CHANGE IN PEAK OXYGEN CONSUMPTION AND EXERCISE ECONOMY IN MALE AND FEMALE WEIGHTLIFTERS AFTER A 20-DAY TRAINING PROGRAM

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Abstract: Maximal oxygen consumption (VO_2max) is an integral indicator of the state of the cardiovascular system, respiration, the capacity of blood to transport oxygen, and the ability of muscles to use oxygen to generate energy for muscle contraction. Another important indicator of the body's adaptation to exercise is exercise economy. Exercise economy (EE) is defined as the required oxygen consumption at a given submaximal exercise intensity with a steady state achieved. It is considered an important indicator in sports physique, which is of particular importance in endurance sports. The EE is easily determined, but behind the value of this index is a complex combination of various metabolic, cardiorespiratory, biomechanical and neuromuscular characteristics that are unique to everyone.
Objective: The aim of the present study was to determine the effect of a 20-day intensive training program on maximal oxygen consumption and exercise economy in elite male and female weightlifting athletes.
Material and methods: A group of 21 elite weightlifters (male, n=12 and female, n=11) voluntarily underwent ergospirometry tests (Shiller ergospirometry system, AT 104, Switzerland) to determine peak oxygen consumption (VO_2peak) before the beginning and after the end of a 20-day intensive training program. All athletes signed informed consent documents and underwent a medical examination before the exercise testing. Ergospirometry tests were performed with a cycle ergometer, with a step increase in load. The obtained data were processed by paired samples *t-test*, $P<0.05$ was considered as statistically significant difference, (SPSS, v. 13).
Results: Peak work power (W) was unchanged in both sexes ($P>0.05$). Peak heart rate was also unchanged ($P>0.05$). Administration of a 20-day intensive training program resulted in a decrease in VO_2peak in male athletes (before 2.17±0.40 l/min, after 1.93±0.31 l/min, $P=0.017$), as well as in female weightlifters (before 1.48±0.15 l/min, after 1.24±0.14 l/min, $P=0.002$). In men, exercise economy defined as oxygen consumption at 70% of peak workload was improved (before 1.64±0.47 l/min, after1.24±0.26 l/min, $P=0.003$). This was confirmed by the determination of EE as oxygen consumption at 70% of peak heart rate (before 0.768±0.25 l/min, after 0.515±0.14 l/min, $P=0.004$). We found no change in exercise economy in women.
Conclusion: Despite the short duration of the intensive training program, VO_2peak significantly decreased in both men and women. Exercise economy was increased only in male weightlifters. Further studies are needed to elucidate in detail the influence of intensive strength training on the body's adaptation to exercise.
Keywords: peak oxygen consumption, exercise economy, weightlifters, strength training.

1. INTRODUCTION

Maximal oxygen consumption (VO_2max) represents the amount of oxygen the body can use at maximum exercise (Evans C. & White R., 2009). It is also called aerobic power. It is one of the main indicators in the field of sports

physiology that is used to assess the cardiorespiratory fitness of athletes. It finds application both in the development of training programs and for reporting the effect of their application. The significance of this indicator has caused researchers to be seriously interested in identifying the physiological factors on which it depends and the relative importance of each of these factors in achieving VO_2max. The main physiological factors on which maximal oxygen consumption depends can be conventionally represented as central and peripheral. The central ones are diffusing capacity for oxygen in the lungs, cardiac output and oxygen-binding capacity of the blood. Peripheral factors are capillary density in muscles, capillary diffusion gradient in a working muscle, activity of muscle mitochondrial enzyme systems (Bassett D. & Howley E., 2000). Exercise economy (EE) is defined as the required oxygen consumption at a given submaximal workload intensity with achieved steady state. It is accepted as an important indicator in sports physiology that is of particular importance in endurance sports. Exercise economy is easily defined, but behind its value stands a complex combination of various metabolic, cardiorespiratory, biomechanical, and neuromuscular characteristics that are unique to each individual. Metabolic efficiency relates to optimizing utilization of available energy, whereas cardiopulmonary efficiency refers to reduced work output in processes related to oxygen transport and utilization. Biomechanical and neuromuscular efficiency refer to the interaction between the nervous system and the musculoskeletal system to transform energy more efficiently into work. Through appropriate training, adaptive changes can occur in many of the metabolic, cardiopulmonary, biomechanical, and neuromuscular characteristics that contribute to EE (Barnes K.R. & Kilding A.E., 2015). Undoubtedly, genetic factors play a dominant role in EE, but to date there is a paucity of data on specific genotypes associated with EE (He Z et al.,2007; Rodas G. et al., 1998).

There are reports in the available literature on the relationship between athletic performance and grip strength in elite weightlifters (Suazo and DeBeliso, 2021; Huebner et al., 2023). Modern literature reports discussions on the relationship between weightlifting, strength training, endurance training and aerobic capacity (Hermawan and Priyono, 2022). There is scientific evidence that total muscle strength is directly related to aerobic capacity (Burich, et al., 2015).

The aim of the present study was to determine the effect of a 20-day intensive training program on maximal oxygen consumption and exercise economy in elite male and female weightlifting athletes.

2. MATERIALS AND METHODS

A group of 21 elite weightlifters (male, n=12 and female, n=11) voluntarily underwent ergospirometry tests (Shiller ergospirometry system, AT 104, Switzerland) to determine peak oxygen consumption (VO_2peak) before the beginning and after the end of a 20-day intensive training program. Administration of this program results in increase grip strengthand maximal efford sustain time in male weightlifters. In female weightlifter group only the maximal strength of the left, non-dominant hand was siggificantly increased (Popov D. et al, 2024). All athletes signed informed consent documents and underwent a medical examination before the exercise testing. Ergospirometry tests were performed with a cycle ergometer, with a step increase in workload.

Cardiopulmonary exercise testing is a non-invasive dynamic physiological method for objective assessment of the body's aerobic capacity. When it is performed, measurements are continuously taken and data on ventilation, cardiac performance and gas exchange are obtained during exercise of increasing intensity until exhaustion occurs (Mezzani A. et al, 2009). Thus, the test performed allows the assessment of the integrated response of the cardiovascular and respiratory systems, as well as information on the metabolic rate at submaximal and maximal exercise (Guazzi M. et al, 2017). Different ergometric devices are used for exercise testing in the laboratory. The most popular among them are treadmill and cycle ergometer (Sietsema K. E. et al, 2020). For cardiopulmonary exercise testing, we used an AT-104 spiroergometry system (Schiller, Switzerland). Its measuring module was the PowerCube (Ganshorn, Germany). It combines a pneumotachograph and a gas analyzer with sensors for O_2 and CO_2, which reads their values at each exhalation and presents averaged data over 30 seconds. Thus, at very short intervals, up-to-date metabolic study data are obtained. We used a cycle ergometer to perform the exercise testing. We followed the recommendations of the American College of Sports Medicine when conducting the tests.

Each test went through several stages. First, we measured the amounts of ingested O_2, expired CO_2 and pulmonary ventilation at rest, for about 40 seconds. We then applied exercise in an ascending step protocol, with an initial load of 30 W. At each successive step the load was increased by 30 W. Individual load levels were 2 min in duration. At each step, we monitored heart and respiratory rates, pulmonary ventilation, oxygen consumption, arterial blood pressure values, and heart rate (Boyadjiev, 2023).

The obtained data were processed by paired *t-test*, $P<0.05$ was considered as statistically significant difference, (SPSS, v. 13).

3. RESULTS AND DISCUSSION

Peak work power (W) was unchanged in both sexes (P>0.05, Table 1., Table 2.). Peak heart rate was also unchanged (P>0.05 Table 1., Table 2.). The application of a 20-day intensive training program resulted in a decrease in VO_2peak in absolute and relative value in male athletes (Table 1., Table 2.), as well as in female weightlifters (Table 1., Table 2.). In men, exercise economy defined as oxygen consumption at 70% of peak workload was improved (Table 1.). This is confirmed by the definition of exercise economy as oxygen consumption at 70% of peak heart rate (Table 1.). In women, we found no change in exercise economy defined as oxygen consumption at 70% of peak workload and oxygen consumption at 70% of peak heart rate (Table 2.).

Table 1. Results of ergospirometry tests of elite male weightlifters. X±SD.

Male, n=12	**before**	**after**	**P**
Wmax	150±21.21	147±23.45	0.347
VO_2max (l/min)	2.17±0.40	1.93±0.31	**0.017**
VO_2max/kg (ml/min/kg)	31.65±7.98	28.07±5.93	**0.032**
HRmax (bpm)	154.33±25.06	148.00±18.67	0.174
VO_2 70%/HRmax	0.768±0.25	0.515±0.14	**0.004**
VO_2 70%/Wpeak	1.64±0.47	1.24±0.26	**0.003**

Table 2. Results of ergospirometry tests of elite female weightlifters. X±SD.

Female, n=11	**before**	**after**	**P**
Wmax	117±18.03	123±23.46	0.169
VO_2max (l/min)	1.48±0.15	1.24±0.14	**0.002**
VO_2max/kg (ml/min/kg)	25.10±4.87	21.15±4.57	**0.002**
HRmax (bpm)	139.00±15.27	141.56±20.92	0.753
VO_2 70%/HRmax	0.796±0.20	0.595±0.28	0.111
VO_2 70%/Wpeak	1.05±0.16	1.07±0.42	0.910

There are scientific reports that resistance training can increase aerobic capacity and muscle strength (Giuliano, et al., 2017; Scribbans, et al., 2016; McRae et al., 2012). However, our study found that applying a 20-day intensive training program significantly reduced VO_2peak in male and female elite weightlifters.

4. CONCLUSION

Despite the short duration of the intensive training program, VO_2peak significantly decreased in both men and women. Exercise economy was increased only in male weightlifters. Further studies are needed to elucidate in detail the influence of intensive strength training on the body's adaptation to exercise.

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