ELECTROMYOGRAPHIC STUDY ON ELEVATION OF SHOULDER JOINT

Tadashi Tomonaga, Nobuyuki Ito and Ryohei Suzuki

Department of Orthopaedic Surgery, Nagasaki University, School of Medicine, Nagasaki, Japan

The flexion, scapular abduction and abduction of the arm were studied in 20 normal shoulders by integrated EMG combined with electrogoniometry permitting simultaneous measurement of the elevation angle. The trapezius and supraspinatus muscles and the anterior and middle fibers of the deltoideus muscle showed high activity and such results indicated that those muscles played an important role in elevation of the arm. From the result of the correlation analysis between the calculated work and the integrated EMG activity, it was suspected that the action pattern of the supraspinatus muscle was different from that of other muscles.

1. INTRODUCTION

The shoulder joints and their connecting muscles cooperate in the normal elevation of the arm, described by Codman as "scapulohumeral rhythm". Though the studies of anatomy and muscle testing had established the basis of the shoulder movement, Inman et al.(1944) introduced the electromyography for analysis of muscle action. Thereafter, numerous electromyographic studies have been reported. Ito(1980) quantitatively analyzed electromyographic activity of shoulder girdle muscles by adopting the method of the linear envelope in electromyography. The present study was undertaken to establish a more reliable quantitative method for comprehending the dynamics of the electromyographic activity in relation to the measurement of the elevation angle during flexion, scapular abduction and abduction of the shoulder joint.

2. SUBJECTS AND METHODS

The subjects of the study were 20 shoulders of 10 normal male students. Ages ranged from 18 to 21 years. The electromyography was performed by using a 6-channeled electromyograph and 70 microns fine wire electrodes, which were assigned to the trapezius (upper segment), supraspinatus, deltoideus (anterior, middle and posterior fibers), pectoralis major (clavicular head), latissimus dorsi, teres major and rhomboideus muscles. Examinees were asked to elevate their arm in three directions with or without a 2.6 kg load at their hand. These three elevations were flexion (elevation in the parasagittal plane), scapular abduction (elevation in the scapular plane, that is the plane of 40 degrees against the frontal plane) and abduction (elevation in the frontal plane). The elevation angle were measured by using an electrogoniometer that was equipped with rotatory potentiometer from Midori Sokki Co.

A simultaneous and continuous recording of the elevation angle and electromyogram was attained by using a magnetic tape data recorder(Nihondenki Co. Model MR-30). The signals were analog-digital converted at 500 Hz of the sampling rate. Then action potentials from examined muscles were integrated over 10 degree intervals of the corresponding elevation angle by using a computer( Nihondenki Co. Model PC-9801M). The action potentials were integrated to 130 degrees of elevation angle. The integrated EMG values from examined muscles were submitted to variance analysis.
Fig. 1 Relation of the average integrated EMG activity to the elevation angle during scapular abduction. (n=20. Error bars represent 90 percent confidence intervals.) (a)-without load. (b)-with load.
Fig. 2 Simplified model of shoulder joint. The theoretical work to elevate the arm was calculated by making simplifying assumptions.
Fig. 3 Average theoretical work at 10 degree intervals of elevation angle obtained from 20 shoulders.

The theoretical work demanded to elevate the arm at 10 degree intervals was calculated by simplifying the shoulder joint (Fig. 2). Assuming that the center of gravity of the upper extremity is located at the midpoint of arm length, the work $W$ demanded to elevate the arm from $B$ to $A$ degree position is calculated in the following way: $W = (m + 2M)gL(\cos B - \cos A)$, $m$; weight of arm, $M$; weight of load, $2L$; arm length (distance from acromion to MP joint of middle finger). The work demanded to elevate the arm at 10 degree intervals was calculated in every subject and the correlation between the calculated work and the integrated EMG activity in scapular abduction was examined.

3. RESULTS

Fig. 1 shows the average integrated EMG obtained from 20 shoulders with 90 percent confidence intervals. The activity of all muscles significantly increased during elevation with load. The trapezius, supraspinatus and deltoidus (anterior and middle fibers) muscles showed high and increasing activity with the magnitude of the elevation angle. The posterior fiber of the deltoidus muscle and the pectoralis major, rhomboideus, teres major and latissimus dorsi muscles showed less activity. The total integrated EMG activity at elevation ranging from 0 to 131 degrees also showed a tendency similar to the above result.

In the raw EMG, the action potentials from the anterior fiber of the deltoidus muscle were observed prior to that from the middle during flexion, but that pattern was reversed during abduction. The integrated EMG activity from the middle and posterior fibers of the deltoidus muscle increased as the plane changed from flexion to scapular abduction and abduction. The difference in total integrated EMG activity for flexion or abduction was significant for these two fibers ($p < 0.05$). The supraspinatus muscle showed higher activity during abduction than during flexion ($p < 0.1$). The integrated EMG activity during elevation ranging from 0 to 10 degrees was very low and it was investigated in order to determine the initiator in elevation of the arm. The trapezius, supraspinatus and deltoidus (anterior and middle fibers) muscles showed higher activity than other muscles.

Fig. 3 shows the average theoretical work from 20 shoulders. Because this value increased to 90 degrees of elevation angle, we investigated the correlation between the calculated work and the integrated EMG activity during scapular abduction from 0 to 90 degrees. Compared with the correlation coefficient for
each muscle, the correlation coefficient of the supraspinatus was significantly lower than that of the trapezius, deltoideus, pectoralis major and rhomboideus muscles (p < 0.05). During elevation with load, the correlation coefficient for the supraspinatus was significantly lower than that of other muscles (p < 0.05, Table 1).

4. DISCUSSION

The primary purpose of this study was to clarify the dynamics of EMG activity in relation to the elevation angle during elevation of the arm. The conversion of the "raw" EMG into its linear envelope was proposed by Inman (1952). Ito (1980) analyzed the EMG activity of shoulder girdle muscles adopting the method of linear envelope in EMG. However, it is considered that action potentials converted into the linear envelope do not accurately coincide with the dynamics of muscle contraction and the linear envelope is not suitable for such a study. The author suspected that the integrated EMG was more accurate method for the quantitative analysis of the dynamics of muscle contraction. The method of integrating action potentials over 10 degree intervals of elevation angle was applied to the present study. As the peak frequency of EMG signals was distributed between 100 and 200 Hz, it was thought that almost all of EMG signals could be converted from analog to digital at 500 Hz of the sampling rate. The integrated EMG as described above was obtained to clarify the muscle activity in relation to the elevation angle.

High activity observed in the trapezius may not be inconsistent with its function as the elevator of the scapula. This result may support the disturbance of elevation of the arm in the paralysis of the trapezius. The rhomboideus muscle showed increasing activity with the magnitude of the elevation angle, though it showed low activity. Such findings seem to suggest that this muscle

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Y: the theoretical work</th>
<th>r: the integrated EMG activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius (upper segment)</td>
<td>Y=9.99X-9.76</td>
<td>r =0.629*</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>Y=8.58X-9.16</td>
<td>r =0.377</td>
</tr>
<tr>
<td>Deltoideus (anterior)</td>
<td>Y=8.45X-8.31</td>
<td>r =0.628*</td>
</tr>
<tr>
<td>Deltoideus (middle)</td>
<td>Y=6.40X-7.22</td>
<td>r =0.584*</td>
</tr>
<tr>
<td>Deltoideus (posterior)</td>
<td>Y=1.97X-2.22</td>
<td>r =0.552*</td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>Y=2.57X-2.69</td>
<td>r =0.557*</td>
</tr>
<tr>
<td>Rhomboideus</td>
<td>Y=3.42X-3.60</td>
<td>r =0.552*</td>
</tr>
<tr>
<td>Teres major</td>
<td>Y=2.17X-2.14</td>
<td>r =0.549*</td>
</tr>
<tr>
<td>Latissimus dorsi</td>
<td>Y=2.56X-3.23</td>
<td>r =0.596*</td>
</tr>
</tbody>
</table>

* was significantly higher than "r" for the supraspinatus (p < 0.05).
participates throughout the elevation movement by stabilizing the scapula. And there is also the serratus anterior muscle as a major muscle participating in scapula movement. However, this muscle was not investigated due to difficulty in assigning electrodes to the muscle.

The anterior and middle fibers of the deltoidus and the supraspinatus presented vigorous discharges and their average integrated EMG activity increased almost in accordance with the magnitude of the elevation angle. These findings seem to suggest that these muscles play an important role in the elevation of the shoulder joint. The middle and posterior fibers of the deltoidus showed higher activity in abduction than in flexion. Such findings were reported by Shevlin et al. (1969), Sugawara (1970) and Ringelberg (1985). The anterior fiber showed no influence of the elevation planes.

The clavicular head of the pectoralis major has been reported to be electromyographically silent in abduction, while active in flexion. In the present study, this portion of the muscle was active in all planes of elevation. Such findings suggest that the role of this muscle is the bridling of the arm.

The activity of the muscles increased after elevation angle exceeded 90 degrees while calculated work decreased. This result indicates that the muscles required higher activity after elevation angle exceeded 90 degrees under the influence of some factors such as changes in muscle length, stabilizing of the humeral head, resistance of the capsule and so on. The correlation coefficient between the calculated work and the integrated EMG activity for the supraspinatus was significantly lower than that of other muscles in elevation with load. From this result, it was thought that the action pattern of the supraspinatus was different from that of other muscles.

REFERENCES