LOCAL ADAPTIVE CHANGES IN THE MYOCARDIUM IN RESPONSE TO STATIC PHYSICAL EXERCISE

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Structural changes in the heart in response to physical exercise have been studied sufficiently well [1, 4, 7, 9, 10]. However, contradictory data have been obtained on hypertrophy of the heart muscle during systematic physical exercise, and there is no general agreement on the morphological and functional changes in the hypertrophied heart [2, 5, 10]. The structural reorganization of local myocardial regions under the influence of static exercise likewise has not been adequately studied.

The aim of this investigation was to study structural changes in different parts of the albino rat heart during systematic static exertion.

EXPERIMENTAL METHOD

The hearts were studied from 30 male Wistar albino rats weighing 180.0 ± 8.4 g, divided into two groups. Group 1 (control) consisted of 12 rats kept under ordinary conditions in the animal house; group 2 consisted of 18 experimental animals, engaged daily for a period of 2 months in static exertion, increasing gradually in duration from 1 to 60 min (moderate loading), and consisting of holding the body suspended on poles above water [5]. After rapid decapitation of the animals the heart was opened by the method in [3] and separated into six parts: the left and right ventricles, ventricular septum, left and right atria, and atrial septum. The weights of the whole heart, the left and right ventricles, ventricular septum, and left and right atria were determined and the ratio between the weights of the ventricles and atria calculated, and weights of the individual parts calculated as percentages of the whole. The area of the endocardial surface of the left and right ventricles and also of the atria was measured and their relative values determined. Pieces of tissue from the regions of the myocardium, after appropriate histological treatment, were embedded in paraffin wax. Sections were stained with hematoxylin and eosin and by Weigert's, Van Gieson's, and Heidenhain's methods. The diameter of the cardiomyocytes and their nuclei, and the nucleo-cytoplasmic and stromal-parenchymatous ratios of the ventricles and atria were determined histostereometrically [1]. The numerical results were subjected to statistical analysis on the "Élektronika-MK-54" programmed microcalculator.

EXPERIMENTAL RESULTS

Analysis of the results of morphometry showed substantial structural changes in the local regions of the myocardium in the experimental animals subjected to systematic static exertion. A tendency was noted for the weights of all parts of the heart to increase, but the right ventricle and right atrium were hypertrophied the most (Fig. 1). Disturbances of the ratios between the weights of the ventricles and an increase in weight (expressed as a percentage) of the right ventricle and left atrium confirmed this conclusion. A similar time course was observed on analysis of the planimetric parameters of the different parts of the heart (Fig. 1). In this case also the greatest degree of dilatation was found in the chambers of the right heart (right ventricle and right atrium).

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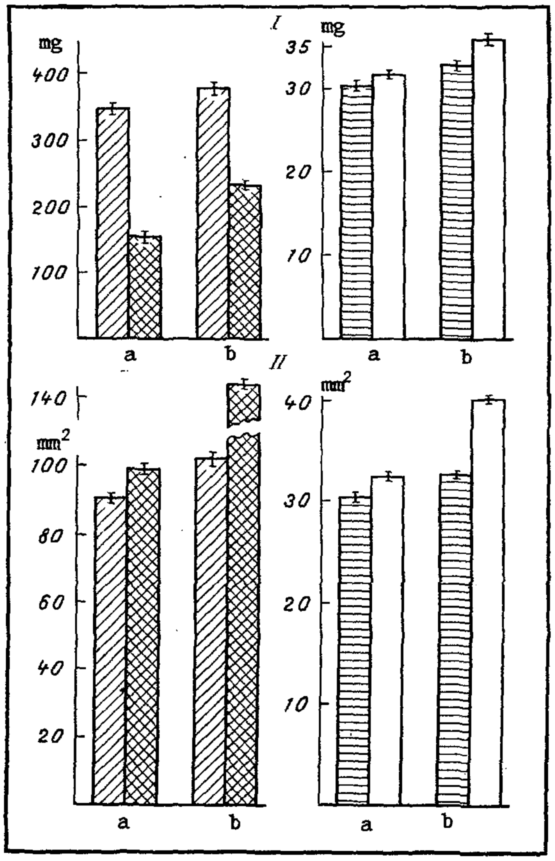

Fig. 1. Changes in weight of parts of the heart (I) and area of their endocardial surfaces (II) in rats under the influence of static physical exertion. Oblique shading – left ventricle, cross-hatching – right ventricle, horizontal shading – left atrium, unshaded columns – right atrium; a) control, b) experimental animals.

TABLE 1. Histostereometric Parameters of Different Parts of the Myocardium of Albino Rats under Normal Conditions and after Static Physical Exertion ($X \pm S_{\overline{X}}$)

Parameter	Group of animals	
	1 (n = 12)	2 (n = 18)
Diameter of cardiomyocytes of LV, μ	15.01 ± 0.48	16.2 ± 0.6
Diameter of nuclei of LV, μ	5.42 ± 0.18	5.97 ± 0.24
Nucleo-cytoplasmic ratios of LV ($\cdot 10^{-2}$)	13.04 ± 0.45	13.60 ± 0.48
Stromal-parenchymatous ratios of LV ($\cdot 10^{-2}$)	15.10 ± 0.51	15.61 ± 0.57
Diameter of cardiomyocytes of RV, μ	13.6 ± 0.3	16.43 ± 0.57*
Diameter of nuclei of RV, μ	5.08 ± 0.15	6.19 ± 0.21*
Nucleocytoplasmic ratios of RV ($\cdot 10^{-2}$)	14.0 ± 0.3	14.2 ± 0.5
Stromal-parenchymatous ratios of RV ($\cdot 10^{-2}$)	15.2 ± 0.5	15.8 ± 0.6
Diameter of cardiomyocytes of VS, μ	15.3 ± 0.4	16.4 ± 0.7
Diameter of nuclei of VS, μ	5.03 ± 0.15	5.98 ± 0.24
Nucleocytoplasmic ratios of VS ($\cdot 10^{-2}$)	13.10 ± 0.36	13.51 ± 0.51
Stromal-parenchymatous ratios of VS ($\cdot 10^{-2}$)	15.06 ± 0.48	15.2 ± 0.6
Diameter of cardiomyocytes of LA, μ	10.7 ± 0.3	11.9 ± 0.4
Diameter of nuclei of LA, μ	4.12 ± 0.15	4.63 ± 0.18
Nucleo-cytoplasmic ratios of LA ($\cdot 10^{-2}$)	14.8 ± 0.5	15.1 ± 0.6
Stromal-parenchymatous ratio of LA ($\cdot 10^{-2}$)	18.63 ± 0.51	18.4 ± 0.7
Diameter of cardiomyocytes of RA, μ	9.6 ± 0.3	12.5 ± 0.5*
Diameter of nuclei of RA, μ	3.82 ± 0.12	4.99 ± 0.18*
Nucleo-cytoplasmic ratios of RA ($\cdot 10^{-2}$)	15.70 ± 0.54	15.93 ± 0.60
Stromal-parenchymatous ratios of RA ($\cdot 10^{-2}$)	18.10 ± 0.57	18.4 ± 0.6

Legend. Values marked with an asterisk differ statistically significantly from the control ($p < 0.05$-0.001). LV) Left ventricle, RV) right ventricle, VS) ventricular septum, LA) left atrium, RA) right atrium.

The dimensions of the cardiomyocytes and their nuclei correlated ($r = +0.673 \pm 0.003$) with the gravimetric parameters for parts of the heart. The diameters of the cardiomyocytes and their nuclei increased proportionally and uniformly, and this was reflected in the stability of values of the nucleo-cytoplasmic ratios (Table 1). Definite correlation is known to exist between the dimensions of the nucleus and cytoplasm [8], and this may be changed in cases of functional or morphological damage to the cell [6, 8]. The constancy of the nucleo-cytoplasmic index in all parts of the heart indicates that during moderate static exertion, despite the presence of hyperfunction and hypertrophy of local regions of the myocardium, no functional overstress or damage to the cardiomyocytes occurs. No significant deviations were found in the ratio of the weight of the stroma and parenchyma in the different parts of the myocardium. The above remarks were completely confirmed by a detailed histological study of microscopic sections of parts of the heart.

The experiments thus showed that under the influence of moderate systematic static exertion, hyperfunction and hypertrophy arise in parts of the heart, with a predominant increase in weight of the right ventricle and right atrium and with dilatation of their chambers. This can be explained by the greater load thrown on the right ventricle and right atrium, compared with other parts of the heart [7, 10]. The disproportion of hyperfunction and hypertrophy of the local regions of the myocardium at the organ level, thus revealed, was characterized by the balanced and proportionate nature of adaptive processes at tissue and cellular levels, as reflected in stability of the nucleo-cytoplasmic and stromal-parenchymatous ratios.

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