Histochemical demonstration of three types of muscle fibers of the intercostal muscles. A study on oxidative enzymes

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Abstract

Since the classic work of Ranvier, it is well known that the mammalian striated muscle is composed of two types of muscle fibers, i.e., the red and white muscle fibers. In the previous paper it has been reported that the limb muscle fibers of mammals can be divided into three types from their activities of the histochemically demonstrable oxidative enzymes. Namely, the small red muscle fibers had a higher activity of oxidative enzymes, the large white muscle fibers a lower activity and the third type of muscle fibers being called “medium fiber” or “intermediate fiber” showed an intermediate activity between those of the red and white muscle fibers.
HISTOCHEMICAL DEMONSTRATION OF THREE TYPES OF MUSCLE FIBERS OF THE INTERCOSTAL MUSCLES. A STUDY ON OXIDATIVE ENZYMES

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Since the classic work of Ranvier, it is well known that the mammalian striated muscle is composed of two types of muscle fibers, i.e., the red and white muscle fibers. In the previous paper it has been reported that the limb muscle fibers of mammals can be divided into three types from their activities of the histochemically demonstrable oxidative enzymes. Namely, the small red muscle fibers had a higher activity of oxidative enzymes, the large white muscle fibers a lower activity and the third type of muscle fibers being called "medium fiber" or "intermediate fiber" showed an intermediate activity between those of the red and white muscle fibers.

Two different theories were reported concerning the functional differences of intercostal muscles. PATON and ZAIMIS, studying the response to D-tubocurarine and to decamethonium, considered that the intercostal muscles resemble the diaphragm and "slow" types of muscle such as soleus, rather than the "fast" types such as tibialis anterior. However, BISCOE concluded that the intercostal muscles were "fast" muscle in the cat from the observation of isometric contraction response to indirect stimulation. In the present investigation, a histochemical study of oxidative enzymes in the intercostal muscles of cat, monkey and man was made and the three different types of muscle fibers were clearly distinguished in the intercostal muscles by the difference of the enzyme activities.

The intercostal muscles of health adult cat and monkey served as materials. The human intercostal muscles were obtained at the thoracotomy. The muscles were cut into 20—40 micron thick sections in a cryostat at $-20^\circ C$ and mounted on a slide glass. For the histochemical demonstration of succinoxidase, lactic dehydrogenase, malic dehydrogenase, $\alpha$-glycerophosphate dehydrogenase and DPNH-diaphorase and TPNH-diaphorase were employed as in the methods described by PEARSE. After the incubation at $37^\circ C$ for 30 minutes, the slides were mounted by glycerin without dehydration.

In transverse sections of *M. intercostalis externus* of cat, three types of muscle fibers were clearly distinguished, i.e., small fibers showed a higher
dehydrogenase activity while large white fibers revealed a lower activity and medium fibers an activity between the red and white muscle fibers (Fig. 1). But a few red fibers and medium fibers have almost the same diameters of white muscle fibers. The intrafusal fibers of muscle spindles were also distinguishable into three types of fibers by their oxidative enzymes activities, as described in the previous paper. M. intercostalis internus likewise was composed of three different types of muscle fibers as those in M. intercostalis externus.

The intercostal muscles of monkey were composed of three different types of muscle fibers as those in the cat intercostal muscles.

The intercostal muscles of man were also composed of three types of fibers, however, the differences of oxidative enzyme activities and their diameters were not so prominent as in cat intercostal muscles.

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