PHYSIOLOGY

Pumping Action of the Heart in Rat Pups Subjected to Muscle Training at Different Terms of Postnatal Ontogeny

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Experiments performed on random-bred rat pups showed that muscle training during earlier terms of postnatal ontogeny produce more pronounced changes in the pumping function of the heart.

Key Words: *age; muscle training; pumping function; heart; control*

Considerable attention was recently focused on the effects of various modes of motor activity on cardiac functions and mechanisms of heart regulation in the postnatal ontogeny [1,5]. Many papers studied peculiarities of the chronotropic function of the heart in the developing organism. The mechanisms of stroke volume (SV) regulation in prepubertal animals are little studied; most of these studies were carried out in Kazan' State Pedagogical University [2,4]. In this work, we studied the pumping function of the heart in rats subjected to muscle training starting from postnatal days 14 and 21.

MATERIALS AND METHODS

The study was carried out on random bred albino rats aging 14, 21, 42, and 70 days. These periods were selected on the basis of anatomic and physiological peculiarities of animals [5].

For modeling different regimens of motor activity, 14-day-old rat pups were divided into control and two experimental groups. Group 1 rats (*n*=8) were kept under standard vivarium conditions with unrestricted motor activity. Groups 2 and 3 rats were subjected to muscle training at the age of 14-70 and 21-70 days, respectively (high motor activity). Tetrapolar thoracic rheography was used to determine SV [7]. Differential rheogram was recorded with a RPG-204 rheograph in rats narcotized with Nembutal (40 mg/kg) under natural ventilation. To examine the sympathetic influences on the pumping function of the heart, 0.1% propranolol (0.8 ml/100 g) and 10^{-7} M prozasin (0.17 mg/100 g) were injected into the jugular vein through a catheter. Parasympathetic influences were blocked with atropine sulfate. Sympathetic and parasympathetic influences on the pumping function of the heart were assessed by changes in HR, SV, and cardiac output (CO) after pharmacological blockade of the corresponding receptors.

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RESULTS

In 14-day-old control rats (group 1), HR was 380.3 bpm, on day 42 this parameter increased to 438.3 bpm (Table 1). In group 2 rats, HR did not change significantly (377-380 bpm).

In group 1 rats, SV increased by 0.067 ml from day 14 to day 42 and by 0.125 ml from day 42 to day 70 (Table 1).

Muscle training significantly increased SV in rat pups. Regular physical exercises (swimming) from postnatal day 14 to day 42 increased SV by 0.196 ml

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(p<0.05) and by 0.089 ml from day 42 to day 70 (p<0.05).

In rats subjected to muscle training (from day 14 to day 42) this increase in SV was 2-fold less pronounced (compared to rats treated from day 21), while from day 42 to day 70 this parameter increased by 0.089 ml (p<0.05). It should be noted that we found no significant differences in SV between rats trained from day 14 and from day 21.

We analyzed weekly increment of SV in rats subjected to physical exercises. In group 3 rats SV increased by 0.032 ml per week until day 42. In group 2 rats this parameter rose by 0.049 ml per week, which in greater by 0.017 ml in comparison with group 3 rats (p<0.05). However, in group 2 and 3 rats from day 42 through 70 SV rose by 0.022 and 0.047 ml per week, respectively.

The analysis of CO in rats trained from day 14 and from day 21 also revealed differences between these groups: in rats trained from day 14 CO increased by 73.7 ml/min to day 42 (p<0.05), which 1.8-fold surpassed CO increment in rats trained from day 21.

In group 3 rats, CO increased by 13.3 ml/min per week from day 21 to day 42. At the age of 42-70 days, weekly CO increment in these rats was more pronounced: 17.2 ml/min. In group 2 rats, CO increased by 18.4 ml/min per week up to day 42, but at the age of 42-70 days this parameter rose less significantly (by 6.8 ml/min). Thus, in rats subjected to physical exercises in the early ontogeny, weekly increment of CO was most pronounced soon after the start of training, but then significantly moderated. By contrast, in rats trained from day 21 the rate of CO changes was low at the initial stages, but then considerably increased.

Thus, in group 2 rats the most pronounced changes in the pumping function of the heart occurred on days 14–42, while in group 3 rats these changes peaked on days 42 through 70.

To study the role of sympathetic and parasympathetic influences in the effects of physical activity on the cardiac function, propranolol, prozasin, and atropine were injected into the jugular vein via a catheter.

In group 2 rats, injections of propranolol and prozasin moderated HR (compared to baseline) by 83.7 and 39.3 bpm, respectively (Table 2). Atropine increased HR in these rats by 87.7 bpm. Swimming from postnatal day 42 through 70 moderated HR response to propranolol and prozasin: on day 70 HR decreased only by 76.0 and 30.2 bpm, respectively (Table 2). In trained rats, injection of atropine on day 70 increased HR by 105.8 bpm. Thus, changes in HR produced by blockers of α-adrenergic, β-adrenergic, and muscarinic cholinergic receptors were less pronounced on day 70, compared to day 42. Therefore, in 14-70-day-old rats subjected to regular muscle training, the decrease in HR resulted from enhanced vagal activity accompanied by moderation of sympathetic influences in the regulation of the chronotropic function of the heart. During training, sympathetic and parasympathetic regulation of HR is realized in different ways: sympathetic influences decreased by 12.7% to postnatal day 70 (compared to baseline), while parasympathetic influences increased by 22.7% (p<0.05). These changes in the regulation of HR were more pronounced in trai-

TABLE 1. Effect of Physical Exercise on HR (bpm) and SV (ml) in Rats (*M*±*m*)

Age, days		*n*	UMA	PE
HR	14	20	380.30±7.71	
	42	19	438.30±9.58*	377.40±7.72
	70	55	427.20±8.04	358.50±5.38
SV	14	19	0.042±0.003	
	42	18	0.109±0.012*	0.238±0.018*
	70	54	0.234±0.011*	0.327±0.014*
CO	14	20	15.90±2.85	
	42	19	47.70±4.92*	89.70±3.97*
	70	105	99.90±4.19*	117.00±6.11

Note. Here and in Tables 2 and 3: UMA — unrestricted muscle activity (control rats); PE — physical exercise. *p<0.05 compared to similar values of the previous group.

TABLE 2. HR Response (%) to Blockade of Adrenergic and Cholinergic Receptors in Rats Subjected to Physical Exercise (*M*±*m*)

Age, weeks	Mode of motor activity	Propranolol	Prozasin	Atropine
2	UMA	33.8±2.3	16.0±2.4	6.5±1.8
6	UMA	29.1±2.6*	14.6±2.3	12.1±2.2*
	PE	22.1±2.5*	14.0±2.5	22.7±1.7*
10	UMA	26.3±1.3*	13.8±3.8	21.6±1.6*
	PE	21.1±2.4*	10.6±2.3	29.2±1.8*

TABLE 3. SV Response (%) to Blockade of Adrenergic and Cholinergic Receptors in Rats Subjected to Physical Exercise (*M*±*m*)

Age, weeks	Mode of motor activity	Propranolol	Prozasin	Atropine
2	UMA	18.5±3.3	26.6±4.8	35.8±3.4*
6	UMA	17.2±2.9*	21.6±4.4	23.5±2.1*
	PE	22.3±3.1*	24.5±3.3	18.8±3.3*
10	UMA	13.60±2.07*	17.3±4.8	18.6±2.4*
	PE	16.60±1.08*	18.5±6.7	15.8±2.1*

ned rats than in controls. In trained rats, sympathetic influences on HR decreased by 11.7% during days 14-42, but decreased only by 1% during days 42-70 ($p<0.5$).

In 70-day-old rats trained from postnatal day 14, HR responses to propranolol and atropine were 21.1 and 29.2%, respectively. Therefore, muscle activity at earlier period of ontogeny resulted in more pronounced moderation of sympathetic influences in HR regulation.

In group 2 rats on postnatal day 42, SV responses to blockers of β-, α-adrenergic receptors and muscarinic receptors were 0.051, 0.046, 0.044 ml ($p<0.05$), respectively (Table 3). Hence, in the period of muscle training from day 14 to day 42, the sympathetic influences on SV decreased insignificantly in comparison with the initial values. During 42-70 days, SV response to propranolol and atropine also decreased. In 70-day-old trained rats, SV responses to propranolol and prozasin were 0.056 and 0.052 ml, respectively (Table 3). Atropine increased SV by 0.053 ml in comparison with the initial data (Table 3). Therefore, sympathetic and parasympathetic influences on SV moderate during continuation of muscle training on days 42-70. To postnatal day 70, the sympathetic influence on SV was more pronounced in trained rats compared to controls. Thus, muscle training started at more early periods of ontogeny resulted in more pronounced moderation of sympathetic and parasympathetic influences on SV.

Therefore, in rat pups subjected to regular muscle training during 21-70 postnatal days, the most pronounced changes in the pumping function of the heart were observed on days 42-70. By contrast, in rats trained from 14 postnatal days through 70 the most pronounced changes were observed on days 14-42. Physical exercises at earlier periods of postnatal development considerably modulate pumping action of the heart and the mechanisms of their regulation.

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