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Original Article

Effect of Duration of Exercise on VO2 Max and Endurance

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Abstract

Introduction: Regular long-term exercise increases VO2 max by increasing stroke volume and arteriovenous oxygen difference. Exercise increases quantity and activity of key enzymes of glycolysis and thus endurance.

Objectives: The objective of this study was to assess the cardiorespiratory fitness using VO2 max and endurance (fatigue index) in healthy males who are involved in regular exercise in gymnasium for ≤1 year (Study group A), for 1–5 years (Study group B) and in sedentary healthy males (Study group C), to compare the VO2 max and endurance among, Study group A, Study group B, and Study group C, and to correlate effect of duration of exercise on VO2 max and endurance.

Materials and Methods: Estimation of VO2 max is done by Bruce Treadmill Test and endurance is done by Harvard step test in 90 healthy males in the age group of 18–35 years after approval from the Institutional Ethics Committee.

Results: The VO2 max is 18.3 times higher in Group A compare to Group C and 196 times higher in Group B compared to Group C ($P < 0.0001$). The endurance is 2.75 times higher in Group A compared to Group C ($P < 0.07$) and 11 times higher in Group B compared to Group C ($P < 0.0001$).

Conclusion: In the present study, we found that there is statistically significant improvement in VO2 max and endurance with duration of exercise. Hence, regular exercise improves the VO2 max and endurance.

Key words: Cardiorespiratory fitness, Endurance, Exercise, Fatigue index, VO2 max

INTRODUCTION

A nonlinear decline in cardiorespiratory fitness occurs with advancing age when not accompanied by regular exercise.[1,2] Cardiorespiratory endurance is related to the ability of body to sustain prolonged and rhythmic exercise.[3] Regular long-term exercise increases cardiorespiratory fitness.[2]

Cardiorespiratory fitness is globally evaluated as maximum oxygen uptake (VO2 max) that reflects the amount of oxygen utilized by working group of muscles during maximal exercise.[4,5] At maximal exercise, the majority of evidence points toward the VO2 max that is limited by oxygen supply, and cardiac output (Q) which is the major factor in determining oxygen delivery.[6] VO2 max is defined as the highest rate of oxygen consumption attainable during maximal or exhaustive exercise.

As we increase exercise intensity, oxygen consumption will eventually either plateau or decrease slightly, even with further increase in intensity, indicating we have reached the VO2 max.[3] Furthermore, research shows that VO2 max increases with physical training for only 8–12 weeks and after that this value plateaus, despite continued higher intensity training. Although VO2 max does not continue to increase, the participants continue to improve their endurance performance. Higher the percentage of VO2 max, greater the ability to perform. During endurance training, more oxygen can be delivered and consumed than in untrained state. An average increase in VO2 max of 15–20% can be observed in previously untrained males

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after training for 6 months. These improvements allow one to perform endurance activities at a higher work rate or faster pace, improving performance potential.[3]

There is a decrement in VO2 max (ml/kg/min) of about 1.6%/year in both males and females.[7] In untrained individuals, a decline in VO2 max of 5–10% per decade of life has been observed.[8]

In this study, an investigation on the effect of exercise and duration of exercise on cardiorespiratory fitness using cardiac and respiratory parameters VO2 max and endurance (fatigue index) was performed.

MATERIALS AND METHODS

After taking approval of the Institutional Ethical Committee, cardiorespiratory fitness of the sedentary healthy individuals and those healthy individuals who were involved in regular exercises in gymnasium (weight lifting exercises for the upper limbs, lower limbs, and torso along with cardio exercises) for ≤1 year and 1–5 years, respectively, was recorded in accordance with the standardized methods from May 2019 to February 2020 in a well-known local gymnasium. A complete medical history of all the subjects were recorded. Data collection was done after informed consent. Procedure of data collection was explained in detailed to subjects.

Sample Size

Total sample size = 90 males. They were grouped as follows.
Group A = Thirty healthy males regularly exercising for duration of ≤1 year.
Group B = Thirty healthy males regularly exercising for duration of 5 years.
Group C (control group) = Thirty sedentary but healthy males.

Collection of Data

VO2 MAX[9]

For estimation of VO2 max, participants were asked to perform Bruce Treadmill Test. The Bruce Protocol is a maximal exercise test, where the athlete works to complete exhaustion as the treadmill speed and incline are increased every 3 min. The length of time on the treadmill is the test score and can be used to estimate the VO2 max value.[9]

VO2 max can be predicted by ergometer more accurately as compared to other methods. In this study, metabolic equation formula available from ACSM was used to calculate VO2 max. VO2 max indirect calculations. Thus, overall, the VO2 max was calculated based on the following metabolic calculations:

Harvard step test[10]

The subjects performing the test were asked to step up and down on a platform in a cycle of 2 s. The platform is at a height of about 50 cm or 20 inches. The rate of 30 steps/min must be sustained for 5 min or until exhaustion. To ensure correct speed, a metronome was used. Exhaustion was the point at which the subject was notable to maintain the stepping rate for 15 s. On exhaustion or completion of test, the subject proceeded to sit on a chair, heartbeats were counted for 1 to 1.5, 2 to 2.5, and 3 to 3.5 min.

The results were recorded as time until exhaustion in seconds (te) and total heartbeats were counted (hb). A simple fatigue index equation was used, the formula is as mentioned below:

Fatigue index = te × 100/hb × 2
The result by above equation is rated in Table 1.

Statistical Analysis

We used descriptive statistics to access median and Inter Quartile Range of continuous characteristics among 1-year exercise, 1–5 years of exercise groups, and no exercise group.

We used to use excel and R programming software. We compared these characteristics using Kruskal–Wallis test after the data were tested normal distribution. The high VO2 max and endurance were categorized using the corresponding overall median value (including all data of three groups). High value defined if the value obtained is equal to or more than corresponding overall median value. Binary logistic regression was used to assess the association between exercise duration and VO2 max as well as the association between exercise duration and endurance. We used two-sided p value and statistical significance was evaluated at 0.05 alpha level.

RESULTS

Table 2 shows comparison between Study group A, Study group B, and Control group C with respect to age, weight, height, and body mass index.

Table 3 shows comparison between Study group A, Study group B, and Control group C with respect to VO2 max and endurance.

Table 4 shows logistic regression to assess the association between VO2 max, endurance, and exercise duration.

Table 1: Endurance or fatigue index rating for Harvard step test

Rating	Endurance (Fitness index)
Excellent	>97
Good	83–96
Average	68–82
Low average	54–67
Poor	<54

Table 2: Comparison between Study group A, Study group B, and Control group C with respect to age, weight, height, and body mass index

Characteristics	No exercise (Group C) Median, IQR *n*=30	≤1 Year exercise (Group A) Median, IQR *n*=30	1–5 Years exercise (Group B) Median, IQR *n*=30	*P*-value
Age (years)	18 (18–19)	19 (18–21)	19 (18–22)	>0.05
Weight (kg)	62.79 (53.60–71.98)	62.53 (53.59–71.47)	61.21 (52.58–69.84)	>0.05
Height (m)	1.70 (1.65–1.75)	1.70 (1.66–1.74)	1.70 (1.65–1.75)	>0.05
BMI (kg/m^2)	22.4 (21.6–23.1)	22.7 (21.7–23.5)	22.7 (22.6–22.8)	>0.05

IQR: Inter Quartile Range, N: Number of subjects, m: meters, kg: kilograms, BMI: Body Mass Index, *P*>0.05 is statistically not significant, *P*≤0.05 was considered as significant at 95% confidence interval, *P*<0.0001 was considered as highly significant

Where, high VO2 max defined as those who had VO2 max >/= 43 (median value of the overall VO2 max)

High endurance defined as those who had endurance ≥98 (median value of the overall endurance).

DISCUSSION

There is statistically significant increase in the mean of VO2 max and endurance (fatigue index) in Group B than Group A than Group C ($P < 0.0001$). $P < 0.0001$ was considered as highly significant.

There is increase in VO2 max with physical training.[3]

Mechanism

After few days of exercise, there is increase in plasma volume, which results in increased venous return. Thus, there is increase in end-diastolic volume. Along with increased end diastolic volume, there is decreased cardiac afterload which results in increased ejection fraction. Therefore, stroke volume increases.[3,11-14]

After few weeks of exercise, there is increased red blood cell volume, increased vascular function, increased capillary density, and increased mitochondrial volume density thus oxidative capacity. All these changes result in better distribution of blood to active muscle fibers and increased muscle oxygen extraction. Therefore, increased arteriovenous oxygen difference and ultimately increased VO2 max.[3,11-14]

Whereas after few months of exercise, there is increased ventricular compliance and ventricular hypertrophy. This causes increased end-diastolic volume and finally VO2 max increases.[3,11-14]

According to Fick's equation[15]

VO2 max = SV × HR × (a – vO2 difference)

Where,
SV is stroke volume

Table 3: Comparison between Study group A, Study group B, and Control group C with respect to VO2 max and endurance

Parameters	No exercise Group C	≤1 Year exercise Group A	1–5 years exercise Group B	P-value
VO2 Max				
Median	37	43	59	0.0001*
IQR	(36–39)	(41–45)	(46–61)	
Endurance				
Median	96	98	99	0.0001*
IQR	(95–98)	(96–98)	(98–100)	

**P*<0.0001 was considered as highly significant

Table 4: Logistic regression to assess the association between VO2 max, endurance, and exercise duration

Parameters	No exercise Group C	≤1 Year exercise Group A	1–5 Years exercise Group B
VO2 Max			
High VO2 Max	2 (7%)	17 (57%)	28 (98%)
OR 95% C.I.	Ref	18.3 (3.96 – 91.2)	196 (26 – 1490)
P value	-	<0.0001	<0.0001
Endurance (Fatigue index)			
High endurance	8 (26%)	15 (50%)	24 (80%)
OR 95% C.I.	Ref	2.75 (0.93–8.10)	11 (3.29–36.75)
P value	Ref	0.07	<0.0001

High VO_2 max: Defined as those who had VO_2 Max >/= 43 (Median value of the overall VO_2 Max). High endurance: Defined as those who had endurance >= 98 (Median value of the overall endurance)

HR is heart rate
(a – vO2 difference) is arteriovenous oxygen difference

Endurance (Fatigue Index)

Physical training results in increase in endurance.[3]

Mechanism

Increased level of anaerobic substrates, that are – Adenosine triphosphate, Phosphocreatine, free creatine, and glycogen.[3,16-18]

Increase in endurance is due to increased level of anaerobic substrates (adenosine triphosphate, phosphocreatine, free

creatine and glycogen), increased activity of key enzymes that control the glycolytic (anaerobic) phase of glucose catabolism and motivation which leads to improved pain tolerance.[3,16-18]

CONCLUSION

In the present study, we found that there is statistically significant improvement in VO2 max and endurance (fatigue index) in ≤1-year exercise group compared to the no exercise group, whereas there is profound improvement in VO2 max and endurance (fatigue index) in 1–5 years exercise group compared to 1-year exercise group. This, thus, shows a positive correlation between duration of exercise and improvement of cardiorespiratory parameters.

It is therefore advisable to make exercise as a part of lifestyle. Thus regular, long-term exercise routines are recommended for a healthy and quality life.

Limitations of the Study

The sample size is less so results can differ in larger population. Experiments with different intensities of cardio exercises were not performed. The reliance on self-reported data for physical training could be influenced by poor recall which may be another limitation of this study. Only males were part of the study.

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