Original Article

DOI: http://dx.doi.org/10.16926/par.2017.05.16

Approaches to describe ventilatory threshold in professional sports

Authors' Contribution:

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Manuscript Preparation
E – Funds Collection

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Abstract

Ventilatory threshold is one of the ways to measure cardiovasculatory fitness of the body. Therefore, in the present study it was decided to demonstrate which physiological parameters most accurately express the second ventilatory threshold (VAT_2) depending on the cardiovasculatory fitness of different groups of athletes and untrained men. The study involved the following athletes: race walkers (n=14), weightlifters (n=16), powerlifters (n=16), runners (n=14), professional soccer players (n=13), amateur soccer players (n=16), martial arts (n=12), and untrained men (n=15). Subjects' VAT_2 and maximal load (ML) were recorded and at these levels were determined the value of achievable maximal power (P), oxygen uptake (VO_2), heart rate (HR), the ratio for oxygen uptake and heart rate (VO_2/HR) and the rate-pressure produkt (RPP). It was shown that subjects were of similar age but different body mass (BM) and BMI. There were also differences between athlete groups at VAT_2 and ML in relation to: P, VO_2, VO_2/HR ($p<0.001$) and RPP only at VAT_2 ($p<0.023$). Reached HR values at VAT_2 as well as at ML have not differed between the groups. There were also intergroup differences at VAT_2 in terms of relative values: %VO_2max ($p<0.002$), %Pmax($p<0.016$), %VO_2max/%HRmax ($p<0.03$). Relatively expressed %HRmax and %RPPmax reached at VAT_2 did not differ between the two groups. Runners, professional soccer players and race walkers achieved the most favorable indicators of physical performance. It has been demonstrated that VAT_2 besides P i %Pmax was best described by VO_2, %VO_2max and by VO_2/HR and %VO_2max/%HRmax, as well as by RPP. On the other hand HR and %HRmax, as well as %RPPmax are not useful in this regard. Furthermore it should be recognized that athletes in whose structure of the training occurred running of varying intensity achieved the highest physical fitness.

Keywords: *ventilatory threshhold, cardiovascular fitness, athletes*

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Recevied: 5.01.2017; Accepted: 31.04.2017; Published online: 16.08.2017

INTRODUCTION

Anaerobic threshold is one of the laboratory indices (in addition to the maximum oxygen uptake - VO_2max) assessing the endurance of healthy or sick organism [1]. Depending on the method for determining the anaerobic threshold, it may be the ventilatory threshold and then shows the point at which the pulmonary ventilation is increasing rapidly, but oxygen uptake increases linearly during exercise test with increasing intensity. In most cases determining the ventilatory threshold is highly repetitive, although sometimes it may be not attainable, or difficult to determine, especially in people with very low physical performance [2]. It should be noted that during exercise with increasing intensity, there are two ventilatory thresholds: first ventilatory threshold (VAT_1) appears at a lower body load ie. at 50-60% VO_2max and the second ventilatory threshold (VAT_2) takes place at 70-90% VO_2max [3, 4, 5, 6]. Body loading that occurs at both ventilatory thresholds can be expressed by relative VO_2max values. It can also be expressed by the relative value of the maximum aerobic power despite that the magnitude of the body loading exercise is generally expressed in power units, quantity of oxygen consumption and heart rate. The value of HR is not used to express the body load at anaerobic threshold (also at both ventilatory thresholds) despite the fact that even one of the methods of determining the anaerobic threshold is based on the disproportionate inhibition of the acceleration of heart rate during a fitness test with increasing intensity [7]. It was also shown that VAT_1 is more useful in assessing physical performance of cardiac patients and in non-cardiac diseases (pulmonary and musculoskeletal diseases) and VAT_2 often is used in competitive sports, as a measure of physical performance of athletes, especially in endurance disciplines [8,9,10]. In strength kind of sport VAT_2 does not reflect specific physical performance [11]. Therefore the aim of this paper was to investigate and answer the question at what workload level occurs VAT_2 in different kind of sport and which metabolic, cardiovascular or respiratory variables should be used to express this physiological phenomenon. This study was conducted with participation of soccer players, martial arts athletes, weightlifters, powerlifters, runners, race walkers and untrained men of a similar age.

MATERIAL

Subjects

The study involved 12 martial arts athletes (6 - taekwon-do and 6 - Brazilian jiu-jitsu athletes), 16 weightlifters, 16 powerlifters, 14 runners (6 - middle and 8 - long distance runners), 14 reace walkers, 13 professional soccer players, 16 amateur soccer players, and 12 untrained men. The subjects were of similar age, length of their athletic training experience was 3-15 years and they performed 3-6 trainings a week for about 1.5 hours each. All of them represent sports class II, I or master, with the exception of amateur soccer players that displayed a lower sport's level since they had performed lower training loads.

Protocol

At the outset the respondents provided information about their age, while their body height (BH), body mass (BM) and BMI were determined by using the body composition analyzer, Tanita BS 418 - MA. Then, in resting conditions (R) heart rate (HR) and systolic blood pressure (SBP) were recorded electronically. Subsequently the next test during rest was conducted with a well-fitting facemask through which the respondents had to breathe and with the help of quick gas analyzer (Ergo Card) was recorded pulmonary ventilation (V_E), oxygen uptake (VO_2) and carbon dioxide excretion (VCO_2). The obtained data was used to calculate ratio VO_2/HR and rate-pressure product according to the formula $RPP=SBP \cdot HR/1000$.

A few minutes later the respondents were subjected to an exercise test (ET) with increasing intensity, performed by the lower limbs on the bicycle ergometer. ET started with the power (P) equal 60W, whereby the load was increased by 30W every 3 minutes up to the maximum individual load (ML) [point of refusal]. At all loads were measured physiological variables and calculations were performed as described above. Based on the dynamics of V_E (on the y-axis) and VCO_2 (on the x-axis) changes VAT_2 was determined graphically by the method similar to the V-slope. The intersection point of regression lines designated for the upper and lower parts relationship of both variables marked the VAT_2 [12]. Variables P, VO_2, HR, VO_2/HR and RPP recorded at VAT_2 and ML are expressed in absolute values. In addition, these variables achieved by VAT_2 also are expressed as a percentage of the maximal values.

Statistics

The results are presented using descriptive statistics by calculating the arithmetic mean and standard deviation. Statistical differences between groups were calculated using one-way analysis of variance with *post hoc* Bonferroni test. The statistically significant values were accepted at $p<0.05$.

RESULTS

The subjects were men of similar age (Table 1) and differed in the range of BM, BMI ($p<0.001$) and BH ($p<0.009$). The lowest BM was in race walkers and it was significantly lower than in weightlifters and powerlifters ($p<0.001$) as well as in amateur soccer players ($p<0.023$). The largest BM was observed in case of powerlifters and it was significantly higher than that in the case of weightlifters ($p <0.003$), and the other groups ($p<0.001$). Calculations *post hoc* also showed that weightlifters were significantly shorter than professional soccer players ($p<0.048$). The lowest BMI occurred in case of race walkers and was significantly lower than weightlifters and powerlifters BMI ($p<0.001$), martial arts athlethes ($p<0.008$), as well as amateur soccer players ($p<0.02$). Powerlifters had a higher BMI than the control group ($p<0.011$), runners and professional soccer players ($p<0.001$). The highest BMI values occurred in powerlifting and were significantly higher than in the other groups ($p<0.001$). In addition, runners had a lower BMI than the representatives of martial arts ($p<0.033$).

Analyzing the absolute values of physiological variables it was shown that VO_2, P and VO_2/HR at VAT_2 and ML differed significantly ($p<0.001$) and RPP at VAT_2 differed between investigated groups ($p<0.023$), as shown in Table 2 and Table 3. *Post hoc* analysis showed that for both VAT_2 and ML, VO_2 was higher in race walkers than in the control group and in the group of weightlifters it was lower than in runners and amateur soccer players; the lower value of this variable was in the control group with respect to the runners and professional soccer players (Table 2). At VAT_2 was observed a lower VO_2 in race walkers than runners ($p<0.045$) and the control group was characterized by a significantly lower VO_2 at the same load than in representatives of martial arts ($p<0.027$) and powerlifters ($p<0.003$). Moreover significantly higher VO_2 occurred in the group of runners in relation to the representatives of martial arts ($p<0.018$) and powerlifters ($p<0.043$).

In terms of P it was observed at VAT_2 and ML lower value of this variable in the control group compared to race walkers, runners, professional soccer players, representatives of martial arts and amateur soccer players. Also runners develop more power than powerlifters at both load levels. However, P values at the VAT_2 were lower in the control group than in powerlifters ($p<0.022$) and in runners were higher than in the amateur soccer players ($p<0.043$). Similarly, at ML professional soccer players achieved a higher P than powerlifters ($p<0.001$). There were not observed significant differences between groups in relation to HR exertion values.

Ratio VO_2/HR calculated for both loads was lower in the control group than in race walkers, runners, professional soccer players, amateur soccer players and powerlifters but for weightlifters it was lower than in case of runners and amateur soccer players (Table 3). Also it was observed that this ratio at VAT_2 was lower in case of weightlifters than in runners ($p<0.03$);

Table 1. Somatic characteristics of subjects (x±SD)

Group	Age [years]		BM [kg]		BH [cm]		BMI [kg/m2]	
	x	±SD	x	±SD	x	±SD	x	±SD
I	22.21	7.16	62.65	8.54	174.28	6.71	20.59	2.41
II	23.31	3.52	79.87	15.22	173.87	8.51	26.21	3.19
III	25.47	7.11	72.43	9.19	177.07	4.73	23.07	2.62
IV	22.21	6.20	68.91	4.63	181.00	4.57	21.05	1.45
V	20.38	2.66	72.86	6.59	181.61	5.07	22.07	1.45
VI	24.92	7.61	73.09	10.00	174.08	7.25	24.13	3.04
VII	24.06	5.19	75.00	7.69	178.25	4.51	23.61	2.29
VIII	25.67	5.45	94.36	13.20	176.20	9.70	30.25	2.20
F	1.400		12.495		2.876		24.740	
p <	0.213		**0.001**		**0.009**		**0.001**	
I-II	1.000		**0.001**		1.000		**0.001**	
I-III	0.801		0.162		0.951		0.115	
I-IV	1.000		0.721		0.146		1.000	
I-V	0.992		0.155		0.093		0.758	
I-VI	0.935		0.154		1.000		**0.008**	
I-VII	0.988		**0.023**		0.735		**0.020**	
I-VIII	0.749		**0.001**		0.994		**0.001**	
II-III	0.968		0.449		0.885		**0.011**	
II-IV	1.000		0.068		0.079		**0.001**	
II-V	0.877		0.578		**0.048**		**0.001**	
II-VI	0.996		0.646		1.000		0.327	
II-VII	1.000		0.870		0.585		0.058	
II-VIII	0.949		**0.003**		0.978		**0.001**	
III-IV	0.801		0.981		0.758		0.328	
III-V	0.297		1.000		0.623		0.956	
III-VI	1.000		1.000		0.943		0.950	
III-VII	0.998		0.996		1.000		0.999	
III-VIII	1.000		**0.001**		1.000		**0.001**	
IV-V	0.992		0.971		1.000		0.957	
IV-VI	0.935		0.964		0.155		0.033	
IV-VII	0.988		0.716		0.950		0.083	
IV-VIII	0.749		0.001		0.530		0.001	
V-VI	0.519		1.000		0.101		0.404	
V-VII	0.689		0.999		0.877		0.679	
V-VIII	0.251		**0.001**		0.396		**0.001**	
VI-VII	1.000		1.000		0.728		0.999	
VI-VIII	1.000		**0.001**		0.992		**0.001**	
VII-VIII	0.994		**0.001**		0.989		**0.001**	

I-race walkers; II-weightlifters; III-untrained men; IV-runners; V-professional soccer players; VI-combat athletes; VII- amateur soccer players; VIII-powerlifters

Table 2. The values of physiological variables achieved at VAT_2 and ML (x±SD)

Group	VO2-VAT2 [l/min]		VO2-ML [l/min]		HR-VAT2 [bpm]		HR-ML [bpm]		P-VAT2 [W]		P-ML [W]	
	x	±SD	x	±SD	x	±SD	x	±SD	x	±SD	x	±SD
I	2.90	0.39	3.69	0.65	161.57	10.20	179.93	8.79	203.57	26.78	244.28	28.48
II	2.50	0.40	3.18	0.49	155.94	12.10	178.56	12.99	172.50	30.00	221.25	30.74
III	2.17	0.49	3.03	0.45	164.07	14.51	186.13	8.68	148.00	34.89	200.00	29.28
IV	3.49	0.49	4.15	0.50	165.57	15.80	181.14	14.68	237.86	43.18	276.43	41.06
V	3.08	0.44	3.79	0.69	157.46	13.90	180.15	11.36	216.92	24.96	279.23	25.64
VI	2.81	0.51	3.57	0.42	164.25	10.94	184.58	7.40	200.00	26.63	247.50	31.66
VII	3.09	0.61	4.07	0.56	158.44	16.37	179.37	10.62	200.00	30.43	253.12	24.42
VIII	2.91	0.60	3.59	0.60	158.93	11.15	177.13	11.18	188.00	36.68	226.00	35.62
F	9.265		7.550		1.032		1.095		10.330		10.879	
p <	**0.001**		**0.001**		0.413		0.372		**0.001**		**0.001**	
I-II	0.390		0.180		0.944		1.000		0.159		0.476	
I-III	**0.004**		**0.034**		1.000		0.797		**0.001**		**0.005**	
I-IV	**0.045**		0.362		0.993		1.000		0.105		0.127	
I-V	0.982		1.000		0.993		1.000		0.961		0.081	
I-VI	1.000		0.999		1.000		0.961		1.000		1.000	
I-VII	0.964		0.574		0.998		1.000		1.000		0.994	
I-VIII	1.000		1.000		0.999		0.997		0.899		0.763	
II-III	0.589		0.996		0.693		0.546		0.418		0.558	
II-IV	**0.001**		**0.001**		0.508		0.998		**0.001**		**0.001**	
II-V	0.052		0.065		1.000		1.000		**0.009**		**0.001**	
II-VI	0.742		0.571		0.733		0.841		0.346		0.359	
II-VII	**0.026**		**0.001**		0.999		1.000		0.225		0.085	
II-VIII	0.344		0.436		0.998		1.000		0.884		1.000	
III-IV	**0.001**		**0.001**		1.000		0.925		**0.001**		**0.001**	
III-V	**0.001**		**0.010**		0.896		0.840		**0.001**		**0.001**	
III-VI	**0.027**		0.196		1.000		1.000		**0.002**		**0.004**	
III-VII	**0.001**		0.001		0.938		0.683		**0.001**		**0.001**	
III-VIII	**0.003**		0.116		0.965		0.338		**0.022**		0.314	
IV-V	0.402		0.963		0.764		1.000		0.701		1.000	
IV-VI	**0.018**		0.141		1.000		0.993		0.069		0.274	
IV-VII	0.375		1.000		0.828		1.000		**0.043**		0.460	
IV-VIII	**0.043**		0.119		0.883		0.976		**0.002**		**0.001**	
V-VI	0.885		0.973		0.909		0.973		0.895		0.191	
V-VII	1.000		0.876		1.000		1.000		0.878		0.337	
V-VIII	0.984		0.976		1.000		0.996		0.273		**0.001**	
VI-VII	0.826		0.263		0.947		0.919		1.000		1.000	
VI-VIII	1.000		1.000		0.969		0.657		0.979		0.636	
VII-VIII	0.968		0.233		1.000		0.999		0.959		0.244	

I-race walkers; II-weightlifters; III-untrained men; IV-runners; V-professional soccer players; VI-combat athletes; VII- amateur soccer players; VIII-powerlifters

Table 3. The values of respiratory and cardiovascular variables achieved at VAT_2 i ML (x±SD)

Group	VO2/HR-VAT2 [ml/bpm]		VO2/HR-ML [ml/bpm]		RPP-VAT2 [mmHg·bpm]		RPP-ML [mmHg·bpm]	
	x	±SD	x	±SD	x	±SD	x	±SD
I	18.00	2.48	20.76	4.20	30.40	4.04	34.94	3.44
II	16.10	2.38	17.79	3.19	29.29	5.02	35.69	5.90
III	13.40	2.64	16.16	2.40	30.75	6.17	37.14	6.08
IV	21.15	2.60	22.88	2.47	35.06	4.06	39.81	3.54
V	19.65	3.41	21.31	4.63	29.61	4.00	36.73	4.28
VI	17.21	2.51	19.45	2.14	31.06	3.69	35.75	4.24
VII	19.56	3.34	22.86	3.56	29.61	3.65	34.81	2.58
VIII	18.28	3.53	21.80	6.75	31.21	4.28	37.12	4.29
F	10.106		5.594		2.438		1.894	
p <	**0.001**		**0.001**		**0.023**		0.078	
I-II	0.631		0.452		0.997		1.000	
I-III	**0.001**		**0.045**		1.000		0.894	
I-IV	0.088		0.850		0.113		0.084	
I-V	0.817		1.000		1.000		0.967	
I-VI	0.997		0.990		1.000		1.000	
I-VII	0.821		0.833		1.000		1.000	
I-VIII	1.000		0.997		1.000		0.890	
II-III	0.171		0.945		0.986		0.986	
II-IV	**0.001**		**0.015**		**0.013**		0.196	
II-V	0.030		0.260		1.000		0.999	
II-VI	0.974		0.956		0.966		1.000	
II-VII	**0.022**		**0.010**		1.000		0.999	
II-VIII	0.431		0.102		0.929		0.986	
III-IV	**0.001**		**0.001**		0.180		0.758	
III-V	**0.001**		**0.019**		0.998		1.000	
III-VI	**0.021**		0.395		1.000		0.993	
III-VII	**0.001**		**0.001**		0.997		0.839	
III-VIII	**0.001**		**0.004**		1.000		1.000	
IV-V	0.880		0.970		**0.039**		0.622	
IV-VI	**0.017**		0.359		0.311		0.292	
IV-VII	0.806		1.000		**0.024**		0.053	
IV-VIII	0.144		0.996		0.288		0.734	
V-VI	0.419		0.937		0.992		0.999	
V-VII	1.000		0.966		1.000		0.942	
V-VIII	0.914		1.000		0.980		1.000	
VI-VII	0.407		0.327		0.989		0.999	
VI-VIII	0.980		0.789		1.000		0.993	
VII-VIII	0.921		0.995		0.973		0.832	

I-race walkers; II-weightlifters; III-untrained men; IV-runners; V-professional soccer players; VI-combat athletes; VII- amateur soccer players; VIII-powerlifters

Table 4. The relative values of physiological variables achieved with VAT_2 in relation to ML (x±SD)

Group	VAT2 [%VO2max]		VAT2 [%HRmax]		VAT2 [%VO2max/%HRmax]		VAT2 [%RPPmax]		VAT2 [%Pmax]	
	x	SD	x	SD	x	SD	x	SD	x	SD
I	79.38	8.95	89.52	5.18	88.06	10.07	86.93	6.76	83.64	8.75
II	78.58	7.99	87.85	3.79	91.18	8.20	83.77	20.17	78.10	10.49
III	69.96	7.62	87.65	5.90	81.82	8.25	82.73	9.64	72.16	12.48
IV	84.33	8.14	91.25	4.93	92.52	6.72	88.07	6.73	85.33	8.18
V	80.77	7.71	86.20	5.40	93.45	10.15	80.54	4.32	76.45	9.24
VI	78.70	10.05	89.01	5.09	88.63	10.09	87.23	7.80	81.03	6.65
VII	75.70	9.13	88.26	6.81	85.41	5.97	85.14	9.15	79.38	10.83
VIII	79.05	7.94	89.71	3.72	86.73	14.57	84.15	6.66	78.58	8.87
F	3.537		1.213		2.328		0.814		2.595	
p <	**0.002**		0.302		**0.030**		0.577		**0.016**	
I-II	1.000		0.987		0.986		0.991		0.772	
I-III	0.064		0.978		0.668		0.960		**0.039**	
I-IV	0.777		0.987		0.919		1.000		1.000	
I-V	1.000		0.713		0.825		0.744		0.537	
I-VI	1.000		1.000		1.000		1.000		0.997	
I-VII	0.934		0.998		0.995		1.000		0.930	
I-VIII	1.000		1.000		1.000		0.996		0.853	
II-III	0.096		1.000		0.141		1.000		0.685	
II-IV	0.581		0.630		1.000		0.946		0.463	
II-V	0.997		0.990		0.998		0.990		1.000	
II-VI	1.000		0.999		0.997		0.987		0.993	
II-VII	0.979		1.000		0.682		1.000		1.000	
II-VIII	1.000		0.974		0.898		1.000		1.000	
III-IV	**0.001**		0.579		**0.070**		0.868		**0.009**	
III-V	**0.022**		0.996		**0.041**		0.999		0.940	
III-VI	0.142		0.997		0.612		0.953		0.272	
III-VII	0.558		1.000		0.969		0.998		0.441	
III-VIII	0.073		0.958		0.863		1.000		0.613	
IV-V	0.957		0.198		1.000		0.555		0.264	
IV-VI	0.691		0.957		0.968		1.000		0.950	
IV-VII	0.108		0.765		0.464		0.994		0.703	
IV-VIII	0.699		0.993		0.730		0.970		0.573	
V-VI	0.999		0.877		0.912		0.736		0.936	
V-VII	0.746		0.964		0.329		0.932		0.992	
V-VIII	0.999		0.632		0.584		0.983		0.999	
VI-VII	0.982		1.000		0.987		0.999		1.000	
VI-VIII	1.000		1.000		1.000		0.994		0.998	
VII-VIII	0.955		0.994		1.000		1.000		1.000	

I-race walkers; II-weightlifters; III-untrained men; IV-runners; V-professional soccer players; VI-combat athletes; VII- amateur soccer players; VIII-powerlifters

in the control group it was lower than in representatives of martial arts ($p<0.021$), and it was higher in the runners than in representatives of martial arts ($p<0.017$).

With regard to RPP *post hoc* analysis showed only that the highest value of this product at VAT_2 was achieved in the group of runners and it was higher than in weightlifters ($p<0.013$), professional soccer players ($p<0.039$) and in the amateur soccer players ($p<0.024$). There were not observed significant differences between groups in relation to RPP computed at ML.

In the investigated groups a difference in the relative values was registered in: VO_2max ($p<0.002$), Pmax ($p<0.016$) i $\%VO_2max/\%HRmax$ ($p<0.03$) reached at VAT_2 and also referenced to ML (Table 4). *Post hoc* analysis showed that in terms of percentage of VO_2max achieved at VAT_2 control group was characterized by significantly lower values of this variable than the group of runners ($p<0.001$) and professional soccer players ($p <0.022$). However, in terms of percentage of Pmax it was observed lower value of this variable in the control group with respect to race walkers ($p<0.039$) and runners ($p<0.009$). On the other hand the $\%VO_2max/\%HRmax$ in the control group was significantly lower than in professional soccer players ($p<0.041$). In terms of % HRmax, there were no differences between the groups.

DISCUSSION

The obtained results show that the study groups had statistically different the following values: VO_2, P, VO_2/HR achieved at VAT_2 and ML, and the value of RPP achieved at VAT_2 (Table 2 and 3) as well as the values of % VO_2max, % Pmax and % VO_2/HR achieved at VAT_2 (Table 4). Inferred to be that kind of adaptation that occurs after training in various types of sport was an important factor in altering the physical performance and metabolism studied groups. These data also indicate that such matabolic variable as VO_2 and its derivative, ie. VO_2/HR are reliable indicators in which the equivalent of the size of P may be expressed VAT_2. However, there were no differences between the groups with respect to HR recorded at VAT_2 and at ML (Table 2), RPP computed after achieving ML (Table 3), and %HRmax and %RPPmax achieved at VAT_2 (Table 4). These data show that VAT_2 occurs at a similar load of the circulatory system, regardless of the type of body adaptation (caused by practicing sports of various kinds) and its level of fitness. It can be concluded that the variables characterizing the functions of the cardiovascular system are not very useful or not useful at all in expressing exercise loading in various sports groups and also in the expression of the VAT_2 level, despite the fact that sports training has a big impact on improving cardiovascular efficiency [3, 13, 14]. Also it is commonly known that, in individual cases, to express the load on the body caused by dynamic physical effort is often used the degree of loading of cardiovascular system, which is expressed by HR.

Therefore the conclusion is that in spite of reaching during the graduated exercise test the reference power output and oxygen uptake by the body on one hand and cardiovascular variables on the other hand in order to express VAT_2, there are useful only absolute and relative values of the power output, oxygen uptake and other derivative physiological values, whereas the cardiovascular variables are not useful in this respect.

The most preferred values of the analyzed physiological variables registered at VAT_2 and ML, calculated with *post hoc* test, were recorded in runners, professional soccer players and race walkers (Table 2, 3 iand 4). Runners can be considered as professional athletes because of the length of their training, sporting achievements, as well as the size of applied training loads. The subjects in this group had achieved significantly higher P, greater VO_2, higher values VO_2/HR at VAT_2 and ML, and higher values of $\%VO_2max$ and %Pmax set at VAT_2 than a group of untrained men. Achieved at VAT_2 $\%VO_2max$, %Pmax in runners group were similar and ranged in 85% bracket of both maximum values, which in the light of the literature classifies this athletes as the group of highly trained; it has been shown that VAT_2 in marathoners and long-distance runners is present at a level of about 85% VO_2max [15] and in middle distance runners at about 80% VO_2max [16]. Similar to the runners level of physical performance was represented by professional soccer players, whose absolute size of the VO_2, P and VO_2/HR occurring at both analyzed loads and the relative size of %VO_2max and %VO_2max/%HRmax observed at VAT_2 were significantly higher than in the control group. Also a group of race walkers was characterized by higher values of VO_2, P and VO_2/HR occurring at both analyzed loads and higher rates of %Pmax achieved at VAT_2 than a group of untrained men. These comparisons indicate that the investigated sports' groups, which have used running as a part of their training were characterized by higher physical performance described by higher values of %VO_2max, %Pmax and %VO_2max/%HRmax in relation to untrained persons. It has been argued that running training to a dreater extent than swimming and cycling workload increases the power output at VAT_2 [17]. In addition, it has been shown that the sprint training and middle distance training enhance and develop the performance ability at different stages of their sports success [18]. In the present study there was also a group of amateur soccer players, but despite that during their training a certain amount of running exercise was performed, they have failed to sufficiently increase their physical performance to significantly differ in terms of P or VO_2 from the group of untrained men or strength sport athletes, because they have trained less than professional soccer players, runners or race walkers. The observed differences in physical performance and physical fitness occur at VAT_2 between the above-mentioned professional soccer players, runners or race walkers in respect of untrained persons probably also result from poor physical fitness of the latter. Taylor and Bronks [19] inform that in case of people who are physically active but are not practicing sport professionally VAT_2 approaches the value of 79% VO_2max, which is a significantly higher value than in untrained and physically inactive students in our control group.

On the other hand, no differences in terms of %VO_2max and %VO_2max/%HRmax and %Pmax at VAT_2 as well as at ML between representatives of martial arts, powerlifters, and the control group did not indicate on a complete lack of training effects in these athletes groups, because in terms of their absolute values such differences were observed (Table 2 and 3). At the same time one needs to be aware of the fact that these so-called anaerobic sports develop only slightly physical fitness, and therefore in the process of specialized training, it has increased but these changes were not statistically significant [20].

The observed changes in physical performance achieved at VAT_2 and ML were caused by applied loads that also affect somatic variables of the studied athletes. Hence, the lowest BMI was observed in athletes with the highest physical fitness, ie. by race walkers and runners (Table 1). It has been shown that a professional endurance training leads to wear down body fat and extreme increase in lean body mass, without evidence of muscle hypertrophy and thus there was no body mass gain [21]. In turn, the athletes with the highest BMI were distinguished by their low overall physical performance (weightlifters, powerlifters), due to the fact that strength training affects only the formation of hypertrophic changes and develops anaerobic performance [11, 22]. There is no doubt that both types of training (endurance and strength) have specific adaptive effects on the body, including the formation of somatic changes. These changes are also determined by sport selection that allows one to recruit people with the right type of somatic requirements for a particular sport. Untrained persons' BMI was similar to the representatives of the martial arts and both groups of soccer players, although a range of physical performance relations between investigated groups were different, because in both of these types of sport overall physical performance, as well as partially specific physical performance are developed. However a level of development of specific physical performance does not determine far reaching changes in the somatic conditions [23, 24].

In summary it should be stated that there is a clear relation in terms of metabolic and cardio-respiratory variables expressing the intensity of the exercise and in describing VAT_2 and ML values together with somatic variables of tested people with different levels and types of physical performance.

CONCLUSIONS

Physiological variables associated with VO_2 and P accurately express the value of VAT_2, while the variables characterizing physical performance are useless in this respect. The greatest physical performance achieved athletes who have in the structure of their training the most running endurance exercises (race walkers, runners and professional soccer players), while weightlifting, martial arts, powerlifting and amateur soccer players training does not lead to a significant increase in cardiovascular fitness. Somatic differences between the tested individuals are mainly the result of the specificity of applied training loads of different character and used the sports' selection, but not the size of applied loads in the training process.

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Cite this article as:
Zych M, Stec K, Pilis A, Pilis W, Michalski C, Pilis K, Kosiński D. Approaches to describe ventilatory threshold in professional sports, Phys Activ Rev 2017, 5: 113-123