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Original Article

Comparison of Maximum Voluntary Contraction Positions for Serratus Anterior Muscle in Men with Scapular Dyskinesis: Electromyography Analysis

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ABSTRACT

Background: The purpose of this study was to quantify the surface EMG activity of the serratus anterior muscle during two main test positions performed with the maximum effort by the subjects with scapular dyskinesis.
Methods: This cross-sectional study included 30 men (aged 18 to 28) who were suffering from scapular dyskinesis. Scapular dyskinesis was measured by scapular dyskinesis test and surface EMG was employed to record the EMG activity of the serratus anterior during two common positions of maximal voluntary isometric contraction.
Results: The results revealed that there is no significant difference in the mean EMG activity of the serratus anterior muscle during two MVIC testing positions (P=0.846). Notably, the test-retest ICC scores for the EMG recordings during position 1 (P=0.97) and position 2 (P=0.96) were excellent.
Conclusion: It was found that no one muscle test produced the highest MVIC for all subjects. Therefore, to perform normalization of every muscle within each subject, it is suggested that two tests identified in this study be performed which usually produce high levels of EMG activity.

Introduction

Electromyography (EMG) analysis techniques are widely used in biomechanical and rehabilitation studies for analyzing neuromuscular factors in order to investigate the demand for specific exercises and to compare different tasks [1]. To facilitate comparison between different subjects, muscles, or times, the EMG data should be normalized. The most common method of normalizing EMG signals from a given muscle is using the EMG recorded from the same muscle during a maximal voluntary isometric contraction (MVIC) as the reference value [2, 3]. MVIC for a muscle, especially an extremity muscle, involves isolated single-joint maximal isometric exertions against a fixated static resistance [4]. Clinically, positions that evoke higher EMG activities (%MVC) have been interpreted to be more challenging to a muscle [5]. However, there is no consensus as to which position of the test produces the maximal activation in all individuals in any given muscle.

One of the main scapular stabilizer muscles is serratus anterior, whose activity may change in some shoulder or scapula problems, i.e., scapular dyskinesis [6]. In people with scapular dyskinesis, significantly less serratus anterior muscle activation is observed during arm elevation [7]. Different tests have been used for MVIC of serratus anterior in different studies [2, 3, 7]. Among them, two positions have been used more commonly in the literature. On the other hand, little effort has been made for identifying which of them is

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the best for maximal neural activation of the serratus anterior muscle. The first position, maximum resistance given to scapular protraction with the shoulder at 90 of flexion (Figure 1-a), is widely utilized for normalization of the serratus anterior muscle during EMG studies [8, 9]. On the other hand, the second position is maximum resistance given to upward rotation of the scapula with the shoulder flexed (figure 1-b).

Previous studies have initiated the process for establishing standard MVIC tests for shoulder muscle EMG normalization, i.e. serratus anterior muscle [2, 10-12]. They concluded that no single test could produce maximal activation of a specific muscle for all subjects. Meanwhile, measurement properties may vary by settings and populations where their subjects were usually healthy people. In this regard, a different pattern of scapular muscle activations has been observed across healthy population compared to those with scapular dyskinesis. To the best of our knowledge, no study has compared the two main MVIC tests of serratus anterior, especially in people with scapular dyskinesis. A standard normalization test for the MVIC of serratus anterior is required and could be the first step to enabling a more comprehensive understanding of normal and abnormal muscle functions. Further, establishing the position consistently producing the maximal electromyographic activity would be a necessary prerequisite for proper execution and interpretation of future kinesiologic investigations of serratus anterior muscle activity during functional motion.

Accordingly, the purpose of this study was to quantify the surface EMG activity of the serratus anterior muscle during two main testing positions performed with the maximum effort by the subjects.

Methods

Participants

This cross-sectional study included 30 young men who suffered from scapular dyskinesis (24.6±3.0 years, 173.5±6.8 cm tall, 78.6±8.5kg, and body mass index, or BMI, 23.3±2.8 kg/m2). The participants were recruited via verbal invitation and advertisements in bulletin boards from among the students of the University of Tehran. The project was part of a larger study approved by the Ethics Committee on Research in University of Tehran, Iran. Before testing, all study participants signed a consent form. Inclusion criteria were being older than 18 years and having scapular dyskinesis as measured by scapular dyskinesis test (SDT), according to the procedure described by McClure et al. [13]. Participants would be excluded from the research process if they had a history of fracture, surgery, or joint diseases in the shoulder; had a body weight outside the normal range (BMI between 18 and 25); and had mild shoulder pain during the arm elevation, with rating of 2/10 or higher on a numeric rating scale with 0 representing no pain and 10 indicating the worst pain possible.

Instrumentation

Surface electromyography was used to record the EMG activity of the serratus anterior using the ME-6000 Megawin system (Mega Electronics, Finland). Bipolar self-adhesive disposable surface electrodes (Ag-AgCl, Skintact, Austria), with a width 2.0 cm and length 2.5 cm, were placed on the muscle belly following the SENIAM guidelines [14] while the subject was sitting upright. The interelectrode distance was 30 mm.

Procedures

EMG data were collected from the serratus anterior muscles of the dominant side of each subject. Before the surface electrode application, the skin surface was shaved, cleansed, and scrubbed with alcohol to reduce impedance (<10kOhm). For electrode placement over the serratus anterior muscle, the shoulder was abducted to 90°, and the electrodes were placed vertically along the mid-axillary line at rib levels 6–8. A common reference electrode was placed over the C7 spinous process. During data collection, the raw EMG recordings were monitored. The sampling rate was set at 1000 Hz. The raw EMG data were full wave rectified and processed

Figure 1: MVIC test position1 (a) and 2 (b) for serratus anterior muscle.

Table 1: Mean % MVIC, ICC scores for test-retest reliability and number of subjects for whom the muscle tests generated the maximum EMG amplitude

Test positions	Mean %MVIC	ICC	Number of subjects
Position 1	79.37±14.06 [a]	0.96	10
Position 2	80.37±14.60 [a]	0.97	20

[a]No significant difference between testing positions 1 and 2 (t=-0.196, df= 29, P=0.846)

using a root-mean-square (RMS) algorithm. To compare electromyographic activity from subject to subject, the mean peak values were normalized to the maximum electromyographic value in that specific muscle across two positions. The rectified, smoothed EMG data were then expressed as a percentage of maximum EMG amplitude produced by the muscle and referred to as percentage of maximum voluntary isometric contraction (% MVIC) [2, 15].

Before EMG recording, each subject was instructed and practiced each muscle test. When participants reported satisfactory familiarization, three 5s MVICs were completed for each position, with at least 30s rest between the different repetitions [10]. At least 1.5-minute rest was performed between the different test positions. The participants were asked to reach maximum effort in 1s, to sustain this maximum for 3s, and then relax for the remaining time.

MVIC Testing Positions Analyzed with EMG

Two muscle testing positions (Figure 1) for the serratus anterior muscle, as demonstrated by Kendall et al. [16] were analyzed while surface EMG activity was recorded.

Position 1: Scapula protracted at 90° of shoulder flexion as resistance was applied over the hand and at the elbow with the subject being in the supine position (Figure 1-a).

Position 2: Shoulder flexed to 125° as resistance was applied above the elbow and at the inferior angle of the scapula attempting to de-rotate the scapula with the subject sitting in an upright posture with no back support (Figure 1-b).

Manual pressure was applied gradually until the muscle could not maintain the isometric contraction. Strong and consistent encouragement from the investigator was given during each MVIC. During the muscle tests in the sitting position, the subject was instructed to sit upright and was not allowed to lean against the backrest [2].

Statistics Analysis

Data analysis was performed using Statistical Package for Social Sciences (SPSS) software (version 21, SPSS, Inc. Chicago, IL USA). Paired t-test was conducted to compare the normalized EMG amplitudes from the serratus anterior muscle between MVIC test positions. An α level of 0.05, with a confidence interval of 95%, was used in determining significant differences.

Results

The mean EMG activity of the serratus anterior muscle during each MVIC testing position, as well as the significant differences between testing positions, is presented in Table 1. The results revealed that there is no significant difference between the two test positions. However, the number of subjects for whom the muscle test generated the maximum EMG amplitude was higher in position two than in position 1. Also, the test-retest ICC scores for the EMG recordings from serratus anterior muscle during each position have again been documented in Table 1. For both positions, the reliability of the EMG recordings was excellent.

Discussion

This study was designed to quantify the EMG activity level of the serratus anterior muscle during the maximum effort isometric manual muscle tests. If an MVIC is to be used as a reference value for normalization of EMG data, it is essential that the neural activation which is being recorded truly reflect the maximal activation that the muscle can generate. Through the quantification of the relative neural activity of the serratus anterior muscle during two common test positions, this study has objectively identified the best MVIC test position which consistently produces maximal neural activation for serratus anterior muscle.

As expected, the results indicated that both testing positions had a very high EMG activity. According to Smit et al., many studies have proposed criteria that describe EMG activation as being low (0%–20% MVC), moderate (21%–40% MVC), high (41%–60% MVC), and very high (>60% MVC)[5]. Further, we found that there was no significant difference between testing positions and the mean EMG activity of the serratus anterior muscle during both testing positions, and they were almost the same. It supports the use of a set of test positions for normalization purposes, rather than a single position. The findings of this study support the results of several previous studies [2, 10, 12]. However, in our study, the number of subjects for whom the muscle test produced maximum EMG amplitude was higher in position two than in position 1. Our findings may be explained in part by the fact that anatomically, the serratus anterior muscle activity would be isolated with position 1. The scapula seems to lock into place with full protraction, and this position is tough to break during manual muscle testing. This suggests that there may be significant muscle co-contraction around the scapula [2]. Brunnstrom stated that scapular protraction is accomplished by the action of the serratus anterior muscles on the scapula and the pectoralis major muscles pull on the humerus [17]. Others also indicated that the pectoralis minor is a strong scapular protractor [16, 18]. Therefore, it seems that the co-contraction of these muscles with the serratus anterior reduces the amount of its activity in position 1. Further, in position 1, the supine position may restrict scapula and the function of the serratus anterior.

Overall, for all muscles, great inter-subject variability was observed whereby MVIC elicited the highest muscular activity. This concern has already been reported in previously published studies investigating MVICs, in the shoulder region [2, 10] and other regions [19, 20]. As demonstrated earlier [21] and supported by our results, the maximum activity in serratus anterior muscle may be generated from various isometric tests in different individuals. Recruiting a set of positions rather than a single position seems to increase the likelihood of generating the highest EMG activity of all scapular muscles [15]. It is in line with the previous studies making recommendations for using a set of tests instead of a single test for a specific muscle [3, 15].

On the other hand, for both positions, the reliability of the EMG recordings was excellent. Therefore, given the very high and reliable EMG activity, it indicates that MVICs examined in this study are appropriate for normalization of EMG data for the serratus anterior muscle.

This study had two primary limitations. Firstly, only standard reference MMT positions were used as these are the most common positions used to normalize EMG data for serratus anterior muscle. Secondly, as is typical of electromyography-based investigations, Crosstalk may be a limitation when using surface electrodes during EMG recordings [22].

Conclusion

This paper provided data regarding the level of EMG activity in the serratus anterior muscle during two different muscle tests. These data may be beneficial to researchers who want to normalize data for an EMG study of this muscle. According to the results, no one muscle test produced an MVIC for all subjects. Therefore, to perform normalization of each muscle within each subject, it is suggested that two tests identified in this study generating high levels of EMG activity be performed.

Conflict of interest: None declared.

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