mean EMG values have been reported for the supraspinatus and infraspinatus during continuous passive motion and therapist-assisted passive elevation and did not exceed 10% MVIC.[11] This is similar to the maximal EMG activity (range, 7% to 13% MVIC) found during gravity-minimized exercises. Even though maximal EMG activity was calculated and indwelling electrodes were used in the current study (which differ from the mean amplitudes and surface electrodes used by Dockery[11]), it appears that all gravity-minimized exercises have muscle activity similar to that of previously reported passive elevation exercises. Therefore, gravity-minimized exercises may be a good first step in progressing from passive range of motion to AAROM exercises.

Upright-assistive exercises fall into the low and moderate categories, and their levels of muscular activity appear to agree with results of other studies.[11,23] Dockery et al[11] found that during rope and pulley elevation, average muscle activity of the supraspinatus, infraspinatus, and anterior deltoid were 18% ± 8% MVIC, 10% ± 5% MVIC, and 25% ± 15% MVIC, respectively (standard deviations estimated from figure), which aligns with the current study's findings.

As expected, active elevation was categorized as moderate demand and served as reference to differentiate active from assistive exercises. The current study's results support a significant difference between active and assistive exercises for the anterior deltoid and supraspinatus but not for the infraspinatus. Kronberg et al[18] reported higher activation levels than those found in this study during forward flexion for the infraspinatus and anterior deltoid (55% MVIC and 75% MVIC, respectively). In both the current study and Kronberg's study,[18] maximum supraspinatus muscular activity was 30% MVIC. Unfortunately Kronberg et al[18] did not report standard deviations nor the speed of movement during EMG recording. Alpert et al[1] documented increased speed of movement and increased EMG amplitudes. Our slow exercise speed (30 degrees per second) may partially account for the lower EMG values observed.

Table 2. Average maximal supraspinatus muscle activity.[a]

| | | | % MVIC | | | | |
|---|---|---|---|---|---|---|---|
| **No.** | **Type** | **Exercise** | **Mean ± SD** | **95% CI** | **SEM** | **ICC** | **Post Hoc** |
| 1 | GM | Side-lying elevation | 7 ± 5 | 4, 9 | 2 | .89 | |
| 2 | GM | Supine band | 8 ± 6 | 5, 11 | 6 | .63 | |
| 3 | GM | Dusting medial | 12 ± 6 | 8, 15 | 3 | .90 | |
| 4 | GM | Dusting center | 12 ± 7 | 8, 16 | 3 | .83 | |
| 5 | GM | Dusting lateral | 13 ± 7 | 9, 17 | 2 | .94 | |
| 6 | UA | T-bar active-assistive forward elevation | 16 ± 9 | 11, 21 | 6 | .69 | 1, 2 |
| 7 | UA | Ball roll | 16 ± 9 | 11, 21 | 2 | .96 | 1, 2 |
| 8 | UA | Rope and pulley | 17 ± 10 | 11, 23 | 4 | .89 | 1 |
| 9 | UA | T-bar active low | 20 ± 11 | 13, 26 | 3 | .96 | 1, 2 |
| 10 | UA | Wall walk | 21 ± 10 | 16, 27 | 2 | .94 | 1-5 |
| 11 | A | Active forward elevation | 29 ± 13 | 22, 37 | 4 | .95 | 1-10 |

[a] Organized in ascending order for the average maximal supraspinatus muscle activity (percentage maximal voluntary isometric contraction; % MVIC) with associated standard deviation and 95% confidence intervals (CIs). The intratrial reliability (intraclass correlation coefficient; ICC) and standard error of measure (SEM) are reported as well as the type of exercise: gravity minimized (GM), upright assisted (UA), or upright active (A). Bonferroni post hoc analysis revealed multiple significant differences between exercises ($P < .05$). Exercises that are significantly less than a particular exercise are indicated by exercise number; for example, ball roll was significantly larger than side-lying elevation (No. 1) and supine band (No. 2). When no significant differences exist between exercises for a muscle, no number is presented.

Table 3. Average maximal infraspinatus muscle activity.[a]

| | | | % MVIC | | | | |
|---|---|---|---|---|---|---|---|
| **No.** | **Type** | **Exercise** | **Mean ± SD** | **95% CI** | **SEM** | **ICC** | **Post Hoc** |
| 1 | GM | Dusting medial | 7 ± 5 | 4, 10 | 1 | .96 | |
| 2 | GM | Dusting center | 8 ± 5 | 5, 10 | 2 | .91 | |
| 3 | GM | Dusting lateral | 9 ± 6 | 6, 13 | 2 | .92 | |
| 4 | GM | Side-lying elevation | 10 ± 7 | 6, 14 | 3 | .92 | |
| 5 | GM | Supine band | 13 ± 8 | 9, 18 | 6 | .51 | |
| 6 | UA | T-bar active-assistive forward elevation | 13 ± 10 | 8, 19 | 9 | .72 | 1, 2 |
| 7 | UA | Rope and pulley | 14 ± 8 | 9, 18 | 1 | .98 | 1, 2 |
| 8 | UA | Ball roll | 18 ± 11 | 11, 24 | 3 | .96 | 1, 2 |
| 9 | UA | T-Bar active low | 18 ± 13 | 11, 26 | 3 | .98 | 1, 2 |
| 10 | UA | Wall walk | 19 ± 13 | 11, 27 | 2 | .98 | |
| 11 | A | Active forward elevation | 21 ± 15 | 12, 30 | 2 | .98 | 1 |

[a] Organized in ascending order for the average maximal infraspinatus muscle activity (percentage maximal voluntary isometric contraction; % MVIC) with associated standard deviation and 95% confidence intervals (CIs). The intratrial reliability (intraclass correlation coefficient; ICC) and standard error of measure (SEM) are reported as well as the type of exercise: gravity minimized (GM), upright assisted (UA), or upright active (A). Bonferroni post hoc analysis revealed multiple significant differences between exercises ($P < .05$). Exercises that are significantly less than a particular exercise are indicated by exercise number; for example, rope and pulley was significantly larger than dusting medial (No. 1) and dusting center (No. 2). When no significant differences exist between exercises for a muscle, no number is presented.

Table 4. Average maximal anterior deltoid muscle activity.[a]

| | | | % MVIC | | | | |
|---|---|---|---|---|---|---|---|
| **No.** | **Type** | **Exercise** | **Mean ± SD** | **95% CI** | **SEM** | **ICC** | **Post Hoc** |
| 1 | GM | Dusting lateral | 14 ± 9 | 9, 19 | 3 | .94 | |
| 2 | GM | Supine band | 15 ± 5 | 12, 18 | 4 | .83 | |
| 3 | GM | Dusting center | 16 ± 8 | 11, 20 | 2 | .92 | |
| 4 | GM | Dusting medial | 16 ± 7 | 12, 20 | 3 | .67 | |
| 5 | GM | Side-lying elevation | 16 ± 8 | 12, 21 | 7 | .82 | |
| 6 | UA | Ball roll | 27 ± 8 | 23, 32 | 6 | .73 | 1-5 |
| 7 | UA | T-Bar active-assistive forward elevation | 30 ± 10 | 25, 36 | 5 | .84 | 1-5 |
| 8 | UA | Rope and pulley | 31 ± 13 | 23, 38 | 11 | .59 | 1-4 |
| 9 | UA | Wall walk | 32 ± 9 | 27, 36 | 3 | .79 | 1-5 |
| 10 | UA | T-bar active low | 35 ± 11 | 29, 42 | 8 | .59 | 1-5 |
| 11 | A | Active forward elevation | 45 ± 9 | 40, 50 | 10 | .57 | 1-10 |

[a] Organized in ascending order for the average maximal anterior deltoid muscle activity (percentage maximal voluntary isometric contraction; % MVIC) with associated standard deviation and 95% confidence intervals (CIs). The intratrial reliability (intraclass correlation coefficient; ICC) and standard error of measure (SEM) are reported as well as the type of exercise: gravity minimized (GM), upright assisted (UA), or upright active (A). Bonferroni post hoc analysis revealed multiple significant differences between exercises ($P < .05$). Exercises that are significantly less than a particular exercise are indicated by exercise number; for example, rope and pulley was significantly larger than dusting lateral (No. 1), supine band (No. 2), dusting center (No. 3), and dusting medial (No. 4). When no significant differences exist between exercises for a muscle, no number is presented.

A progression of AAROM elevation exercises has been suggested, beginning with gravity-minimized exercises and progressing to upright-assisted elevation exercises,[6,19,21-23] as based primarily on a biomechanical rationale. Gravity-minimized elevation exercises provide minimal resistance to the forward elevation movement and are typically performed supine (to decrease the lever arm) or side lying (to support the weight of the arm).[6,19,21,22] Inclined active exercise or upright-assisted elevation exercises increase gravity's resistance to the forward elevation by positioning the patient in more upright positions and are theorized to be less demanding than fully upright active elevation exercise because of the reduced gravitational resistance.[6,19,21,22] Before this study, the assumption of increased demand was based on the biomechanical rationale—namely, that assisted movement directly against gravity would be more demanding than movement in a gravity-minimized position—but without empirical data to document the magnitude of muscular activity change between these exercise types.

Although the average maximal EMG activity level reflects a gradual progression, beginning with gravity-minimized and progressing to upright-assisted elevation exercises for both the supraspinatus and the infraspinatus, a strong distinction between the 2 exercise types for both muscles was not found. Post hoc analysis revealed statistically significant differences between only selected exercises (Tables 2 and 3) and a large overlap in the 95% confidence interval; therefore, our hypothesis was rejected that upright-assisted elevation exercises generate more EMG activity than that of gravity-minimized exercises for the supraspinatus and infraspinatus.

For protection of the supraspinatus and infraspinatus, it appears that a subdivision of AAROM elevation exercises into gravity-minimized exercises and upright-assisted elevation exercises is not necessary. Therefore, progression of exercise should be based on other factors, such as available range of motion, pain tolerance, and presence of substitution patterns. Because a clear distinction between gravity-minimized and upright-assisted elevation exercise was found for the anterior deltoid, subdivision of these AAROM exercise types is warranted in the rare situations where deltoid protection is necessary, such as an open rotator cuff repair or deltoidplasty.

The current study identified 2 exercises worthy of further comment. The wall walk, which is commonly prescribed to gain active and passive elevation, was found to generate more EMG activity than that of all gravity-minimized AAROM exercises for the anterior deltoid and supraspinatus. The EMG data suggest that it should not be considered a passive range of motion exercise and that it is most appropriately used late in the AAROM progression. The "supine forward elevation with elastic resistance" exercise generated comparable EMG activity as the other gravity-minimized exercises and the passive elevation exercises reported by Dockery et al.[11] The current study's results suggest that this resistance exercise is similar to a beginning AAROM exercise and highlights the importance of body positioning in determining muscle activity for lower level forward elevation.

This study's results are limited in their interpretation because no direct relationship has been established between dynamic EMG activity and tension in the respective musculotendinous structures. Only in isometric contractions has a moderate correlation been found between muscle tension and EMG activity.[4] All surface EMG research is subject to cross-talk from surrounding musculature, and the possibility of other muscular activity may have contributed to the electrical signal recorded. This was minimized by using small electrodes with a 2-cm interelectrode distance near the midsection of the muscles studied.[3] Indwelling EMG data do not depict the muscular activation of the entire muscle.[17] Therefore, the indwelling and surface EMG data were analyzed and reported separately.

The results are also limited owing to a study population of healthy young participants instead of older participants with shoulder girdle pathology. The EMG amplitudes and activation patterns during particular motions may be altered by the effect of pain or altered movement patterns because of range of motion restrictions in a patient population. Previous EMG studies have used similar populations in making recommendations for shoulder exercises.[5,24,27]

In conclusion, a clear distinction in EMG activity level between active elevation and both types of assistive elevation exercise was found for the supraspinatus and anterior deltoid but not for the infraspinatus. In comparing EMG activity levels for gravity-minimized exercises and upright-assisted elevation exercises, a clear distinction between exercise types was found for only the anterior deltoid. No widespread differences were observed for the supraspinatus and infraspinatus. The results of this study do not support the biomechanical rationale of assumed increased muscle demand to the supraspinatus and infraspinatus with AAROM elevation exercises that progressively exercise the arm against gravity. It appears that subdividing AAROM elevation exercises based on muscle activity is not necessary to protect the supraspinatus or infraspinatus.

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