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Shoulder Musculature Activation During Upper Extremity Weight-Bearing Exercise

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Study Design: Repeated-measures design comparing 7 static weight-bearing shoulder exercises.
Objective: The purpose of this study was to determine the demand on shoulder musculature during weight-bearing exercises and the relationship between increasing weight-bearing posture and shoulder muscle activation.
Background: Weight-bearing shoulder exercises are commonly prescribed in the rehabilitation of shoulder injuries. Limited information is available as to the demands placed on shoulder musculature while these exercises are performed.
Methods: Eighteen healthy college students volunteered for this study. Surface bipolar electrodes were applied over the infraspinatus, posterior deltoid, anterior deltoid, and pectoralis major muscles. Fine-wire bipolar intramuscular electrodes were inserted into the supraspinatus muscle. Electromyographic (EMG) root mean square signal intensity was normalized to 1 second of EMG obtained with a maximal voluntary isometric contraction (MVIC). Subjects were tested under 7 isometric exercise positions that progressively increased upper extremity weight-bearing posture.
Results: There was a high correlation between increasing weight-bearing posture and muscular activity ($r = 0.97$, $P<0.01$). There was relatively little demand on the shoulder musculature for the prayer and quadruped positions (2%–10% MVIC). Muscular activation was greater for the infraspinatus than for other shoulder muscles throughout most of the exercise positions tested.
Conclusion: These results indicate that alterations of weight-bearing exercises, by varying the amount of arm support and force, resulted in very different demands on the shoulder musculature. Specifically, the infraspinatus was particularly active during the weight-bearing exercises used in this study. *J Orthop Sports Phys Ther, 2003;33:109–117.*

Key Words: *electromyography, muscles, progressive resistive exercise, rehabilitation*

The use of weight-bearing exercises during shoulder rehabilitation has been gaining popularity.[16,31,37] These exercises, termed by some as closed kinetic chain (CKC) exercises in which the hand is in contact with a stable surface, have been suggested to promote proprioception, joint stability, and muscle coactivation around the shoulder.[9,19,28,30,34] Joint proprioception has been shown to improve following training with upper extremity weight-bearing exercises[28,34] and joint compression increases the force necessary to displace the humeral head in cadaveric shoulders, thereby increasing stability.[19,36] Rotator cuff and scapular musculature is active during push-up exercises, however, limited information exists regarding other weight-bearing exercises that are commonly used in rehabilitation.[4,9,17,21]

The incorporation of weight-bearing exercises has been suggested at various phases of the rehabilitation program. Some authors have recommended that they be performed late in the rehabilitation program,[9,31] while others have advocated using them early in the rehabilitation of shoulder injuries.[16,37] At what point upper extremity weight-bearing exercises

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should be included in a progressive resistive exercise program is unclear due to the limited information related to the demand placed on the shoulder during these exercises.

The use of electromyography (EMG) has provided clinicians with valuable information as to which exercises activate specific musculature about the shoulder.[5,21,33] As clinicians design an appropriate rehabilitation program it is necessary to have evidence to support a progression from low- to high-demand exercises on recovering tissues. Therefore, further investigations considering the demands of upper extremity weight-bearing exercises on the shoulder musculature are needed. The purposes of this study were to determine the relationship between increasing upper extremity weight-bearing positions on muscle activity around the shoulder joint and to determine if differences exist in shoulder muscle activity across 7 static weight-bearing exercise positions.

METHODS

Subjects

Eighteen healthy subjects (mean age ± SD = 22 ± 3 years, mean height ± SD = 175 ± 10 cm, mean body mass ± SD = 73 ± 17 kg) volunteered for this study. The dominant shoulder, determined as the throwing arm, of all subjects was examined. A sample of convenience was recruited from the local University community. Subjects were excluded if they had a previous history of shoulder, elbow, wrist, hand, or cervical injury in the preceding 6 months. Prior surgery to the dominant shoulder excluded potential subjects from study participation. All subjects volunteering for this study signed an institutional-review-board-approved consent form after the testing procedures were verbally described to them.

Familiarization

An orientation session was used to familiarize each subject with the procedures and to ensure that they would be able to maintain all exercise positions for the required duration. The biacromial width was determined by measuring the distance between the subject's acromions. This distance was used to control and align each subject in midline between 2 analog scales (Taylor Precision Products, Las Cruces, NM) in a consistent manner (Figure 1). To be included in the study, the subject was required to maintain each exercise position for 15 seconds. The load under the dominant arm was then recorded for each exercise position and this value was used to control for load during data collection.

FIGURE 1. Prayer position is illustrated to represent a standing upper extremity weight-bearing exercise in which minimal weight is placed through the upper extremities. Note the subject places his middle fingers along 2 taped lines on the scales; these are used to standardize hand position based on individual biacromial widths.

Procedures

EMG electrodes were applied to determine muscle activation during weight-bearing exercise positions. The subject's skin was prepared in a standard manner prior to electrode application to minimize electrical impedance.[3] Bipolar surface electrodes (Medicotest, Olstykke, Denmark) were placed over the sternal portion of the pectoralis major, anterior deltoid, posterior deltoid, and infraspinatus in a standardized manner.[2,38] A position one-fifth of the distance from the anterior and posterior acromion to the lateral epicondyle was used to place the anterior and posterior deltoid electrodes, respectively. The pectoralis major electrodes were placed one-third of the distance from the greater tuberosity to the xiphoid process with the subjects arm abducted to 90°.[38] The infraspinatus surface electrodes were placed one-half the distance from the inferior angle to the scapular spine root, 2 cm lateral from the scapula's medial border.[35]

Any surface EMG recording is subject to interfering cross-talk activity from surrounding musculature. To minimize cross-talk, small electrodes made of Ag/AgCl with an interelectrode distance of 2 cm were used. The electrodes were located near the midsection of each muscle, thereby maximizing the recording from the nearest motor unit action potential and minimizing surrounding muscular interference.[3]

Sterile bipolar fine-wire electrodes (California Fine Wire, Grover City, CA) were inserted into the midbelly of the supraspinatus with a 27-guage hypodermic needle.[24] The 50 μm electrodes were prepared in a standard bipolar format.[3] The needle was removed and the wires were taped down to minimize wire movement. The sampling area from the fine wires is limited to the few surrounding motor units.[15,22] Therefore, the sampling of electrical data from fine-wire electrodes may not be directly comparable to sampling from surface electrodes because of the greater number of motor units contributing to surface EMG signal.[3]

Maximal voluntary isometric contractions (MVICs) were performed for each muscle to normalize EMG data. The root mean square peak 1 second of a 5-second MVIC recording was used to normalize the EMG activity of each muscle. Normalization provides a standard reference of electrical activity for each muscle. All EMG data are reported as a percentage of the MVIC, allowing for data to be statistically compared. Test positions and procedures previously described were used for each muscle studied.[15] The subject was then asked to perform a series of 7 weight-bearing upper extremity exercise positions.

The testing order of the upper extremity weight-bearing exercise positions was randomized to minimize the effects of fatigue and prevent order biasing. The 7 exercises studied represented common weight-bearing exercises used during upper extremity rehabilitation programs. These exercises were selected so that the load applied to the dominant arm was progressively increased. A description of the 7 exercises used in this study is provided in Table 1.

TABLE 1. Description of upper extremity weight-bearing exercises used in this study.

	Exercise Position	Exercise Description
1	Prayer	Subject kneels with weight shifted primarily over ankles, leans forward and places hands on each analog scale, similar to standing weight shift[37] (Figure 1).
2	Quadruped	Subject is positioned with hands and knees on the ground with shoulder flexed to 90°.
3	Tripod	Subject remains in the quadruped position, then flexes nondominant shoulder to 180° (Figure 4).
4	Pointer	Subject maintains same position as tripod position and extends contralateral hip to 0° (Figure 5).
5	Push-up	Subject maintains push-up position with elbows in full extension and shoulder flexed to approximately 90°.
6	Push-up feet elevated	Subject maintains push-up position with feet elevated 45 cm, elbows in full extension and the shoulder flexed to 90° (Figure 6).
7	One-arm push-up	Subject maintains 1-arm push-up position with elbow in full extension, dominant shoulder flexed to 90° and nondominant hand placed behind the back during testing (Figure 7).

The subjects were asked to assume each exercise position for 5 seconds. Each subject's weight-bearing force under the dominant arm was observed continuously by 1 of the investigators during data collection. The weight value for each exercise position was maintained within ±1.36 kg of the previously determined value during the familiarization period. Inability to maintain the appropriate amount of weight on the scale resulted in discarding these data from further analyses. There was a 1-minute rest between each of the 3 trials performed in each position. Subjects were given a 2-minute rest between each exercise position tested. A standard universal goniometer was used to assure a 90° shoulder flexion angle was maintained during each testing trial, except for the prayer position. The mean (±SD) shoulder joint flexion angle for the prayer position was 72° ± 7.5°.

EMG Analysis

A Myopac transmitter belt unit (Run Technologies, Laguna Hills, CA) transmitted all raw EMG data at 1000 Hz via a fiber optic cable to its receiver unit. This device has a common mode rejection ratio of 90 dB. The gain for the surface electrodes was set at 2000 μV while the gain for the indwelling electrode was set at 1000 μV. Raw EMG data were collected for all 5 muscles for a period of 5 seconds. The raw EMG data were filtered at a frequency bandwidth of 20 to 500 Hz and root mean squared smoothed with a 30-ms time constant using Datapac software (Run Technologies, Laguna Hills, CA). All data were recorded, stored, and analyzed using Datapac software on a personal computer. For each trial, the EMG data from the middle 1 second of the 5 seconds were expressed as a percent of the corresponding MVIC. Then, for each subject the 3 trials for each position were averaged and recorded as the mean EMG value for that position. These data were then used for statistical analysis.

Statistical Analysis

A bivariate Pearson correlation was performed to determine the degree of association between normalized upper extremity weight-bearing force and mean muscle activity. The upper extremity weight-bearing force was recorded as the weight subjects transmitted through their dominant arm in each exercise position. Each weight at each exercise position was recorded and divided by the subject's body weight to provide a normalized upper extremity weight-bearing value for each position. Mean muscle activity was calculated by averaging the normalized EMG data of all muscles together at each position for all subjects. Five additional separate bivariate Pearson correlations were calculated to determine the degree of association between normal axial compressive force and each individual muscle activity.

A 2-factor (position, muscle) within-subjects repeated-measures ANOVA was used to determine whether differences might exist between muscular activity level across each muscle monitored and exercise position tested. Significance was set at an alpha level of $P<0.05$ and any significant differences were evaluated using a Tukey's post hoc analysis ($P<0.05$). Due to the limited sampling area of the supraspinatus, the EMG activity of this muscle was analyzed independently across all exercise positions using a 1-factor (position) repeated-measures ANOVA. A 1-factor (position) repeated-measures ANOVA was also performed to determine differences in upper extremity weight-bearing force across the 7 exercise positions.

RESULTS

Descriptive statistics for the normalized EMG activity for each muscle at each weight-bearing exercise position are shown in Table 2. A strong and statistically significant degree of association was demonstrated between normalized upper extremity weight-bearing load and mean muscle activity level (all muscles combined) ($r = 0.97$, $P<0.01$) (Figure 2). Significant associations were also found between the EMG activity level of each individual muscle and normalized upper extremity weight-bearing force ($r = 0.88$–0.99, $P\leq0.01$) (Table 3).

The 2-factor repeated-measures ANOVA revealed a significant interaction between positions and muscles ($F_{18,306} = 6.95$, $P<0.01$) (Figure 3). Tukey's post hoc analysis also revealed a number of statistically significant differences across exercises for each muscle. The differences in EMG level across exercises for each muscle are presented in Table 2. The differences in EMG level across muscles for each exercise are presented in Figure 3. The primary findings were that there were no significant muscle activity differences between the first 2 positions and that the 1-arm push-up exercise position was significantly more demanding than the other positions tested for the majority of tested muscles ($P<0.05$).

The 1-factor repeated-measures ANOVA revealed significant difference in supraspinatus muscle activity between the 7 exercise positions ($F_{1,17} = 36.5$, $P<0.01$). Tukey's post hoc analysis findings are summarized in Table 2. Supraspinatus EMG activity was greatest in the 1-arm push-up position. Significant differences were also found between upper extremity weight-bearing forces across the 7 exercise positions ($F_{1,19} = 400$, $P<0.01$) (Table 2).

DISCUSSION

The expected relationship of increased shoulder muscle activity with increasing levels of upper extremity weight-bearing positions was supported by these results. Previous studies have shown in a similar fashion that as load to the shoulder girdle increases, there is a resultant increase in muscle activity.[1,9] These results are consistent with previous observations that weight-bearing upper extremity exercises or closed kinetic chain exercises can produce muscular demands similar to open chain exercises and supports the concept that the exercise progression in this study progressively increased shoulder muscular demands.

TABLE 2. Descriptive statistics (mean ± SD) for the weight-bearing force represented as a percentage of the subject's body weight (BW) and the normalized EMG activity (% maximum voluntary isometric contaction [MVIC]) for each muscle at each exercise position studied. Comparisons are made between each position for each column separately ($P<0.05$).

Position	Force[*] (% BW)	Supraspinatus[†] (% MVIC)	Infraspinatus[‡] (% MVIC)	Anterior Deltoid[§] (% MVIC)	Posterior Deltoid[‖] (% MVIC)	Pectoralis Major[¶] (% MVIC)
Prayer	6 ± 3	2 ± 2	4 ± 3	2 ± 4	4 ± 3	7 ± 4
Quadruped	19 ± 2^{C}	6 ± 10	11 ± 8	6 ± 6	6 ± 4	10 ± 4
Tripod	32 ± 3^{B}	10 ± 11	37 ± 26^{B}	12 ± 10	27 ± 16^{B}	16 ± 8
Pointer	34 ± 4^{B}	12 ± 13^{C}	42 ± 33^{B}	18 ± 10	28 ± 16^{B}	22 ± 10
Push-up	34 ± 3^{B}	14 ± 14^{C}	44 ± 31^{B}	31 ± 16^{B}	18 ± 12	33 ± 20^{B}
Push-up feet elevated	39 ± 5^{B}	18 ± 16^{B}	52 ± 32^{B}	37 ± 15^{E}	23 ± 14	42 ± 28^{E}
One-arm push-up	60 ± 6^{A}	29 ± 20^{A}	86 ± 56^{A}	46 ± 20^{D}	74 ± 43^{A}	44 ± 45^{D}

[*] A, the force is significantly greater than for all other positions; B, significantly greater than for quadruped and prayer position; C, significantly greater than for prayer position

[†] A, EMG activity is significantly greater than for all other positions; B, significantly greater than for quadruped and prayer positions; C, significantly greater than for prayer position.

[‡] A, EMG activity is significantly greater than for all other positions; B, significantly greater than for quadruped and prayer positions.

[§] D, EMG activity is significantly greater than for the pointer, tripod, quadruped, and prayer position; E, significantly greater than for tripod, quadruped, and prayer position; B, significantly greater than for quadruped and prayer positions.

[‖] A, EMG activity is significantly greater than for all other positions; B, significantly greater than for quadruped and prayer positions.

[¶] D, EMG activity is significantly greater than for pointer, tripod, quadruped, and prayer positions; E, significantly greater than for tripod, quadruped, and prayer positions; B, significantly greater than for quadruped and prayer positions.

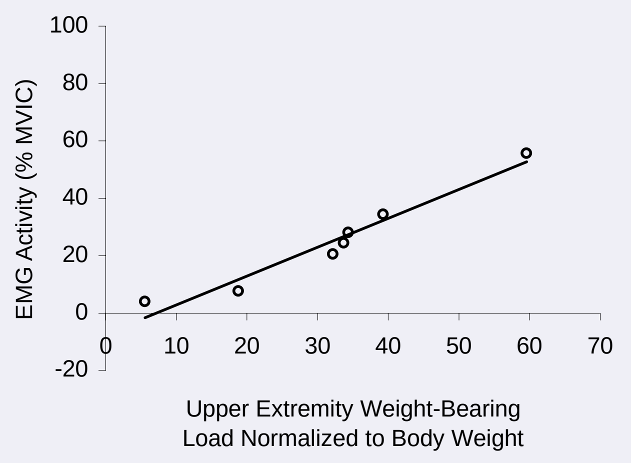

FIGURE 2. This graph represents the association between mean shoulder muscle activity expressed in percent of maximum voluntary isometric contraction (MVIC) and the normalized upper extremity weight-bearing force. On the x-axis, each data point represents each exercise position studied from left to right in the following sequence: prayer, quadruped, tripod, pointer, push-up, push-up feet elevated, and 1-arm push-up (*r* = 0.97).

This research describes the demand on the surrounding shoulder musculature associated with common upper extremity weight-bearing exercise positions. This information can aid the clinical understanding of what shoulder muscles are being activated and to what degree when such exercises are performed. Relative muscular demand has been previously classified into 4 categories based on EMG activity: low (<20%), moderate (20%–40%), high (41%–60%), and very high (>60%).[8]

The prayer and quadruped exercise positions fell in the low-activity category for all musculature. These positions and weight-bearing forces would appear to facilitate cocontraction and be appropriate for early rehabilitation exercises in which the muscular demands need to be kept to a low level. The tripod and pointer exercise elevated the activity of the posterior deltoid and infraspinatus to the moderate category perhaps due to the increased demand of stabilizing the upper body and trunk on fewer points of support. These exercise postures appear to place an intermediate demand on the infraspinatus and deltoid musculature.

Both push-up positions elevated the demand on the infraspinatus to a high level. These 2 positions also elevated anterior deltoid and pectoralis major activity to moderate levels while the posterior deltoid diminished to a low level of activity. The 2-handed activities appear to decrease the demand on the posterior deltoid and shift more of the load to the anterior deltoid and pectoralis musculature. This may be due to the more stable position for the upper extremity and trunk requiring less posterior deltoid activation.

The 1-arm push-up resulted in high to very high activity levels for all muscles except the supraspinatus, which could be described as moderate activity. The 1-arm push-up would be considered a high-demand activity and appropriate for later stage rehabilitation program because the demands placed on the infraspinatus and posterior deltoid are comparable to the most challenging open kinetic chain exercises such as prone external rotation and prone horizontal abduction.[33]

The progressively greater weight-bearing forces increased shoulder muscle demands in general. Therefore, higher weight-bearing forces should be deferred until tissues and muscle can tolerate greater demands. Caution should be used to avoid overgeneralization of this interpretation because individual muscle activity is dependent on the exercise that is being performed. These results support previous research indicating that it is not necessarily the type of exercise, but rather the load and position of the joint that determines the degree of muscle activity.[4,9,12,23]

Rotator Cuff Responses

Previous EMG studies have examined exercises that optimally activate specific muscles.[5,21,33] The intention of this study was not to identify which muscle was most active with a particular activity but rather to examine the progression of activation with increasing forces. However, the results warrant further discussion regarding the 2 specific rotator cuff muscles studied. It is important to remember that all surface EMG data are susceptible to cross-talk and can record electrical activity from surrounding musculature.[3] The interpretation of these findings should be read with the understanding that neighboring muscular activity may have some representation in the data.

The weight-bearing exercise positions appear to preferentially activate the infraspinatus through most of the exercise positions. The position of the subject's arm during the testing most likely produced a poste-

TABLE 3. Pearson correlation coefficient between the EMG activity level of each muscle and the normalized upper extremity weight-bearing force for 7 upper extremity weight-bearing exercises ($P \leq 0.01$).

	Supraspinatus	Infraspinatus	Anterior Deltoid	Posterior Deltoid	Pectoralis Major
r	0.97	0.99	0.91	0.91	0.88

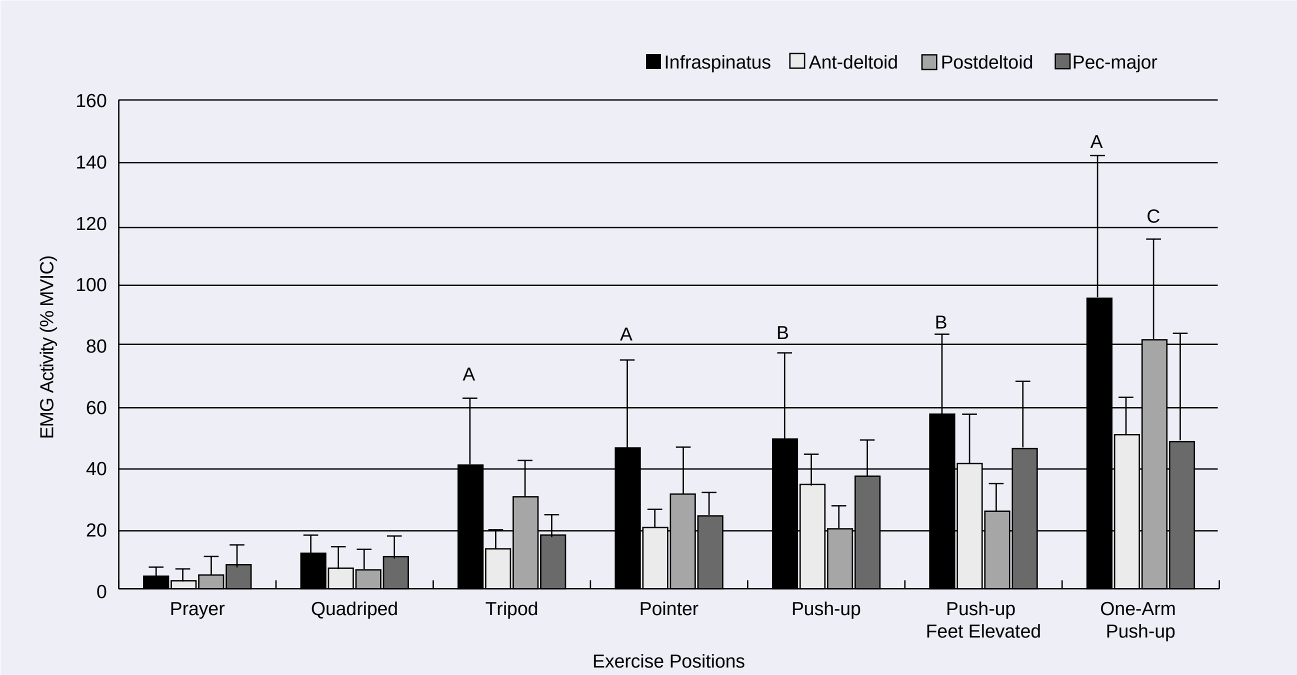

FIGURE 3. Normalized EMG activity of the infraspinatus, pectoralis major, anterior and posterior deltoid muscles at each exercise position (n = 18). A, infraspinatus > anterior deltoid and pectoralis major ($P<0.05$); B, infraspinatus > posterior deltoid ($P<0.05$); C, posterior deltoid > anterior deltoid and pectoralis major ($P<0.05$).

FIGURE 4. Tripod exercise position.

FIGURE 5. Pointer exercise position.

rior shear force at the glenohumeral joint, though this was not measured. The relatively greater infraspinatus activity is likely due to its role as a compressor of the humeral head to dynamically stabilize the glenohumeral joint.[6,18,29] The orientation of the infraspinatus muscle fibers and position of the arm would result in activation as part of the transverse force couple to stabilize the humeral head against the glenoid and to prevent posterior shear forces from subluxing the humeral head posteriorly. This relative increased activation supports the importance of dynamic stabilizers in midrange motions as previously suggested.[6,7,29]

Strengthening of the posterior musculature, specifically the infraspinatus is commonly recommended for patients with posterior instability.[10,27,32] However, the position of greatest vulnerability for the occurrence of posterior subluxation/dislocation is forward flexion, adduction, internal rotation, and a longitudinal force applied to the humerus[11,27]; this is the same position as the weight-bearing exercises studied. Patients with posterior glenohumeral instabilities may find that similar weight-bearing exercises make the shoulder vulnerable to subluxation or too uncomfortable to perform the exercises. Future research should investigate whether weight-bearing exercises at other

FIGURE 6. Push-up with feet-elevated position.

FIGURE 7. One-arm push-up position.glenohumeral joint angles, without placing the joint in a vulnerable position, will activate posterior shoulder musculature in a similar manner.

glenohumeral joint angles, without placing the joint in a vulnerable position, will activate posterior shoulder musculature in a similar manner.

The static upper extremity weight-bearing exercise positions studied minimally stressed the supraspinatus muscle. According to DiGiovine,[8] all exercises except the 1-arm push-up would be considered a low-demand activity for the supraspinatus.[8] One important consideration should be remembered when interpreting these findings: fine-wire EMG detects electrical activity in a relatively small area of the muscle.[14,20] Therefore, additional electrical activity could be occurring outside of the limited detection area. However, previous research has employed this same technique to determine optimal supraspinatus activity with particular exercises.[5,9,21,33]

Minimizing supraspinatus muscle stress is important in the rehabilitation of healing tendons following injury and surgery. Applying early aggressive resistive exercises following rotator cuff repair has been implicated in resultant failure.[22] The relatively low supraspinatus muscle activity may be because of the high activity of the infraspinatus producing the primary compression of the humeral head into the glenoid to stabilize the glenohumeral joint. One of the primary roles of the supraspinatus along with other rotator cuff muscles is to produce a resultant compressive force to stabilize the humeral head.[13,25,29] Some of the weight-bearing exercise positions studied appeared to diminish that requirement as indicated by the lower muscular activity. Significant increase in supraspinatus demand was required in the more challenging and higher loaded 1-arm push-up exercise position to dynamically stabilize the glenohumeral joint.

The exercise positions tested in this study resulted in minimal glenohumeral joint movement. Caution should be taken in applying these results to exercises in which large joint movements are occurring. Different activation patterns would be expected during dynamic movements due to the changing resultant forces across the shoulder complex. Future research of muscular activation during dynamic weight-bearing exercises would assist clinicians in designing an appropriate rehabilitation progression. Additionally, future studies need to determine the effect of weight-bearing upper extremity exercises on patients with shoulder pathology.

Two-Handed Versus 1-Handed Weight-Bearing Exercise Positions

An interesting finding in this study was the change in muscle activity between the 2-handed and 1-handed positions. During 2-handed weight-bearing exercise positions, the anterior deltoid, pectoralis major, and infraspinatus were primarily active. The 1-handed exercises emphasized posterior deltoid and infraspinatus muscle activity. This is particularly evident when comparing the tripod, pointer, and push-up exercise positions (Figure 3). These exercise positions place approximately the same load on the dominant shoulder (Table 1).

One explanation for this observation is that during 1-handed activities the infraspinatus and posterior deltoid muscle function much like the hip abductors during single-limb stance. When a person unloads the opposite limb prior to the swing phase in walking, the abductor muscles of the stance limb must be activated to prevent excessive drop of the contralateral pelvis.[26] Removal of the nondominant arm during testing had similar effects in the upper extremity, as the posterior deltoid and infraspinatus primarily controlled or prevented excessive drop of the contralateral shoulder, maintaining the frontal aspect of the trunk parallel to the floor.

The 2-handed exercise positions diminished the demands on the posterior deltoid due to the return of the base of support. The relationship between muscular demands and base of support should be taken into consideration when designing a rehabilitation program to assure that the appropriate muscles are targeted by the particular exercise.

Clinical Implications

The results of this study provide clinicians with information regarding the approximate load applied across a shoulder while performing common weight-bearing upper extremity exercises and offer insight into the demands placed on shoulder girdle musculature while performing these exercises. Weight-bearing postures and the demand for shoulder muscles studied appears to be linearly related. Shoulder muscular activity increased as the weight-bearing loads progressed from the prayer position, quadruped, tripod, pointer, push-up, push-up feet elevated, and then to the 1-arm push-up. The results of this study support the notion that increasing upper extremity weight-bearing requires increasing shoulder musculature demand. This study did not consider potential negative effects that shear and compressive forces might have at the glenohumeral joint in patients with pathologies.

In regard to hand position, 1-handed positions preferentially activated the posterior deltoid while the 2-handed exercise positions diminished posterior deltoid demand. Throughout the weight-bearing exercise progression the infraspinatus stands out as the muscle demonstrating the greatest activity of the muscles studied. The relationship and progression of shoulder muscular demand established in this study of a healthy population may not be applicable in individuals with shoulder pathology and this should be taken into consideration when designing a progressive rehabilitation program. Ultimately, studies comparing rehabilitation programs using weight-bearing versus non–weight-bearing activities and the effect of different programs on patient outcomes are needed.

CONCLUSION

This study provides further insight into the common clinical practice of using weight-bearing upper extremity exercises. The evidence derived from this study supports the contention that the forces across the arm, the position of the arm, and base of support affect the demand placed on shoulder musculature. Lastly, muscular activation percentages are presented to guide clinicians when designing rehabilitation protocols and as a reference for future comparison with data obtained on patients with pathological conditions.

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