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# ASSESSMENT OF CARDIO-PULMONARY EFFICIENCY IN ATHLETES AND NON-ATHLETES

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**Abstract :** Cardiopulmonary efficiency was studied in 18 Indian medical students and 19 state level athletes by estimating maximal oxygen uptake ($\dot{V}O_2$ max), and other parameters related to oxygen transport i.e., heart rate, $O_2$ pulse, respiratory quotient, ventilation volume, breathing reserve and dysponoeic index, following graded exercise on a treadmill. Higher $\dot{V}O_2$ max observed in athletes, was due to higher stroke volume and arterio-venous $O_2$ difference. Though athletes had higher breathing reserve at $\dot{V}O_2$ max work load, their dysponoeic index and ventilation volume at $\dot{V}O_2$ max did not differ significantly from non-athletes suggesting that athletes were economical in expending energy for work of breathing during exercise.

**Key words:** cardiopulmonary efficiency $\dot{V}O_2$ max heart rate $O_2$ pulse RQ breathing reserve dyspnoeic index M.V.V.

## INTRODUCTION

Persons possessing higher values of maximal oxygen uptake ($\dot{V}O_2$ max) have the capacity to yield larger amounts of energy and are capable of performing better in athletic and other field activities. Determination of $\dot{V}O_2$ max is thus one of the important criteria to assess the oxygen transport system, or the cardiopulmonary efficiently (1,2,3,). Sufficient data are still lacking in our country regarding the values of $\dot{V}O_2$ max in various healthy population groups as well as sportsmen. The present study was undertaken to determine during exercise the $\dot{V}O_2$ values for max and other parameters related to oxygen transport viz. heart rate (HR), ventilation volume ($\dot{V}E$), breathing reserve (BR), dysponoeic index (DI), Oxygen pulse ($O_2$ pulse) and respiratory quotient (RQ) of both non- athletes (NATH) and athletes (ATH).

## METHODS

A total of 18 healthy NATH and 19 ATH were tested for cardiopulmonary efficiency. The ATH group comprised of runners selected from a team of state level athletes undergoing training in the Physical Education Department of Banaras Hindu University. The ages of both groups were similar while their heights, weights and resting pulse rates were somewhat varying. $\dot{V}O_2$ max for all the subject was determined by exposing them to graded exercise of running at 11 km/h on a treadmill (Quinton Co., Washington), with the inclination being increased by $2^1/_2$% after completion of each 4 minutes run. About 10 minutes rest was given in between each running session. The graded exercise test was continued till the subject failed to complete a given work load for 4 minutes. The expired air volume was measured with Respiration Gas meter (Max Plank Institute, Germany); and the expired air samples collected in Bailey's air sample bottle and subsequently analysed with Lloyds gas analysis apparatus. These samples were collected during the last minute of the 4 minutes run. $O_2$ consumption and $CO_2$ output at the various work loads were determined from the compositions of inspired air (room air) and expired air and the expired air volume (STPD). From this RQ was cal-

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culated. The value for $\dot{V}O_2$ max was considered to be that which did not increase despite an increase in work load, or when the difference in $\dot{V}O_2$ between two successfully completed work performances differed by less than 150 ml/min (1).

The HR was noted immediately after the stoppage of exercise. The maximum Voluntary Ventilation (M.V.V.) values were determined prior to the exercise tests. From the values of M.V.V. and $\dot{V}$.E. the values for BR and DI (4) were calculated. $O_2$ pulse was calculated by dividing $O_2$ consumption in ml/mm by the HR/min at respective work loads. The above values at $\dot{V}O_2$ max work load were designated as max HR, max $\dot{V}E$, max $O_2$ pulse, max RQ, BR at $\dot{V}O_2$ max and DI at $\dot{V}O_2$ max.

Standard statistical methodologies were applied in terms of mean and standard deviation, and 't' test for comparison between the groups.

## RESULTS

The Results are summarised in Tables I, II and III.

TABLE III: $\dot{V}O_2$ max and other parameters of both the group (Mean ± SD).

| | *NATH* | *ATH* | *Significance* |
|---|---|---|---|
| $\dot{V}O_2$ max (lit $min^{-1}$) | 2.07<br>0.27 | 2.98<br>0.34 | S* |
| $\dot{V}O_2$ max (ml $Kg^{-1}$ $min^{-1}$) | 37.42<br>4.92 | 48.42<br>4.72 | S* |
| $\dot{V}O_2$ max (ml $cm^{-1}$ $min^{-1}$) | 12.39<br>1.77 | 17.08<br>1.96 | S* |
| $\dot{V}O_2$ max (lit $m^{2\cdot1}$ $min^{-1}$) | 1.27<br>0.17 | 1.70<br>0.17 | S* |
| $\dot{V}E$ max (lit $min^{-1}$) | 79.50<br>12.05 | 87.81<br>14.96 | NS |
| MVV (lit min-1) | 107.67<br>13.61 | 137.00<br>19.25 | S* |
| BR at $\dot{V}O_2$ max | 29.95<br>15.82 | 47.52<br>19.64 | S* |
| DI at $\dot{V}O_2$ max | 26.67<br>11.68 | 33.56<br>10.67 | NS |
| Max HR | 204.22<br>14.99 | 197.58<br>21.44 | NS |
| max $O_2$ pulse | 10.24<br>1.58 | 15.32<br>2.09 | S* |
| max RQ | 1.05<br>0.08 | 0.98<br>0.07 | S** |

S = Significant * = $P < 0.001$
NS = Not significant ** = $P < .01$

TABLE I : Age, physical characteristics and resting pulse rate of NATH and ATH. Mean ± SD (range).

| | *Age (Yr)* | *Height (cm)* | *Weight (kg)* | *Surface Area ($m^2$)* | *Resting pulse rate / min* |
|---|---|---|---|---|---|
| NATH | 24.1<br>3.94<br>(19-31) | 168.31<br>5.09<br>(162.0-177.5) | 57.28<br>6.47<br>(48.0-67.0) | 1.65<br>0.09<br>(1.49-1.86) | 86.09<br>8.01<br>(74-102) |
| ATH | 27.26<br>3.29<br>(22-33) | 175.33<br>4.72<br>(170.0-184.0) | 63.90<br>7.62<br>(52.9-88.30) | 1.78<br>0.12<br>(1.61-1.78) | 68.26<br>9.71<br>(50-88) |

TABLE II: Work loads on treadmill successfully completed by subjects of respective groups.

| *Inclinations at 11 km/hr speed* | *No. of ATH completed* | *No. of NATH completed* |
|---|---|---|
| 0% | 19 | 18 |
| $2^1/_2$% | 19 | 18 |
| 5% | 19 | 13 |
| $7^1/_2$% | 19 | 5 |
| 10% | 16 | 1 |
| $12^1/_2$% | 10 | — |
| 15% | 4 | — |

## DISCUSSION

As seen from Table I, higher mean values of body weight, height and body surface area in ATH, reflect a higher growth pattern in them. Regular physical activity and training may be one of the contributing factors in attainment of such growth. Further, ATH show a significantly lower value for resting pulse rate ($P<.001$) which is in accordance with their level of fitness (5,6).

ATH show significantly higher values of $\dot{V}O_2$ max than NATH (Table III) and therefore have higher aerobic capacity, or physical work capacity which enabled them to sustain higher work loads (Table II).

On comparing the values of $\dot{V}O_2$ max in ml $kg^{-1}$ $min^{-1}$ in NATH as obtained in the present study with similar studies carried out on Indian subjects of similar age group, these are found to be similar to those reported by Gupta et al (7), but less than those reported by Dua et al (8), and Jain et al (9). The present group of NATH comprised of undergraduate and post-graduate medical students who usually have very little physical activity. This also explains lower values of $\dot{V}O_2$ max in them (10). Walter and Nancy (11) studied students of age group between 18-22 years who had higher values of $\dot{V}O_2$ max, than the present group of students of age group between 19-31 years (12). Malhotra et al (13) studied the functional status of some Indian runners at the time of pre-selection training for Mexico Olympics of 1968. They reported values of $\dot{V}O_2$ max of 48.4-63.5 ml $kg^{-1}$ $min^{-1}$ which are higher than those observed in ATH in the present study having values of 38.4 - 55.4 ml $kg^{-1}$ $min^{-1}$. The reported range of values in world class athletes is 74.4 - 82.0 ml $kg^{-1}$ $min^{-1}$ (14), which are much higher than the Indian standard.

The higher values of $\dot{V}O_2$ max in athletes are the result of training besides may be some genetic endowment in them (15). Training increases $\dot{V}O_2$ max by increasing the cardiac output secondary to high stroke volume, and an increase in arterio-venous $O_2$ difference (16-17). It appears that physical training increases $\dot{V}O_2$ max by about 50% due to an increase in cardiac output and the rest 50% due to increased extraction of $O_2$ by working muscles, which is reflected in an increased arterio-venous $O_2$ difference (16, 17, 18). Since the presently obtained values of max HR do not differ significantly between the two groups, the athletes increase their $\dot{V}O_2$ more capacity by increasing their stroke volume. This is further substantiated by the max $O_2$ pulse between the two groups, as the $\dot{V}O_2$ per heartbeat is an index representing both the stroke volume and the average arterio-venous $O_2$ difference.

Significantly lower max RQ in ATH (Table III) is due to the fact that during exercise, trained persons utilise a higher percentage of fatty acids with a lower percentage of carbohydrates than NATH (20). The values for max VE do not differ significantly between the two groups (Table III). On the other hand BR at $\dot{V}O_2$ max in ATH is significantly higher (Table III), due to a significantly higher value of MVV in ATH (Table III). It thus appears that ATH, who have higher capacity of increasing $\dot{V}E$ during exercise are more economical in the energy expenditure, since all of the additional oxygen thus gained by increasing $\dot{V}E$ would be required for work of breathing (21).

DI, or percentage BR at rest, in adult Indians had been shown to be between 80-90% (22). When it falls below 60% dyspnoea is manifested (4). In the present study the values of DI at $\dot{V}O_2$ max did not differ significantly between the two groups. This suggests that both the groups become equally breathless at their respective $\dot{V}O_2$ max work load. This implies that the limit to exercise tolerance in an individual, can be evaluated by noting the DI during work. Thus the measurement of DI at work may be an alternative simple method to determine physical work capacity without measuring $\dot{V}O_2$ max.

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