

Isolated Activation of the Infraspinatus Muscle in Four Manual Muscle Testing Positions

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Background To normalize infraspinatus muscle activity among different exercises or positions, it is necessary to isolate the infraspinatus from the surrounding musculature.

Purpose We sought to determine the best position in which to obtain an isolated infraspinatus electromyography (EMG) signal for normalization of the infraspinatus muscle in four selected positions.

Study design Comparative, repeated measures design.

Methods To measure infraspinatus maximal voluntary muscle contraction (MVIC), 13 healthy participants performed four test positions (side-lying with the shoulder adducted, prone, shoulder abducted, and side-lying wiper external rotation [SWE]). EMG activity was measured in the infraspinatus, middle trapezius, and posterior deltoid muscles.

Results The EMG ratio was significantly higher for SWE than for the other test positions. To maximize the EMG ratio, high infraspinatus activity and low surrounding muscle (middle trapezius and posterior deltoid) activity are required.

Conclusions We recommend switching from prone external rotation to SWE to normalize the infraspinatus EMG signal.

Key words Electromyography; Infraspinatus; Normalization; Side-lying wiper external rotation.

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INTRODUCTION

The most common way to generate a reference level for muscle activation to normalize infraspinatus electromyography (EMG) data is to record the maximum voluntary isometric contraction (MVIC) to identify the effects of exercise or intervention on infraspinatus muscle strengthening¹⁻³. Unlike other normalization methods, including sub-MVIC and reference voluntary contraction (RVC), MVIC is advantageous because it has physiological meaning; derived data are expressed relative to the maximum⁴.

For infraspinatus normalization, clinicians or researchers

commonly take measurements while the subject is in the prone position⁵⁻⁸. However, the prone position can lead to over-activation of the posterior deltoid, and sub-optimal activation of the infraspinatus contributes to an increase in anterior humeral gliding in the glenoid^{9,10}. From this point of view, increased translation of the instantaneous center of rotation of the humeral head may be associated with muscle imbalance between the rotator cuff (e.g., infraspinatus) and the scapulohumeral (e.g., posterior deltoid and middle trapezius) muscles⁸.

Recent shoulder external rotation exercises focus on decreasing the contribution of the posterior deltoid to

shoulder external rotation to strengthen the infraspinatus muscle isolately^{2, 11}. Adducted shoulder position isolates the infraspinatus from the posterior deltoid, and side-lying external rotation exercise may be the most effective maneuver to increase infraspinatus activity in isolation^{5, 6}. To normalize infraspinatus muscle activity among different exercises or positions, it is necessary to isolate the infraspinatus from the surrounding musculature.

Several studies have been conducted to identify methods to normalize the infraspinatus muscle^{7, 12}. However, there has been no attempt to investigate the optimal MVIC test position for the isolation of the infraspinatus muscle. The objective of this study was to determine the optimal position among four tested positions in which to obtain an isolated infraspinatus EMG signal for the normalization of infraspinatus muscle EMG activity.

Subjects

The participants in this study were 13 subjects with no known shoulder dysfunction. The mean age, weight, and height of the subjects were 25.2±3.9 years, 60.3±1.2 kg, and 168.4±5.3 cm, respectively. Before the initial measurements were conducted, each subject completed a health questionnaire and provided informed consent. A screening evaluation of the cervical spine and both upper extremities was performed by a physical therapist.

Instruments

EMG data were collected using a Noraxon TeleMyo 2400T and analyzed using MyoResearch Master Edition 1.06 XP software (Noraxon Inc., Scottsdale, AZ, USA). Skin preparation of the electrode sites involved shaving and cleaning with rubbing alcohol. Surface electrode pairs were positioned at an interelectrode distance of 2 cm. The reference electrode was placed on the ipsilateral clavicle. EMG data were collected for the following muscles: middle trapezius (midway on a horizontal line between the root of the spine of the scapula and the third thoracic spinous process), upper trapezius (midway between C7 and the acromion), posterior deltoid (lateral border of the spine of the scapula and angled on an oblique angle toward the arm running parallel to the muscle fiber), and infraspinatus (4 cm below the spine of the scapula, on the lateral aspect over the infrascapular fossa of the scapula). The sampling rate was 1,000 Hz. The raw signal was full-wave rectified and filtered using a Lancosh FIR digital filter. The band-pass filter frequency was between 20 and 300 Hz. EMG data were converted to root mean square (RMS) values, which were calculated from 50 ms windows within the data points.

Procedure

The dominant arm, defined as the upper extremity used to eat and write, was tested for all participants. All participants were right-arm dominant, as determined by a questionnaire. A target bar was placed such that the radial border of the participant's wrist touched it in each test position. To measure MVIC in the side-lying with the shoulder adducted (ADD) position, subjects lay on their sides with the shoulder in a neutral position and the elbow at 90° flexion. From the starting position, with the forearm resting on the abdomen, subjects moved the tested arm to a position of external rotation (45°) until the dorsal forearm touched the target bar and maintained the shoulder at 45° external rotation⁶. The subject then performed maximal contraction of the dominant side arm by applying manual resistance to pressure by an examiner to the subject's wrist. All subjects were given consistent verbal encouragement during maximal contraction. In the prone position, the subject was required to lie prone with the shoulder abducted at 90° and the elbow flexed to 90°, while the forearm was in neutral position⁵. Additionally, the subject's elbow was fastened to the table using a non-elastic belt to prevent compensatory shoulder motion. To measure MVIC in the prone position, the subject moved to a position with shoulder external rotation to 90°. The subject then performed maximal contraction of the dominant side arm by applying manual resistance to pressure by an examiner to the subject's wrist. All subjects were given consistent verbal encouragement during maximal contraction. To measure MVIC in shoulder abducted (ABD) position, the participant stood with the dominant arm abducted and internally rotated to 90° and the elbow flexed to 90°. From the starting position, the participant moved the extremity to a position of full lateral rotation until the wrist joint touched the target bar. The subject then performed maximal contraction of the dominant side arm by applying manual resistance to pressure by an examiner to the subject's wrist. All subjects were given consistent verbal encouragement during maximal contraction. To measure MVIC in the side-lying wiper external rotation (SWE) position, the participant lay in the side-lying position with the extremity flexed and internally rotated to 90° and the elbow flexed to 90°. The participant supported the distal humerus of the dominant arm with the palm of the opposite hand. From the starting position, the participant moved to a position of full lateral rotation until the wrist joint touched the target bar. We instructed the participant to use the opposite hand to support the dominant arm during external rotation to maintain the center of rotation in the same position.

The familiarization period was completed when the subject was able to maintain three normalization methods for 5 s. All subjects were comfortable after the familiarization period, and none reported fatigue. A 15-min rest period was allowed after the familiarization period before data collection began. The order of testing was randomized using a random number generator (Microsoft Corp., Redmond, WA, USA).

EMG activity was measured during each normalization trial for 5 s. The first and last seconds of the EMG data from each trial were discarded, and the remaining 3 s of data were used for further analysis. Subjects performed the second session 1 h after the first session, following the identical protocol. Three trials were performed with a 1-min rest period between trials. A 3-min rest period was provided between conditions to minimize muscle fatigue.

Statistical analysis

The Shapiro-Wilks test was performed to verify the normality of the data distribution. A repeated one-way analysis of variance was performed to determine the muscle activity ratio among four test positions. The Bonferroni procedure was used as a post-hoc analysis. The level of significance was set at $p < 0.05$. Significant differences were evaluated using the Bonferroni adjustment at a level of 0.013 (0.05/4). All statistical tests were performed using SPSS v. 23.0 software (SPSS, Inc., Chicago, IL, USA).

RESULTS

The EMG ratio ($100 \times \frac{\text{infraspinatus muscle activity}}{\text{middle trapezius} + \text{infraspinatus muscle activity} + \text{upper trapezius} + \text{posterior deltoid muscle activities}}$) and results of the statistical analyses are shown in Table 1 ($F=24.96, p < 0.00$). The EMG ratio was significantly greater when the subject was in the SWE position than in all other test positions ($p < 0.05$), following the order SWE > ADD > PRE > ABD.

DISCUSSION

The objective of this study was to determine the best position in which to obtain an isolated infraspinatus EMG signal that could be used to normalize the infraspinatus

EMG activity among four selected positions. Kelly et al. (1996) reported that standardizing normalization test positions for MVIC is one step toward the elimination of external variation¹³. Specifically, compensatory movement or muscle activation in the surrounding muscles leads to decreasing reliability of the normalization of the infraspinatus muscle.

Our study shows that the EMG ratio was significantly higher in the SWE position than in all other test positions. To maximize the EMG ratio, high infraspinatus activity and low surrounding muscle (middle trapezius, upper trapezius, and posterior deltoid) activity are required. Our results are consistent with those of several previous studies, which reported that SWE is an effective exercise position to isolate the activity of the infraspinatus muscle while minimizing surrounding muscle activity^{6,11,14}. There are several possible explanations for our results. First, infraspinatus muscle activation is more dependent on arm and body position than that of the surrounding muscles¹¹. Previous studies have reported that maximum infraspinatus muscle activity occurred during shoulder forward flexion at 90°. In this study, SWE was performed with the shoulder flexed to 90°, whereas the other exercises were performed with the shoulder abducted to 90° or 0°. Second, SWE allowed the subject to maintain the instantaneous center of rotation of the humeral head. Shoulder external rotation is often accompanied by unnecessary shoulder movement. In the SWE position, manual fixation of the humerus prevented unnecessary movement, which induced increased infraspinatus muscle activity while decreasing surrounding muscle activity. The other normalization positions led to an over-activated posterior deltoid and a less-activated infraspinatus (i.e., a low EMG ratio). Hyper-activation of the surrounding muscle (middle trapezius and posterior deltoid) often induces abnormal gleno-humeral and scapula-thoracic joint motion, which consequently increases the instability of the shoulder joint^{9,10}. When the posterior deltoid is the dominant external rotator, unwanted anterior glide of the humeral head during shoulder external rotation can result. Based on the results of our study, we recommend a switch from prone external rotation to SWE for the normalization of infraspinatus EMG activity.

This study has some limitations. The generalizability of the study is limited because we recruited only young

Table 1. Comparison for EMG ratio among 4 different manual muscle testing position (n=19)

	PRE	SWE	ABD	ADD	F	p
EMG ratio	28.72±6.33	77.46±34.20	20.68±3.52	33.15±14.69	24.96	<0.00

PRE, prone external rotation; SWE, side-lying wiper exercise; ABD, shoulder abducted; ADD, shoulder adducted.

Table 2. Multiple comparison between tests.

Test comparison	<i>p</i>
PRE versus SWE	0.00*
PRE versus ABD	0.01*
PRE versus ADD	1.00
SWE versus ABD	0.00*
SWE versus ADD	0.00*
ABD versus ADD	0.03

PRE, prone external rotation; SWE, side-lying wiper exercise; ABD, shoulder abducted; ADD, shoulder adducted.

healthy subjects; future studies should determine whether our findings can be generalized to subjects beyond this age range. We also did not measure force or torque during normalization measurements; force and torque should be examined in future studies. Multiple comparisons between positions are presented in Table 2.

CONCLUSION

We investigated the EMG ratio of the infraspinatus muscles and surrounding muscle (middle trapezius and posterior deltoid) during normalization of the infraspinatus muscle in four selected positions. Our findings show that the EMG ratio was significantly higher in the SWE position than in all other tested positions. To maximize the EMG ratio, high infraspinatus activity and low surrounding muscle (middle trapezius and posterior deltoid) activity are required. Our results are consistent with those of several previous studies, which reported that SWE is an effective exercise position to isolate the activity of the infraspinatus muscle while minimizing surrounding muscle activity. These findings suggest that SWE is more effective than other positions for the normalization of infraspinatus EMG activity.

Key Points

Question Which position isolatable activate the infraspinatus muscle?

Findings Our study showed that the electromyography (EMG) ratio was significantly higher and side-lying external rotation (SWE) than other test position. For the highest EMG ratio, it necessary high infraspinatus and low surrounding muscle (middle trapezius and posterior deltoid) activities. Consistent with our results, several studies have been reported that SWE is effective exercise position for isolate activating the infraspinatus muscle while minimizing sur-

rounding muscle activation.

Meaning Based on the results of our study, it seems necessary to change the normalization for infraspinatus EMG from PRE (prone external rotation) to SWE.

Article information

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