Maximal Anaerobic Power Test in Athletes of Different Sport Disciplines

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Abstract

Popadic Gacesa, JZ, Barak, OF, and Grujic, NG. Maximal anaerobic power test in athletes of different sport disciplines. *J Strength Cond Res* 23(3): 751–755, 2009—The aim of this study was to investigate the values of anaerobic energetic capacity variables in athletes engaged in different sport disciplines and to compare them in relation to specific demands of each sport. Wingate anaerobic tests were conducted on 145 elite athletes (14 boxers, 17 wrestlers, 27 hockey players, 23 volleyball players, 20 handball players, 25 basketball players, and 19 soccer players). Three variables were measured as markers of anaerobic capacity: peak power, mean power, and explosive power. The highest values of peak power were measured in volleyball $11.71 \pm 1.56\ W \cdot kg^{-1}$ and basketball players $10.69 \pm 1.67\ W \cdot kg^{-1}$, and the difference was significant compared with the other athletes ($p \leq 0.05$). The lowest value of peak power ($8.58 \pm 1.56\ W \cdot kg^{-1}$) was registered in handball players. The mean power variable showed a similar distribution as peak power among groups. The highest values of explosive power were also registered in volleyball $1.75 \pm 0.33\ W \cdot s^{-1} \cdot kg^{-1}$ and basketball players $1.64 \pm 0.35\ W \cdot s^{-1} \cdot kg^{-1}$, but there was no significant difference in values between volleyball players and wrestlers, between boxers and wrestlers, between boxers and basketball players, and between volleyball and hockey players ($p > 0.05$). The measured results show the influence of anaerobic capacity in different sports and the referral values of these variables for the elite male athletes. Explosive power presented a new dimension of anaerobic power, i.e., how fast maximal energy for power development can be obtained, and its values are high in all sports activities that demand explosiveness and fast maximal energy production. Coaches or other experts in the field could, in the future, find useful to follow and improve, through training process, one of the variables that is most informative for that sport.

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Introduction

A sport result depends on at least 5 components: energetic capacity, consisting of an anaerobic and aerobic part, tactics, technique, and motivation of the sportsmen for maximum use of their potentials on the sporting field (7). All these components represent complex functional systems, which are created and modified during physical activities. The quality of these interactions determines sport result.

Some components can be exactly measured, such as anaerobic and aerobic capacity, by applying different tests (Wingate test, Conconi test, anaerobic threshold, etc.) or techniques by biomechanical research. Tactics and motivation are the components that cannot be exactly measured. However, their influence is not minor.

Because of the different influences that each component has on sport results, every sport discipline must be observed individually. For example, the most important part in rowing will be aerobic capacity, anaerobic capacity in sprint, volleyball, basketball, and hockey, technique in jumping, and all five components in soccer, with the advantage of anaerobic capacity (6,8,11).

Having an adequate methodology for energetic capacity measurement in sports helps sportmen to achieve the best sport results and fully develop their biological potential (7).

The aim of this study was to investigate the values of anaerobic energy capacity variables in athletes engaged in different sport disciplines and to compare these values in relation to specific demands of each sport discipline.

Methods

Experimental Approach to the Problem

This investigation was designed as a prospective study. All participants were active athletes who visited the Laboratory for Functional Diagnostics to perform a 30-second Wingate anaerobic test (WAnT). Testing was performed in the morning hours and under identical microclimate conditions. These performance measures were the same as those in previous studies, with the addition measure of explosiveness. Besides the standard variables in WAnT, we included a new one, namely, how fast the peak power (PP) is reached,

TABLE 1. Anthropometric characteristics of athletes.

Type of sport	*n*	Age (y)	Height (cm)	Weight (kg)	Activity (y)
Boxing	14	22.21 ± 4.76	179.47 ± 7.43	77.00 ± 11.24	9.41 ± 2.35
Wrestling	17	20.64 ± 3.36	175.41 ± 7.42	79.35 ± 16.43	10.35 ± 3.12
Hockey	27	21.37 ± 4.66	180.41 ± 6.46	81.74 ± 10.67	13.04 ± 4.09
Volleyball	23	20.44 ± 3.39	196.96 ± 5.05	88.04 ± 9.14	7.96 ± 2.21
Handball	20	21.40 ± 3.11	186.55 ± 7.16	87.80 ± 11.14	7.95 ± 3.11
Basketball	20	22.17 ± 5.00	197.90 ± 6.68	94.25 ± 9.59	9.75 ± 4.02
Soccer	19	23.21 ± 3.85	181.21 ± 4.74	76.42 ± 6.79	12.16 ± 3.65

by dividing the PP by the time to PP (PP/time to PP [$W \cdot s^{-1}$]). It tells us not only about time to PP, but also about the increase in power in the unit of time. Our wish was to measure WAnT variables in different sport disciplines and to establish possible differences. Also, by introducing the explosive power (EP) variable, we wanted to determine its validity as one of the anaerobic capacity variables. By measuring WAnT with load registration on every 0.1 second, we had the possibility to calculate this variable.

Subjects

In the present study, 145 elite athletes participated: 14 boxers, 17 wrestlers, 27 hockey players, 23 volleyball players, 20 handball players, 25 basketball players, and 19 soccer players. All athletes were healthy and voluntarily participated in the study. The Institutional Review Board of the Medical School of Novi Sad approved the research protocol. All tests were conducted at the end of the preparatory period before the start of the competition season. All athletes are at the national competition level without international results.

Anthropometric characteristics of all athletes, divided by their sport disciplines, are presented in Table 1. All participants were between 20.44 and 23.21 years of age, and volleyball players were the youngest and soccer players the oldest. Basketball and volleyball players were the tallest. The highest values of body mass were in the group of basketball, volleyball, and handball players. These anthropometric values correlate with specific characteristics and demands of each sport.

Testing

WAnT is a cycle-ergometric all-out test that lasts 30 seconds. Maximal load is accomplished by a built-in air-resistance system on the wheels (4).

Load registration was in real time, using a computer with a module for measuring the number of wheel turns. Software backup was provided by a program for graphic registration of load during 30 seconds (in 0.1-second intervals) with data memory. This provided a follow-up of the whole test and a quick analysis of the basic variables of anaerobic performance (13). Also, the software provided data related to the quantitative anaerobic power values for every second or period of time during 30 seconds of the test.

The following variables were determined: PP and mean power (MP), determined as the mean value of anaerobic power during the entire test. Besides the standard ones,

TABLE 2. Ergometric characteristics of participants.

	Values of anaerobic power parameters					
Sport	PP (W)	PP/BW ($W \cdot kg^{-1}$)	EP ($W \cdot s^{-1}$)	EP/BW ($W \cdot s^{-1} \cdot kg^{-1}$)	MP (W)	MP/BW ($W \cdot kg^{-1}$)
Boxing	715.14 ± 90.27	9.27 ± 1.16	116.49 ± 28.22	1.49 ± 0.28	517.31 ± 56.76	6.72 ± 0.86
Wrestling	765.53 ± 174.57	9.76 ± 1.80	125.32 ± 33.90	1.59 ± 0.33	516.11 ± 89.98	6.63 ± 1.14
Hockey	835.19 ± 238.09	10.14 ± 2.26	130.37 ± 42.90	1.57 ± 0.41	565.70 ± 131.05	6.89 ± 1.14
Volleyball	1023.48 ± 128.05	11.71 ± 1.56	153.53 ± 31.29	1.75 ± 0.33	671.92 ± 67.10	7.77 ± 1.10
Handball	754.85 ± 175.28	8.58 ± 1.56	104.26 ± 33.74	1.19 ± 0.35	528.35 ± 95.66	6.02 ± 0.80
Basketball	1001.60 ± 149.70	10.69 ± 1.67	153.52 ± 32.90	1.64 ± 0.35	669.15 ± 77.07	7.15 ± 0.96
Soccer	742.95 ± 120.12	9.72 ± 1.35	107.22 ± 23.85	1.41 ± 0.32	517.78 ± 78.54	6.78 ± 0.87

PP = peak power; EP = explosive power; MP = mean power; BW = body weight.

TABLE 3. Results of *F* values from analysis of variance statistical analysis for the variable peak power (PP).

F value for PP (PP/BW)	Soccer	Basketball	Handball	Volleyball	Hockey	Wrestling
Box	0.53 (1.01)	13.59* (5.58)*	0.60 (1.92)	62.05* (25.43)*	3.28 (1.79)	2.22 (2.48)
Wrestling	1.04 (0.48)	4.42* (0.48)	0.47 (8.22)*	21.67* (11.10)*	0.35 (0.02)	
Hockey	2.41 (0.51)	1.97 (0.26)	1.62 (6.90)*	11.52* (7.80)*		
Volleyball	52.79* (18.95)*	7.87* (11.06)*	33.51* (42.59)*			
Handball	0.06 (5.83)*	9.56* (17.58)*				
Basketball	12.37* (2.38)					

BW – body weight.
*Statistically significant difference, $p \leq 0.05$.

another new variable was included in the testing, i.e., EP. We defined this variable as how fast the PP is reached ($W \cdot s^{-1}$).

The same testing procedure was used before and during their previous visits, so all the participants were familiar with the test protocol in detail. Previously determined intraclass correlation coefficient (ICCR) for WAnT variables was 0.94. Warm-up was standardized and consisted of 10 minutes of moderate bicycle riding. The aim of the warm-up was to achieve adaptation of physiological variables on a higher level to accomplish maximum results during the test (1).

The test started after a computer sound simultaneously with the beginning of load registration (13). Participants were told to start pedaling immediately after the signal, with maximal speed, which was held at maximal levels during the entire test (2).

Statistical Analyses

All results were presented as mean ± *SD*. For statistical analyses, which included analysis of variance (one-way ANOVA), specialized software package Statistica for Windows (StatSoft, Tulsa, Okla) was applied. The probability level accepted for statistical significance was set at $p \leq 0.05$.

RESULTS

The highest values of PP were measured in volleyball and basketball players. The lowest values of these variables were measured in boxers.

The PP variable in volleyball and basketball players shows significant differences compared with boxers, wrestlers, handball players, and soccer players ($p \leq 0.05$). Volleyball and basketball players were also showing the best results of PP related to body mass, but the difference was smaller compared with hockey and soccer players and wrestlers. Difference was similar between boxers and handball players for absolute values (Table 3).

MP shows similar distribution among the compared sportsmen. The highest values of variable EP were measured in volleyball and basketball players and wrestlers. There was no significant difference ($p > 0.05$) observed in the values of EP between the group of volleyball players and wrestlers, between boxers and wrestlers, between boxers and basketball players, and between volleyball and hockey players, as well (Table 4).

Pearson correlation showed a positive correlation for body mass with all Wingate variables in absolute values.

TABLE 4. Results of *F* values from analysis of variance statistical analysis for the variable explosive power (EP).

F value for EP (EP/BW)	Soccer	Basketball	Handball	Volleyball	Hockey	Wrestling
Box	1.04 (0.59)	3.64 (0.42)	1.23 (7.43)*	13.10* (5.75)*	1.19 (0.44)	1.94 (3.13)
Wrestling	6.30* (6.75)*	0.05 (1.70)	6.15* (21.52)*	3.19 (0.64)	0.07 (0.69)	
Hockey	4.53* (2.11)	0.39 (0.05)	5.07* (11.59)*	4.61* (2.60)		
Volleyball	28.09* (11.13)*	4.12* (5.51)*	24.66* (29.35)*			
Handball	0.09 (4.35)*	11.90* (17.84)*				
Basketball	10.78* (2.77)					

BW – body weight.
*Statistically significant difference, $p \leq 0.05$.

There is no correlation for body height with power variables or for duration of sport activities with power variables, as well.

Discussion

To improve the sport result, it is required to develop the most important part of this complex functional system. Potential individual limits must also be taken into consideration. The aim of science is to find the weakest spot of every athlete and to apply adequate training protocol for maximum development of their biological potentials.

Muscle strength is significant for activities in which power is dominant, such as jumps in basketball, smatch in volleyball, kicking the ball in soccer, and some movements in tennis, boxing, and wrestling, as well as other sports. Endurance is also an important variable because all these activities must be repeated for a few hundred times during the game.

Comparing the results of testing maximum anaerobic performance between different elite athletes, a significant difference was found in values of the measured variables. Anaerobic power and capacity show high values in anaerobic types of sports such as volleyball, basketball, hockey, boxing, and wrestling. Smaller amounts of anaerobic energy production are observed in sports like soccer, rowing, and long-distance running, which are predominantly aerobic types of sports (7,16).

In the present study, the highest values of PP were measured in volleyball players 1023.48 ± 128.05 W and basketball players 1001.60 ± 149.70 W (or related to the body mass 11.71 ± 1.56 $W\cdot kg^{-1}$ and 10.69 ± 1.67 $W\cdot kg^{-1}$, respectively). Volleyball is the sport with the predominant anaerobic characteristic, especially with the new rules. The specificity of training and the game itself are short, explosive activities, with significant anaerobic energy production, which, after a period of continuous training and physical performance, bring the cellular metabolic control to a higher level. Quantification of these adaptations is given through the Wingate variable PP, which is directly related to degradation of highly energetic phosphates. This variable shows significant differences compared with boxers, wrestlers, handball players, and soccer players. In basketball, dominant types of activities are sprints and jumps. These types of activity in basketball players stimulate the development of anaerobic metabolic mechanisms and pathways. Similar motor characteristics are also present in hockey players, which place them at a high third place in the group of sportsmen with the highest values of PP (835.19 ± 238.09 W and related to body mass 10.14 ± 2.26 $W\cdot kg^{-1}$). Body mass is a major contributor to power (15). When the variable PP is shown related to the body mass, values are higher in the group of boxers and soccer players, and handball players are showing the lowest values. Volleyball and basketball players are also showing the best results of PP related to body mass, but the difference is smaller compared with boxers, hockey players, and soccer players. Difference is similar between wrestlers and hockey players, just like in absolute values. Italian Olympic judokas showed high levels of muscle power (PP: 12.1 ± 2.4 $W\cdot kg^{-1}$; MP: 5.4 ± 1.1 $W\cdot kg^{-1}$) (17). In elite male Taiwanese Taekwondo athletes, the PP and MP were 8.42 ± 0.86 $W\cdot kg^{-1}$ and 6.56 ± 0.60 $W\cdot kg^{-1}$, respectively (12). McArdle (14) emphasizes that the highest values were measured in volleyball and hockey players.

MP represents the average power throughout 30 seconds and metabolically correlates with the power of anaerobic glycolysis. This variable, together with PP, describes the anaerobic energetic capacity of athletes, and its values are very high in predominantly anaerobic types of physical activities. Its values show similar distribution among the compared groups of sportsmen.

EP is related to explosiveness of the participants actions, and it explains the ability of the neuromuscular system to momentarily activate and reach initialy maximal muscle contractions until PP is reached. EP suggests not only the time to PP, but also the increase in power in the unit of time. There is no significant difference in its values between the groups of volleyball players and wrestlers, between volleyball players and hockey players, and between boxers and basketball players, although the difference in PP between these groups was significant. This explanation lies in the fact that EP shows a new dimension in the metabolic pathway of phosphocreatine degradation. In wrestling and boxing, besides the power, explosiveness is a very important characteristic as a measure of how fast the power can be developed. The opponent must be beaten fast with technique used in a very short period of time. In hockey, with frequent changes in movement direction and velocity, the athlete is on ice up to 1 minute (because of the frequent changes), and it is very important how fast maximal power can be obtained. Some authors (9,18) registered the time point(s) at which the PP is reached, which is less informative than how fast this peak is reached ($W\cdot s^{-1}$), as a new dimension of maximal anaerobic power. We also noticed that this variable can be compared among different sport disciplines. This variable inauspiciously belongs to anaerobic capacity, and in our point of view, it can be considered as EP, which tells us about an athlete's explosiveness.

Values of PP and MP shown in other studies as a part of an overall physiological profile of athletes in diferent disciplines (16) can be used for comparison. However, it should be emphasized that different protocols were applied and athletes of different sports were tested with age and sex differences that must be taken into account. For example, after the warm-up with music, peak anaerobic power in adolescent volleyball players was 11.1 ± 0.3 $W\cdot kg^{-1}$ (5). Qin et al. (16) measured the highest values of PP in cycle athletes and sprinters. Values of PP in adolescent swimmers and water polo players were 6.71 ± 0.88 $W\cdot kg^{-1}$ (3). Kohrt et al. (11) showed significantly higher values of PP in sportsmen with anaerobic sport performances compared with those with predominantly aerobic type of physical activities. Inbar et al. (10) found the highest values of PP and MP in rowers and the lowest in marathon runners.

Practical Applications

Anaerobic capacity variables determined by the WAnT are showing the highest values in anaerobic types of sports, such as volleyball, basketball, and hockey. The new variable of EP reveals the new dimension in defining and quantification of anaerobic energy, and its values are high in all sports activities that demand explosiveness and fast maximal energy production. Therefore, EP could be included in a routine WAnT analysis to get a new insight in anaerobic capacity of an individual. By introducing EP, we wanted to determine its validity as one of the anaerobic capacity variables. Coaches or other experts in the field could, in the future, find it useful to follow and improve, through the training process, one of the anaerobic power variables, which is the most informative for that sport. This can also enable coaches in the evaluation of anaerobic abilities and in the objective selection of athletes.

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