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EFFECT OF HYPOKINESIA AND MUSCLE TRAINING ON MYOCARDIAL CATECHOLAMINE LEVELS DURING POSTNATAL DEVELOPMENT IN RATS

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The study of myocardial catecholamine levels is of great importance for an understanding of the mechanisms of regulation of cardiac activity, especially under extremal conditions [3, 11-13]. An increase in the specific noradrenalin content in the myocardium, i.e., expressed as a ratio of weight of the heart, has been observed [1] during postnatal development under the influence of muscle training, whereas the adrenalin concentration remained unchanged. Data on the effect of hypokinesia on catecholamine levels in the myocardium of the developing animal could not be found in the literature.

The aim of this investigation was to determine the effect of hypokinesia and muscle training on the catecholamine concentration in the myocardium of rats during postnatal ontogeny.

EXPERIMENTAL METHOD

Experiments were carried out on noninbred albino rats. Rats aged 3 weeks were divided into three groups. The animals of group 1 were kept under conditions of restricted movement (according to the writer's own program) in individual restraining cages specially made for this purpose. Animals of group 2 were kept for the same period in ordinary cages, six to eight rats in each cage (control). Rats of group 3 were subjected to an increasing muscular load due to swimming six times a week for 50 days [1]. Some animals were decapitated 24 h after the end of the last period of training and of hypokinesis to determine catecholamines in their myocardium at rest. The remaining animals were compelled to swim carrying a load equal to 5% of body weight, until exhausted. The maximal duration of swimming was indicated by the time when the rat could no longer rise to the surface of the water to breathe. Animals which had reached this state were quickly removed from the water and killed. After decapitation, thoracotomy was performed and the beating heart removed. By immersion several times in distilled water blood was removed from the heart, which was then freed from the remains of the great vessels. Before weighing, the heart was dried with filter paper. The adrenalin and noradrenalin concentrations in the myocardium were determined by a fluorometric method and expressed in μg/g [6]. Catecholamines were oxidized with aluminum oxide by Brockman's method.

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TABLE 1. Catecholamine Concentrations (in μg/g) in Myocardium of Rats during Postnatal Development, at Rest and after Exhausting Muscular Work

Age of animals, weeks	Experimental conditions	Number of animals	At rest			After exhausting muscular work				
			adrenalin	noradrenalin	A:NA	Number of animals	duration of swimming, min	adrenalin	noradrenalin	A:NA
3		19	0,049±0,003	0,121±0,006	1:2,4	21	148.9±9,26	0,039±0,004	0,72±0,004	1:1.9
10	Hypokinesia	22	0,057±0,002	0,147±0.004	1:2,6	20	244,5±7,73	0,036±0,008	0,093±0.003	1:2.6
	Control	20	0,063±0,001	0,193±0,007	1:3	20	307,2±17,5	0,041±0,002	0,120±0.003	1:2.9
	Training	21	0.078±0,002	0,242±0.007	1:3.2	20	390.6±21,3	0,041±0,009	0,149±0.003	1:3.6

EXPERIMENTAL RESULTS

The weight of the heart in rats adapted to swimming (665.9 ± 28.8 mg) was greater than in intact animals (498.6 ± 19.2 mg). The weight of the heart in rats exposed to hypokinesia (372.0 ± 12.0 mg) was much greater than in animals aged 3 weeks (162.2 ± 7.5 mg), but less than the weight of the heart of animals in the control group. Consequently, muscle training causes the development of relative hypertrophy of the myocardium whereas hypokinesia delays the increase in weight of the heart. Whereas in mature rats hypokinesia leads to atrophy of myocardial tissue [9], in the developing animal it delays the rate of natural development of heart tissue.

Training by swimming accelerated the age increase in catecholamine concentrations in the myocardium, as a result of which the specific content of both amines in myocardial tissue of the trained rats was higher than in the control animals (Table 1). During hypokinesia the catecholamine concentration in the myocardium remained lower than in rats of the control group. Both during natural growth of the rats and also under the influence of muscle training and hypokinesia, changes in the nonadrenalin concentration in the myocardium were more marked than those of adrenalin. The adrenalin : noradrenalin (A:NA) ratio thus varied with age and, in particular, under the influence of training by swimming in favor of predominance of noradrenalin (1:3.2). In rats exposed to hypokinesia the ratio was only 1:1.26.

Consequently, muscle training stimulates whereas hypokinesia delays the development of age predominance of the noradrenalin level in the myocardium.

One session of swimming until exhaustion caused considerable changes in the myocardial catecholamine levels. The specific adrenalin content in the myocardium of the control rats and rats exposed to hypokinesia fell compared with resting levels by 35 and 37% respectively. Changes in the adrenalin concentration in the myocardium of the trained rats amounted to 49%. In rats 3 weeks old exertion caused a decrease in the specific adrenalin content by only 25%. The post-exercise adrenalin level in the myocardium of all rats studied was therefore identical, i.e., the differences observed at rest were smoothed out.

The specific noradrenalin content in the myocardium after exercise compared with initial values at rest showed a reduction in rats 3 weeks old by 0.049, in rats 10 weeks old and exposed to hypokinesia by 0.054 μg/g, in control rats by 0.073 μg/g, and in trained rats by 0.131 μg/g. Intergroup differences in the myocardial noradrenalin level after exercise, although considerably reduced, still remained significant.

Under conditions of systematic muscular training an increase in the adrenalin and noradrenalin concentrations took place in the rat myocardium during postnatal development. Meanwhile, in previous investigations on guinea pigs of the same age, only noradrenalin was found to accumulate in the myocardium [1]. This could be a manifestation of a species difference between the animals as regards adaptation of catecholamine levels to motor activity. Hypokinesia in rats during postnatal development delays catecholamine accumulation in the myocardium, as a result of which the concentrations of both amines were lower in these rats than in the control animals. In mature rats, on the other hand, the adrenalin concentration rises during hypokinesia [11]. This is evidently due to the development of a stress syndrome in the animals because of the strict limitation of motor activity imposed by the restraining cages [7]. Our conditions of hypokinesia completely ruled out the development of stress. The young rats tolerated hypokinesia after the first days of their stay in the specially constructed individual cages in a relaxed manner.

The A:NA ratio was found to correlate with motor activity. The trained rats had more marked, those exposed to hypokinesia less marked predominance of the myocardial nonadrenalin level.

On the basis of views of a number of workers [5, 12] it can be postulated that conditions of functioning of the trained heart are more favorable than those of rats exposed to hypokinesia in postnatal development.

Differences in the catecholamine concentration in the myocardium of the rats exposed to swimming and to hypokinesia indicate, first, changes in the functional reserve capacity of the heart in postnatal development. At the same time, changes in myocardial catecholamine levels determine the regulatory behavior of the heart [1, 3, 8, 10]. Depressed sensitivity of the adrenoreceptors of the heart corresponds to a high catecholamine concentration in the myocardium of trained rats during postnatal development. During hypokinesia, the relatively low catecholamine concentrations help to maintain the adrenoreceptor sensitivity of the myocardium at a higher level. Consequently, the character of the chronotropic function of the heart of the developing animal, exposed to training or to hypokinesia, is determined by interaction between catecholamines and special protein structures, namely the adrenoreceptors of the myocardium.

A single exhausting exposure of the animals to swimming caused a sharp decrease in myocardial catecholamine concentrations. Similar changes in the myocardial catecholamine concentrations of mature rats were observed previously during exhausting exercise [4]. However, irrespective of age and of adaptation to different levels of motor activity, in rats during postnatal development there is a critical level of the minimal adrenalin concentration in the myocardium (on average 0.04 μg/g), a fall of which makes further continuation of muscular activity impossible.

Consequently, muscle training facilitates whereas hypokinesia inhibits the formation of catecholamine reserves in the myocardium, and this exerts a significant effect on the function of the heart in postnatal ontogeny.

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