ORDER OF MATURATION OF SKELETAL-MUSCLE GROUPS IN RATS DURING POSTNATAL DEVELOPMENT

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The formation of the membrane potential (MP) of skeletal-muscle fibers in the neck and fore- and hind limbs was investigated in rats during early postnatal development. At birth the muscles of the neck were most mature and muscles of the hind limb least mature. The formation of a steady MP level in the neck muscles takes place during the first week of life, in the forelimb muscles by the 10th-12th day, and in the hind limb muscles by the 15th-20th day. The order of maturation of the various groups of skeletal muscles is connected with differences in neurotrophic influences at different age periods. The neck muscles at all stages of development are characterized by low-frequency regular electromyographic activity. Regular electromyographic activity in the limb muscles is transformed into high-frequency volley activity by the time that growth of the MP is complete.

KEY WORDS: electromyography; muscle membrane potential; postnatal ontogeny.

In Amblystoma the muscles of the forelimbs develop in ontogeny sooner than those of the hind limbs [9]. In mammals the first reflex arcs in the spinal cord mature in the cervical and thoracic segments, and those in the lumbar and sacral segments mature later [13]. In mammalian fetuses ability to give a reflex response to exteroceptive stimulation arises earlier in the forelimbs than in the hind limbs [1, 3]. On the basis of these facts the principle of cephalo–caudal maturation of nerve centers was formulated [12].

The dynamics of the membrane potential (MP) and variations in the pattern of electromyographic activity (EMG) in different muscle groups were investigated in rats during early postnatal development.

EXPERIMENTAL METHOD

Experiments were carried out on 76 albino rats. MP of the muscle fibers of the trapezius, triceps brachii, and gastrocnemius muscles were measured under superficial urethane anesthesia (0.2-0.5 μg/kg, intraperitoneally) when the body temperature of the animal was 35-36° C. The exposed surface of the muscle was constantly moistened with warm Ringer's solution for warm-blooded animals. MP was measured with glass microelectrodes, filled with 3 M KCl solution [6]. The diameter of the electrode tip was less than 1 μ and its resistance 20-50 MΩ. The KP cathode follower (Biofizpribor) and the amplifier of the S1-19B oscillograph were used. The electromyographic activity of the various muscles of the unanesthetized animals was recorded by type 9013 and 0592 concentric electrodes on the "Disa" electromyograph. The EMG was recorded at a slow speed (less than 1 cm/sec) on the N-102 loop oscillograph. After the electrophysiological measurements the tested muscles (except the muscles of the neck) were weighed.

EXPERIMENTAL RESULTS AND DISCUSSION

The results in Table 1 show that at birth MP differs in different muscles: it is higher in the neck muscle than in the forelimb muscle and higher still than in the hind limb muscle. Since MP is an important parameter of the functional state of excitable tissue [5], conceivably in mammals born blind such as rats,

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TABLE 1. Weight and Level of Polarization of Skeletal Muscles in Rats at Different Age Periods (M ± m)

Age (in days)	Body weight (in g)	M. trapezius	M. triceps brachii		M. gastrocnemius	
		membrane potential (in mV)	weight of muscle (in mg)	membrane potential (in mV)	weight of muscle	membrane potential (in mV)
1	5,6±0,7	64,7±1,2	3,1±0,4	54,3±2,4	9,5±0,6	28,4±1,7
5	7,9±0,8	78,6±0,91	5,2±1,2	61,0±1,3	17,4±3,2	36,9±1,4
10	14,8±0,9	81,3±0,9	8,9±1,7	79,7±0,9	30,6±4,1	51,2±1,7
15	20,5±1,9	81,1±1,0	14,6±2,2	80,0±1,2	58,7±7,3	67,3±1,8
20	33,1±2,0	81,4±1,2	22,5±2,9	80,1±0,8	92,6±8,6	79,8±1,4
30	53,8±3,6	81,2±0,9	40,4±4,7	80,4±0,7	186±12	80,5±0,8

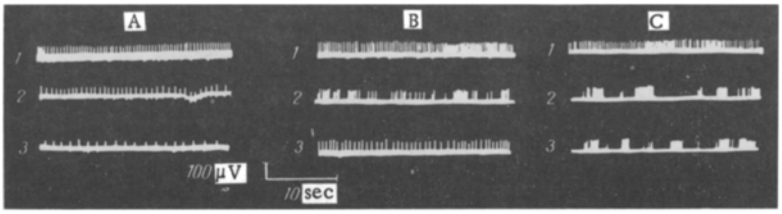

Fig. 1. Electromyographic activity of single motor unit of a muscle of the neck (1), forelimb (2), and hind limb (3) in rats aged 1 (A), 10 (B), and 90 (C) days.

the neck muscles at birth are functionally more mature than the limb muscles. This is confirmed by comparative physiological and biochemical investigations [7, 8, 10, 11]. With growth of the organism, there is a gradual increase in the MP level in all the muscles. However, the times of formation of a stationary MP value differ. MP for fibers of the neck muscles reaches its maximum during the first week after birth. Development of a stationary level of MP in the forelimb muscles takes place by the age of 10-12 days, when the weight-bearing reaction is first organized in these limbs. In the hind limb muscles this maturation is not complete until the 15th-20th day. By this time the type of activity of the limb muscles has been transformed from tonic into phasic-tetanic and the animals can now perform antigravity (weight-bearing) reactions on all four limbs [2].

The change in the level of polarization of the muscles takes place against the background of a gradual increase in their size and weight. However, growth of the linear (diameter and length of the fiber) dimensions and weight of the muscles continued even after the MP has reached its maximal level. The writer previously [4] drew attention to the close correlation between the MP values and the protein concentration in muscles. The total protein is evidently an indicator of the state of electrogenesis of muscle tissue, for up to a certain degree it reflects the state of the plasma membrane. The view can be accepted that growth of MP of the muscle cell is due to certain processes taking place in the muscle itself [8], but these processes are controlled by neurotrophic impulses from the successively maturing centers of innervation of the skeletal muscles [2].

Records of the EMG of three groups of muscles at different age periods are shown in Fig. 1. Clearly, during the first days after birth a regular electromyographic activity, differing in frequency, is recorded in all the muscles. With age the character of the electromyographic activity of the neck muscles is preserved, and only its frequency changes very slightly (from 6-7 to 8-10 spikes/sec). The stable frequency, as with the MP, is established during the first week of postnatal life. The electromyographic activity of the limb muscles is of a different character. During functional maturation of the corresponding nerve centers its rhythmic character is transformed into a series of volleys; the frequency of spikes in the volleys is increased, but the distance between the volleys is reduced. The change to volley activity is complete at the moment of stabilization of MP: in the forelimb muscles by the 10th-12th day and in the hind limb muscles by the 15th-20th day after birth.

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