DOI: https://doi.org/10.32345/2664-4738.2.2024.02
УДК: 612.014.1:612.216]:613.72(049.5)

MAXIMAL AEROBIC CAPACITY (VO_2max): A COMPREHENSIVE OVERVIEWУ

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Background. The ability to perform extended, intense activity and the combined capacity of the respiratory and cardiovascular systems are known as cardio-respiratory fitness (CRF), also referred to as maximal aerobic power. It typically reported as VO_2 max.

Aim: To investigate the maximal aerobic capacity (VO_2max) in young adults.

Materials and methods. This observational research was done on 100 seemingly healthy 18–25-year-old individuals at the RUHS College of Medical Sciences in Jaipur, Rajasthan, India. Maximal Aerobic Capacity was assessed by analyzing the gases involved in pulmonary ventilation directly while completing exercise stress test on treadmill using various protocols.

Results. The VO_2 max and tidal volume had a weak positive association (r = 0.345). There was a weak positive association between VO_2 max and tidal volume in male (r = 0.128) and female (r = 0.039) respectively. There was a weak negative association between VO_2 max and oxygen saturation in male individuals (r = −0.216) and female individuals (r = −0.059). There was a weak positive relationship between VO_2 max and GPAQ in both male (r = 0.009) and female (r = 0.065) participants.

Conclusion. Both male and female individuals had a weak positive correlation between VO_2 max and tidal volume, but a weak negative correlation for O_2 saturation, which was caused by increased oxygen demand during exercise. There was a weak positive correlation between VO_2 max and GPAQ. This concluded weak but statistically non-significant relationship of daily physical activity with VO_2 max and GPAQ.

Key words: global physical activity questionnaire, graded exercise protocol, maximal aerobic capacity, O_2saturation, tidal volume.

Background. Fitness is a multidimensional state that often refers to two goals: performance that combines six skill-related fitness components and health that incorporates five health-related fitness components, each of which plays a role in fitness, which contributes to the overall quality of life. Six skill-related components make up fitness: agility, balance, coordination, power, speed, and response time. The health-related aspects of physical fitness are muscular strength, cardio-respiratory endurance, flexibility, and body composition [1]. Among its components, great importance has been given to cardiopulmonary capacity (CRF), also known as aerobic capacity or maximal aerobic strength [2]. It refers to the cardiovascular and respiratory systems' total capability, as well as the ability to execute continuous high-intensity activity [3].

Among other factors, regular physical activity is an important aspect for achieving optimal fitness. Insufficient physical activity is a risk factor for non-communicable diseases such as cardiovascular disease, diabetes, stroke, cancer, and health problems such as mental disorders and obesity [4]. Cardiovascular fitness plays an important role not only in athletic performance but also in everyday activities such as walking, running and climbing stairs. In adults, fitness is a strong and independent predictor of cardiovascular disease as well as all-cause mortality and morbidity. Studies suggest that the respiratory and cardiovascular capacities of young people are declining. Accurate

measurement of cardiovascular fitness is essential to determine appropriateness and monitor the effects of interventions. Cardiovascular fitness is often reported as VO_2 max, the maximum oxygen consumption achievable with maximum intensity exercise [5].

VO_2 max, or maximum oxygen uptake, is the fastest rate at which the body can take in and use oxygen when engaging in physical activity. It is one of the key variables in the field of exercise physiology, a gold standard for indicating cardiovascular-respiratory endurance or aerobic capacity and for understanding an individual's mechanism of exercise tolerance [6].

VO_2 maximal can be estimated using peak or submaximal tests, by direct or indirect methods. The most commonly used tests are the walk/run test followed by the cycling and walking test. Sub-decimal testing can be helpful in making appropriate operational recommendations, in recognizing the need for modification of medical regimens, or the need for other interventions. Submaximal tests are also appropriate for patients with a high likelihood of serious arrhythmias. An individual's maximum oxygen consumption during exercise is known as maximal oxygen uptake (VO_2max) and is influenced by age, sex, exercise habits, genetics, and health. It can be measured directly when gas exchange data are collected in cardiopulmonary ET, or predicted in standard ET using equations.

A person's maximum aerobic strength (VO_2max) can be estimated using direct or indirect methods. The direct method (laboratory method) measures VO_2 maximal by directly analyzing the gases involved in pulmonary ventilation, while performing maximal and maximal effort tests. Field testing is an example of an indirect technique; it gauges an individual's aerobic capacity by measuring heart rate, distance walked, and/or test duration while following a specific protocol. [7]. Field tests to assess cardiovascular health using an indirect method to estimate VO_2 max have significant measurement errors.

MATERIALS AND METHODS

With approval from the Institutional Ethical Committee (EC/P-31/2020), this observational study was carried out in the Research Laboratory of the Department of Physiology, RUHS College of Medical Sciences, Jaipur, Rajasthan, India, from December 2020 to May 2021. Following a comprehensive explanation of the protocols that would be adhered to throughout the study, every participant gave their informed consent. One hundred young adults, aged between eighteen and twenty-five, of both sexes, who appeared healthy, were enrolled in the research.

Inclusion criteria

The study included 100 seemingly healthy young individuals (50 males and 50 women) between the ages of 18 and 25. There was no physical exercise (bike, aerobics, skating, scuba diving, professional sports, athletics, water jogging, 5 mph walking, competitive gymnastics) for the subjects.

Exclusion criteria

Excluded were smokers, drinkers, individuals with high blood pressure, diabetes, and various mental health conditions; heart problems; respiratory conditions like COPD, asthma, pneumothorax, and respiratory tract infections; musculoskeletal conditions; and patients on prescription medications that affect cardiovascular control.

Experimental Protocol

The baseline demographics of all participants, including as height, weight, gender, and age, were gathered. All individuals were told to fast overnight and not exercise for 48 hours before to measurement. They were instructed not to consume alcohol, smoke, or consume caffeine in the prior 24 hours. Subjects were told to rest for around 30 minutes after arriving at the facility before being forced to wear a mask that allowed just them to breathe in and out. The mask was connected to the gas analyzer via a connecting hose and a gas mixing chamber. The individuals were instructed to perform to the best of their abilities while the treadmill speed and intensity were gradually increased in accordance with the Graded exercise regimen.

Tidal volume was measured through direct analysis of the gases involved in pulmonary ventilation with help of gas analyzer. Oxygen saturation was measured by pulse oxymetry. A clip like device called probe was placed on fingertip of subject and was left on for ongoing monitoring. Maximal Aerobic Capacity was assessed scientifically and consistently in the lab by analyzing the gases involved in pulmonary ventilation directly while completing exercise stress test on treadmill using various protocols. The treadmill test parameters were measured using a Graded exercise protocol. After a 3-minute walking warm-up period at 0% elevation, subjects were asked to walk briskly at a self-selected pace (4.3 to 7.5 mph) at the same incline for 3 minutes, then at constant speed, treadmill incline increased by 2.5% per minute until steady-state heart rate (HR) ≤ 180 beats/min or subject fatigue and unable to continue exercise volume [8,9]. During the process, the device is connected to a control screen, which shows us different values such as volume of oxygen (VO_2), volume of carbon dioxide (VCO_2), energy consumption at rest3 (REE), and respiratory exchange rate. (RER), metabolic equivalence of tasks (MET), etc. every 10 seconds.

Information on sedentary behaviour and physical activity participation was done through GPAQ included of 16 questions (P1–P16) in three settings (or domains) as Activity at work, Travel to and from places, Recreational activities.

Statistical analysis

The study's findings are presented as mean + standard deviation. VO_2 max and HRV data were compared using a student t-test. SPSS version 16.0 (Chicago, Inc., USA) was used for the analysis, with a p-value of 0.05 chosen as the significance level.

RESULTS AND DISCUSSION

This observational research was undertaken in the department of physiology at the RUHS College of Medical Sciences in Jaipur on 100 apparently healthy students (50 male and 50 female) between the ages of 18 and 25 who were recruited by convenience sampling.

The subjects had a mean age of 21.03±2.45 years, height 1.64±0.08 meters, weight 59.66±11.15 kg and BMI of 22.08±3.75 kg/m^2. The mean height was 1.69±0.06 meters for male subjects and 1.58±0.06 meters for female subjects, which was statistically significant. The mean weight was 62.52±9.52 kg for male subjects and 56.80±11.64 kg for female subjects, which was statistically significant. Mean BMI was 21.57±3.06 kg/m^2 for male subjects and 22.59±4.3 kg/m^2 for female subjects.

Table 1 shows the distribution of Total 100 subjects according to GPAQ, VO_2max, tidal volume and oxygen saturation. Mean±S.D. of GPAQ Score was 1588.6±747.10 MET per week. Mean±S.D. of VO2 max was 41.58±9.02 mL/kg/min. Mean±S.D. of tidal volume was 1.67±0.59 Liter. Mean±S.D. of Oxygen saturation was 96.9±1.1%.

Table 2 shows distribution of GPAQ, VO_2max, tidal volume and oxygen saturation in 100 subjects (50 male & 50 female). GPAQ score: mean±S.D. of GPAQ Score was 1588.6±747.10. VO2 max: mean±S.D. of VO_2 max was 41.58±9.02 mL/kg/

Table 1

Distribution of GPAQ, VO_2 max, tidal volume and oxygen saturation in total subjects

S. NO	Parameters	Total Subjects mean±S.D. (n= 50)
1.	GPAQ score (MET)	1588.6±747.10
2.	VO_2 max (mL/kg/min)	41.58±9.02
3.	Tidal volume (Litre)	1.67±0.59
4.	Oxygen saturation (%)	96.9±1.1

GPAQ: Global Physical Activity Questionnaire, VO_2max: maximum oxygen consumption

Table 2

Distribution of 50 male & 50 female subjects according to GPAQ, VO_2 max, tidal volume and oxygen saturation

S. NO.	Parameters	Male Subjects (n=50) mean±S.D.	Female Subjects (n=50) mean±S.D.	p-value
1.	GPAQ score (MET)	1754±820.93	1347.4±577.10	0.002
2.	VO2max (mL/kg/min)	45.69±8.57	37.47±7.50	0.00001
3.	Tidal volume (Litre)	2.03±0.59	1.32±0.29	0.00001
4.	Oxygen saturation (%)	97±1.2	96.9±1.0	0.332

The result is significant at $p<0.05$,
GPAQ: Global Physical Activity Questionnaire, VO2max: maximum oxygen consumption

min. Tidal volume: mean±S.D. of tidal volume was 1.67±0.59 Litre. Oxygen saturation: mean±S.D. of Oxygen saturation was 96.9±1.1 %.

The correlation of VO_2 max with tidal volume and oxygen saturation in 100 subjects were observed. Figure 1 shows moderate positive correlation (r = 0.345) of VO_2 max with tidal volume and the association was statistically significant.

Figure 2 shows weak negative correlation (r=-0.137) of VO_2 max with Oxygen saturation and the association was not statistically significant.

Table 3 shows the correlation of VO2max with tidal volume and oxygen saturation in 50 male and 50 female subjects. There was weak positive correlation of VO_2 max with tidal volume and the association was not significant for both male subjects and female subjects. There was weak negative correlation of VO_2 max with Oxygen saturation and the association was not significant for both male subjects and female subjects.

The correlation of VO_2 max with GPAQ for 100 subjects was observed. Figure 3 shows weak positive correlation (r=0.220) of VO_2 max with

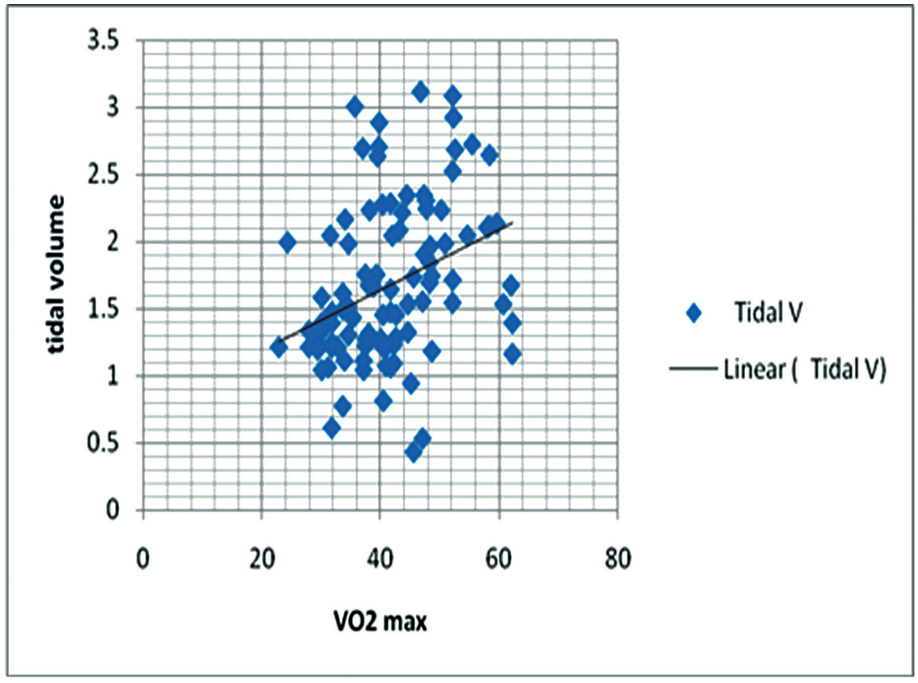

Fig. 1. Correlation of VO_2max with tidal volume in total subjects
VO_2max: maximum oxygen consumption

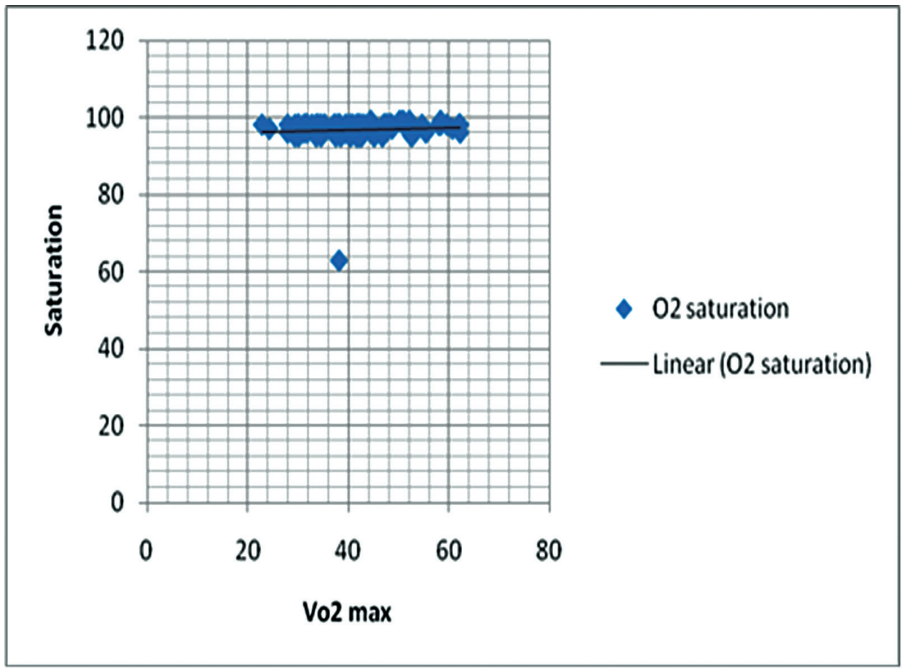

Fig. 2. Correlation of VO_2 max with O_2 saturation in total subjects
VO_2max: maximum oxygen consumption

GPAQ and the association was statistically not significant.

Table 4 shows the correlation of VO2 max with GPAQ for 50 male and 50 female subjects. There was weak positive correlation of VO2 max with GPAQ and the association was not significant for male subjects and female subjects.

DISCUSSION

The purpose of the current observational study was to compare young people's maximum aerobic capacity (VO_2 max). The Department of Physiology at the RUHS College of Medical Sciences in Jaipur provided the research lab for this study. The study included one hundred medical students, aged between eighteen and twenty-five (fifty male and fifty female).

In this study, maximal aerobic capacity (VO_2max) was assessed where the mean VO_2max in the total subjects was 41.58±9.02 mL/kg/min, mean VO_2max for men and women were 45.69±8.57 mL/kg/min and 37.47±7.50 mL/kg/min respectively. In our study, VO_2max in men was higher than in women, this is similar to the study results of Soni H. et al. (2023) [10]. However, the mean VO_2max value was found to be lower for both male and female participants compared to the study mentioned above, possibly due to the different age group (20-29 years old) recruited by Loe et al., who have a high level of physical activity.

In our study the mean tidal volume for all

Table 3

Correlation of VO_2 max with tidal volume and oxygen saturation in male and female subjects

S.NO.	Correlation parameters	Male (n = 50)		Female (n = 50)	
		r-value	p-value	r-value	p-value
1.	VO_2 max with Tidal volume	0.128	0.375	0.039	0.788
2.	VO_2 max with O_2 saturation	-0.216	0.131	-0.059	0.684

The result is significant at $p < 0.05$,
VO_2max: maximum oxygen consumption

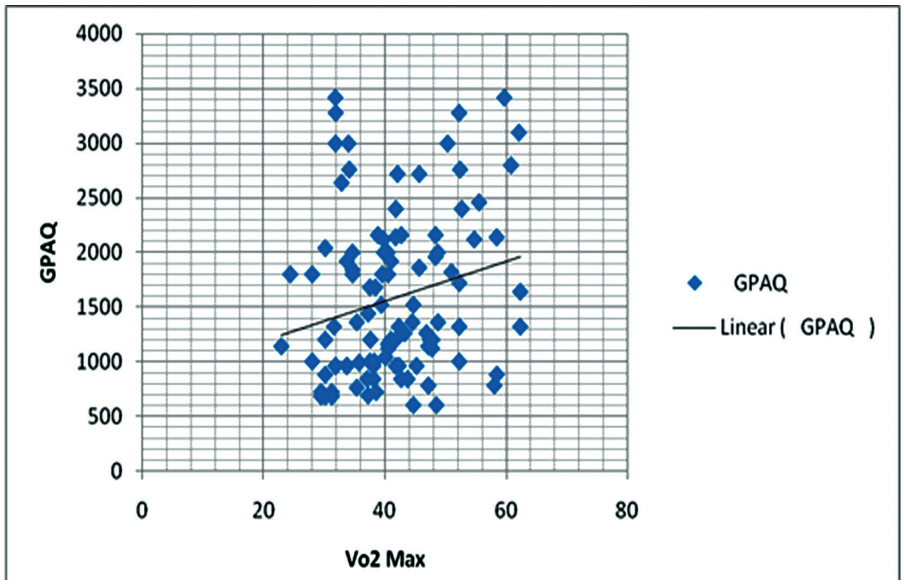

Fig. 3. Correlation of VO_2 max with GPAQ in total subjects
GPAQ: Global Physical Activity Questionnaire,
VO_2max: maximum oxygen consumption

Table 4

Correlation of VO_2 max with GPAQ in male and female subjects

VO_2 max & GPAQ	Male		Female	
	r-value	p-value	r-female	p-value
	0.009	0.502	0.065	0.653

The result is significant at $p<0.05$,
GPAQ: Global Physical Activity Questionnaire,
VO_2max: maximum oxygen consumption

subjects was 1.67±0.59 liter, while the mean tidal volume during exercise for males and females was 2.03±0.59 liter and 1.32±0.29 liter, respectively. Our study indicated that mean tidal volume was increased due to increase in whole body oxygen demand during muscular exercise, which is similar to earlier studies conducted by Clark et al. (1983) [11], Glallagher as al. (1987) [12], and Mc Parland et al. (1991) [13]. In our study, males had a greater mean tidal volume than females, which was similar to another study conducted by Phillips DB et al. (2019) [14].

The mean GPAQ score of total subjects in our study was 1588.6±747.10 MET per week and of male and female subjects 1754±820.93 MET per week and 1347.35±577, respectively. This indicates that all subjects are physically active individuals [15].

The mean O_2 saturation of total subjects under the study was 96.95±1.14 and that of male and female subjects was 97±1.27 % and 96.9±1.01 % respectively. The values were higher for males as compared to female subjects. However the mean values of O_2 saturation was found to be lower for both male and female participants as compared to study conducted by Bichay et al. (2016) [16], which may be due to the moderate level exercise as compared to our's (moderate to severe category of exercise).

The relationship between VO_2 max and tidal volume was investigated in our study. The VO_2 max and tidal volume had a weak positive association (r=0.345). There was a weak positive association between VO_2 max and tidal volume in male (r=0.128) and female (r=0.039) respectively. In our study, mean tidal volume was found to be increased as a result of exercise, which is

comparable to another study by Mihailova et al. (2016) [17], who showed a statistically significant and positive association with physical fitness (VO_2 max) and tidal volume. Both male and female subjects had a direct and statistically significant correlation between VO_2 max and tidal volume after gender was adjusted.

Due to the influence of exercise, there was a weak negative association between VO_2 max and oxygen saturation (r=−0.137). There was a weak negative association between VO_2 max and oxygen saturation in male individuals (r =−0.216) and female individuals (r=−0.059). This negative correlation may be due to an increase in whole body oxygen demand during muscular exercise as observed by Viale et al. (1994) [18].

The relationship between VO_2 max and GPAQ was investigated in this study. For all participants, there was a weak positive association between VO_2 max and GPAQ (r=0.220). There was a weak positive relationship between VO_2 max and GPAQ in both male (r=0.009) and female (r=0.065) participants. In a similar research done by Aadahl et al. (2007) [19], it was discovered that the daily physical activity exhibited a weak, but not statistically significant, relationship with VO_2 max, whereas vigorous exercise (>6 MET) was substantially related with VO_2 max.

Limitations

The study had a small sample size and only a healthy young adult population was included. More study into a variety of exercise regimens, and other physiological parameters such as VO_2max in MET, REE, and tidal volume may be required.

CONCLUSIONS

In our study VO_2 max was found higher in males than females and mean tidal volume was increased due to increase in whole body oxygen demand during muscular exercise. Mean GPAQ score indicates that overall subjects are falling under the category of physically active individuals. Mean O_2 saturation were higher for males as compared to female subjects. Both male and female individuals had a weak positive correlation between VO2 max and tidal volume, but a weak negative correlation for O_2 saturation, which was caused by increased oxygen demand during exercise. For both male and female subjects, there was a weak positive correlation between VO_2 max and GPAQ. This concluded weak but statistically non- significant relationship of daily physical activity with VO2 max and GPAQ. Estimating VO_2 max by direct method provided normal data of VO_2max in Indian population and comparing results accounting gender for better cardio-respiratory fitness.

Acknowledgements – not applicable.

Conflict of interests. The authors of this manuscript claim that there is no conflict of interest during the research and writing of the manuscript.

Sources of funding. The authors received no financial support for the research, authorship, and publication of this article.

Author contributions: Ravi Saini – literature review, writing text, statistical data processing; Naina Jangid, Jitender Sorout, Ambreen Zenab, Preeti Bishnoi – collection and processing of materials; Sudhanshu Kacker – concept and design of research. All authors have made significant contributions to the development concepts, research and manuscript preparation, read and approved final version before publication.

Consent for publication. Written consent was obtained from the patients for the investigation and publication of relevant medical information according to WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects, 2013.

Ethics approval – Prior to starting the study, institutional ethical committee clearance (EC/P-31/2020) was taken. Received 04.09.2020. Accepted 17.10.2020.

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Article history:
Received: 10.03.2024
Revision requested: 20.03.2024
Revision received: 15.04.2024
Accepted: 25.06.2024
Published: 30.06.2024

МАКСИМАЛЬНА АЕРОБНА ПОТУЖНІСТЬ (VO_2max): КОМПЛЕКСНИЙ ПОГЛЯД

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Актуальність. Здатність виконувати тривалу, інтенсивну діяльність і сукупна потужність дихальної та серцево-судинної систем відомі як серцево-респіраторна підготовленість, яка також називається максимальною аеробною потужністю (VO_2max).

Ціль: Дослідити максимальну аеробну потужність (VO_2max) у молодих людей.

Матеріали та методи. Дане обсерваційне дослідження було проведено у 100 здорових 18-25-річних особах у Коледжі медичних наук RUHS у Джайпурі, Раджастан, Індія. Максимальну аеробну потужність оцінювали шляхом аналізу газів, які беруть участь у легеневій вентиляції безпосередньо під час виконання тесту навантаження на біговій доріжці з використанням різних протоколів. Інформація про фізичну активність була отримана за допомогою опитувальника загальної фізичної активності (GPAQ), що включав 16 запитань у трьох сетах: активність на роботі, поїздки до місць і назад, рекреаційні заходи.

Результати. VO_2max і дихальний об'єм мали слабкий позитивний зв'язок (r=0,345). Був слабкий позитивний зв'язок між VO_2max і дихальним об'ємом у чоловіків (r=0,128) і жінок (r=0,039). Був слабкий негативний зв'язок між VO_2max і насиченням киснем у чоловіків (r=-0,216) і жінок (r=−0,059). Існував слабкий позитивний зв'язок між VO_2 max і GPAQ як у чоловіків (r=0,009), так і в жінок (r=0,065).

Висновок. І чоловіки, і жінки мали слабку позитивну кореляцію між VO_2max і дихальним об'ємом, але слабку негативну кореляцію для насичення O_2, що було спричинено збільшенням потреби в кисні під час фізичних вправ. Була слабка позитивна кореляція між VO_2max і GPAQ. Це свідчило про слабкий, але статистично незначущий зв'язок щоденної фізичної активності з VO_2max і GPAQ.

Ключові слова: опитувальник загальної фізичної активності, градуйований протокол вправ, максимальна аеробна потужність, насичення O_2, дихальний об'єм