THE PROBLEM OF SPECIALIZED MUSCLE FIBERS IN MAMMALS

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The theory that there is present in mammals specialized muscle fibers adapted to tonic or tetanic activity can be debated. Thus, S. N. Gorshkov and E. A. Guseva [1], having obtained both tonic and tetanic contractions in the same mammalian muscles subjected to various stimulating conditions, are inclined to the opinion that there is but one single substrate effecting both tonic and tetanic reactions. S. Kuffler [6] holds to the same opinion, asserting that such specialized muscular fibers as are present in frogs are absent in mammals. However, R. R. Sharipova [5], on the basis of her investigations, arrived at the conclusion that specialized muscular mechanisms are present in mammals. E. K. Zhukov [4] also considers the presence of specialized muscular mechanisms in mammals to be a reality.

Evidently, some light could be shed on this matter by carrying out experiments on individual fibers separated from mammalian muscles. In the literature available to us we did not find any investigations carrried out on isolated mammalian muscle fibers with the aim of discovering fibers specialized for tetanic or tonic function. In the work of Honcke [7], where investigations on the structure and function of isolated live mammal striated muscle fibers are described, there are no experiments devoted to revealing specialized tonic and tetanic fibers. We therefore considered it expedient to undertake an investigation of this nature.

EXPERIMENTAL METHODS

The methods of preparing, sustaining, and recording the contractions of the muscle fibers do not differ from those adopted by E. K. Zhukov and L. I. Leushina [2, 3] in experiments with isolated frog muscle fibers.

Initially experiments were carried out on fibers extracted from the heel muscle of a rat (that known in the literature as the red static muscle). The fibers were extracted both from the surface area of the muscle close to the nerve junction and from other parts of the muscle. The second part of the experiment was carried out with fibers separated from the sole muscle. The preparation of the fibers was undertaken on a heated stage at a temperature of 30-32° under a binocular microscope. The preparation technique here is somewhat more complicated than that for preparation of frog muscle fibers since the connective tissue membrane of the rat muscle is thicker and the muscle fibers themselves are finer and looser than in the frog. After separation the fiber was placed in Ringer-Locke solution warmed to 30-32°, and left there for some time in order to better ascertain whether it had suffered damage during preparation. After examination under the microscope the fiber, ready for experimentation, was placed in a parallel-sided glass chamber and supported by a thread fastened to the tendon on the anode of nonpolarized Dubois-Raymond electrodes. To the other tendon a tension lever was attached. The cathode of the nonpolarized electrodes consisted of a tuft of silk thread immersed in the solution within the chamber.

The constancy of the temperature within the chamber was ensured by a special heater. The temperature fluctuation did not exceed 0.5°. Thus, from the beginning of preparation to the end of the experiment the muscle fiber was under a temperature equal to that within the rat's body.

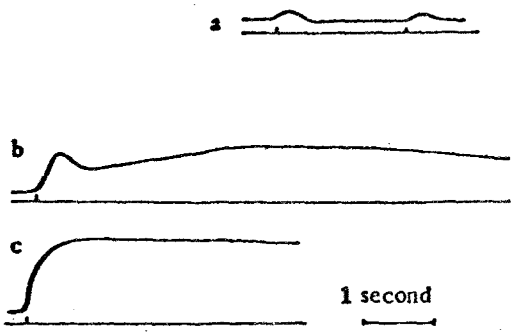

Fig. 1. Contractions in response to single stimuli of fibers of the transitional type extracted from the heel muscle of a rat.
a) With a distance between inductor coils of 15 cm; b) with 10 cm; c) with 5 cm.

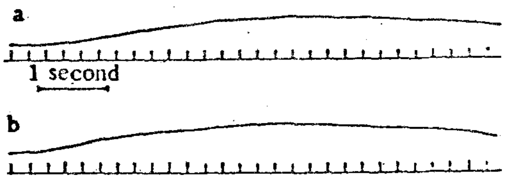

Fig. 2. Contractions in response to stimulation by an induction current for a distance between inductor coils of 8 cm displayed by fibers of the tonic type extracted from the heel muscle.
a) At the beginning of the experiment; b) after 1 hour and 15 minutes.

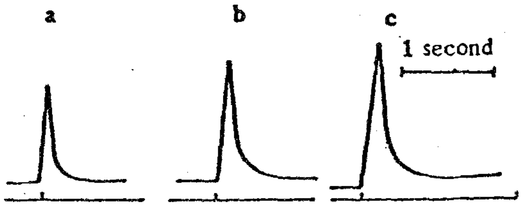

Fig. 3. Contractions in response to single stimuli of a group of 3 fibers of the tetanic type extracted from the sole muscle.
a) With a distance between inductor coils of 15 cm; b) with 10 cm; c) with 5 cm.

Stimulation of the fiber was by single induction pulses from an induction coil with a primary circuit tension of 6 volts. The technique for recording fiber contractions did not differ from that described in the work of E. K. Zhukov and L. I. Leushina.

EXPERIMENTAL RESULTS

The contraction of heel muscle fibers separated from the surface of the muscle, when subjected to near-threshold stimulation, is characterized by a fairly smooth increase and a slow decrease in the contraction curve. On a myogram these contractions have a cupola shaped appearance (Fig. 1,a). The contraction of fibers obtained from deep within the heel muscle takes place much faster. Their amplitude is greater and on a myogram they have the appearance of peaks with sharp apices. With stronger stimulation of these fibers, as a rule, a tonic component appears with the shape of a more or less pronounced slow supplementary contraction wave (see Fig. 1,b). The stronger the stimulation, the more pronounced is the tonic part of the contraction and the quicker it develops. With sufficiently strong stimulation one may observe that the tetanic part of the contraction and the tonic component merge together, as it were. One obtains a generally high contraction which quickly develops and slowly decreases after the excitatory stimulus (see Fig. 1, c). Evidently, from the nature of its contraction a fiber of this type can be considered a transitional fiber displaying both tonic and tetanic contraction components [3].

This is the means by which the overwhelming majority of the fibers contract. This brings to mind the great diversity of the transitional fibers within which fast and slow contraction components are combined in the most variable proportions.

Aside from these, fibers may be extracted from the heel muscle which contract only on stimulation of considerable strength (7-5 cm on the induction coil). The character of their contraction is extremely similar to the contraction of the tonic fibers of the frog (Fig. 2). To evoke contraction in these fibers prolonged stimulation is necessary. That these contractions are not the result of incipient degeneration of the fiber is attested to by the fact that under the microscope these fibers appear completely undamaged and uniform and are capable of producing contractions for an indefinite length of time (2-3 hours) the same as fibers of the transitional and tetanic types. These muscle fibers evidently must belong to the tonic type.

The majority of fibers extracted from the white sole muscle, which is characterized by many authors as a fast dynamic muscle, are distinguished by fast high contractions not unlike the contractions of the tetanic fibers of frog muscles. This type of contraction persists for all stimulation intensities; with increasing stimulus strength, only the amplitude of contraction increases somewhat (Fig. 3). However, with very strong stimulation of these fibers there appears a small unstable plateau which evidently is a result of damage occurring within the fiber under the influence of an excessively strong stimulation. By the nature of their contraction these fibers evidently should be considered tetanic fibers. It should be mentioned that sometimes these fibers also occur in the heel muscle, especially in its deeper portions.

Therefore, during the course of our work we succeeded in extracting from skeletal muscles of the rat diverse muscle fibers, some contracting in a tetanic manner and others in a tonic manner. These facts enable us to adhere to the view that specialized muscle fibers are also present in mammals. In addition it appears that together with specialized tetanic and tonic fibers there are huge numbers in a transitional stage combining the ability to contract fast and tonically in varying degrees.

The distribution of muscle fibers according to their contraction characteristics evidently is represented by a normal curve, the extreme ends of which are occupied by specialized tetanic and tonic mechanisms; all the rest of the area is occupied by transitional mechanisms approaching in varying degrees either the tetanic or the tonic type.

SUMMARY

The problem of the presence in mammals of specialized muscular fibers adjusted to tonic or tetanic activity is debatable. Experiments were performed in order to investigate this question.

Single muscular fibers were isolated from the muscles of mammals. It was established that specialized muscular fibers, contracting tonically or tetanically are present in rat muscle. Fibers of the transitional type combining both functions were also found.

LITERATURE CITED

[1] S. I. Gorshkov and E. A. Guseva, Tr. fiziol. nauchno-issled. in-ta Leningr. gos. un-ta, Leningrad, 1934, No. 14, pp. 78-111.

[2] E. K. Zhukov, Investigations on the Tonus of Skeletal Muscles,* Moscow, 1956.

[3] E. K. Zhukov and L. I. Leushina, Doklady Akad. Nauk SSSR, 1948, 62, 3, 425-428.

[4] E. K. Zhukov and L. I. Leushina, Doklady Akad. Nauk SSSR, 1948, pp. 565-568.

[5] R. R. Sharipova, Fiziol. Zhur. SSSR 1955, 41, 2, 243-248.

[6] S. W. Kuffler, Amer. I. physical. med., 1955, v. 34, N. 1, pp. 161-171.

[7] P. Honcke, Acta physiol., Scandinav. (Suppl. 48), 1947, v. 15, pp. 3-230.

* In Russian.