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Long-Term Regular Exercise Increases VO2max for Cardiorespiratory Fitness

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Abstract

This study tries to discuss maximum oxygen consumption (VO_2max) strategy and its importance to build up a healthy society worldwide. VO_2max is an important predictive factor of cardiovascular health, morbidity, and all-cause mortality; and consider it as the gold standard measure of cardiorespiratory fitness. Regular and long-time physical exercise, and exercise training are effective means of increasing VO_2max. This research aims to increase VO_2max and endurance capacity through the prolonged strenuous exercise, hardworking, and exercise training.

Keywords: VO_2max, exercise, cardiorespiratory fitness

1. Introduction

VO_2max is the maximum rate of oxygen consumption capacity during an intense physical effort, which is an indicator of the basic concepts of physical fitness. Here "V" is for volume, "O_2" for oxygen, "max" for maximum, and the dot over V means per unit of time (Smirmaul et al., 2013). When a gymnast increases exercise intensively, oxygen consumption will eventually be either plateau or decrease slightly, even with further increase in intensity of exercise; then s/he will confirm that s/he has reached in the VO_2max (McArdle et al., 2010). The concept of maximal oxygen uptake (VO_2max) and oxygen (O_2) debt is developed in 1922 by the British physiologist Archibald Vivian Hill (1886-1977) (Hill, 1926; Hale, 2008).

VO_2max is an indication of cardiorespiratory fitness (CRF). It incorporates multiple organ systems that are influenced by a number of factors, from respiration to end-organ oxygen consumption; and later consume through the cellular metabolism (Stringer, 2010). Factors that determine VO_2max are heart-lung function, age, aerobic muscle metabolism, body fatness, state of exercise, genetics, gender, and multivitamin (Huldani et al., 2020; Mohajan & Mohajan, 2023c, d). When an individual organize exercise, the increase in metabolism is expressed as the whole-body oxygen uptake that increases with exercise intensity to reach at VO_2max (Moxnes & Hausken, 2012).

VO_2max is also called cardiopulmonary exercise testing (CPET) and it is considered as an exercise stress test. It reflects cardiorespiratory fitness and endurance capacity for a heavy exercise or any laborious work. The results during exercise show the fitness level and aerobic endurance of a gymnast (Dlugosz et al., 2013). VO_2max can be expressed in two ways as; i) absolute, where unit of VO_2max is liters of oxygen per minute (L/min), and ii) normalized, milliliters of oxygen per kilogram of subject bodyweight per minute (mL/kg/min). The latter is used to compare the performance of endurance sports athletes (Scribbans, 2016).

The velocity that is reached at VO_2max is called vVO_2max, and the time that vVO_2max can be sustained for is

called T_{max}. When a person starts physical exercises, increase in plasma volume that results in increased venous return. Consequently, increased end-diastolic volume, there is decreased cardiac afterload. Consequently, stroke volume of the person increases (Maughan & Leiper, 1983; Little et al., 2010).

2. Literature Review

To be familiar with the research field, literature review is an important item for a researcher. In any research, it is a starting section, where works of previous researchers are emphasized (Polit & Hungler, 2013). It helps the new researchers to understand the subject area for performing their research efficiently (Creswell, 2007). Shahinaj Dcosta and her coauthors have wanted to assess the cardiorespiratory fitness using $\dot{V}O_2max$ and endurance among healthy males who are involved in regular exercise in gymnasium. They have found that there is statistically significant improvement in $\dot{V}O_2max$ and endurance with duration of exercise, i.e., regular exercise improves the $\dot{V}O_2max$ and endurance (Dcosta et al., 2022). Steven A. Hawkins and Robert A. Wiswell have shown that cardiorespiratory fitness on quality of life, cardiovascular disease and all-cause mortality are age-related, and with advancing age $\dot{V}O_2max$ decreases. Over the age of 70 years, the decline in $\dot{V}O_2max$ seems to be reduced both in maximal heart rate (HRmax) and lean body mass (LBM). Exercise training does not influence declines in HRmax, but LBM can be maintained to some degree by physical exercise (Hawkins & Wiswell, 2003).

Andrzej Klusiewicz and his coauthors have explained the usefulness of indirect methods of assessment of $\dot{V}O_2max$ to estimate physical capacity of trained male and female rowers during a training cycle. In their study they have observed that two elaborated methods of estimation of maximal oxygen uptake yield more accurate results in male compared to female rowers (Klusiewicz et al., 2016). Anabel N. Rodrigues and her coworkers have noticed that inactivity is a growing problem that affects an ever growing number of children and adolescents. The identification of population levels of $\dot{V}O_2max$ is an aid to studies that propose to relate physical fitness to cardiovascular risk for prescribing exercise and analyzing the effects of training (Rodrigues et al., 2006). Devajit Mohajan and Haradhan Kumar Mohajan have tried to discuss obesity and overweight with the physical effects (Mohajan & Mohajan, 2023a,d). They have also stressed on various indices, such as Body Mass Index (BMI), Ponderal Index, and Broca Index with the importance in health sciences (Mohajan & Mohajan, 2023b,c,e).

Stephen Seiler has informed that hundreds of laboratories are doing physiological tests on endurance athletes. In these labs three core variables are routinely measured, such as the maximal oxygen consumption, the lactate threshold, and work economy or efficiency (Seiler, 2011). Süleyman Gönülateş wants to determine whether there is a difference between the VO_2max values in the field and laboratory tests. He has obtained that the VO_2max value in the applications of the laboratory environment is higher than the VO_2max value in the applications of the field test (Gönülateş, 2018).

John F. Moxnes and Kjell Hausken present a theoretical study comparing the improvement of the whole body $\dot{V}O_2max$ when training is performed at different intensities. They compare $\dot{V}O_2max$ improvement in five training methods. Later, they have established a weight function that is important for aerobic utilization and stroke volume utilization (Moxnes & Hausken, 2012). Daizong Wen and his coauthors have examined the effects of different protocols of high-intensity interval training (HIIT) on $\dot{V}O_2max$ improvements in healthy, overweight/obese and athletic adults, based on the classifications of work intervals, session volumes and training periods (Wen et al., 2019). J. Susie Woo and her coauthors want to determine whether changes in oxygen efficiency occur with aging or exercise training in healthy young and older subjects. Exercise capacity declines with age and also improves with exercise training (Woo et al., 2006).

3. Research Methodology of the Study

There is no alternative but research to an academician and it is considered as an essential and influential work for his/her carrier development (Pandey & Pandey, 2015). Methodology is a clear guideline to do a good research that follows scientific methods properly (Kothari, 2008). It tries to describe the types of research and the types of data (Somekh & Lewin, 2005). Therefore, research methodology is a working procedure for planning, arranging, designing, and conducting a meaningful and valuable research (Remenyi et al., 1998; Legesse, 2014). In this mini review we have started main body of research with a discussion on aerobic and anaerobic fitness capacity and boundary level of VO_2max. Then we have stressed on VO_2max measurements methods. Also we have observed and worked on VO_2max variations due to age, sex and hemoglobin level. Finally, we have briefly highlighted the benefits of VO_2max. To prepare this paper we have consulted books of famous authors, national and international journals, handbooks, theses, etc.

4. Objective of the Study

The key objective of this study is to discuss $\dot{V}O_2max$ in some details. Other minor related objectives of the study are as follows:

- to highlight on benefit of VO_2max
- to show variation of VO_2max due to age and sex level, and
- to indicate boundary of VO_2 max.

5. Aerobic and Anaerobic Fitness Development

Aerobic fitness depends on cardiovascular, respiratory, and hematological components that are determined by means of the cardiopulmonary exercise testing. Regular long-term exercise increases VO_2max by increasing stroke volume and arteriovenous oxygen difference. Physical exercise increases quantity and activity of key enzymes of glycolysis to develop endurance of a person (Dcosta et al., 2022). Aerobic fitness is typically measured as VO_2max and is used frequently as an indicator of cardiorespiratory fitness (Wen et al., 2019). Higher relative aerobic capacity represents better physical performance and lower risk of cardiovascular/coronary heart diseases and all-cause mortality (Kodama et al., 2009).

High-intensity interval training (HIIT) is an effective alternative approach for improving VO_2max in healthy, overweight/obese, and athletic adults. It improves both aerobic and anaerobic fitness, and also improves endurance performance (Wen et al., 2019). When high-intensity exercise is done by a gymnast or an athlete for a few seconds, adenosine triphosphate (ATP) is resynthesized by both aerobic and anaerobic processes, which are conventionally evaluated by VO_2max. Due to high-intensity exercise an athlete's ability is grown up to release energy both aerobically and anaerobically (Taylor et al., 1955).

6. Boundary Level of VO_2max

The untrained healthy males and females can achieve a VO_2max about 35-40 and 27-31 mL/(kg.min) respectively (Heyward, 2010). The VO_2max values for elite athletes can be achieved above 90 mL/(kg.min), mice have about 140 mL/(kg.min), running horses have about 193 mL/(kg.min). Some strength animals, such as Alaskan huskies can be achieved VO_2max values as high as 240 mL/(kg.min), and pronghorn antelopes have as high as 300 mL/(kg.min) (Lindstedt et al., 1991; Dlugosz et al., 2013; Smirmaul et al., 2013).

7. Measurement of VO_2max

VO_2max measurements are used for prescribing exercise and analyzing the effects of training programs, and to relate physical fitness against cardiovascular risks (Rodrigues et al., 2006). VO_2max is the golden standard measure for the individual's aerobic fitness level. A commonly used value for O_2 consumption at rest is 125 mL O_2 per minute per square meter of body surface area during an intense, maximal effort. VO_2max can be estimated from a race performance through many tests, such as the Cooper test, Rockport method, Bruce Treadmill Test, Harvard step test, etc. (Cooper, 1968; Dcosta et al., 2022). The measurement of cardiac output can be performed using Fick equation, which is developed in 1870 by German born physician and physiologist Adolf Eugen Fick (1829-1901), and can be written as (Fick, 1870),

$$VO_2 = CO \times \left(C_aO_2 - C_vO_2\right) \tag{1}$$

where CO is cardiac output, VO_2 is oxygen consumption (mL/min), C_aO_2 is arterial oxygen consumption, and C_vO_2 is venous oxygen consumption (Gazibarich et al., 2019). Equation (1) provides us the information that the rate of oxygen uptake from alveolar gas. The term $\left(C_aO_2 - C_vO_2\right)$ is also known as the arteriovenous oxygen difference (Ross et al., 2016). The concept of accumulated oxygen deficit is first introduced by Danish Professor August Krogh (1874-1949) and a Danish physiologist and gymnastic writer Johannes **Lindhard** (1870-1947) in 1920 (Krogh & Lindhard, 1920).

8. VO_2max Due to Age, Sex, and Hemoglobin Level

VO_2max has a strong relationship with age. The functions of heart and lungs are different between young and elderly people. The VO_2max of elderly people decreased due to decline function of the lungs, heart, and blood vessels. The age level of 20-30 years is the peak age of the endurance of the heart and lungs of human body, and then VO_2max will decrease with age (Woo et al., 2006). Age-related loss of VO_2max seems to occur in a non-linear manner in association with declines in physical activity (Pugh & Wei, 2001). Older age, female, and the untrained state are related to decrease in exercise capacity and also decrease VO_2max. Maximum heart rate is decreased with aging and stroke volume is reduced in females and the untrained persons (Woo et al., 2006).

VO_2max are different for male and female due to differences in composition and body size, and also a male has more hemoglobin concentrations than a female, which binds more oxygen to produce energy. A woman's body carries more fat than men which causes women to have a smaller VO_2max (McArdle et al., 2006). It is evidence that the VO_2max a 10% decline per decade in men and women regardless of activity level from age 20 to 60 years (Robinson, 1938; Rogers et al., 1990) and a 22% decline per decade in athletes over the age of 70 years

(Pollock et al., 1974). Also high intensity exercise is maintained for a long-term, may reduce this loss up to 50% in young and middle-aged men, but not in older men (Meredith et al., 1987). On the other hand, middle-aged and older women do not appear to be able to reduce this loss less than 10% per decade (Hawkins & Wiswell, 2003).

9. Benefit of $\dot{V}O_2max$

A gymnast can know the maximum heart beats per minute at the maximum working situation. S/he can realize the starting time of lactic acid gathering starts in the muscles during anaerobic threshold (Buttar et al., 2019). Also s/he can determine the level of efforts of aerobic threshold before anaerobic threshold. After few weeks of exercise, there is increased red blood cell volume; increased vascular function, increased capillary density, and increased mitochondrial volume density thus increase oxidative capacity (Ross et al., 2016; Dcosta et al., 2022).

Prolonged and rhythmic regular exercise increases cardiorespiratory endurance. If an individual is not accompanied by regular exercise, cardiorespiratory fitness must decline (Fleg et al., 2005). Well-established risk factors, such as hypertension, diabetes, smoking and obesity, hypercholesterolemia, and cardiovascular fitness are more powerful predictors of mortality, and $\dot{V}O_2max$ practice can reduce these to lead a healthy life (Myers et al., 2002; Mohajan & Mohajan, 2023a,b).

10. Conclusions

In this study we have observed that $\dot{V}O_2max$ is one of the most fundamental measures of human physiology. Regular and long-term routinely exercises can present human beings a healthy and quality life. We have realized that exercise efficiency and exercise capacity are decreased in older age. Also $\dot{V}O_2max$ varies on gender, and women have lower $\dot{V}O_2max$ than men. We have also understood that maintaining cardiovascular fitness we can reduce the risk of all-cause morbidity, mortality, and cardiovascular diseases. Insufficient physical activity results overweight and obesity that are the risk factors of various non-communicable diseases (NCDs), such as cardiovascular disease, stroke, diabetes, cancers, etc. Physical activity and lifestyle modification irrespective of age are the key factors for primary prevention of cardiovascular, metabolic, and mental disorders.

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