Comparison of the Muscle Activities of Upper Trapezius and Middle Deltoid between Subjects with and without Elevation of Shoulder Girdle during Arm Elevation

Jong-Hyuck Weon, Do-Young Jung
Department of Physical Therapy, College of Tourism & Health Science, Joongbu University

Purpose: Muscle imbalance between upper trapezius (UT) and serratus anterior (SA) during arm elevation is a factor causing shoulder dysfunction. However, there is no study to compare the muscle activities of the UT and middle deltoid (MD). The purpose of this study was to compare the muscle activities of the UT and MD between with and without elevation of shoulder girdle (ESG) during shoulder abduction.

Methods: The subjects without (control group=9) or with (ESG group=8) participated in this study. The muscle activities of the UT and MD were measured using a electromyography during 90° shoulder abducted position in both group. The data in middle of 3-second of the 5-second periods were used. The mean value of three trials was used in the data analysis. For each muscle, independent t-tests were performed to compare for group differences.

Results: The muscle activity of UT was significantly greater in ESG group, compared to that of the control group (p<0.05). The muscle activity of MD was significantly smaller in ESG group, compared to that of the control group (p<0.05).

Conclusion: These findings showed that low muscle activation of MD as well as SA may contribute to hyperactivity of UT during arm elevation.

Keywords: Middle deltoid, Scapular upward rotators, Shoulder dysfunction, Upper trapezius

I. Introduction

Arm elevation for overhead activities is accomplished by combined motion at the scapulothoracic (ST) as well as glenohumeral (GH) joints.1 Proper positioning of the humerus head in the glenoid cavity is essential to the normal function of the GH joint during overhead activities. It is important to rotate upwardly the scapular in ST joint in maintaining normal scapularhumeral rhythm.2 The upper trapezius (UT), serratus anterior (SA) and lower trapezius (LT) are considered to be the only upward rotators of the scapular during arm elevation.3

A failure of the normal scapulohumeral rhythm cause inappropriate positioning of the glenoid cavity relative to the humeral head, result in microtrauma during arm elevation in daily.1,4 One of the primary muscles responsible for maintaining normal rhythm and shoulder motion is the SA. Previous many researchers reported that there was reduced muscle activity of SA in shoulder dysfunctions such as impingement syndrome, GH instability, and pain.5,6 Also, excessive muscle activity of the UT was observed in patients as a way to compensate for weakness of the SA.5,7 Because SA and UT act as the abductor and elevator of scapular, respectively, the hyperactivity of UT cause to elevate excessively the shoulder level during arm elevation.8 Thus, the clinicians commonly perform specific exercise program to restore the normal scapulohumeral rhythm focusing on the UT and SA in rehabilitation and sports fields.9,10

As above, many studies have addressed only the hyperactivity of the UT to compensate for the weakening of the SA.
However, it was not considered relationship between GH joint and ST joint in previous studies. Based on a generalized 2:1 scapulohumeral rhythm, active shoulder abduction occurs as a result of simultaneous abduction of GH joint as well as upward rotation of scapular of ST joint. The scapular upward rotators as well as abductors of GH joint were resisted by weight of the object and arm and hand during arm elevation. Then, we assume that abductors of GH joint affect the muscle activity of the scapular upward rotators. Although many research focused on only upward rotators including SA and UT in restoring the normal scapulohumeral rhythm, there is no study to determine the relationship between GH joint and ST joint muscles during arm elevation.

The muscles primarily responsible for abduction in GH joint are deltoid and supraspinatus during arm elevation. Payne et al. reported that forces of the rotator cuff, together with the deltoid muscle force, were important in centering the humeral head in the glenoid during arm elevation in shoulders with subacromial impingement. However, although many researches addressed muscle imbalance between UT and SA during arm elevation, there is no study to compare the muscle activities of the UT and deltoid between subjects with and without elevation of shoulder girdle (ESG). Thus, the purpose of this study was to compare the muscle activities of the UT and middle deltoid (MD) between with and without ESG during 90° shoulder abduction. We hypothesized that a difference in the muscle activities of the UT and middle deltoid (MD) between with and without ESG during 90° shoulder abduction.

II. Materials and Methods

1. Subjects

The asymptomatic subjects with (n=8) or without (n=9) ESG participated in this study (Table 1). The subjects were enrolled in ESG group if elevation height of acromion from starting position was exceeded 4 cm or more during 90° shoulder abduction. The subjects were enrolled in control group if elevation height of acromion process from starting position was 2 cm less than during shoulder abduction. A reflective marker was placed on the skin at the midpoint of the acromion to measure its displacement in the frontal plane during shoulder flexion. Video files captured during the shoulder flexion test were used to calculate the displacement of the marker. The displacement of the acromion was measured from the starting position to the end of the predetermined shoulder flexion position by the video motion analysis software. The exclusion criteria were current shoulder surgery and history of neurological, musculoskeletal, or cardiopulmonary disease that could interfere with shoulder motion in the testing positions. The principal investigator explained the procedure to the subjects in detail prior to the experiment and all subjects signed an informed consent form.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total (N=17)</th>
<th>Control group (n=9)</th>
<th>ESG group (n=8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>41.9±6.2</td>
<td>39.4±7.4</td>
<td>44.8±3.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>172.8±3.6</td>
<td>173.9±3.4</td>
<td>171.6±3.6</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>75.2±9.3</td>
<td>73.7±10.7</td>
<td>77.0±7.7</td>
</tr>
<tr>
<td>Height of ESG</td>
<td>3.1±1.5</td>
<td>1.7±0.2</td>
<td>4.6±0.4*</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.
ESG: elevation of shoulder girdle.
*Statistically significant at the level of p<0.05.

2. Experimental methods

1) Instrumentation

Electromyographic (EMG) data were collected using a Noraxon Telemyo DTS Telemetry and analyzed using MyoResearch Master Edition 1.07 XP software (Noraxon, Scottsdale, AZ, USA). The sampling rate was 1000 Hz. A band-pass filter between 20 and 300 Hz was used. EMG data were processed into the root-mean-square (RMS) value, which was calculated from 50-ms data points of windows.

2) Procedures

The dominant arm (the preferred arm when performing eating and writing tasks) was used in all tests. All subjects reported the right arm as their dominant arm. The EMG electrode sites was shaved and cleaned with rubbing alcohol. Surface electrode pairs were positioned at an interelectrode distance of 2 cm. EMG data were collected for the UT muscle (placed approximately halfway between the spine and the
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lateral edge of acromion, MD muscle (placed 3 cm below the acromion over the muscle mass on the lateral upper arm), LT muscle (placed at an oblique vertical angle with one electrode superior and one inferior to a point 5 cm inferomedial from the root of the spine of the scapula) and the SA muscle (placed vertically along the mid-axillary line at rib levels 6~8). EMG activity in the UT, MD, LT and SA muscles was tested at the 90° abducted position. A target bar was placed so that the dorsal side of subject’s wrist touched it at each subject’s 90° abducted position in sitting. Before testing, the subject was asked to sit upright on a chair with his feet on the floor and to look straight ahead. From starting position, the subject moved to a position of 90° abducted position until the wrist joint touched the target bar (Figure 1).

Subjects were familiarized during a 2-minute period prior to testing. A 2-kg dumbbell was provided. During the familiarization period, the principal investigator instructed the subjects to move their dominant arm until the dorsal side of the wrist touched the target bar, which was located at subject’s 90° abducted position. All of the subjects were comfortable after the familiarization period, and none reported fatigue. A 5-minute rest period was allowed after the familiarization period before data collection began.

The subjects abducted their dominant arm from starting position to the 90° abducted position and then sustained an isometric contraction for 5 seconds while touching the target bar. A metronome was used to control duration of contraction. Three repetitions of each test were performed, with a 2-minute rest interval between each repetition to minimize muscle fatigue. EMG data were collected during the middle of 3-second of the 5-second period. The mean value of the three trials was used in the data analysis.

3) Data processing and statistical analysis

For normalization, the RMS of a 5-second maximum voluntary isometric contraction (MVIC) was measured three times for each muscle by Kendall’s method. Each contraction was held for 5-second with maximal effort. The first and last second of each MVIC trial was discarded and the remaining 3-second of EMG data was used in the analysis. The data for each trial were expressed as a percentage of the calculated mean RMS of the MVIC (% MVIC), and the mean % MVIC of the three trials was used in the analysis. Data were tested for normal distribution with the Kolmogorov-Smirnov normality test.

For the each muscle, independent t-tests were conducted to compare for group differences. Statistical analyses were performed using SPSS 12.0 for Windows (SPSS Inc., Chicago, IL, USA). A value of p<0.05 was used to indicate statistical significance.

III. Results

The subjects in control group and ESG group did not differ significantly in age, body mass, height (p>0.05). Differences of height of ESG between starting position and 90 degree during shoulder abduction were significantly different between the subjects in control group and ESG group (p<0.05).

Table 2. Comparison of muscle activities at 90° shoulder abducted position

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Control group (n=9)</th>
<th>ESG group (n=8)</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>UT</td>
<td>48.15±15.91</td>
<td>70.64±16.03</td>
<td>2.90</td>
<td>0.011*</td>
</tr>
<tr>
<td>MD</td>
<td>83.60±16.83</td>
<td>60.46±10.87</td>
<td>-3.32</td>
<td>0.005*</td>
</tr>
<tr>
<td>LT</td>
<td>59.93±21.58</td>
<td>56.98±15.58</td>
<td>-3.19</td>
<td>0.754</td>
</tr>
<tr>
<td>SA</td>
<td>45.98±20.09</td>
<td>56.71±26.09</td>
<td>0.96</td>
<td>0.354</td>
</tr>
</tbody>
</table>

Values are presented as mean±standard deviation.
*Statistically significant at the level of p<0.05.
The muscle activity of UT was significantly greater in ESG group, compared to that of the control group (p<0.05). The muscle activity of MD was significantly smaller in ESG group, compared to that of the control group (p<0.05). However, there were not significant differences in muscle activities of LT and SA between control group and ESG group (p>0.05) (Table 2).

IV. Discussion

In this study, we examined whether if it is differences in muscle activities of scapular upward rotators (UT, SA, and LT) and abductor (MD) of GH joint between control group and ESG group during arm elevation. The muscle activity of UT was significantly greater in ESG group, compared to that of the control group. The muscle activity of MD was significantly smaller in ESG group, compared to that of the control group. However, there were not significant differences in muscle activities of LT and SA between control group and ESG group.

Previous many researchers reported that decreased control of the LT and SA and excessive activation of the UT resulting in compensation for weakness the SA, LT contribute to abnormal scapular motion in subjects with in shoulder dysfunctions such as impingement syndrome, GH instability. As with previous studies, this study also found that the muscle activity of UT was significantly greater in ESG group, compared to that of the control group. However, there were not significant differences in muscle activities of LT and SA between control group and ESG group. These results may be due to differences in subject selection criteria. The subjects with impingement syndrome or neck-shoulder pain were selected in previous studies.

In this study, subjects had no impingement or pain in shoulder-neck region during arm elevation and only ESG. Then, we speculate that non-significant differences in muscle activities of LT and SA between control group and ESG group may be due to differences in subject selection criteria. As the other factors, the movement plane of arm elevation may have influenced the results in this study. In previous studies, the arm elevations were performed in sagittal plane or scapular plane. This difference of movement plane may have influences the our results.

In many previous studies, the muscle imbalance in scapular upward rotators has been regarded as primarily the cause of the hyperactivity of the UT. Eventually, it was concluded that the weakness of SA contributes to increased muscle activation of UT in previous studies. Also, lack of upward rotation of scapular or dominance of MD has been described as a cause of primary impingement. Until now, the deltoid mainly has been considered only as a factor causing the impingement of the shoulder joint. However, there is no study to find as a factor causing hyperactivity of UT. In our study, the muscle activities of UT and MD were significantly greater and smaller, respectively, in ESG group, compared to that of the control group. Although hypoactivity of MD contributes to cause the impingement or hyperactivity of UT, in this study, it can be speculate the weakness as well as overuse of deltoid may be a factor causing impingement. We enrolled in ESG group subjects with ESG, more than 4-cm, during arm elevation, and in control group subjects with ESG, less than 2-cm. In healthy subjects, clavicle at the sternoclavicular joint was elevated 25° degree during full abduction of the shoulder. Kaur et al. reported that length of clavicle was about 13.2 to 15.2 cm. We determine the height of excessive ESG through mathematical calculations. Also, Weon et al. reported that displacement of shoulder level was approximately 3~3.6 cm during shoulder 90° flexion in normal healthy subjects. Therefore, we selected subjects with more than 4-cm in ESG group and subjects with less than 2 cm in control group during shoulder 90° flexion.

Also, we collected the muscle activities during shoulder abduction with a 2-kg dumbbell. We tested to determine the weight of dumbbell before the experiment. Then, we selected the 2-kg dumbbell because subjects felt comfortable to lift the dumbbell and meaningful data in muscle activity were collected. This study had two limitations. The first limitation was that we selected the subjects with no shoulder-neck pain. Therefore, we suggest that clinical applications require attention. The second limitation is that sample size was small. Thus, the results of this study cannot be generalized.

In this study, we compared the muscle activities of the
UT and MD between two groups with and without ESG during shoulder abduction. The muscle activity of UT was significantly greater in ESG group, compared to that of the control group. The muscle activity of MD was significantly smaller in ESG group, compared to that of the control group. These findings showed that low muscle activation of MD as well as SA may contribute to hyperactivity of UT during arm elevation. In further study, it is needed to determine relationship muscle activity in MD and UT in subjects with shoulder dysfunctions.

References