

EFFECT OF ADAPTATION TO HYPOXIA ON THE WORKING  
PROPERTIES OF MUSCLES AND ENERGETICS OF MUSCULAR  
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The working properties and heat formation of skeletal muscles were investigated during contraction in laboratory rats adapted to hypoxia and corresponding controls. During indirect electrical stimulation of the muscle the strength of contraction, work, and fatigue ability of the muscle were determined and the increase in temperature of the muscle as a result of the contraction was measured. Adaptation to hypoxia was shown not to affect the strength of contraction of the muscle or the quantity of work done. However, hypoxia leads to a reduction in the temperature effect of muscular contraction, expressed per unit work done. This indicates an increase in the efficiency of muscular work during adaptation to hypoxia. The fatiguability of muscles is increased in "hypoxic" rats. The changes in the energetics of muscular contraction during adaptation to hypoxia and to cold are different in direction.

KEY WORKS: adaptation; hypoxia; muscle.

According to a well-argued opinion, in hypoxia considerable changes take place in the thermoregulatory system and, in particular, in the muscular system—the main source of controlled heat production in the body [3, 4, 9–12]. The writers showed previously [1] that during adaptation to hypoxia, unlike cold adaptation [5, 6], heat formation in the muscles per unit of electrical activity falls during thermoregulatory contraction. The question of changes in the working properties of muscles and the efficiency of muscular contraction during prolonged exposure to hypoxia requires experimental verification.

This paper describes an investigation of the working capacity of skeletal muscles and heat formation in them during contraction in albino rats adapted to hypoxia.

## EXPERIMENTAL METHOD

Experiments were carried out on male albino rats weighing 250–300 g. To produce adaptation of the animals to hypoxia, they were "raised" in a pressure chamber to an "altitude" of 7000 m for 3 h daily for 30–35 days. The temperature in the pressure chamber was maintained at between 22 and 24°C. Animals of the control groups were kept at the same temperature. During electrical stimulation of the motor nerve in situ the following indices were recorded: the strength of contraction of the muscle, the work done by it, and its temperature. The method of recording these indices was fully described previously [7, 8]. During the experiments the "core" temperature of the body was measured constantly by means of an electrothermometer. The rectal detector was inserted to a depth of 6 cm. Fatiguability was assessed from the decrease in the strength of muscular contraction at the end of a 10-sec period of tetanus, as a percentage of the initial level. The parameters of 146 muscular contractions (in ten animals adapted to hypoxia and 5 controls) were investigated.

## EXPERIMENTAL RESULTS AND DISCUSSION

The results are given in Table 1. The "core" temperature of the body in the rats adapted to hypoxia did not differ significantly from that of the controls. As the results in Table 1 show, prolonged exposure to hypoxia

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TABLE 1. Effect of Prolonged Exposure to Hypoxia on Working Capacity of Skeletal Muscles and Their Energetics

	Increase in temperature of contracting muscle, °C $\times 10^{-3}$ ( $\Delta T$ )	Strength of contraction, g	Work, g $\cdot$ cm (A)	Fatigue, %	$\Delta T/A$ , °C / (g $\cdot$ cm) $\times 10^{-3}$
Control	242,98 $\pm$ 11,8	49,24 $\pm$ 2,84	269,9 $\pm$ 29,9	31 $\pm$ 3,14	0,895 $\pm$ 0,143
Hypoxia	143,75 $\pm$ 12,5	51,9 $\pm$ 1,7	294,63 $\pm$ 17,9	54 $\pm$ 5,1	0,489 $\pm$ 0,082
P	<0,001	>0,05	>0,05	<0,01	<0,001

did not affect the strength of muscular contractions induced by electrical stimulation of the motor nerve. The quantity of work done likewise did not differ in the two groups of animals. However, there was a marked decrease in the temperature effect of muscular contraction per unit of work done in animals adapted to hypoxia. This indicates an increase in the efficiency of muscular contraction (and of muscular work) during prolonged exposure of the animal to hypoxia. Under these circumstances greater fatigue developed in the muscle of the rats adapted to hypoxia than in the controls: the ability to maintain the original strength of contraction during a 10-sec period of tetanus was reduced.

Despite the decrease in energy expenditure on the production of muscular work, the reserves for performance of work were evidently reduced after adaptation to hypoxia. The main component of the effect of hypoxia on the body is a shortage of energy, evidence of which is given by a decrease in the content of high-energy compounds in the tissues [2]. Prolonged exposure to a hypoxic atmosphere is evidently accompanied by changes of an adaptive character, aimed at the preservation of energetic homeostasis under conditions of a shortage of high-energy compounds, through a reduction in energy expenditure for the production of physical work. A change in the energetics of muscular contraction takes place both during adaptation to the temperature factor and to hypoxia. The change in efficiency, it is suggested, may be a general physiological principle of the regulation of functions during adaptation to different environmental factors.

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