CHANGES IN THE FUNCTIONAL STATE OF THE PERIPHERAL PORTION OF THE CIRCULATORY APPARATUS IN CONNECTION WITH MUSCULAR ACTIVITY

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During recent years the changes arising in the peripheral portion of the circulatory apparatus under the influence of muscular work has interested many investigators [2-7]. They have shown that the study of the blood stream can reveal some aspects of the mechanism of adaptation of the vascular system to physical effort.

The object of the present investigation was to study the vascular reactions arising under the influence of prolonged muscular activity.

EXPERIMENTAL METHOD

As the experimental load, work for 40 min on a bicycle ergometer at the fastest speed possible for each subject was chosen. Altogether 30 investigations were made of 23 athletes trained for prolonged work and on 9 untrained persons. The tachyoscillograms and sphygmograms were recorded by N. N. Savitskii's method [8] before exertion and 30 and 90 sec and 3, 5, 10, and 15 min after the beginning of recovery. The systolic blood volume was calculated by the method of Bremser and Ranke. The peripheral resistance (W) of the precapillary system was calculated in conventional units from the formula:

$$W = \frac{MP \cdot 60}{MV}$$

where MP is the mean arterial pressure and MV the minute volume of the circulation.

Knowing the velocity of spread of the pulse wave along the arteries of elastic (S_e) and muscular (S_m) types, the modulus of elasticity of the wall of these vessels was determined:

$$E_e = \frac{C_e^2}{74}, \quad E_m = \frac{C_m^2}{112},$$

where E_e is the modulus of elasticity of the vessels of elastic type and E_m the modulus of elasticity of vessels of muscular type.

EXPERIMENTAL RESULTS

In persons trained for prolonged work, the mean value of W at rest was 1.15 conventional units (c.u.). According to Parin [9], in healthy subjects W varies between 0.85 and 1.0 c.u. Under the influence of physical exertion, W usually falls in connection with dilatation of the arterioles of the working muscles. After work on the bicycle ergometer, W fell to 0.5 c.u. It had not fully recovered after rest for 15 min.

In the subjects of the control group the value of W before work (1.27 c.u.) was higher than in the subject of the experimental group (the difference is significant, $P < 0.01$), while immediately after work it was the same in both groups (0.5 c.u.). Recovery took place more slowly in the experimental group than in the control.

In the trained subject the mean value of E_e before work was 4910 dynes/cm^2, and the value of E_m 5910 dynes/cm^2. A matter of considerable interest is the ratio E_m/E_e, characterizing the elastic properties of the arteries irrespective of the level of the arterial pressure. In this case the value of the ratio was 1.2. After recovery for 30 sec,

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TABLE 1. Changes in E_e in Connection with Work for 40 min on the Bicycle Ergometer (M ± m)

Subjects	Before work	After work					
		30 sec	90 sec	3 min	5 min	10 min	15 min
Trained	4 910±270	8 900±440	6 620±350	5 960±330	5 680±230	5 580±220	5 190±220
Untrained	6 800±320	8 900±410	10 600±520	9 950±360	9 600±310	7 700±200	8 360±210

TABLE 2. Changes in the Ratio E_0/W in Connection with Work for 40 min on the Bicycle Ergometer (M ± m)

Subjects	Before work	After work				
		30 sec	3 min	5 min	10 min	15 min
Trained	0,54±0,03	2,5±0,15	1,41±0,08	1,15±0,07	1,02±0,04	0,98±0,05
Untrained	0,70±0,1	3,48±0,3	2,05±0,29	1,61±0,21	1,49±0,15	1,29±0,18

E_e was 82% higher than before work (Table 1), i.e., under the influence of prolonged work the rigidity of the aortic wall was increased. The ratio E_m/E_e fell in connection with work from 1.2 to 1.06 ($P < 0.01$). If the relative increase in the degree of stretching of the wall of the aorta protects it from overstretching at a high arterial pressure, the increase in the elasticity of the arteries of muscular type facilitate the more active direction of the blood flow into these vessels of the working muscles. In addition, since the total capacity of the vessels of muscular type is much greater than the capacity of the aorta, according to N. N. Savitskii [8], during the systolic period they may accumulate the greater part of the energy liberated by the heart.

In the subjects of the control group, E_e at rest was 39% higher than E_e in the subjects of the experimental group (Table 1). The difference between the mean values is significant ($P < 0.01$). E_m was also higher in the untrained subjects (6850 dynes/cm^2), so that the ratio E_m/E_e was equal to unity. After work E_e did not rise immediately (see Table 1), but eventually reached much higher values than in the persons of the experimental group. The ratio E_m/E_e fell under the influence of work to 0.82. The value of E_m in these circumstances remained unchanged (6850 dynes/cm^2). This means that the ratio E_m/E_e changed entirely on account of an increase in the degree of stretching of the wall of the aorta, and no decrease in the rigidity of the vessels of muscular type took place, and their elasticity was not increased. This fact also demonstrates that the reactions to prolonged work of the blood vessels were more efficient in the trained subjects than in the untrained.

The total elastic resistance of the vessels overcome by the heart during systole may be designated E_0. The work of the heart, except for a small fraction, ultimately goes on overcoming the peripheral resistance. Because of the elasticity of the vessels this work is distributed throughout the period of the cardiac cycle, thus calling for cardiac contractions of less power. It is, therefore, important to know the relationship between the total elastic resistance of the arteries (E_0), and the resistance of the precapillaries. Calculating methods of determining the minute volume of the blood flow are unsuitable for the calculation of E_0. Accordingly, N. N. Savitskii [8], suggested a formula from which the ratio E_0/W could be calculated at once, without the need for determining E_0:

$$\frac{E_0}{W} = \frac{\Delta p}{MP \cdot D},$$

where Δp is the true pulse amplitude and D the duration of diastole.

Before work the mean value of the ratio E_0/W in the trained subject was 0.54 (Table 2), and the limits of variation of this index for healthy subjects were 0.37-0.56. Under the influence of work the ratio E_0/W was increased by more than four times (plus 355% of the resting level). Recovery was not complete after rest for 15 min.

In the subjects of the control group the value of E_0/W at rest was 30% higher than this index in the experimental group, after resting for 30 sec it was 40% higher, and for 3 min—46% higher. However, these differences are not statistically significant. Nevertheless, it may be considered that in trained subjects, by comparison with untrained, a small proportion of the energy of cardiac contraction is expended directly on the movement of the blood, and the greater proportion is accumulated by the blood vessels.

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