DOCUMENT RESUME

ED 106 260 SP 009 169

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TITLE	Athletes and Sedentary Individuals: An Intergroup Comparison Utilizing a Pulmonary Function Ratio Obtained During Submaximal Exercise.
PUB DATE	Mar 75
NOTE	9p.
EDRS PRICE	MF-$0.76 HC-$1.58 PLUS POSTAGE
DESCRIPTORS	Athletes; *Cardiovascular System; *Exercise (Physiology); Groups; Higher Education; Human Body; *Physical Fitness; Statistical Data
IDENTIFIERS	*Ergometer

ABSTRACT

A pulmonary function ratio describing oxygen extraction from alveolar ventilation was used for an intergroup comparison between three groups of athletes (rugby, basketball, and football players) and one group of sedentary subjects during steady-state submaximal exercise. The ratio and its component parts are determined from only three gas fractions: (a) alveolar carbon dioxide, (b) expired carbon dioxide, and (c) expired oxygen. Exercise was conducted on a bicycle ergometer at a power load of 900 kpm/min, and an open circuit method, adapted for the determination of end-tidal carbon dioxide, was used for gas analysis. Significant differences (.025 level) were found between each of the three athletic groups and the sedentary group, but no differences were found between the athletic groups. Athletes had a higher pulmonary function ratio, a higher oxygen extraction, and a lower alveolar ventilation than the sedentary subjects. (Author/JS)

ATHLETES AND SEDENTARY INDIVIDUALS: AN INTERGROUP COMPARISON UTILIZING A PULMONARY FUNCTION RATIO OBTAINED DURING SUBMAXIMAL EXERCISE

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March, 1975

ATHLETES AND SEDENTARY INDIVIDUALS: AN INTERGROUP COMPARISON UTILIZING A PULMONARY FUNCTION RATIO OBTAINED DURING SUBMAXIMAL EXERCISE

It was the purpose of this study to asses whether a pulmonary function ratio and its component parts, obtained during submaximal steadystate exercise, were differentiating factors when comparisons were made between sedentary subjects and athletes and between different athletic groups.

The pulmonary function ratio (VO_2/V_A) describes oxygen extraction (OEF) from alveolar ventilation (AVF) or in other words describes the ability of the pulmonary system to extract O_2 from the ventilated and perfused areas of the lungs. The basic equation for this ratio is:

$$VO_2/V_A=[0.265(1 - F_ECO_2 - F_EO_2) - F_EO_2] / (F_EXO_2/F_ACO_2)*$$

The numerator in the equation is a factor (OEF) by which V_E must be multiplied in order to obtain VO_2, and the denominator is a factor (AVF) by which V_E must be multiplied in order to obtain V_A. Hence,

$VO_2 = V_E \times OEF$ and

$V_A = V_E \times AVF$. Therefore,

$VO_2 / V_A = OEF/AVF$.

As can be seen from the basic equation, the ratio is determined by knowledge of only the three gas fractions: alveolar CO_2, expired CO_2, and expired O_2.

It should be noted that for the purpose of this study and end-tidal CO_2 is taken to represent the alveolar CO_2 fraction.

*See appendix for detailed derivation of the equation.

Subjects were obtained from four groups. They were Varsity basketball players (7), Varsity football players (10), Rugby players (7), and Sedentary subjects (7). All of the athletic groups were tested during their regular playing season and the sedentary subjects were tested during the same period. Obviously there were differences between the three athletic groups with regards to training duration, training frequency and training type.

The exercise test was conducted on a Monark bicycle ergometer at a pedaling rate of 60 rpm, with a power load of 900 kpm/min. An open circuit method, adapted for the on-line analysis of end-tidal CO_2 samples, was used for respiratory gas analysis. Heart rate was also recorded.

The test method of Sears _et al._ had necessitated only the analysis of end-tidal CO_2 and collection of a sufficient volume of expired gas for analysis of F_EO_2 and F_ECO_2. No volumetric determinations were necessary. However, in the present study V_E was recorded in order that VO_2 could be determined. Therefore, the typical open circuit, Douglas bag, method was used with the addition of on line analysis of end tidal CO_2 analysis for each breath during collection period. To take end tidal CO_2 data, a small hole was drilled in the face valve as close to the mouth as possible and expired gas constantly drawn off through the CO_2 analyzer at a flow rate of 500 ml./min. Heart rate was also recorded.

Data collected included, therefore, F_ACO_2, F_ECO_2, F_EO_2, V_E, and Heart Rate, and from these the following were determined, OEF, AVF, VO_2/V_A, Heart Rate, and VO_2.

In order to compare the differences between athletic and sedentary groups, analysis of variance was used, with individual t tests employed to investigate the relationship between individual groups. The type of t tests employed was determined by the result of a between-group variance test. $P < .025$ was used to signify statistical differences between groups.

Heart rate during exercise had been obtained purely to confirm that the athletic groups were statistically different from the sedentary group with regard to fitness level. Results showed that all three groups of athletes exhibited heart rates which were significantly lower than those of the sedentary group.

Intergroup comparison of the VO_2/V_A ratio, OEF, and AVF revealed that in all cases significant differences existed between the three athletic groups and sedentary group, but that few differences existed between the different athletic groups. Athletes had a higher VO_2/V_A ratio, and higher OEF, and a lower AVF than did the sedentary subjects, (See Figure I).

Both the increased OEF and decreased AVF were contributory to the increase in the VO_2/V_A ratio exhibited by the athletic groups. It was theorized that the higher athletic OEF could have been the result of either a facilitated lung diffusion or a reduced V_E. V_E measurements had been recorded and did show the athletic groups to have a lower value than the sedentary subjects. Although D_L was not directly measured in this investigation, it could have had an augmenting effect

AVF was found to be significantly lower in the athletic groups than in the sedentary groups. This was an unexpected finding but there are two explanations which could account for it.

At relatively high work loads, forced ventilations occurs, as a result of which the end expiration airway resistance increases. This has been shown to enlarge the functional residual capacity at the expense of the inspiratory was well as expiratory reserve volumes. The resultant effect on the composition of the alveolar air of a smaller effective ventilation is an increased end-expiration CO_2 containing space remaining in the lungs. This volume will result in an increased CO_2 fraction in the expired air. By the same token, the alveolar CO_2 fraction, being determined by the arterial CO_2 fraction in healthy subjects, should be expected to remain relatively constant. The resultant effect could be an increased F_ECO_2 and a constant F_ACO_2, hence causing the AVF to be increased.

Another possible explanation concerns the distribution of ventilation. There are, evidently, regional differences in distribution of ventilation from moment to moment within the lungs, and exercise results in a more uniform ventilation. Therefore, if a positive relationship exists between uniformity of ventilation and relative exercise intensity, sedentary subjects, who exercise closer to their maximum, may have an even more uniform ventilation than do more fit subjects.

There were small but significant differences between some athletic groups. The basketball players had a significantly lower exercise heart rate than the football players and also a significantly higher OEF than the rugby players.

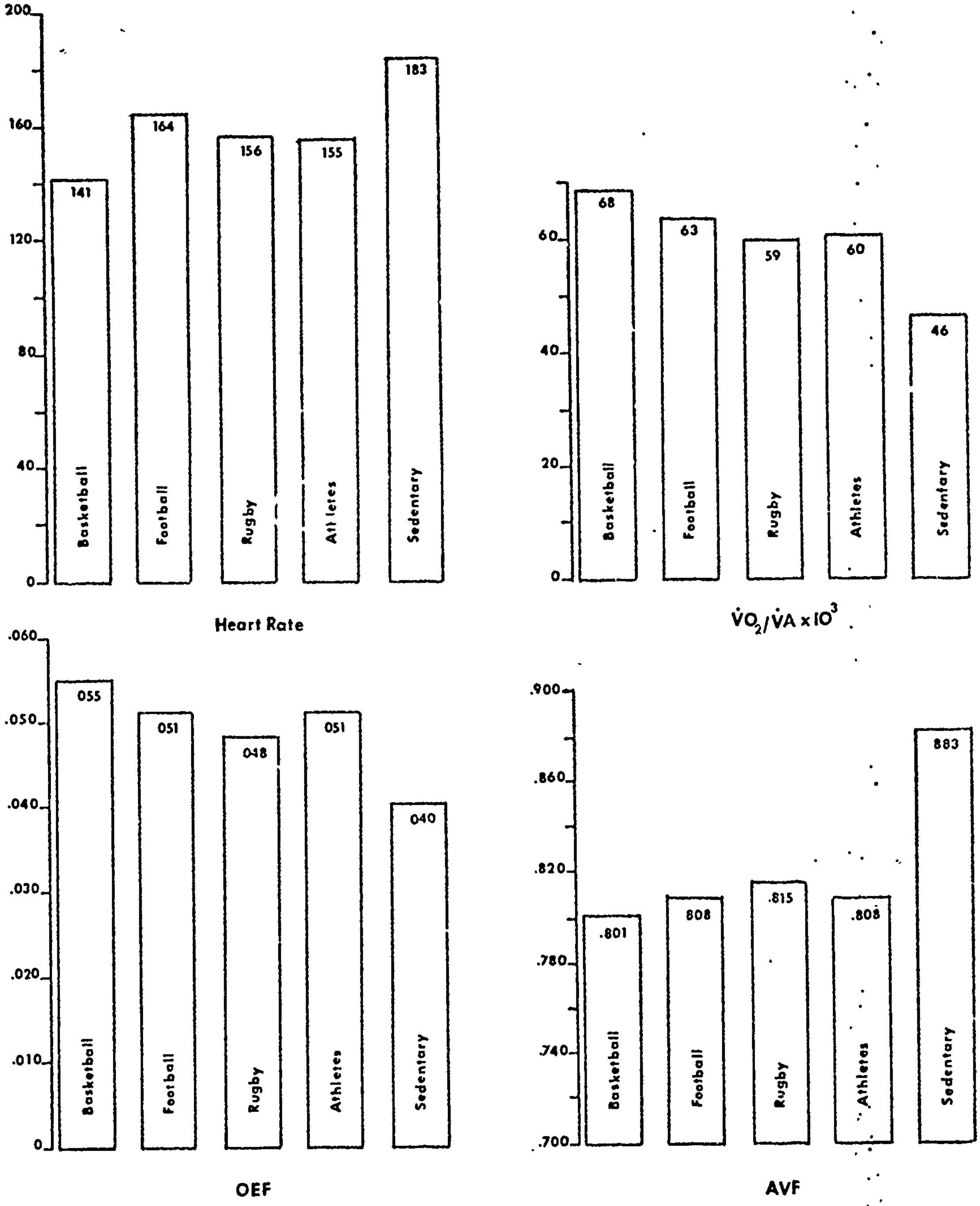

FIGURE I

HISTOGRAM OF THE STEADY STATE SUBMAXIMAL EXERCIS. HEART RATE, $\dot{V}O_2/\dot{V}A$, OEF, AND AVF FOR ATHLETIC AND SEDENTAR GROUPS

DERIVATION OF THE OXYGEN UPTAKE FROM ALVEOLAR VENTILATION RATIO

The following is a brief explanation of the derivation of the oxygen uptake from alveolar ventilation ratio as developed by Sears *et al.*[1] Standard symbols are used where not specifically defined. Basic pulmonary expressions are those of Comroe *et al.*[2] It is assumed in the following description that all volumes and fractions are measured over the same time period.

Expired air is composed of a combination of alveolar air and dead space air:

(1) $\dot{V}_E = \dot{V}_D + \dot{V}_A$

Physiological dead space can be defined as that air which does not gain CO_2 nor lose O_2 during ventilation. All CO_2 in the inspired air, therefore, with the exception of a small amount (0.034%) from the inspired air, is the result of CO_2 being gained from the blood across the blood-air interface in the alveoli:

(2) $\dot{V}_ECO_2 = \dot{V}_E \times F_ECO_2$

(3) $\dot{V}_ECO_2 = \dot{V}_A \times F_ACO_2$

Combining expressions (2) and (3):

(4) $\dot{V}_E(F_ECO_2) = \dot{V}_A(F_ACO_2)$

or: (5) $\dot{V}_A = \dot{V}_E(F_ECO_2/F_ACO_2)$

Oxygen uptake can be expressed as:

(6) $\dot{V}O_2 = (\dot{V}_I \times F_IO_2) - (\dot{V}_E \times F_EO_2)$

The oxygen uptake from alveolar ventilation equation was derived in order to determine the fraction of O_2 removed from a unit volume of alveolar air and is the ratio VO_2/V_A, which is obtained by combining expressions (6) and (5):

$$(7)\quad VO_2/V_A = (\dot{V}_I F_I O_2 - \dot{V}_E F_E O_2) \;/\; \dot{V}_E (F_E CO_2/F_A CO_2)$$

Provided that all gas volumes and fractions are measured under the same environmental conditions (ATPD, STPD, BTPS, etc.), the ratio can be considered dimensionless.

Correction for the volume differences between inspired and expired air is readily obtained by means of the N_2-ratio method

$$(8)\quad \dot{V}_I = \dot{V}_E (F_E N_2/F_I N_2)$$

Substituting for V_I in (7):

$$(9)\quad VO_2/V_A = [(\dot{V}_E F_E N_2/F_I N_2) F_I O_2 - \dot{V}_E F_E O_2] \;/\; \dot{V}_E (F_E CO_2/F_A CO_2)$$

V_E in the above equation (9) cancels out and, for the purpose of this study, $F_I O_2 = 0.2094$ and $F_I N_2 = 0.7903$.

Therefore:

$$(10)\quad VO_2/V_A = [0.265(F_E N_2) - F_E O_2] \;/\; F_E CO_2/F_A CO_2$$

But: $$(11)\quad F_E N_2 = (1 - F_E CO_2 - F_E O_2)$$

Therefore:

$$(12)\quad VO_2/V_A = [0.265(1 - F_E CO_2 - F_E O_2) - F_E O_2] \;/(F_E CO_2/F_A CO_2)$$

The VO_2/V_A ratio can be calculated, therefore, by determination of but three gas fractions: $F_A CO_2$, $F_E CO_2$, and $F_E O_2$.

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2. Comroe, J. H., R. E. Forster, A. B. Dubois, W. A. Briscoe, and E. Carlsen, The Lung. Chicago: Year Book Publishers, Inc. 1955, pp. 171-212.