THE ELECTROMYOGRAM IN VOLUNTARY CONTRACTION OF THE MUSCLES IN OLD AGE

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Electromyography is widely used to study muscular activity and its pathological variations. However, among the large number of investigations on this subject, practically none deal with the electrical activity of muscles in very old people. Nevertheless, in old age all tissues undergo profound changes, and therefore a study of the electromyogram in this condition is of great interest. The present investigation is a study of features of the electromyogram shown by old people.

METHOD

We studied the electromyograms in 50 subjects aged 70 to 90 years produced by voluntary actions of the agonist and antagonist muscles of the arm and leg. As a control, we recorded electromyograms from 15 subjects aged 25-35 years.

The traces were obtained by applying silver electrodes and connecting them through an A. C. amplifier (which was free from distortion over a frequency range of 0.5-1500 cycles) to two channels of a MPO-2 oscillograph. Simultaneous recordings were made from a muscle and its antagonist, and a time marker giving $1/50$ second intervals was recorded on the third channel.

After first training the subject to respond to a verbal signal, a movement was made producing a maximal contraction of one of the muscles investigated.

Each pair of muscles was activated in turn, so that the duration of contraction of the muscle was $1\frac{1}{2}$-3 sec, as determined from the electromyogram.

RESULTS

In old people, after the signal had been given, voluntary contraction as a rule began later than it did in the control group, i.e., the latent period of the response was prolonged in most cases (see Table).

Characteristics of the Contraction of the Skeletal Muscles in Old People

Time between presentation of the signal and electrical response (in seconds)	Number of electromyograms		As percentage of the number of electromyograms	
	in group of people	in control group	in group of people	in control group
0.1-0.5	95	39	40	65
0.6-0.9	68	18	28	30
1.0-2.6	75	3 *	32	5

In people over 70, judged by the increase of amplitude and frequency of the potentials, the contraction of the muscles was produced slowly and gradually to attain the maximum value of which the subject was capable. In 77 %

of the cases the maximal potentials occurred 0.6-3 sec after the onset of the contraction, but in the control group, in 67% of the subjects maximum contraction occurred after 0.1-0.5 sec (Fig. 1).

Thus in old age, the different neuromuscular units become active slowly and at different times. The effect may depend on a number of causes, including: the small number of cortical cells excited, a reduced excitability of the motoneurones of the spinal cord, and some failure of the muscle fibers themselves. We are inclined to accept the last of these causes, which we will discuss further below.

In the electromyograms of old people, another characteristic trait can be made out, and that is the short duration of the maximal contraction. The large-amplitude potentials characteristic of maximum tension continue in this group only for a short time, and their amplitude begins to fall before a signal to relax has been given. In 60% of the cases, in the aged group, the time for which the maximum amplitude was maintained was 0.4-0.9 sec, and in 40% it was 1-2 sec. In the control group, the maximal activity was maintained constant until the signal to relax was received (Fig. 2).

The electromyograms of old age also show a large number of small-amplitude potentials. Information on this point was obtained by measuring the potentials at the beginning of the contraction, at full contraction, and during

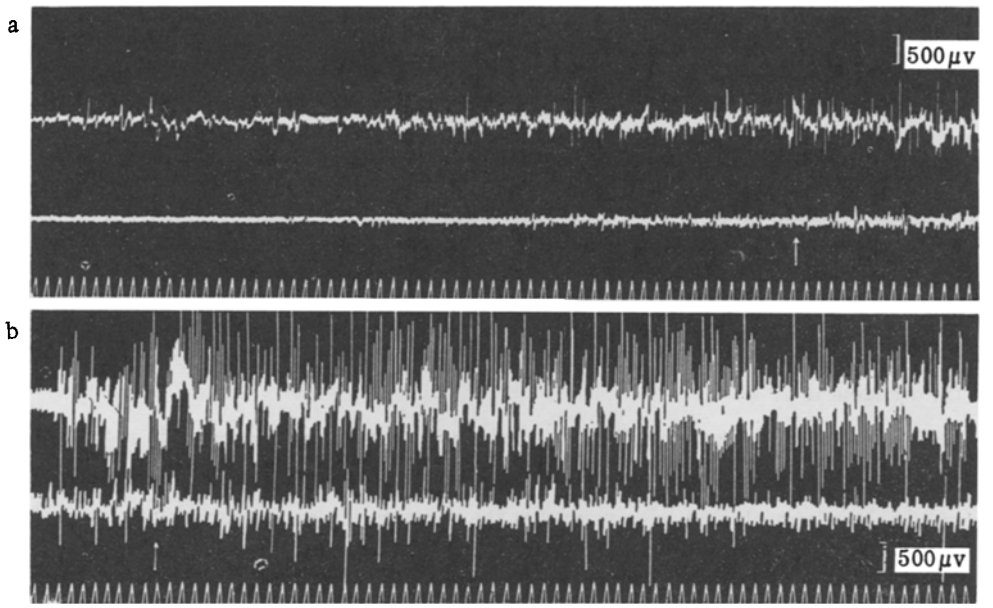

Fig. 1. Electromyogram in the old age group. a) Subject Kh., 73 years old; b) subject M., 25 years old. Contraction of the m. gastrocnemius. Time from the moment of appearance of the first action potentials until the maximum value occurs (as indicated by arrows) was in Kh. 1.42 sec, and in M. 0.2 sec. Curves, from above downwards: electromyograms of m. gastrocnemius, m. tibialis anticus, time marker ($^1/_{50}$ seconds).

relaxation. In the great majority of cases the potentials initially had an amplitude of 50-100 and 200-300 μv. In the leg muscles the amplitude was lower than in the arms. Next, the amplitude of the potentials increased to 400-500 μv. Among them there were a comparatively small number of potentials of 600-800 μv. Only in 2% of the 400 electromyograms taken are the potentials of 900-1200-1500 μv typical of the normal electromyogram present. We must note that the larger amplitude potentials were observed in patients in whom there was a general sense of well-being and in whom the muscles were more elastic and of an unaltered configuration and size.

In this way an analysis of the electromyograms showed that the majority of potentials in the old-age group were less than 400 μv in amplitude, even during maximal contraction, whereas in the control group under equivalent conditions most of the potentials lay between 900 and 1200 μv, and among them there were higher amplitude potentials of 1400-1600 μv.

The amplitude of the potentials is known to depend upon the synchronous contraction of different muscle fibers and on the number of motor units contracting simultaneously. The presence in the electromyograms of a large number

of potentials of low amplitude appears to indicate that the number of motor units contracting at any one time is reduced, an effect which might be produced at this age by destructive changes in the muscle fibers [6]. From 50 years onwards the number of muscle fibers showing degenerative changes increases progressively with age [1]. Owing to the pathological condition of the muscle fibers, their electrical activity is reduced, as was shown by comparing the electromyograms with other pathological indices in spastic children [2].

The electromyograms of the legs show lower potentials than do those of the arms, particularly in the thigh. Here in subjects aged between 70 and 80 years the amplitude did not exceed 200-400 μv, whereas in the control group it was 3-4 times greater.

In quite a large number of old people the electromyogram consisted of grouped discharges. Each group consisted of 3-4 action potentials which were separated by a pause of 0.04-0.08 sec. This effect occurred most frequently during contraction of the leg muscles, and when these muscles showed morphological and functional changes such as shortening of the belly of the muscle through elongation of the tendon, reduced tone, or reduced electrical excitability.

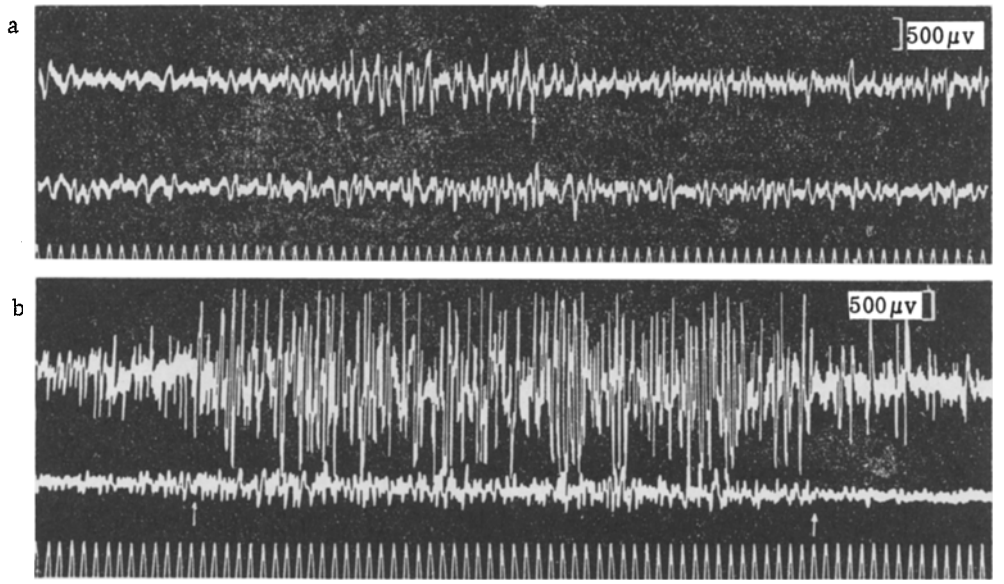

Fig. 2. Electromyograms of the subject M., aged 72 years (a) and subject L., aged 34 years (b). Contraction of the m. biceps br. Time for which maximal activity was maintained was 0.33 sec in M., and 1.04 sec in L. Curves, from above downwards: m. biceps br., m. triceps br., time marker ($^1/_{50}$ seconds).

The electromyogram of the gastrocnemius muscle of the subject S. aged 81 years will serve as an example of grouped impulses (Fig. 3).

Group discharges have been observed during muscular fatigue [4], but in our experiments in which there was no fatigue, this arrangement of impulses must be attributed to the aged muscle. Most probably the reduction in the number of functional motor units is due to degenerative changes present at this age which presents rhythmical alternation of activity among them. It has been shown that the number of motor units in the anterior horns of the spinal cord is reduced in old age [7, 8], and this effect together with the degenerative changes of the muscle fibers must play a considerable part in determining muscle function.

In the electromyogram of old people there are considerably more polyphasic potentials than normally (Fig. 3,b). When such potentials last more than 10 msec, it is usual to regard them as representing a scatter of impulses arriving at muscle fibers having different excitabilities [11]. Further, muscle fibers may have different velocities of conduction of excitation [10]. Possibly, as Jasper and Ballem [12] suggest, polyphasic potentials may be formed from grouped action potentials originating in different motor units, or to successive discharges from one and the same unit. There is therefore no agreed opinion on this problem.

In old age, when involution of the tissue occurs, there must be considerable differences between muscle fibers with respect both to excitability and conduction velocity. The increase which we have found in the potentials of long duration is most probably a consequence of an altered condition of the motor units. Many authors have also observed a greater duration of electrical potential in old age. Thus, according to Hodes [11], the mean duration of a muscle action potential of a man of moderate age is 3.8 mseconds, but in persons over 60 it is increased to 7.2 m-seconds. The rate of conduction of excitation increases until seven years of age, then it remains constant, and is not reduced until after 60. Buchtal, Pinelli and Rosenfalck [5] have shown that in man at 80 years the action potential lasts for 10 m sec, and they attribute the effect to a slowing of the conduction of excitation.

The frequency of the successive impulses in both groups was the same and equal to 60-100 per second, rising to 130-150 in strong contraction. The fact that there was no difference in the frequency indicates the normal action

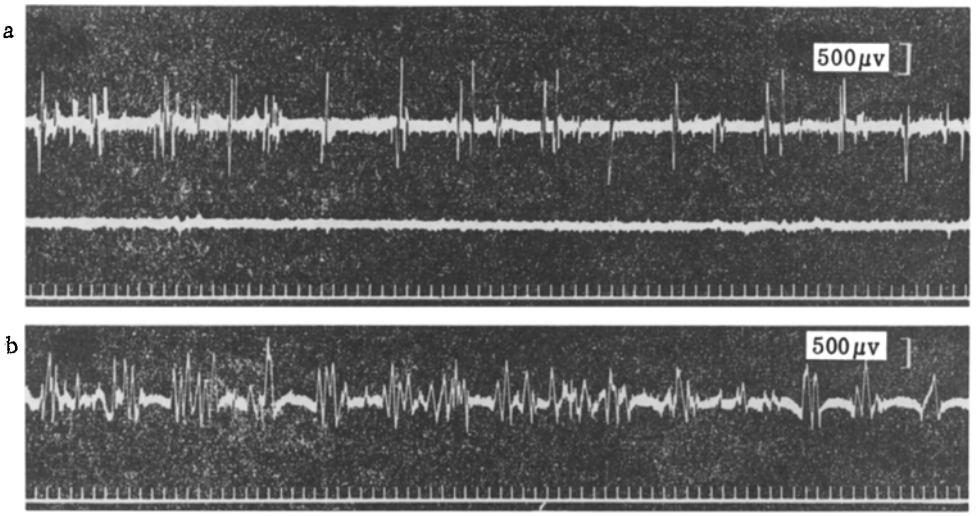

Fig. 3. Types of electromyogram in old age. a) Subject S., 81 years old, grouped discharges in the m. gastrocnemius; b) subject A., 72 years old, grouped discharges and polyphasic potentials lasting 10-20 σ in m. triceps brachii. Curves, from above downwards: for a – m. gastrocnemius, m. tibialis anticus, time marker ($\frac{1}{50}$ sec); for b – m. triceps brach., m. biceps br., time marker ($\frac{1}{50}$ sec).

of the motoneurones [9]. Therefore, the small amplitude of electrical potentials in old people is not to be attributed to central changes but to physiological characteristics of the motor units as was pointed out above.

After the muscles have contracted actively in old people, occasional or grouped potentials continue for a long time. The same effect has been observed when the excitability of muscle fibers has been enhanced through their re-innervation [12], or when inhibitory processes have been weakened. Naturally, the former effect does not apply in our case, because there is no reason to think that there is any increased excitability of the motor units in people of this age. Probably there is some reduction of suprasegmental inhibitory influences.

Judging from the electromyogram, reciprocal relation of the antagonist muscles is maintained, and potentials from a muscle active at a particular time are always greater in potential than those from the antagonist when the former contracts.

The electromyograms which we have obtained give a picture of the changes which occur in the muscular system in old age. Naturally, in this way it is not possible to reveal the whole of these changes, but we have reason to suppose that certain specific effects associated with voluntary contraction are shown in this way. Firstly there are a large number of potentials of small amplitude which immediately distinguish the electromyogram from that of young middle-age people which show a larger number of high-potentials. The second feature of the electromyogram in old age is the way the amplitude of the potentials gradually increases during a muscular contraction. Having attained a maximum value, the potentials are maintained at this level only for a short time, and then decrease, although the muscle remains contracted. Here it is interesting to observe that there are a large number of potentials which last longer than normally, and this effect constitutes a third feature of the electromyogram in old age.

All the changes in the electromyogram in old people, as described above, appear to be due to the following causes: a reduction of the total protoplasmic mass of the muscle [3], degeneration of a proportion of the muscle fibers [1], a change of their excitability, and possibly also a change of the electrolytic composition of the fluid of the tissues and tissue spaces, and a reduction in the number of active motoneurones of the spinal cord [7, 8].

SUMMARY

Electromyograms of agonist and antagonist muscles of the arms and legs were studied during voluntary muscular contraction in 50 persons aged from 70 to 90 years, and in 15 control individuals between 25 and 35 years old. The electromyograms of the aged individuals showed a number of specific features differentiating them from those of the control group. The electrical potentials were lower in the older people, having a value of 200-400 mv. The amplitude of the electrical potentials increased gradually during a voluntary contraction. The large electrical potentials were maintained for only a brief period, and then declined rapidly despite the fact that the contraction of the muscles was maintained. Numerous polyphasic potentials lasting for over 10 mseconds were also observed. The frequency of the impulses did not differ from that of the control group. We attribute all these changes to functional and pathological changes in the motor units of the old people.

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