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COMPARISON OF MAXIMAL OXYGEN CONSUMPTION, RESTING METABOLIC RATE AND BODY COMPOSITION ANALYSIS BETWEEN AEROBIC AND ANAEROBIC SPORTS

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(Original scientific paper)

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Abstract
The aim of this study is to compare the values of maximal oxygen consumption (VO2 max), resting metabolic rate (RMR) and body composition between aerobic and anaerobic sports. 90 male subjects (25,34 ±5,6 age; 179,78±6.9 height/cm; 78,66±6,9 weight/kg; 24,34±2,75 BMI; 13,1±5,53 percentage body fat-PBF and 49,7±3,2 % skeletal muscle mass-% SMM) were tested for this study. The subjects were divided in 2 groups, I group- aerobic sports (endurance) (n=63), II group- anaerobic (strength) sports (n=26). Height was measured with stadiometer - СЕКА, body composition with bioelectrical impedance analysis - InBody 720, (Great Britain), RMR with indirect calorimetry- Fit Mate, COSMED, (Italy) and VO2 max with ergometric test Bruce on treadmill (ergo _run medical_α 24). Results showed that anaerobic sports have significantly higher values for weight, BMI and PBF compared to aerobic, while aerobic sports have significantly higher values for % SMM and VO2 max (p<0,05) and higher values for RMR compared to anaerobic sports. SMM has an impact on RMR in athletes. To keep high SMM, endurance athletes need to have higher caloric intake. To achieve higher VO2 max values and better performance athletes tend to have combined submaximal and maximal training sessions.

Keywords: *sports, body composition, resting metabolic rate, maximal oxygen consumption.*

Introduction

There are many classifications of sports, but in the manner of physiological adaptations from the effects of physical activity the sports are divided into two types: aerobic and anaerobic. Aerobic (endurance) sports mostly include low intensity and long duration, while anaerobic (strength) sports include high intensity but in a short period of time. However, it is very hard to strictly distinguish these two types of sports and most of the sports disciplines involve both types of sports (aerobic and anaerobic).

The classic aerobic sports contribute to increased: cardiac stroke volume, maximal oxygen consumption (VO2 max) and mitochondrial biogenesis[1]. The overall improvement of central and peripheral tissues allows the athlete to increase efficiency during exercise and to have better performance in long distance and long duration disciplines. Unlike aerobic sports, anaerobic sports result with increasing muscle mass, neural adaptation (motor response) and increased strength (maximal force production). All these changes affect the athlete and allow them to be more strong and powerful. Both types of sport have an effect on age related illnesses by delaying them [2]. Maximal oxygen consumption (VO2 max) is the maximum rate of oxygen consumption attainable during physical exertion. VO2 max is the most commonly used tool for determining individual aerobic capacity. It is the best parameter for determining the physical level of an athlete. In aerobic sports oxidative phosphorylation has a major role and VO2 max (aerobic capacity) has become one of the determining factors in high intensity sport disciplines. VO2 max is related to oxygen uptake, transport and utilisation.VO2 max has a major role in performance at marathon athletes and other types of aerobic sport disciplines. VO2 max can be the most important and the most measured parameter in monitoring and improving performance in well-trained athletes[3]. In aerobic types of sports like soccer the athletes should have a higher value of VO2 max in order to have better performance.

In human skeletal muscles there is a combination of two types of muscle fibres: type I (slow-twitch) and type II (fast-twitch)[4]. Slow- twitch muscle fibres are characterised with relatively high oxygen capacity indicated by high respiratory capacity and high activity of oxidative enzymes [5,6]. Fast-twitch muscle fibres have relatively high glycolytic potential and are more susceptible to fatigue than slow-twitch muscle fibres [7,8].

Aerobic or endurance training increases oxidative capacity at both types of muscle fibres. Athletes compared to the sedentary population have higher muscle mass which is the result of the active lifestyle which contributes to higher glycogen storage.

Most of the glycogen is stored in the skeletal muscles (∼500 g) and the liver (∼100 g). Glycogen is considered the main source of energy, especially during high-intensity physical activity (over 70% of VO2 max), and fatigue occurs when glycogen reserves in active muscles are depleted [9]. The goal of athletes is to maintain an adequate body mass with a proper and balanced diet. A high percentage of skeletal muscle mass (SMM) and a normal to low percentage of fat mass (FM) allows them to have constant high performance during the whole season, but also fast recovery.

Depending on the sport discipline sometimes the athlete should reduce or increase the weight. This results in changing the body composition, glycogen storages, vitamin status and mineral content of the bones. In those sport disciplines where smaller and lean physique have advantage in performance or the athletes should reduce the weight to get in the weight category (mostly at wrestling sports), many of the athletes are in caloric deficit. All these changes have an impact on energy balance and nutritive status and affect the performance and recovery of the athlete[10].

General recommendations for sports nutrition are balanced meals which will provide all the macro and micronutrients. The proper sports nutritional regimen should include: 60% of carbohydrates, 20-25% of fats and 10-15% of proteins. The athletes often have more than 3 meals per day which makes their thermic effect of the food (TEF) higher. TEF is the energy that our body uses for digestion, absorption and utilisation of the nutrients. TEF is 5-15% for carbs, 0-5% for fats and 20-35% for proteins of the caloric intake. Higher muscle mass at athletes contributes to a higher value of resting metabolic rate (RMR) which results in higher total daily energy expenditure (TDEE). Total daily energy expenditure (TDEE) is the total energy your body burns through the day. Its combination of basal metabolic rate (BMR), thermic effect of food (TEF), non-exercise activity thermogenesis (NEAT) and thermic effect of activity (TEA).

BMR is the minimal energy requirement the body needs to function and it is 60-80% of TDEE [11]. More often used and reliable measure for minimal energy expenditure is RMR. BMR is 10-15% lower than RMR. TEA is the number of calories burned as a result of exercise (i.e. steady-state cardio, resistance training, HIIT, sprints, CrossFit, etc.). Similar to NEAT, the thermic effect of exercise is highly variable from one person to another or even from one day to another for the same person, as the intensity of training, length of the workout, and training frequency all impact your weekly thermic effect of activity. Athletes tend to have higher TDEE which have an impact on increasing RMR. Aim of this study is to make comparison of VO2 max, RMR and body composition analyses between aerobic and anaerobic sports. This will provide evaluation of individual energy expenditure of athletes which will be helpful in better planning of the nutritional regimen and training cycle of the athletes.

Material and methods

The study was prospective cross-sectional and was done during the period of one year from March 2022 to March 2023, at the Institute of Physiology at Medical faculty-Skopje. All participants were asked questions about their medical, pharmaceutical and family history and they filled questionnaires about their lifestyle. All participants underwent several procedures which included: measuring height, bioelectrical impedance analysis (BIA) for body composition, measuring RMR and stress-test for calculating VO2 max.

90 male athletes (25,34 ±5,6 age; 179,78±6.9 height/cm; 78,66±6,9 weight/kg; 24,34±2,75 BMI; 13,1±5,53 % body fat (%BF) and 49,7±3,2 % SMM) underwent procedures for the needs of this study. The athletes were divided into two groups according to sports: I group-aerobic sports (n=63), which included soccer (n=35), handball (n=19) and athletics (n=9) and II group- anaerobic sports (n=27) which included bodybuilding (n=19) and wrestling (n=8). Before the testing all of the participants were informed about the procedures and signed informed consent.

The height of the participants was measured with stadiometer – CEKA in cm. During the procedure all participants were barefooted and standing still.

Analysis of the body composition was done with bioelectrical impedance analyzer, InBody 720, (Great Britain). All participants fasted in the last 8 hours, were rested without vigorous physical activity in the last 12 hours, and wore lightweight clothes. All the metal things were taken off participants, who were standing still during the measuring which lasted 2 minutes. The analysed parameters were: weight-kg, BMI-kg/m^2, SMM-% and BF-%.

RMR was measured with an indirect calorimeter Fit Mate, COSMED, (Italy). The respiratory coefficient was 0.85 because all the participants were on nutritional regimen which included all types of macronutrients (carbs, protein and fats). The measuring was done in supine position, participants were awake, still in a quiet and dark room with normal room temperature and humidity. The duration of the testing was 6 minutes, and the first minute was the test phase in which the depth and the frequency of the respiration was stabilising. At the end of the test the machine gives value for RMR in kcal/day and gives a % ratio compared to Harris-Benedict predictive equation. Harris- Benedict equation is a mathematically calculated equation for RMR and includes the parameters: sex, height, weight and age. For males (RMR=66.473 + (13.7516 ×weight in kg) + (5.0033 × height in cm) – (6.755 × age). To have an evaluation of the TDEE, the value for RMR was multiplied with the physical activity factor for professional athletes - 2,25. (Energy Requirements of Adults,Report of a Joint FAO/WHO/UNU Expert Consultation).

The stress test that was conducted in this study was a submaximal ergometric test- Bruce protocol on ergo-treadmill (ergo _run medical_α 24). During the test the subjects were placed with electrodes from 12 channel ECG according to propositions. Submaximal heart rate (HR) is 85% of maximal HR. Maximal HR is calculated with the equation: 200 minus the age of the subject. In the rest stage were monitored subject's ECG, HR and blood pressure. Then the treadmill was started with 10% elevation slope and 2.7 km/h speed, every 3 minutes the protocol goes level up and the speed and elevation was increased until the subject reached submaximal HR, when the test was stopped. The duration of the test was marked. Then the recovery phase was started in which there was no elevation and the speed was 2,7 km/h for one minute and then the recovery phase proceeded for 2 min. without movement or elevation of the treadmill. The subject stood still and all the parameters mentioned above were continuously measured. From the minutes of the test duration from Bruce nomogram was calculated indirect relative VO2 max (ml/min/kg). According to this value for VO2 max on table for classification we are calculating subjects relative VO2 max. (New York Health Association-NYHA)

Statistical analysis was performed in the program Statistica 7.1 for Windows и SPSS 23,01. The numerical data (height, weight, BMI, %SMM, %BF, RMR and VO2 max) were calculated using Descriptive Statistics (Mean; Std.Deviation; ± 95,00%CI; Median; Minimum; Maximum). The differences between values for the parameters in relation to sport was analysed with t- test, independent, by groups (t / p) depending on the distribution of the values. Correlation between two parameters was made with Pearson-овиот coefficient of correlation (r) and Spearman Rank Order R (R), in relation to the distribution of the parameters. Results were considered statistically significant if $P < 0{\cdot}05$.

Results

Anaerobic athletes have significantly higher values for BMI and %BF compared to aerobic athletes, while aerobic athletes have significantly higher values for %SMM compared to anaerobic athletes (p<0,05). The results are presented in the table below.

Table 1. Comparison of the body composition values between aerobic and anaerobic sports

	Age	Height (cm)	Weight (kg)	BMI (kg/m^2)	%SMM	%BF
Aerobic (n=63)	23 ± 4	180 ±6	76 ±7	23±1,5	50 ±2	12 ±3
Anaerobic (n=26)	29 ± 5	179 ± 8	83 ± 12	26 ± 3	48 ± 4	15 ± 8
p*(<0,05)	0,0000*	0,2880	0,0007*	0,00001*	0,008*	0,005*

**BMI-body mass index: SMM-skeletal muscle mass: BF-body fat.*

For RMR the results show that aerobic athletes have higher values for RMR compared to anaerobic, but there is no statistically significant difference. Harris-Benedict predictive equation for RMR underestimate the RMR value from IC. The equation underestimate the RMR value from IC for 22% at aerobic sports with mean difference of 420 kcal/day, and 18% at anaerobic sports with mean difference of 356 kcal/day. The results are shown in table 2.

The correlation between RMR and body composition showed that RMR has a positive correlation with % SMM in both types of sports. (r=0,52 for aerobic и r=0,38 for anaerobic).

Table 2. Comparison of the RMR values between IC and Harris-Benedict equation between sports

	RMR (kcal/day)	Harris-Benedict (kcal/day)	% of Harris-Benedict	Mean difference
Aerobic (n=63)	2265 ±276	1844±132	122	420
anaerobic (n=26)	2258 ± 314	1901±188	118	356
p*(<0,05)	0.4	0.055	0.16	

*RMR-resting metabolic rate

Aerobic athletes have significantly higher values for VO2 max compared to anaerobic athletes (p=0.001). The results are shown in table 3. The results also showed that SMM has positive correlation with VO2 max in both sports (r=0.13 for anaerobic), (r=0.32 for aerobic sports).

Table 3. Comparison of VO2 max values between aerobic and anaerobic sports

	VO2 max (ml/kg/min)	% VO2 max
Aerobic (n=63)	50,1 ± 4	114 ± 10
Anaerobic (n=26)	45,9± 5	106 ± 11
p*(<0,05)	0.001*	0.001*

**VO2 max-maximal oxygen consumption*

Discussion

The aim of this study was to compare the values of the body composition, RMR and VO2 max between different types of sports which will help in evaluation of individual TDEE and aerobic capacity of the athlete. This will be helpful for better planning and organising nutritional regimen and training process in different types of sports.

From the result we can see that aerobic athletes have higher values for RMR compared to anaerobic athletes and that is because aerobic athletes have higher muscle mass compared to anaerobic athletes.

The data from previous studies shown that that RMR is directly proportional with SMM [12,13,14]. High muscle mass at athletes contributes to higher RMR. Lean body mass (LBM) which is part of the SMM has a major impact on energy expenditure [15]. Webb [15] has found strong correlation between 24 hours energy expenditure (in rest) and LBM at males and females. The first and widely used predictive equation for RMR is the Harris-Benedict equation . This equation includes parameters: sex, age, height and weight, but excludes SMM [16]. This equation collected old data from the sedentary population. Today's modern lifestyle includes a very active lifestyle even in the recreational population and can not be completed with the lifestyle in the last 20 years. This can be the reason why the Harris-Benedict equation underestimates RMR values measured with IC in both types of sports. Body composition has a major impact on athletic performance [17,18]. In some sports like handball where high power is needed in a short period of time, a bigger physique and higher muscle mass have advantages [19]. BMI is widely used parameter for determining obesity in the general population, but in athletes is not accurate. Athletes have higher muscle mass which makes their BMI above normal ranges, but is not accurate for determining obesity [20]. From the results we can see that BMI at anaerobic athletes is significantly higher compared to aerobic athletes. Anaerobic athletes have a higher weight and higher fat mass, but lower muscle mass compared to aerobic athletes which in this case have shown that BMI is an accurate parameter for determining obesity in anaerobic athletes.

The results for VO2 max showed that aerobic athletes have significantly higher aerobic capacity (VO2 max) compared to anaerobic athletes. It has been known for decades that aerobic athletes have higher values for VO2 max compared to the other athletes [21,22]. It is expected marathon runners to have high VO2 max. Ronnestad and Mujika [23] have find out that aerobic athletes who exercising at submaximal and maximal heart rate have better neuromuscular efficiency, high power ability and delayed activation of type II muscle fibres and conversion of the fast-twitch IIx muscle fibres into fatigue susceptible type IIa muscle fibres [23]. This can be the reason why aerobic athletes have higher values for VO2 max compared to anaerobic athletes.

Conclusion

We can conclude that LBM and SMM have a high impact on RMR in the sports population. Also in sports with short intervals with high impact like handball and soccer high muscle mass contributes to better performance. High muscle mass increases RMR and TDEE. Aerobic athletes in order to have constant weight with high muscle mass need higher caloric intake compared to anaerobic athletes. For achieving better aerobic capacity (VO2 max) and also better performance, aerobic athletes should exercise at submaximal and maximal heart rate.

References

1. Favier RJ, Constable SH, Chen M, Holloszy JO. "Endurance exercise training reduces lactate production" ,(1986). *J Appl Physiol.*
2. Hughes DC, Ellefsen S, Baar K. "Adaptations to Endurance and Strength Training" (2018), *Cold Spring Harb Perspect Med*.
3. Ghosh A. "Anaerobic threshold: its concept and role in endurance sport" (2004) *The Malaysian journal of medical sciences.*
4. Padykula, H,A, and Herman, E. "The specificity of the histochemical method for adenosine triphosphatase" (1995), *Journal of Histochemistry and Cytochemistry*
5. Ivy, J.L.; Withers. R.T.; van Handel. P.J.; Elger, D.H. and Costill. D.L. "Muscle respiratory capacity and fiber type as determinants of the lactate threshold" (1980) *Journal of Applied Physiology: Respiratory. Environmental and Exercise Physiology* .
6. Essen, B.; Jansson, E.; Henriksson, J.; Taylor, A.W. and Saltin, B. "Metabolic characteristics of fibre types in human skeletal muscles" (1975) *Acta Physiologica Scandinavica.*
7. Tesch, P. "Muscle fatigue in man with special reference to lactate accumulation during short term intense exercise" (1980), *Acta Physiologica Scandinavica (Suppl. 480)*
8. Thorstensson, A. "Muscle strength, fibre types and enzyme activities in man", (1976), *Acta Physiologica Scandinavica (Suppl. 443).*
9. Jensen J, Rustad PI, Kolnes AJ, Lai YC. "The role of skeletal muscle glycogen breakdown for regulation of insulin sensitivity by exercise", (2011) *Front Physiol.*
10. Janice L. Thompson "Energy Balance in Young Athletes" ,(1998)*International Journal of Sport Nutrition*.
11. Carpenter WH, Poehlman ET, O'Connell M, and Goran MI. "Influence of body composition and resting metabolic rate on variation in total energy expenditure a metaanalysis", (1995)*The American journal of clinical nutrition.*
12. P A Tataranni 1, E Ravussin, "Variability in metabolic rate: biological sites of regulation",(1995) *Int J Obes Relat Metab Disord*.
13. C J Henry "Mechanisms of changes in basal metabolism during ageing" , (2000) *Eur J Clin Nutr.*
14. G Paolisso , A Gambardella, V Balbi, S Ammendola, A D'Amore, M Varricchio "Body composition, body fat distribution, and resting metabolic rate in healthy centenarians" , (1995) *Am J Clin Nutr.*
15. Webb P. „Energy expenditure and fat-free mass in men and women", (1981) *The American journal of clinical nutrition.*
16. Harris JA, Benedict FG. „A Biometric Study of Human Basal Metabolism." ,(1918) *Proc Natl Acad Sci* U S A.
17. Alejandro L Arrese , Enrique S Ostáriz "Skinfold thicknesses associated with distance running performance in highly trained runners", (2006) *J Sports Sci.*
18. Beat Knechtle, Patrizia Knechtle, Christoph Alexander Rüst, Thomas Rosemann "Leg skinfold thicknesses and race performance in male 24-hour ultra-marathoners" ,(2011) *Proc (Bayl Univ Med Cent).*
19. Takako Koshimizu , Yoshiko Matsushima, Yukari Yokota, Kae Yanagisawa, Satsuki Nagai, Koji Okamura, Yutaka Komatsu, Takashi Kawahara "Basal metabolic rate and body composition of elite Japanese male athletes", (1012), *J Med Invest.*
20. C N Meredith 1, M J Zackin, W R Frontera, W J Evans "Body composition and aerobic capacity in young and middle-aged endurance-trained men" (1987) *Med Sci Sports Exerc.*
21. Astrand. P, Robinson S, Edwards, H.T. and Dill, D.B.: "New records in human power", (1995), *Nature Science*
22. Saltin, and Astrand, P.-O. "Maximal oxygen uptake in athletes", (1967) *Journal of Applied Physiology*.
23. Ronnestad B.R. and Mujika I. "Optimizing strength training for running and cycling endurance performance: A review", (2014) *Scand. J. Med. Sci. Sports*.