Original Article

Ventilatory Anaerobic Threshold and Maximal Exercise Performance in Untrained and Endurance Trained Men

Maj KK Tripathi*, Dr PK Banerjee

Institute of Aerospace Medicine, IAF
Vimanapura, Bangalore - 560 017.

Twelve untrained men with no history of routine physical training in the last one year and 10 trained men with 10 to 15 km a day, 6 days a week, endurance running in the past 1 to 3 years were studied for their exercise performance by cycle ergometry.

The trained group had a 35% higher mean value of VO_2 max (46.7 ± 3.7 ml/min/kg) than that in the untrained group (34.7 ± 5.2 ml/min/kg). The mean VAT value on the other hand, was 73% higher in trained group (30.5 ± 3.8 ml/min/kg) than in the untrained (17.7 ± 4.9 ml/min/kg). The aerobic status of the trained group vis-a-vis the untrained group was thus better appreciated in terms of VAT in comparison with the maximal exercise performance.

Key words :- ***Aerobic capacity, anaerobic threshold, endurance training.***

Maximal oxygen uptake (VO_2max) defined as the highest oxygen uptake that an individual can attain during physical work breathing air at sea level, has received wide acceptance as the primary determinant of cardiorespiratory endurance capacity[1]. However, individuals with similar values of VO_2max often perform differently in an endurance event. These observations suggest that measures other than VO_2max may be important determinants of endurance performance[2]. One such measure is the Anaerobic Threshold (AT), defined as the highest work rate for which the energy requirements are solely obtained from oxygen uptake and hence without concomitant anaerobiosis[3]. Wasserman et al[3] postulated that the AT can be determined during progressive exercise by observation of this point just above which a disproportionate increase in ventilation (V_E) occurs against increment in work rate or oxygen uptake. The fundamental premise of this postulation is that the changes in muscle and blood lactate concentration occur almost simultaneously and the point of elevation in blood lactate can be used to characterise metabolic acidosis and threshold of altered ventilation - oxygen uptake relationship[3].

With respect to endurance performance, the AT has recently been described as a key parameter which, to a large extent, defines the ability to sustain high intensity work without a concomitant lactic acidosis which otherwise would have adversely affected the performance[4-7]. AT deduced by parameters of altered V_E and VO_2 relationship is better termed 'Ventilatory Anaerobic Threshold' (VAT), to distinguish it from that determined by measurements of changes in blood lactate concentration

In this study, evaluation of VAT and other parameters of exercise tolerance was made in two different groups of individuals, one with a relatively sedentary life style and the other comprising endurance trained athletes.

Material and Methods

Twenty two healthy male nonsmokers ranging from 19-30 years in age served as subjects for this study. The nature and purpose of the study and the risk involved were explained to these volunteers who were ascertained to be normal by history, physical examination and resting ECG.

* Present Address: Military Hospital Dovlali, Maharashtra

Out of these 22 subjects, 12 were untrained individuals from the laboratory personnel, whereas 10 were undergoing endurance training (running for 10-15 km per day) for a period ranging from 1-3 years. The physical characteristics of the subjects are given in Table I.

Table I : Physical Characteristics of Subjects

Groups	Age (Yrs)	Height (cms)	Weight (kgs)	BSA (sq m)
Untrained (n=12)	28.0 ± 4.2	171.2 ± 4.7	59.2 ± 6.3	1.70 ± 0.12
Endurance Trained (n=10)	22.2 ± 3.7	165.2 ± 4.4	62.5 ± 1.2	1.68 ± 0.01

The study was carried out in a comfortable laboratory environment, with an ambient temperature from 21-29 deg C, in the Department of Physiology at Institute of Aerospace Medicine, IAF, Bangalore.

Each subject performed incremental exercise test to the point of tolerance on an electrically braked cycle ergometer (LODE, Holland). After 4 minutes of unloaded exercise,work rate increased in increments of 25 watts each minute. The pedaling rate was maintained at 60 rpm.

During the test, subjects breathed room air through a low resistance breathing valve (Hans-Rudolph) connected to an on-line spirometric system (OXYCON-4, MIJNHARD, HOLLAND). An electrocardiographic monitoring was done continuously on CM-5 lead. VO_2max was taken as the maximal oxygen uptake a subject could attain during the experiment. VAT was determined for each subject from the plot of his pulmonary ventilation against work rate by the observation of the point where VE began to increase non linearly.

Results

Table II presents the maximal work load reached (PWC), VO_2max and VAT values for the untrained and endurance trained groups. PWC in untrained group shows a mean value of 200 ± 30 watts whereas in endurance trained group the mean value was 240 ± 13 watts. The VO_2max in the untrained and trained groups was 2.17 ± 0.33 l/min and 2.75 ± 0.21 l/min respectively. Expressed in ml/kg/min, the values were 34.7 ± 5.2 and 46.7 ± 3.7 respectively. Thus, the endurance trained group exhibited values of VO_2max 26.7 and 34.6% higher than the untrained groups, expressed in l/min and ml/kg/min respectively. The differences were highly significant ($p<0.01$).

VAT had a mean value of 100 ± 23.8 watts in untrained group. Expressed in VO_2, VAT values were 1.10 ± 0.32 l/min or 17.6 ± 4.9 ml/kg/min. In endurance trained group, the corresponding values were 155 ± 19.7 watts, 1.78 ± 0.23 l/min and 30.5 ± 3.8 ml/kg/min.

Thus, expressed in watts, VO_2(l/min) and VO_2 (ml/kg/min) respectively, VAT values in the endurance trained group were 55%, 62% and 73% higher than in untrained group, the differences being highly significant ($p<0.01$).

Table II: VAT and Other Parameters of Exercise Tolerance

	Untrained Group	Endurance Trained Group	't'
PWCmax (watts)	200 ± 30.0	240 ± 12.9	3.90*
VO_2max (l/min)	2.17 ± 0.33	2.75 ± 0.21	4.77*
VO_2max (ml/kg/min)	34.7 ± 5.2	46.7 ± 3.7	6.15*
VAT (watts)	100 ± 23.8	155± 19.7	5.82*
$VATVO_2$ (l/min)	1.10 ± 0.32	1.72 ± 0.28	5.53*
$VATVO_2$ (ml/kg/min)	17.7 ± 4.9	30.5 ± 3.8	6.78*

* $p<0.01$

Discussion

In this study, VAT, PWC and VO_2max were evaluated in two different groups of individuals. The untrained group was constituted of the Institute staff and student members with no routine endurance training exercise in the last one year. The other group comprised of a homogeneous congregation of Army Personnel engaged in heavy endurance training viz running for 10-15 Km per day for 1-3 yrs. The endurance trained group, was found to have an average VO_2max of 2.75±0.21 l/min or 46.7±3.7 ml/kg/min, a value 26.7% and 34.5% respectively higher than that attained by the untrained group viz 2.17±0.33 l/min or 34.7±5.2 ml/kg/min. Thus, it is evident that the values of VO_2max per unit body weight in

the untrained group are conforming to an untrained population, whereas in the endurance trained group, the mean VO_2max value was indicative of a 'very good' level of physical fitness though not representative of elite athletes[1].

Values of VAT ranged from 75-175 watts with a mean of 125.7 ± 35.3 watts when the data for the two groups were pooled together. Wasserman et al[3], studying VAT values in a much larger (n=85) and varied population (ranging from 17-91 yrs in age), reported values ranging from 45-180 watts. A value of 45 watts was stated to be the lower limit of normal while values for very fit normal adults were as high as 180 watts.

Expressed in terms of VO_2, the VAT values in the present pooled data ranged from 0.68-2.01 l/min or 11.9-35.5 ml/kg/min with mean of 1.41±0.44 l/min or 23.5±7.9 ml/kg/min. Deriving AT from the similar respiratory gas exchange parameters, Caizzo et al[8] have reported a mean VAT value of 1.78 l/min in 14 male and 2 female subjects between 20 and 30 yrs of age. The activity level of these subjects varied considerably (sedentary to jogging seven miles/day). These subjects were comparable to the subjects of the present study except that their body weight was higher (72.9 ± 3.0 Kg). Findings of Caizzo et al[8], computed to express VAT in ml/kg/min present a mean value of 23.1 and is comparable to the corresponding value of 23.5 in the present study. VAT constituted 56.9±12.1% (range : 37.5-77.8%) of VO_2max in the pooled data of present study. This is in agreement with the previous studies wherein VAT has been found varying from 50-80% of VO_2max[1,8].

The endurance trained subjects were found to score 20% higher in PWC, 34.6% higher in VO_2max (ml/kg/min) as compared to untrained subjects. In VAT data, the trained group revealed further higher scoring in comparison. VAT expressed in watts and VO_2 (ml/kg/min) in them was 55% and 73% higher than those observed in the untrained group. Also, the trained subject had mean VAT at around 65% of their PWC as compared to that seen at 50% of PWC in the untrained subjects.

The aerobic conditioning status of the trained subjects in the present study was thus much more appropriately revealed on the basis of VAT score as compared to measures of maximal work capacity viz. PWC and VO_2max values.

A high endurance performance as measured by VO_2max has often been found to be associated with susceptibility to motion sickness[9] as well as cardiac dysrhythmias[10]. On the basis of the present study, it is reasonably conceived that estimation of VAT would be more appropriate to assess the current aerobic status of the aircrew for any such attempt as optimizing their routine exercise programme.

References

1. Astrand PO, Rodahl K : Text Book of Work Physiology, 3rd edition, New York, McGraw Hill, 1985.

2. Davis JA, Frank MH, Whipp BJ et al : Anaerobic threshold alteration caused by endurance training in middle aged men. J Appl Physiol 1979; 46 : 1039-1046.

3. Wasserman K, Whipp BJ, Koyal SN et al : Anaerobic Threshold and respiratory gas exchange during exercise. J Appl Physiol 1973; 35 : 236-243.

4. Trivedi B, Danforth R : Effect of pH on the kinetics of frog muscle phosphofructokinase. J Biol Chem 1966; 241 : 4110-12

5. Thomas BI : Effects of lactate on FFA and glycerol turnover in resting and exercising dogs. J Appl Physiol 1975; 39 : 349-53.

6. Nakamura Y, Schwart S : The influences of hydrogen ion concentration on calcium binding and release by skeletal muscle sarcoplasmic reticulum. J Gen Physiol 1972; 59 : 22-32.

7. Fitts RH, Holloszy JO : Lactate and contractile force in frog muscle during development of fatigue and recovery. Am J Physiol 1976; 23 ; 430 - 433.

8. Caizzo VJ, Davis JA, Ellis JF et al : A comparison of gas exchange indices used to detect the anaerobic threshold. J Appl Physiol 1982; 53 : 1184-1189.

9. Cheung BSK, Money KE, Jacobs I : Motion sickness susceptibility and aerobic fitness : a longitudinal study. Aviat Space Environ Med 1990; 61 : 201-204.

10. Convertino VA, Montgomery LD, Greenleaf JE : Cardiovascular response during orthostasis : effect of an increase in VO_2max. Aviat Space Environ Med 1984; 55 : 702-708.