CHARACTERISTICS OF ACTION POTENTIALS OF SKELETAL MUSCLE FIBERS DURING POSTNATAL ONTOGENESIS OF DOGS

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UDC 612.743:612.65-019:599.742.1

The action potential (AP) of fibers of the dog's gastrocnemius muscle increases from the first day of life to the adult state from 21.8 to 116.9 mV, and falls in old animals to 72.5 mV. Reversion of the membrane potential is absent in puppies one day old and appears by the 5th day of life, and in adult dogs it amounts to 34.29 mV, falling in old animals to 14 mV. The duration of the AP and synaptic delay falls until the adult state is reached and increases in old animals.

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Characteristic features distinguishing the neuromuscular apparatus of mammals in the early stages of ontogenesis have been described by Soviet and Western workers and established by systematic investigations in our laboratory [1-6, 10-22]. In the present investigation, a continuation of previous work in this laboratory to study the formation of the neuromuscular apparatus of mammals in ontogenesis, the object was to assess the parameters of the action potentials (AP) of gastrocnemius muscle fibers in dogs at different age periods.

EXPERIMENTAL METHOD

Experiments were carried out on dogs whose ages ranged from 1 day to the adult state and on old animals (age 12-15 years). The test object was the gastrocnemius muscle with its blood supply and innervation intact. The muscle fibers were stimulated indirectly with single square pulses of maximal strength and 0.5 msec in duration. The AP were detected by capillary microelectrodes filled with 2.8 M KCl solution, with an impedance of 12-75 MΩ, except that for recording AP in animals during the first days of life microelectrodes with an impedance of 45 MΩ or above were used. In each experiment the amplitude and duration of the AP (from the base to the beginning of after-potentials), reversion of the membrane potential (RMP), and synaptic delay were measured. Technical details were described previously [13].

EXPERIMENTAL RESULTS

Experiments were carried out on 60 animals. Results of the measurements are given in Table 1. Recordings of the AP of the muscle fibers in dogs of different age groups are shown in Fig. 1. On the first day of life AP below the initial level of the membrane potential (MP) were recorded (Fig. 1, Ia) or AP reaching the original MP level (Fig. 1, Ib). In our experiments on puppies during the first day of life no AP with RMP were observed. RMP appeared toward the 5th day of life, and in animals of this group (2-5 days) and in the group aged 7-9 days, AP were recorded both with RMP (Fig. 1, IIc, IIIc) and without it (Fig. 1, IIa, IIIa, b). In animals aged 17-22 days, AP without RMP were still recorded (Fig. 1, IVa), although approximately 76% of recorded AP were generated with RMP (Fig. 1, IVb). In animals aged 1.1-5 months, 2.3% of the fibers gave AP without RMP, the rest with RMP (Fig. 1, Va, b), even in the case of a comparatively low initial MP (Fig. 1, Va). In dogs aged two months and over, all fibers regardless of the initial MP generated AP with RMP only (Fig. 1, VIa, b). In dogs aged up to 6 months (Fig. 1, VIIa, b) and in adult dogs (Fig. 1, VIIIa, b) the AP were increased both because of growth of the initial MP and because of an increase in RMP, although in the adult dogs a certain number of fibers generated AP with an RMP not

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TABLE 1. Characteristics of Bioelectrical Phenomena in Gastrocnemius Muscle Fibers of Dogs of Different Ages (M ± m)

Age of animals	No. of fibers investigated	Amplitude of AP (in mV)	Reversion of MP (in mV)	Duration of AP (in msec)	Duration of synaptic delay (in msec)
1 day	37	21,81± 1,044	—	3,58± 0,087	4,17± 0,201
2—5 days	46	28,92± 1,882	2,41± 0,527	3,10± 0,094	3,38± 0,128
7—9 days	45	31,69± 2,444	4,56± 0,814	2,69± 0,089	3,18± 0,121
17—22 days	42	53,09± 3,237	9,79± 0,905	2,11± 0,065	2,46± 0,086
1—1½ months	43	64,53± 3,176	15,00± 1,105	1,71± 0,057	1,80± 0,054
2—3 months	45	81,77± 3,446	21,44± 1,788	1,10± 0,036	1,37± 0,038
up to 6 months	48	94,58± 2,362	26,04± 1,784	0,98± 0,028	1,25± 0,027
adult animals	48	116,90± 1,869	34,29± 1,893	0,83± 0,024	1,08± 0,024
old "	46	72,50± 3,204	14,02± 1,094	1,64± 0,084	2,12± 0,101

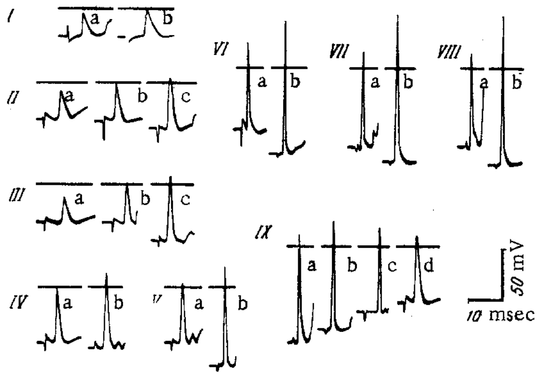

Fig. 1. Action potentials of gastrocnemius muscle fibers of dogs in different age periods. I) 1st day of life; II) 2nd-5th day; III) 7th-9th day; IV) 17th-22nd day; V) 1-1.5 months; VI) 2-3 months; VII) up to 6 months; VIII) adult dogs; IX) old dogs. Horizontal lines show initial level of membrane potential of muscle fibers.

exceeding 18 mV (Fig. 1, VIIIa). In old dogs fibers were found with a fairly high initial MP (of the order of 90 mV; Fig. 1, IXa) and with normal AP and RMP (Fig. 1, IXb), and also with lowered AP and RMP (Fig. 1 IXd).

The duration of the AP and the synaptic delay diminished from the first day of life until the adult state (Table 1). In old animals fibers were found with the AP duration and synaptic delay characteristic of adult dogs, but also fibers the duration of whose AP was greatly increased (Fig. 1, IXd). A few fibers gave AP of normal duration, but with a greatly increased synaptic delay (Fig. 1, IXc).

In early age periods parallel development of the MP and AP was not observed. For example, in puppies aged 5 days AP of equal amplitude were recorded for different values of the initial MP (Fig. 2, Ia, b). The opposite picture could also be observed; in one puppy aged 9 days, with equal initial MP values of the fibers, AP of different amplitudes were recorded (Fig. 2, IIa, b).

In early aged periods the muscle fiber is characterized by generalized chemoreception [8, 20]. With age the chemoreceptive zone becomes smaller in size to correspond to the size of the end-plate [8], so that it can be postulated that in the early age periods the absence of clear boundaries between the myoneural synapse and the tonic character of the muscle fibers do not allow generation of an AP of high amplitude together with RMP. High-amplitude AP, and especially RMP, evidently appear only after the muscle fibers and synapses have acquired the corresponding structure. Changes in the amplitude of the AP and RMP and in the duration of the AP and synaptic delay in old animals are probably associated with destruction of the myoneural synapses, for which there is morphological evidence [7, 9, 13, 23, 24].

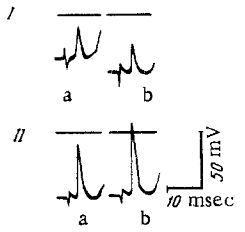

Fig. 2. MP and AP of fibers of the same muscles in puppies aged 5 (I) and 9 days (II). Explanation in text.

LITERATURE CITED

1. T. A. Adzhimolaev and V. V. Gavrilov, Dokl. Akad. Nauk SSSR, 147, No. 4, 981 (1962).
2. I. A. Arshavskii and V. D. Rozanova, Fiziol. Zh. SSSR, 26, No. 6, 629 (1939).
3. I. A. Arshavskii and V. I. Kushnarev, In: Problems in Experimental Biology and Medicine [in Russian], No. 1, Moscow (1951), p. 48.
4. I. A. Arshavskii, Uspekhi, Sovr. Biol., 32, No. 1, 18 (1951).
5. I. A. Arshavskii, Izv. Akad. Nauk SSSR, Ser. Biol., No. 1, 71 (1958).
6. I. A. Arshavskii, In: Physiology and Pathology of the Neurons System [in Russian], Moscow (1964), p. 12.
7. O. M. Babak, Dokl. Akad. Ped. Nauk RSFSR, No. 1, 159 (1957).
8. A. G. Ginetsinskii and N.M. Shamarina, Uspekhi Sovr. Biol., 15, No. 3, 283 (1942).
9. L. F. Mavrinskaya, Comparative Morphological Investigation of Motor Nerve Endings in Skeletal Muscles of Vertebrate Animals [in Russian], Author's abstract of candidate dissertation, Kuibyshev (1953).
10. T. N. Oniani, Problems in Comparative Physiology of the Neuromuscular Apparatus [in Russian], Tbilisi (1964).
11. V. D. Rozanova, Fiziol. Zh. SSSR, 30, No. 3, 346 (1941).
12. L. K. Semenova, Izv. Akad. Ped. Nauk RSFSR, No. 60, 87 (1954).
13. S. S. Solomatin, Byul. Éksperim. Biol. i Med., No. 3, 21 (1967).
14. S. I. Fudel'-Osipova and O. A. Martynenko, Biofizika, No. 1, 45 (1963).
15. S. I. Fudel'- Osipova and O. A. Martynenko, Biofizika, No. 5, 796 (1963).
16. A. J. Buller, J. C. Eccles, and R. M. Eccles, J. Physiol. (Lond.), 150, 399 (1960).
17. A. J. Buller, Brit. Med. Bull., 22, 45 (1966).
18. J. C. Cerbelle, C. R. Soc. Biol., 156, 2016 (1962).
19. R. Close, Nature, 206, 831 (1965).
20. J. Diamond and R. M. Miledi, J. Physiol. (Lond.), 393 (1962).
21. J. Needham, Chemical Embryology, Vol. 3, Cambridge (1931), p. 1674.
22. W. Ruckert, Arch. Exp. Path. Pharmak., 150, 221 (1930).
23. B. Scillik, Z. Zellforsch., 52, 150 (1960).
24. J. Zelena and J. Szentagothai, Acta Histochem. (Jena), 3, 284 (1957).