THE ELECTRICAL ACTIVITY OF SINGLE MOTOR UNITS UNDER SLIGHT CONTRACTION IN HUMAN MUSCLE

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ABSTRACT

A simple modification of a commercial electrode (Beckman "Biopotential Skin Electrode") made it possible to record from single motor units of biceps brachialis without penetrating the skin. Such recordings were subject to specific experimental conditions including the use of lean subjects, slight contraction and careful placement of electrodes. The results were reproducible in each subject and had the great advantage that irritation from needle electrodes was completely eliminated.

Using this electrode system several aspects of the control of single motor units were investigated. The variation in frequency of single-unit discharge was found to be constant at constant tension with a coefficient of variation in the order of 10%. This variation contains information on the stability of the feedback system.

The tension was increased in two ways: (a) in steps of 100 grams and (b) continuously. The discharge of the single motor unit was quite different under these two conditions and the analysis suggests that in (a) there may be a rearrangement of tension among the motor units while in (b) a single motor unit adapts continuously.

This analysis may be useful in designing myoelectric control systems for prosthetics using surface electrodes.

INTRODUCTION

The purpose of this investigation was to study some aspects of the control system of a single motor unit in a human skeletal muscle (biceps brachialis). We were primarily interested in the activity of a single motor unit to a constant low tension when the arm lifts a small load and to the response when the tension is increased. We studied the discharge frequency of a single motor unit at constant tension over periods up to seven minutes and the pattern of discharge when the tension was increased in steps and continuously.

The tension exerted by a muscle is determined by the frequency of discharge of the individual motor units and the number of motor units that are active. In order to study single motor units we used low forces to produce a minimal tension in the muscle and thus eliminated the interference due to the activity of other motor units that are recruited at higher tensions.

METHOD

Electrodes. Other investigators (1) have used needle or wire electrodes to study single motor units but in order to reduce discomfort and irritation we attempted to use electrodes placed on the outside surface of the skin. The Beckman "Biopotential Skin Electrodes" were adapted by closing 3 of the 4 holes on its surface in order to reduce its area of sensitivity. It is estimated that the responding area on the skin was reduced by about one hundred times and the volume beneath the skin by an even larger factor. This suggests that the reduced depth of electrode sensitivity and the electrical insulation of the subcutaneous fat layer prevented the myoelectric potentials from reaching the electrode in other than lean subjects.

Recording System. The electrical activity of the motor unit was amplified with a variable passband amplifier (Tektronix 122) and recorded on magnetic tape using F.M. at 60 or 15 in/sec (Sanborn 3907-06A). The tapes were played back at 1 7/8 in/sec into a pen recorder (Beckman R Dynagraph). All recordings were monitored on an oscilloscope (Hewlett-Packard 140A).

Subjects. Healthy students were used as experimental subjects and lean specimens produced the best recordings of single motor units. The performance of each student was improved with training as was shown by Basmajian (1).

RESULTS

The frequency of discharge when the tension was changing rapidly as occurred when the arm was loaded or unloaded exhibited several types of irregularity. Under these transient conditions a random type of discharge and a double response were noted. The double response has been reported by others (2). Since we are interested in the steady state response and slow changes in tension we will not consider these results any further.

Constant Tension. The results for five subjects exerting a constant force are given in Table I.

Table I

Subject	Duration Sec	Freq Hz	S.Dev.
1	142	11.35	0.73
2	105	9.29	0.11
3	70	8.43	0.12
4	420	10.68	0.88
5	300	5.82	0.55

The frequency did not exhibit any pattern of variation when the data was analyzed in intervals of 4 sec. The occurrence of the frequencies when plotted on a histogram gave a Gaussian distribution.

Tension Increasing in Steps of 100 Grams. The results were highly variable and correlation coefficients between weight lifted and frequency were from 0.45 to 0.98.

Tension Increasing Continuously. The results are shown in Fig. 1 and the correlation coefficients were between 0.88 and 0.98.

DISCUSSION

Constant Tension. The constant frequency of discharge was maintained for periods of as long as 7 min. with no interruption, change or alteration in the pattern of response. The variations in frequency with time were small and their distribution appeared to be random. From a model for the control system of muscle presented by Deutsch (3) this observation would correspond to a large gain in one of the feedback loops.

Tension Increasing in Steps of 100 Grams. The great variability in the results is thought to be due to the experimental procedure where relaxation was allowed between each loading. This procedure may cause a redistribution of the motor units which are producing the tension.

Tension Increasing Continuously. The resulting discharge frequencies correlate extremely well with the weight when the load was increased continuously but whenever the arm was unloaded and allowed to relax the frequencies dropped when the loading was continued. This provides further evidence that the results observed for step increases of weight were due to a redistribution of tension among the motor units.

CONCLUSIONS

1. The electrical activity of single motor units can be detected from lean subjects using surface electrodes.
2. The frequency of discharge of single motor units remains constant for periods of up to 7 min. when the muscle exerts a constant tension.
3. The frequency of discharge increases linearly with continuously increasing tension from zero to 2 kg. Due to the redistribution of motor units the frequency for the same load does not remain constant after relaxation.

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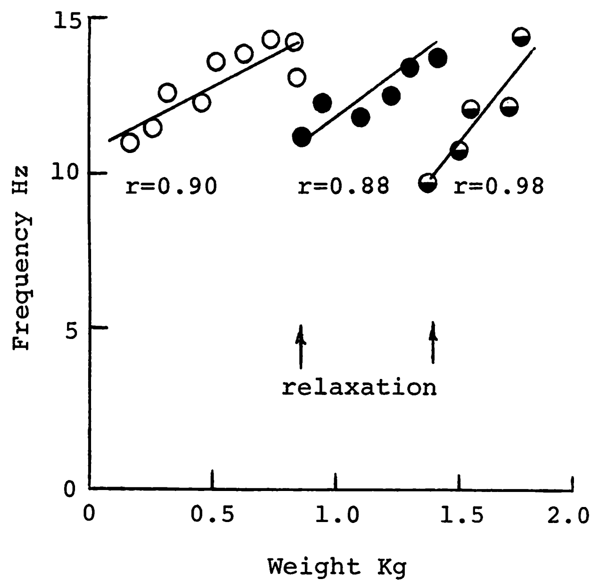

Fig. 1