Original Article

Evaluation of Maximal Oxygen Uptake Capacity as a Measure of Cardiorespiratory Fitness in Indian Air Force Personnel

PK Banerjee, P Bandopadhyay, NS Baboo, EM Iyer

Seventy normal healthy Indian Air Force personnel, 30 of them aircrew and 40 ground duty subjects, in the age range of 21-39 years, were studied on bicycle ergometric exercise to assess their maximal oxygen uptake capacity($\dot{V}O_2$max). Their mean absolute $\dot{V}O_2$ max values were found around 2.5 and 2.4 l/min in 21-29 and 30-39 years age group respectively. $\dot{V}O_2$ max per Kg body weight values, viz. 38.6 and 35.2 ml/min/Kg in the aircrew and 40.8 and 35.5 ml/min/Kg in the ground duty subjects, in the age group 21-29 and 30-39 years respectively, are indicative of relatively lower levels of cardiorespiratory fitness in them as compared to Army personnel and industrial worker population in India. The aircrew scores of $\dot{V}O_2$ max per Kg body weight are found comparable with those reported on USAF and Canadian Force aircrew. The specificity of aerobic fitness in relation to aircrew job requirement and the need for an appropriate conditioning programme in the subject population are discussed.

Keywords: Aerobic fitness, bicycle ergometry.

Maximal oxygen uptake capacity ($\dot{V}O_2$max) is defined as the highest oxygen uptake an individual can attain during dynamic physical work[1]. It is considered as the best index of work capacity and cardiorespiratory fitness[2,3] and that of physical fitness, having accepted the definition of physical fitness as individual's capacity for prolonged heavy work[4]. Appropriately, $\dot{V}O_2$max is the most commonly used index in the laboratory assessment of the functional state of adaptation of the oxygen transport system[5].

The individual variations in $\dot{V}O_2$max values are quite large in any general population, mostly arising of the natural endowment factors and the levels of physical activity or conditioning habit of the individual. The average $\dot{V}O_2$max per unit body weight has been found to be remarkably constant in different ethnic groups once they are matched in physical activity habits[6]. Significant improvements in $\dot{V}O_2$max through physical exercise programmes are very well documented [1,5,7,8].

The significance of a high level of physical fitness in military personnel can not be over emphasized. The rationale of ensuring fitness in military is historically based on the assumption that the military duties involve a considerable amount of hard physical work. This assumption does not appear to be valid in Air Forces where job related requirements of heavy physical activity are few. In all probability, Air Force personnel in general fall in the category of population where physical fitness has become a personal responsibility. It is the purpose of the paper to present the $\dot{V}O_2$max values determined in a total number of 70 normal healthy IAF personnel and discuss the significance of this measure of cardiorespiratory fitness in relation to aviation requirements.

Material and Methods

In all 70 normal healthy male IAF personnel in the age range of 21 to 39 years made the subjects of this study. Thirty of them were the aircrew officers taken from the neighbouring flying units and from those undergoing Indoctrination courses at this Institute. The remaining 40 were ground duty personnel taken from the staff and student members of this Institute.

The maximal exercise test was conducted on a Lanooy type Bicycle Ergometer(Lode), with initial load of 75 watts and 25 watts increase every 3 min till subjective exhaustion. The pedalling rate was kept at 60 rpm. Oxygen uptake values in STPD were recorded on an on-line

ergospirometric system(Oxycon-4, Mijnhardt) using a low resistance breathing valve (Rudolph).Heart rate measurements were made from ECG tracings on an electrocardiograph(Nihon-Kohden) using CM5 lead.

Results

Table I shows the mean values with standard deviation of age and physical characteristics of the aircrew and the ground duty subjects separately presented for the two age ranges viz. 21 to 29 and 30 to 39 years. In both aircrew and ground duty subjects, the mean body weight values were about 5 Kg higher in 30-39 years compared to 21-29 years age group, the difference being statistically significant for the ground duty subjects ($p < 0.05$) and the combined group($p < 0.01$), but not for the aircrew group considered separately.

Table II presents the mean values with standard deviation of maximal oxygen uptake of aircrew and ground duty subjects separately for the two age groups. The mean $\dot{V}O_2$max values in

Table - I Age and physical characteristics of the subjects (m ± sd)

Subject	Age(Yrs)	Height(cm)	Weight(Kg)
Age Group : 21-29 Yrs			
Aircrew (n = 17)	23.5 ± 2.79	173.4 ± 5.56	64.1 ± 5.91
Ground Duty (n = 23)	24.0 ± 2.77	169.3 ± 5.51	61.7 ± 7.49
Combined (n = 40)	23.8 ± 2.76	171.0 ± 5.82	62.7 ± 6.89
Age Group : 30-39 Yrs			
Aircrew (n = 13)	35.5 ± 2.76	173.7 ± 6.37	69.0 ± 7.38
Ground Duty (n = 17)	33.9 ± 3.63	170.0 ± 5.95	**67.0 ± 8.16** *
Combined (n = 30)	34.6 ± 3.32	171.6 ± 6.31	**67.9 ± 7.77** **

* Significant increase compared to younger age group ($p < 0.05$)
** Significant increase compared to younger age group ($p < 0.01$)

Table - II Maximal oxygen uptake and maximal heart rate on bicycle ergometric exercise (m±sd)

Subject	$\dot{V}O_2$ max (l/min)	$\dot{V}O_2$ max (ml/min/Kg)	HR_{max} (bpm)
Age Group : 21-29 Yrs			
Aircrew (n = 17)	2.47 ± 0.28	38.6 ± 3.7	193.6 ± 6.2
Ground Duty (n = 23)	2.51 ± 0.50	40.8 ± 6.8	193.1± 10.1
Combined (n = 40)	2.49 ± 0.42	39.9 ± 5.8	193.3 ± 8.5
Age Group : 30-39 Yrs			
Aircrew (n = 13)	2.41 ± 0.20	**35.2 ± 5.2** *	190.1 ± 11.6
Ground Duty (n = 17)	2.35 ± 0.25	**35.5 ± 5.8** *	**185.9 ± 8.7** **
Combined (n = 30)	2.37 ± 0.25	**35.4 ± 5.4** **	**188.1 ± 10.2** *

* Significant decrement from younger age group ($p < 0.05$)
** Significant decrement from younger age group ($p < 0.01$)

absolute were found comparable in aircrew and ground duty subjects, both in 21-29 years (2.47 and 2.51 l/min respectively) and in 30-39 years(2.41 and 2.35 l/min) age group. In the higher age group, there were marginal decrements in the mean $\dot{V}O_2max$ values in both aircrew and ground duty subjects. $\dot{V}O_2max$ per unit body weight values showed significant age bound decrements in both groups. In aircrew,the mean $\dot{V}O_2max$ per Kg body weight was found reduced from 38.6 ml/min at 21-29 years to 35.2 ml/min at 30-39 years($p < 0.05$). In ground duty subjects the respective values were 40.8 and 35.5 ml/min($p < 0.05$). For the combined group of subjects, the age bound decrement was highly significant: from 39.9 ml/min at 21-29 years to 35.4 ml/min at 30-39 years of age($p < 0.01$). In the younger age group, the ground duty subjects were found to have a relatively higher mean value of $\dot{V}O_2max$ per Kg body weight compared to the aircrew, the difference was however not statistically significant. The mean maximal heart rate were found to be lower in the older age groups in both categories, the differences being significant($p < 0.05$) in the ground duty subjects.

Discussion

The mean absolute $\dot{V}O_2max$ values of the aircrew : 2.47 and 2.41 l/min,and the ground duty personnel:2.51 and 2.35 l/min, in the age groups of 21-29 and 30-39 years respectively, are found to compare well with those reported for nonathlete civil and military population in India. Sengupta et al[9] observed mean $\dot{V}O_2max$ values of 2.59 and 2.49 l/min in Indian Army personnel of comparable age groups. Saha[10] reported $\dot{V}O_2max$ values around 2.2 l/min in 21-43 years old Steel Industry workers in India. However, $\dot{V}O_2max$ per unit body weight values of the present subjects :38.6 and 35.2 ml/min/Kg in the aircrew and 40.8 and 35.5 ml/min/Kg in ground duty subjects in 21-29 and 30-39 years age group respectively, are indicative of relatively lower levels of cardiorespiratory fitness in them as compared to moderately trained Indian Army personnel with reported mean $\dot{V}O_2max$ values of 44.3 and 42.1 ml/min/Kg in the comparable age groups[9] and Indian Steel Industry workers with a mean $\dot{V}O_2max$ value of 42.6 ml/min/Kg in 21-43 years age group[10]. Understandably, $\dot{V}O_2max$ values of the present subjects are far less in comparison with the values (51-55 ml/min/Kg) reported on Indian athletes[11].

On the other hand, $\dot{V}O_2max$ per unit body weight values of the present subjects, aircrew in particular, are found to compare well with those reported on USAF aircrew : 37.6 and 34.6 ml/min/Kg in 20-29 and 30-39 years age group respectively[12], and Canadian Air Force Elements: 37.1 and 33.8 ml/min/Kg in 25-29 and 30-39 years respectively[13]. In this context, it is worthwhile reiterating the observation of Wyndham et al[6] that $\dot{V}O_2max$ per Kg body weight values are found similar in different ethnic groups, once the population is matched in their physical activity habits. The observed similarity in $\dot{V}O_2max$ per Kg body weight values in the subjects of the present study and those of two other Air Forces are reflective of the routine occupational physical activity and physical fitness culture that is normally permitted within the specificity of their occupational slot.

Age bound decrement in aerobic fitness since 20 years of age is a well documented observation in men. This occurs partly due to a decrease in maximal heart rate with age; relative inactivity in higher age group is another factor that reduces the functional range of the oxygen transport system[1,14]. In the present study, the age bound decrements in maximal heart rate as well as $\dot{V}O_2max$ per Kg body weight were more marked in ground duty subjects than in the aircrew, whereas the aircrew had a relatively lower mean value of $\dot{V}O_2max$ per Kg body weight compared to ground duty subjects in 21-29 years age group itself. It is quite likely that the specific job related physical activity and the scope or orientation to physical conditioning programme in the aircrew subjects settle down in 21-29 years age group itself.

Interpreting the mean $\dot{V}O_2max$ per Kg data of the present subjects as per the rating scale

proposed by Balke and Ware[12], it is found that the aircrew subjects in both age groups and the ground duty subjects in 30-39 years scored "Fair" degree of physical work capacity (i.e. $\dot{V}O_2max$: 35-40 ml/per/Kg), and the ground duty personnel in 21-29 years scored a "Good" level of work capacity (i.e. $\dot{V}O_2max$: 40-45 ml/min/Kg).

Specificity of a high degree of aerobic fitness in relation to aircrew job requirement is a controversial issue at the moment. Most of the earlier literature recommended a high degree of physical fitness in aircrew emphasizing its positive association with preparedness for survival situation and tolerance to + Gz[15,16]. Though no research data to date have been able to find any significant correlation of increased aerobic capacity with improved acceleration tolerance[17,18,19], aerobic conditioning would still be considered beneficial from the overall performance standpoint and as an adjunct in reducing cardiovascular risk factors[20,21]. However, the exact amount of aerobic conditioning to be recommended for an individual aircrew is undefined as yet.

The doubt regarding a possible upper limit of aerobic status for the aircrew has arisen from some recent observations of cardiac dysrhythmia on +Gz stress test in a group of highly conditioned individuals($\dot{V}O_2max$: 57.5 ml/min/Kg)[19] and of increased Incidence of motion sickness on vestibular stimulation test again in highly conditioned individuals($\dot{V}O_2max$: 63.1 ml/min/Kg)[22]. These studies are suggestive of the requirement of defining an optimal level of aerobic conditioning in the cases of aircrew. Nevertheless, in an occupation with low potential for heavy physical work manifesting in a relatively low level of aerobic fitness as that seen in the aircrew, a moderate intensity of aerobic conditioning programme would always be considered beneficial. As such, a conditioning programme aiming at the maintenance of existing fitness level itself demands at least 2 sessions per week of 20-30 min aerobic exercise at 70-90% loading of the cardio-respiratory system[5].

REFERENCES

1. Astrand PO, Rodahl K: Text Book of Work Physiology. New York,McGraw-Hill,1970

2. Mitchell JH, Blomquist G: Maximal oxygen uptake. New Eng J Med 1971;284:1018-1022

3. Taylor HL, Bushkirk E, Henschel A: Oxygen uptake as an objective measure of cardiorespiratory fitness. J Appl Physiol 1955;8:73-80

4. Astrand PO: Human physical fitness with special reference to sex and age. Physiol Rev 1956;36:307-342

5. Wenger HA, Bell GJ: The interaction of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. Sports Med 1986;3:346-354

6. Wyndham CH, Strydom NB, Morrison JF et al: Differences between ethnic* groups in physical working capacity. J Appl Physiol 1963;18:361-366

7. Hickson RC, Bomze HA, Holloszy JO : Linear increase in aerobic power induced by a strenuous programme of endurance exercise. J Appl Physiol 1977;42:372-376

8. Ong TC, Sothy SP: Exercise and cardiorespiratory fitness. Ergonomics 1986;29:273-280

9. Sengupta J, Srinivasalu N, Sampat Kumar T et al: Influence of age on the maximum oxygen uptake and maximum heart rate of Indians during work. Ind J Med Res 1974;62:1228-1232

10. Saha PN: Aerobic capacity of steel workers in India. Ergonomics 1978;12:1021-1025

11. Ramaswamy SS, Mathur DN, Joseph NT et al: Physical performance and pulmonary function of athletes at sea level and at moderate altitude. Report 2/70, DIPAS, Ministry of Defence, R&D Orgn, New Delhi,1970

12. Balke B, Ware RW: The present status of physical fitness in the Air Force. Report 59-67, SAM USAF, Randolf AFB,1959

13. Myles WS, Allen CL: A Survey of aerobic fitness in Canadian military population. Aviat Space Environ Med 1979;50:813-815

14. Clausen JP: Effects of physical training on cardiovascular adjustment to exercise in man. Physiol Rev 1977;57:779-

15. Flight Surgeon's Manual, US Deptt of Air Force, Washington DC,1962

16. Lamb LW: Cardiopulmonary aspects of Aerospace Medicine. In : Aerospace Medicine, Editor: Randel HW, Williams & Wilkins, Baltimore,1971, p.469

17. Cooper KH, Leverett SD: Physical conditioning versus + Gz tolerance. Aerospace Med 1966;37:462-465

18. Epperson WL, Burton RR, Bernauer EM: The influence of different physical conditioning regimens on simulated aerial combat maneuvering tolerance. Aviat Space Environ Med 1982;53:1091-1097

19. Whinnery JE, Parnell M: The effects of long-term aerobic conditioning on +Gz tolerance. Aviat Space Environ Med 1987 ; 58 : 199-204

20. Froelicher VF, Yanowitz F, Thompson AJ, et al: Treadmill testing at the USAF School of Aerospace Medicine: Physiological responses in aircrewmen and the detection of coronary artery disease. Report AG 210, AGARD, Paris,1975

21. Brown TE, Myles WS, Allen CL: The relationship between aerobic fitness and certain cardiovascular risk factors. Aviat Space Environ Med 1983;54:543-547

22. Banta GR, Ridley WC, McHugh J et al: Aerobic fitness and susceptibility to motion sickness. Aviat Space Environ Med 1987 ; 58 : 105-108