AEROBIC WORKING CAPACITY IN RUNNERS

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UDC 612.231/.234-06:612.761:796.422

Fourteen trained runners were investigated by performance tests involving exertion increasing by 50 W every 2 min on a bicycle ergometer until refusal. The gas exchange, pulse rate, ventilation of the lungs, and the state of the acid-base balance were determined. The maximal O_2 consumption (MOC) correlates with the maximal CO_2 elimination, the maximal pulmonary ventilation, the maximal oxygen pulse, and the watt-pulse. The pH was reduced during work by a lesser degree in those runners whose MOC was higher. The mean error for determination of the maximal O_2 consumption by Margaria's indirect method is +10%.

The aerobic performance reflects the functional state of athletes and, in particular, their endurance [1, 5, 3]. Recently the integral index of aerobic performance, the maximal oxygen consumption (MOC), has frequently been determined by the use of exertion of increasing magnitude until the subject refuses to work [2, 4, 7]. The value of MOC depends on many factors and, primarily, on the functional state of the cardiovascular and respiratory systems and the composition of the blood [2, 3, 6, 9].

In the investigation described below the MOC was correlated with certain indices of respiratory and cardiovascular function and the informativeness of Margaria's indirect method of determining the MOC was studied [8].

EXPERIMENTAL METHOD

Fourteen trained medium- and long-distance runners (age 21-28 years) were investigated at the end of the intermediate period of their training. The volume of the heart was determined in these athletes and their pneumotachometric indices were measured. The mean height of the subjects was 177.7 ± 1.2 cm (M ± m), their mean weight 65.8 ± 1.6 kg, the vital capacity of the lungs 5.887 ± 124 ml, and pneumotachometry at inspiration was 6.9 ± 0.4 liters/sec and at expiration 5.9 ± 0.2 liters/sec.

The work was done on a bicycle ergometer, and its power was increased every 2 min by 50 W until the subject could carry on no longer. The initial power of work was 150 W, and it ended with pedaling for 1 min as fast as possible. The speed of pedaling during work (75 rpm) was fixed by means of a metronome. Gas exchange was studied by the Douglas-Haldane method. Samples of expired air were collected in a Douglas bag before work and during each stage of exertion during its last 30 sec. The heart rate was recorded continuously on a cardiotachograph.

Before and during work (at the 5th or 6th minute) and 2-5 min after the end of work, samples of capillary blood were taken. The indices of acid-base balance were determined by Astrup's micromethod.

Coefficients of correlation were calculated between all the indices found. The MOC was determined indirectly by Margaria's step test [8]. The runners exercised for two periods, each of 5 min, at the rate of 15 and 25 steps per minute on a stool. The height of the stool was 40 cm.

Tartu University. (Presented by Academician V. V. Parin (deceased).) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 73, No. 1, pp. 25-27, January, 1972. Original article submitted April 30, 1971.

TABLE 1. Mean Results of Function Tests

Test	M ± m	x_{min}–x_{max}
MOC (in liters/min)	4.05 ± 0.15	3.35–5.10
MOC (in ml/kg · min)	62.1 ± 2.7	45.0–81.0
Maximal CO_2 excretion (in liters/min)	4.63 ± 0.19	3.66–5.70
MOC determined from nomogram (in ml/kg · min)	68.9 ± 1.3	60.0–75.0
Maximal pulmonary ventilation (in liters/ min)	163.4 ± 8.7	114.0–224.0
Maximal oxygen pulse (in ml/beat)	21.5 ± 0.9	17.0–28.6
Maximal pulse rate	192.2 ± 3.8	175–220
Watt-pulse (in W/ beat)		
pH:	1.79 ± 0.07	1.37–2.20
Before work	7.39 ± 0.01	7.36–7.43
During work	7.33 ± 0.02	7.28–7.39
After work	7.22 ± 0.02	7.10–7.31
Standard bicarbonate (in meq/liter):		
Before work	24.1 ± 0.6	22.0–26.0
During work	22.0 ± 0.5	20.0–23.0
After work	15.6 ± 0.5	13.6–18.4

EXPERIMENTAL RESULTS

The results indicating physiological changes in the indices of the circulation, respiration, and acid-base balance are given in Table 1.

The investigation showed that the MOC was higher in those runners who obtained better results in running 1500 m ($r = -0.763$). The correlation between MOC and performance in running 800 m was not significant ($r = -0.366$). Anaerobic processes are evidently more important in running 800 m [1, 9].

Correlation analysis shows that MOC correlates closely with the maximal pulmonary ventilation ($r = 0.649$), the maximal CO_2 excretion ($r = 0.751$), and the maximal oxygen pulse ($r = 0.905$). The correlation found between MOC and the maximal pulmonary ventilation during work emphasizes the part played by the functional capacity of the external respiratory system in providing the body with its largest possible supply of oxygen. Maximal ventilation during increasing loading is a more informative index than the maximal ventilation measured at rest with the aid of hyperventilation [2].

Aerobic working capacity is also correlated with the maximal watt-pulse, i.e., the ratio between the maximal power of work and the pulse rate during the maximal exertion ($r = 0.543$).

This investigation shows that in runners with higher values of MOC the changes in pH of the capillary blood both during and after work were smaller than in runners with lower MOC values ($r = 0.944$ and $r = 0.782$ respectively). It is interesting to note that other indices of acid-base balance (standard bicarbonate, pCO_2) do not correlate with aerobic working capacity.

The use of Margaria's step test [8] is recommended for the determination of MOC. This investigation showed that MOC calculated from Margaria's nomogram is on the average 10.7% higher than the true MOC values. Correlation between these values was relatively high ($r = 0.811$).

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