ELECTROMYOGRAPHIC STUDY OF ELEVATION OF THE ARM

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Introduction

There are many electromyographic studies on the muscle functions during various movements, either the fundamental movements or the athletic activities. We have recorded many electromyograms on these activities during past several years. In our studies of the athletic activities involving the extension of the arm, for instance, in the kip, the stroke of a kayak or a boat and the bent-over-rowing, etc., we found that there were approximately the same patterns on discharges of the muscles concerning the extension of the arm. However, as for each athletic activity, there were wide variations in the discharge patterns obtained in the individual subject as well as between subjects. The studies so far conducted which dealt with the fundamental movements of the upper extremity are those by Scheving and Pauly¹⁾, Inman et al²⁾, Yamshon and Bierman³⁾, McCloy⁴⁾, Sigerseth⁵⁾, Slaughter⁶⁾, but no detailed studies, as far as we are aware, have been made on the variation of the discharge pattern on the movements of the arm. Herman⁷⁾ described in his study that when the similar patterns could not be recorded, the measurements were repeated until four similar records were obtained. However he did not mention the reason why the variation appeared. Slater-Hammel^{8,9)} reported in his studies that there were extensive variations in timing and general co-ordination between subjects. He attributed the variations to the individual differences in the size and distribution of muscles around a joint and those would conceivably result in different timing relationships, and also to the variations in posture which change the line of the muscle pull, and result in different co-ordination.

We have anatomically and mechanically analyzed this point and have made several findings. In our studies on the extension¹⁰⁾ and flexion¹¹⁾ of the arm in sagittal plane, we have indicated that the direction of resistance given during the movements caused the variation of discharge patterns. Nevertheless there was no perceptible change in the form of the movements.

Purpose of Study ; The experiment was performed to investigate more detailed findings on the variations when the arm was elevated in various vertical planes.

Methods of Study

Electromyograms and roentgenograms were taken during the elevation of the arm in various vertical planes.

The three well trained subjects, adult males were used in this study in order to perform strictly controlled movements.

The apparatus shown in Fig. 1 was employed for the experiment in order to give the constant external resistance to the elevating arm during the movement and to automatically mark the angle of the elevating arm on the electromyogram. The arm was elevated in the 45 degree medial vertical plane, the sagittal plane, the 45 degree lateral vertical plane and the frontal plane as shown in Fig. 2. Also in each movement there was a resistance of a slightly lateralward or medialward direction, although there was no perceptible change.

The electromyographic recordings were made with a 13 channel electro-encephalograph by surface electrodes, 10mm in diameter. (an electroencephalograph of Sanei Instrument Co. Ltd. was used)

The muscles from which the action potentials were recorded were as follows;

m. pectoralis major; the clavicular, sternocostal and abdominal portion

m. deltoideus; the clavicular, acromial and spinal portion

m. teres major

m. infraspinatus

m. biceps brachii; the long and short head

m. triceps brachii; the long head

The roentgenograms were taken at the 45 degree interval from the erect position during the elevation of the arm.

The myograms obtained were anatomically and mechanically examined basing on the points of muscular attachments and the lines of muscle pull from the roentgenograms.

Analysis of Results

Although the elevation of the arm was a very simple movement, the myograms obtained demonstrated some differences in spite of the same movement. The range of the variation in the patterns of the myograms was wide but after adequate training such a range was remarkably narrowed. In these myograms obtained from well trained subjects, the most typical ones are presented in Fig.2, 3, 4, 5, 6.

Fig. 1 The apparatus employed in the experiment. The angle of the elevating arm is automatically marked by the micro switches.

Fig. 2 E. M. G. during the elevation in the 45 degree medial vertical plane, the sagittal plane, the 45 degree lateral vertical plane and the frontal plane.

Fig. 2 shows the myogram of the subject when the arm was elevated forcibly straight forward in different vertical planes. Fig. 3, 4, 5, 6 show the myograms in which the subjects elevated their arms against a slightly medialward or lateralward resistance in different vertical planes—Fig. 3, in the 45 degree medial vertical plane; Fig. 4, in the sagittal plane; Fig. 5, in the 45 degree lateral vertical plane; Fig. 6, in the frontal plane. In these figures, the first column (B) shows the influence of a slight horizontal medialward component of the force of resistance, the second column (C), control and third column (D), lateralward horizontal component. As presented in Fig. 3, 4, 5, 6, though the elevations of the arm were performed through strictly controlled ways, nevertheless, a slight difference in the direction of resistance caused a remarkable change in the patterns of the myograms of the two muscles—the clavicular portion of the pectoralis major and the spinal portion of the deltoideus. The other muscles except these two did not show remarkable change.

In general, the resistance including a slight lateralward horizontal component caused the increase in action potentials of the clavicular portion of the pectoralis major and the decrease in the ones of the spinal portion of the deltoideus. On the contrary, the resistance including a slight medialward horizontal component caused reversed patterns.

There were some differences as follows when the arm was elevated in various planes. In Fig. 2, the discharge of the spinal portion of the deltoideus did not appear during the movements in the frontal plane, but strong discharge appeared above 135 degrees in other planes.

Strong discharge of the clavicular portion of the pectoralis major were recorded up to 90 degrees in the sagittal plane and the 45 degree medial vertical plane, but beyond 90 degrees the discharge ceased. While in the 45 degree lateral vertical plane and the frontal plane these patterns of discharges reversed.

In the case of Fig. 5 (D), a strong discharge immediately occurred from the beginning of the movement, unlike the patterns of discharges in other planes.

Fig. 3

Fig. 4

Fig. 7 and 8 were taken from the roentgenograms and prepared as adiagram to show the insertion and the origin of the muscles. Fig. 7 shows the roentgenogram and the diagram at the erect position and Fig. 8 at the position of 135 degrees in the frontal plane. When the arm, moving from the erect position, reached the full elevation, the upward rotation of the scapula became greater with the elevation of the arm than when the arm was at the side of the body.

Fig. 9 shows the vertical and horizontal components of the force of the fibre of the clavicular portion of the pectoralis major in which the electrodes were placed during the movements.

Fig. 5

Fig. 6

Fig. 3, 4, 5, 6 show E. M. G. during the elevation in the 45 degree medial vertical plane, the sagittal plane, the 45 degree lateral vertical plane and the frontal plane.

(B): The influence of a slightly medialward resistance.

(C): Control.

(D): The influence of a slightly lateralward resistance.

The diagram was illustrated by analyzing the roentgenograms. In this figure, no change was found on the horizontal component during the movements. And the largest horizontal

The vertical component of the force of the muscle caused the elevation of the arm until it reaches 90 degrees, and beyond 90 degrees caused the extension in the 45 degree medial vertical plane and the sagittal plane. However, in the 45 degree lateral vertical plane and the frontal plane the reversal patterns were produced.

As the results mentioned above (Fig. 3, 4, 5, 6), the discharge patterns of the clavicular portion of the pectoralis major and the spinal portion of the deltoideus were remarkably different when strictly controlled movements were performed against the resistance which has somewhat different directions. In other words, the discharge of the clavicular portion of the pectoralis major remarkably increased and the one of the spinal portions of the deltoideus decreased when the resistance included the lateralward horizontal component. These results exhibited the same inclination in all the planes of elevations. In Fig. 4 (C), the discharge of the pectoralis major was found until 90 degrees was reached but beyond this ceased.

Fig. 8 The roentgenogram and the diagram to show the insertion and the origin of the muscles at the position of 135 degrees in the frontal plane.

However Scheving and Pauly¹⁾ reported action potentials from the clavicular portion of the pectoralis major during flexion. Also Inman et al²⁾ found that in forward flexion the clavicular portion was most active, reaching a primary peak at 75 degrees and a secondary peak at 115 degrees.

Our findings were not always in accord with those of other authors. As we have already reported in the electromyographic study on the flexion of the arm, the angle of elevation in which the discharge of the muscle disappeared, converged to 90 degrees, but there were some variations in this angle. When the movements were performed against the resistance having a medialward horizontal component, the angle was larger

than 90 degrees and having a lateralward horizontal component, the angle was smaller.

Analyzing the relationship between the line of this muscle pull and the shoulder joint, the vertical component was recognized up until 90 degrees was reached. This fact agreed with the pattern of the myogram shown in Fig. 4 (C). As this muscle primarily functions as a horizontal adductor, the strong discharge shown in Fig. 4 (D) can be readily understood anatomically.

As for the spinnal portion of the deltoideus, according to Inman et al²⁾, they found that the greatest activity in the deltoideus occurred when the arm was elevated between 90 and 180 degrees. Scheving and Pauly¹⁾ and Yamshon and Bierman³⁾, stated that all parts of the muscle were active in all movements at the shoulder. While McCloy⁴⁾ reported that when the arm was raised forward, diagonally forward-sideward and sideward, there was no observable contraction of the posterior deltoid. However we found that strong discharge shown in Fig. 4 (C) was recorded above 135 degrees. In this figure, as for the angle which the action potential appeared, it became smaller in (B) and larger in (D) than 135 degrees in (C).

Practically, from the roentgenograms, the vertical component causing elevation was found above 135 degrees during the flexion of the arm. Since this portion of the muscle acts strongly as a horizontal abductor, it is prospected that the remarkable discharges are exhibited when the movement in Fig. 4 (B) is performed.

We can indicate the direction of load from the variation of the discharge patterns of the myograms obtained.

However, in Fig. 6 (C), a strong discharge did not appear above 135 degrees in the frontal plane. As shown in Fig. 8, the upward rotation of the scapula is larger in the frontal plane

Fig. 9 The vertical and horizontal component of the force of the clavicular portion of the pectoralis major during the elevation.

I: in the sagittal plane

II: in the 45 degree lateral vertical plane

III: in the frontal plane

than in other planes as the humerus is elevated. Therefore the line of this muscle pull is always lower than the shoulder joint and we can not find any upward vertical component during full elevation. For this reason the strong discharge does not appear above 135 degrees in the frontal plane.

In the clavicular portion of the pectoralis major as mentoined above, the discharge appeared below 90 degrees in the 45 degree lateral vertical plane as shown in Fig. 2. The diagram shows in Fig. 9, the distribution of the vertical component of the force of the muscle reversed at a vertical plane which is between the sagital plane and the 45 degree lateral vertical plane. The reversal point was calculated from the roentgenograms and was assumed it might be about the 30 degree lateral vertical plane from the sagital plane.

In the case of the Fig. 5 (D), the pattern of the myogram showed different inclination when compared to the other figures (D). Namely, the action potentials immediately occurred and large averaged potentials continued to be recorded as long as the arm was held elevated. As the medial horizontal component is larger than the vertical component, it may be considered to be the cause for such a discharge pattern.

Summary

- 1) Electrmयोगrams were recorded during elevation of the upper extremity in various vertical planes and these were examined anatomically and mechanically basing upon roentgenograms.
- 2) The variation of discharge pattern indicates the direction of resistance given during the elevation of the arm. The resistance including a slight lateralward horizontal component causes the increase in the discharge of the clavicular portion of the pectoralis major, and the decrease in the one of the spinal portions of the deltoideus. A slight medialward horizontal component causes the reversal patterns
- 3) The clavicular portion of the pectoralis major acts in elevation up until 90 degree in the more medial vertical plane than the 30 degree lateral vertical plane, and above 90 degrees in the more lateral vertical plane than this.
- 4) The spinal portion of the deltoideus acts in elevation above 135 degrees in the other planes than the frontal plane.

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