Biology of Sport, Vol. 23 N^{o}4, 2006

CONSECUTIVE CHANGES DURING STANDARTISED CARDIOPULMONARY TEST IN BASKETBALL PLAYERS

A. Andziulis[1], A. Gocentas[2], N. Jaszczanin [3], J. Jaszczanin[4], W. Starosta[5]
[1]Vilnius University, Lithuania; [2]Institute of Experimental and Clinical Medicine, Vilnius University, Lithuania; [3,4]University of Szczecin, Poland; [3]Vilnius Pedagogical University, Lithuania; [4]Lithuanian Academy of Physical Education, Lithuania; [5]Academy of Physical Education in Poznan – Faculty of Physical Culture in Gorzów, Poland

Abstract. The purpose of the study was to determine the dynamics of cardiopulmonary and metabolic response of trained basketball players during different stages of exhaustive exercise test. A total of 42 male athletes were studied. They performed incremental multistage (50W each 2 min) exercise test until exhaustion. During the test, the expired air was analyzed using breath-by-breath VMAX229 system. Parameters of ventilation, heart rate, power, indices of gas exchange were measured during the tests. Samples were formed for each 30 s interval. All samples were checked according to the Kolmogorov-Smirnov criterion and standard grouping into classes was used; the degree of freedom was established according to the normal distribution standard (k=m-p-1). Confidence intervals were calculated for samples similar to normal (95% level, $p<0.05$ considered sufficient).The results of this study suggest that the increase in VO_2 is a linear progression, which approximately corresponds to the function $VO_2 \approx 4.68+0.14*P$ in relation to load ($VO_2 \approx P/8$) or $VO_2 \approx 7,34+0,04*T$ in relation to time ($VO_2 \approx t(s)*19$. Graphic expression of cardiopulmonary and metabolic variables is useful nomograms for the routine assessment of response during exercise in players of invasion games. ***(Biol.Sport 23:379-387, 2006)***

Key words: Athlete- Exercise testing - Oxygen uptake - Metabolism

Introduction

Competitive sports represent most extreme stress to which the body can be exposed [1,4,5,11]. Physical ability of an athlete's body is determined by the quality of external breathing and cardiovascular functions and by features of

---

Reprint request to: Prof. Jan Jaszczanin, Institute of Physical Education, University of Szczecin, Al. Piastów 41-6, 70-540 Szczecin , Poland
E mail: jjaszczanin@univ.szczecin.pl

metabolism related to the tissue breathing and transport of substrates. There exist many models of human physical activity, with their specificity determined by the relevant kind of sport and inherent features of the individual as well as by time and geographic factors [3,10,11]. Physiological testing of athletes requires the correct description and evaluation of sports-specific factors [4]. Athletes are influenced not only by general differences in geographic and cultural factors or specificity of the sport concerned but also by different schools of sport, i.e. methods of training [1,4,9].

Basketball as a sport may be defined as invasion game of high intensity with considerable stress on system of oxygen delivery [4,7]. It is most popular sport in Lithuania. However, we have as yet no physiological profile of basketball players [6]. On the other, there exist no norms for a comprehensive evaluation of the Lithuanian residents' physical capacity and breathing system and metabolic function capacity including persons going in for sports. It is not clear whether one may rely upon the nomograms drawn up by other authors.

The aim of this study was to evaluate the dynamics of indices of functional cardiorespiratory and metabolic capacity in highly trained basketball players during exercise testing, to determine their critical values and to draw up nomograms.

Materials and Methods

Subjects: We studied 42 men aged 18-29 years. All were trained players with international experience from Lithuanian Basketball League. The control group (n=19) consisted of healthy men aged 18-29 practicing no sports in whom no diseases which could potentially influence functional condition were diagnosed during medical examination. All the subjects had an electrocardiogram and a spirogram at rest before the test. All tests were carried out under laboratory conditions complying with the ATS regulations [3].

The subjects performed an exercise test on the electrically braked cycle ergometer Ergometrics 800 (Ergoline, Bitz, Germany). During the investigation under consideration, computer-controlled rate of 60-70 rpm was set. All athletes were examined using an incremental multistage protocol (50W every 2 min). The tests were continued until peak oxygen uptake (VO_{2peak}) or up to decrease in the efficiency of the heart or lungs activity. The VO_{2peak} was considered achieved if VO_2 was not increasing more than 1 min under stable loading or without increase in mechanical efficiency. The decrease in the efficiency of the heart/lung activity was established if no increase was recorded in the heart rate (HR), double product (DP) indicator or ventilation volume for more than one minute. No limitation of load according to the AHA recommendations was applied. The anaerobic threshold was determined by the V-slope method using the ratio of VCO_2 and VO_2.The indicators were evaluated according to the ATS regulation and Morris-Polgar manual. The breathing reserve was assessed according to the classical ATS regulation and Johnson -Weisman loop analysis method. Samples were formed for each 30 s interval for the evaluation of the lung ventilation indicators (VE, PEF and RR), heart activity (HR) and aerobic uptake (VO_2). A sample was marked with an index reflecting the moment of time counted from the start of the test. Thus the numerical value provided is an average of the last 30 s, with the recording of moments of establishing of each breathing cycle indicator.

Data analysis: The Shapiro-Wilks indicator for reverse accuracy of means was calculated; if the value was not lower than 0.95, it was assumed that the sample could be represented by the mean. All samples were checked according to the Kolmogorov-Smirnov criterion and standard grouping into classes was used; the degree of freedom was established according to the normal distribution standard (k=m-p-1); it was considered that appropriate α was 0.9, critical p was 0.1. Confidence intervals were calculated for samples similar to normal (95% level, $p<0.05$ considered sufficient). A hypothesis of difference in means was checked by verifying samples reflecting the same phenomenon at different moments of time with the samples considered independent; the t criterion was used for the evaluation of the reliable mean interval and dispersion, provided that the similarity of dispersion was proved based on Fisher's distribution (if $F<F_{\alpha}$). A regress linear analysis according to a standard model (Y=a+b* X) was made following a standard confidence level (α=0.05) between time, load intensity, VO2, VE, HR, RR and PEF.

Results

All the subjects reached maximal effort, and all criteria for the tests performed were maximum. The dynamics of oxygen uptake is expressed in Fig. 1. The volume of samples decreased along with increase in load, since increasing intensity meant smaller number of individuals able to continue the test. The data were evaluated until a 350 W load was achieved. The sample distribution characteristics changed because there remained only 17 tested individuals who were able to continue the test on the load intensity 400 W. It has been established that the mean anaerobic threshold reached by the tested individuals was 25 mL/min/kg (CI=22.3-27.6; $p<0.05$) or 50-54% VO_{2peak}. This occurred at the load of 150-200 W (moda 150 W).

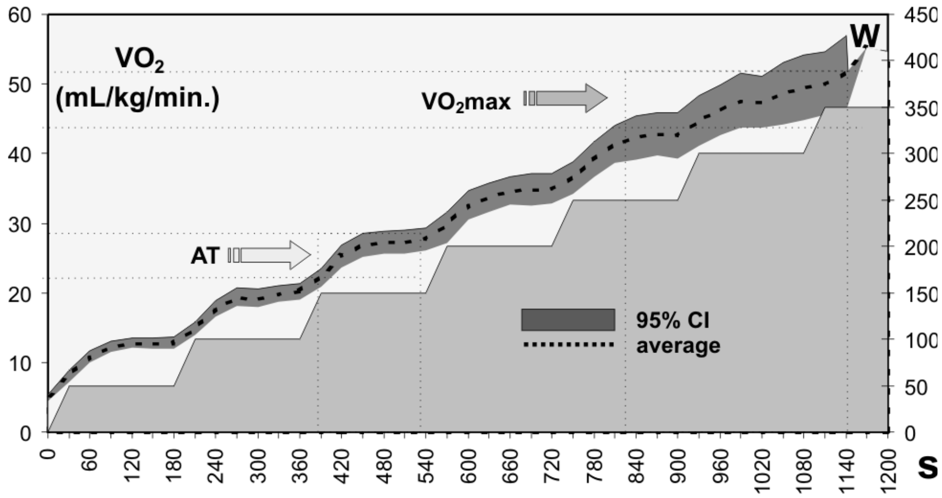

Fig. 1
Exercise-induced changes in oxygen uptake during exercise test

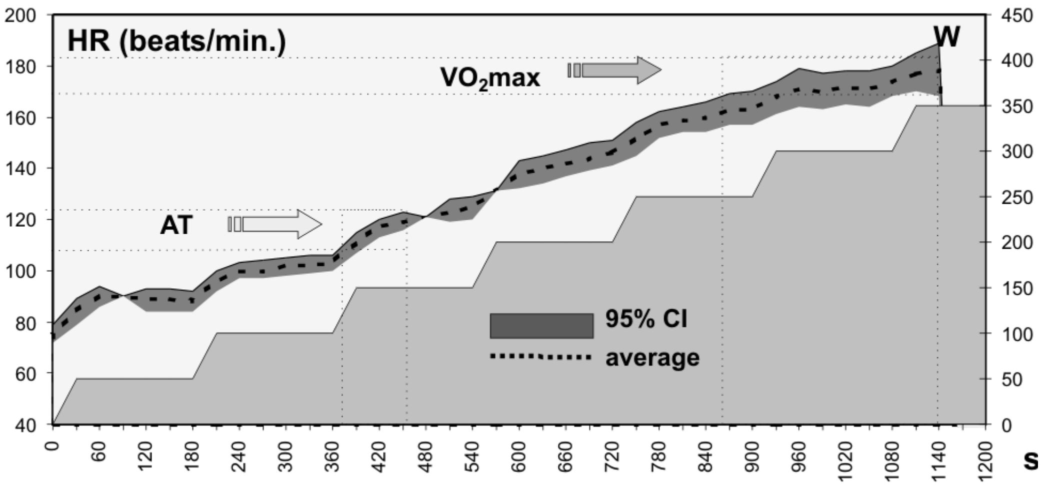

Fig. 2
Exercise-induced changes in heart rate during exercise test

The changes of the heart rate during physiological testing are presented in Fig. 2. The results of the test show that the heart rate reached under VO_{2peak}

conditions is within the range 170-182 bpm. At the time of establishing the anaerobic threshold the heart rate was 110-125 bpm within 150-200 W.

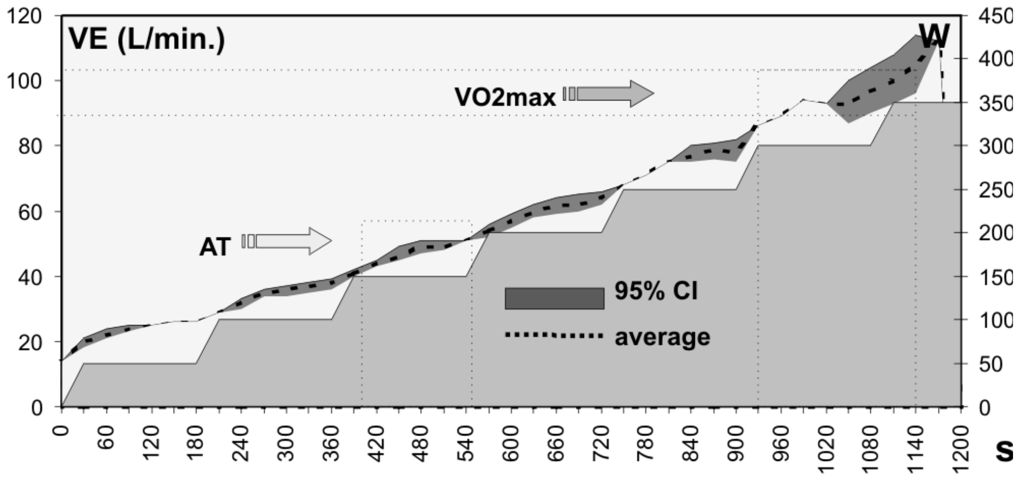

Fig. 3
Exercise-induced changes in minute ventilation during exercise test

The volumes of min ventilation are greatly varied during time intervals as showed in Fig. 3. The interval of 510-540 s is in the approximate anaerobic threshold passing area and corresponds to the time of s varying interval of the heart rate. The very high variation interval of 720-840 s takes place during the last intense increase in VO_2. As showed in Fig. 3 the minute ventilation reached under VO_{2peak} conditions is within the range of 300-350 W loads and is 95-105 l/min. In the graphs 2 and 3, the interrupting region of the confidence interval of the minute lungs ventilation dynamics under standard physical load is marked by a dotted line because the indicator of minute lung ventilation is not statistically verified in these intervals and the line shows just the projected potential dynamics of the indicator.

The verified intervals of respiratory rate under the conditions of the anaerobic threshold and the maximal oxygen uptake are presented (Fig. 4). The respiratory rate achieved under VO_{2peak} is within the interval of load of 250-350 W and is 29-37 times/min. The AT interval respiratory rate is within the interval of 100-250 W, it is achieved on the 6th -9th minute and is 22-25 times/min. Confidence interval of respiratory rate is not statistically verified during all stages of exercise. Those intervals marked as dotted line. The line shows just the projected potential dynamics of the respiratory rate.

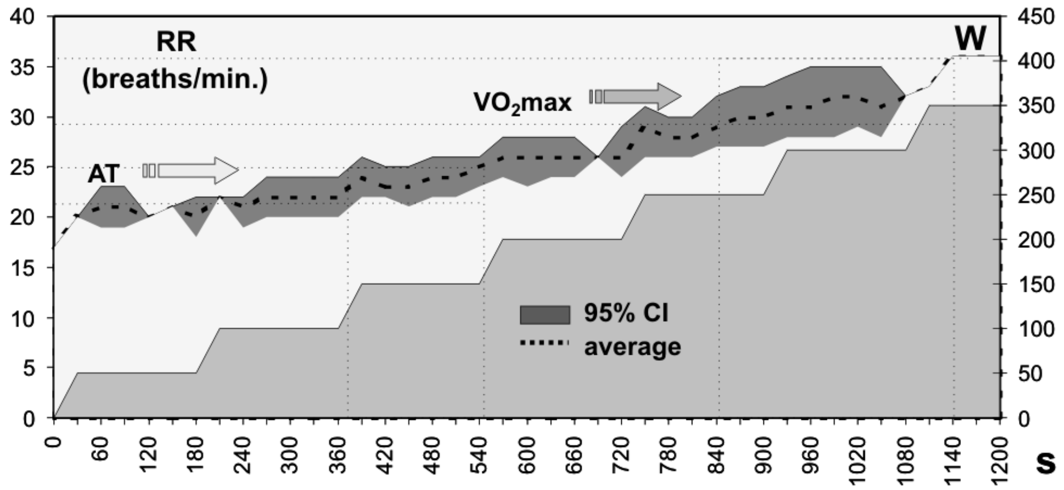

Fig. 4
Exercise-induced changes in respiratory rate during exercise test

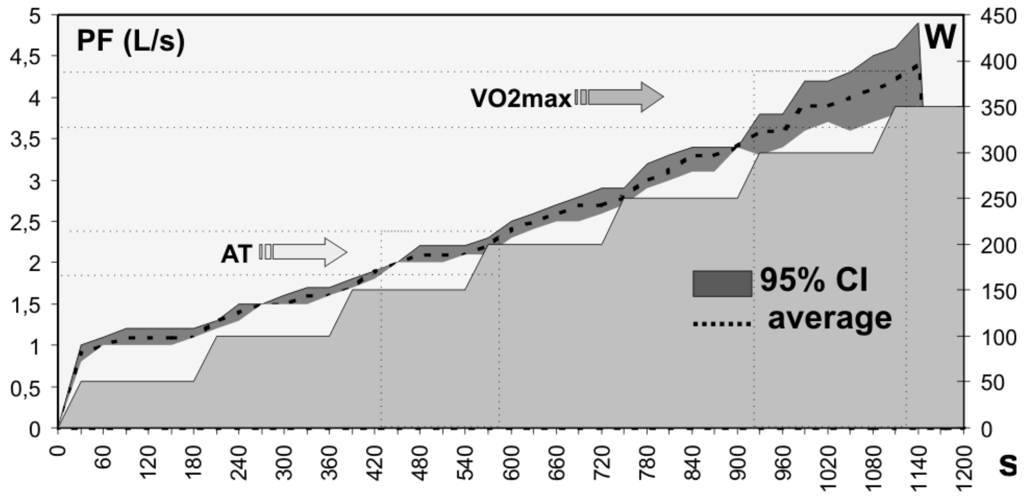

Fig. 5
Exercise-induced changes in peak flow during exercise test

The dynamics of the peak expiratory flow rate (Fig. 5) shows that a 3.6-4.4 l/s PEF (peak expiratory flow) is achieved under VO_{2peak} within the load interval 300-350W.

The PEF of the AT interval is within 150-200 W, it is developed on the 7th–10th min. The intervals verified under the PEF anaerobic conditions and the maximal oxygen uptake are shown. The peak expiratory flow interrupted on the 8th and 10th minute is shown in Fig. 5 by a dotted line because in these intervals the indicator cannot be statistically verified; therefore the line shows just the projected potential dynamics of the indicator. Based on the data of the distribution analysis, a hypothesis that the samples PEF 30-1140 s fall within the normal distribution ($p<0.05$) was not denied on the standard confidence level. An analysis according to Fischer's criterion has confirmed that the difference in the scattering of samples cannot be proved on standard level, except for the intervals 240-270 s, 420-450 s and 870-900 s from the beginning of the test. This process cannot be explained as yet, however, it is noted that the intervals correspond to the intermediate stabilization intervals of the indicator (with the indicator of an individual remaining stable for at least one minute). Irrespective of the "fall out" of these intervals from the nomogram, the mean and the confidence interval data may be assessed up to the 1140 s of the test, with the parameters of the numerical characteristics marked on the graphical axes.

The established PEF under the conditions of maximal oxygen uptake amounting to 4.0 L/s (CI=3.7-4.4 L/s). No data on PEF_{EF} for athletes are available. The PEF in the individuals tested under the conditions of anaerobic threshold is 2.1 l/s (for the 1.8-2.3 values the data of the H0 hypothesis denial test corresponded to the standard level), or 22% of PEF. Taking account of the fact that no considerable intensification of lung ventilation was established before exceeding the anaerobic threshold, one may assume that up to 22% of changes in PEF are not determined by the chemical breathing-stimulating factors. The indicator is close to the errors for evaluating forced PEF as provided in the manual. Thus one may assume that approximately 20% of changes in PEF were accidental or determined by psychogenic factors. It has been established that $PEF_{VO2peak}$ differs in the athletes group and the control group ($p<0,05$), though no difference in PEF was determined in still condition (in the individuals tested the average PEF under VO_{2peak} is 4.03, average square deviation 0.99, confidence interval 3.71-4.35; in the control group, the average PEF is 3.54L/s, average square deviation 0.69, confidence interval 2.96-4.11). This shows that under P_{peak} the lungs of athletes activate to a larger extent than those of the individuals who do not go in for sports, though peak possibilities may be equivalent. On the other hand, it is obvious that the compensational adaptation occurs on account of the air flow rate even if equal volumes are ventilated. Such compensation determines greater mechanical efficiency in athletes. A regress analysis has shown that the coefficients of correlation of all indicators are larger than 0.95, with the determination coefficient larger than 95%, and $p<0.01$.

The increase in VO_2 is a linear progression, which approximately corresponds to the function $VO_2 \approx 4.68+0.14*P$ in relation to load ($VO_2 \approx P/8$) or $VO_2 \approx 7,34+0,04*T$ in relation to time ($VO_2 \approx t(s)*19$.

Discussion

There are no well-established or widely accepted standardized testing profiles for basketball players [4,6]. Peak values of oxygen consumption, heart rate and minute ventilation are comparable with data from other investigations [2,8]. Aerobic performance of the studied basketball players is on upper border of widely accepted normative values [3,11].

HR also increases along with load, the linear progression being similar to that of VO_2, which corresponds to the data found in the literature [2,8,9,11] at 350 W it scatters up to the rate of 168-190 bits/min. We have established that the individuals whose HR>190 bits/min. belong to another set at the load of 350 W (the indicator is normal according to AHA for healthy individuals, with HR_{peak} corresponding to VO_{2peak}) but their myocardium activity is less economical than that of athletes. The athlete who's HR_{peak} at VO_{2peak} is lower than 168 bits/min. is well adapted for physical load, with the economical heart activity.

Despite a linear increasing of VE, there are many non-verifiable intervals, which show that the external respiratory compensational mechanisms are activated at different rates. The variations in lungs ventilation during intervals of light physical load (intensity 50-100 W) may be caused by differences in the athletes' psychogenic factor or central nervous regulation [1,10,11].

The fact that upon reaching 350 W and VO_{2peak}, the scattering of VE reaches its peak and approximately corresponds to that of VO_2 is well verified. This shows that under extreme physical loads VO_{2peak} may be determined by VE, while the regulation of external breathing depends on chemical factors of respiratory regulation. Though the RR confidence intervals are well verified and identified (Fig. 4), their progression is not so pronounced. An assumption can be made that RR is not the critical factor of the external respiratory compensation. The characteristics of the PEF dynamics is very similar to that of VO_2 and well verified, therefore, one may assume that this indicator is related to the oxygen uptake level, while the air flow rate developed may be a determinant of VO_{2peak}. It is seen that under extreme physical load the scattering of VO_2 and PEF is similar, while the PEF dynamics depends on the degree and quality of activation of the expiration muscles, thus the respiratory compensation may be determined by the condition of the fast cross-striated muscles of the chest.

In conclusions, the results showed that the different VO_{2peak} indicators reflecting the dynamic potential of the body are recorded in trained basketball players during the standard exercise test. This is most pronounced at the load of 350 W of prolonged incremental activity, with the values varying from 46.2 to 56.9 mL/min/kg. The confidence intervals shown in the graphs depicting dynamics of cardiopulmonary indices have been statistically verified and the region shown in the graphs may be considered nomograms of the dynamics of oxygen uptake by basketball players during standardized exercise testing.

References

1. ACSM's Guidelines for Exercise Testing and Prescription. (2005) 7th Ed. Lippincott Williams & Wilkins, Philadelphia, 366 pp.
2. Apostolidis N., G.P.Nassis, T.Bolatoglou, N.D.Geladas (2004) Physiological and technical characteristics of elite young basketball players. *J. Sports Med. Phys. Fitness* 44:157-163
3. ATS/ACCP Statement on Cardiopulmonary Exercise Testing (2003) *Am.J.Respir. Crit.Care Med.* 167:211-277
4. Gore C.P. (2000) Physiological tests for elite athletes. Australian Sports Commission. Human Kinetics, Champaign, 480 pp.
5. Harris K.M., A.Sponsel, A.M.Hutter Jr, B.J.Maron (2006) Cardiovascular screening practices of major North American professional sports teams. *Ann.Intern.Med.* 145:507-511
6. Hoffman J.R. (2003) Physiology of basketball. In: Mc Keag (ed.) Basketball. Blackwell Science, pp. 12-24
7. Hughes M.D., R.M.Bartlett (2002) The use of performance indicators in performance analysis. *J. Sports Sci.* 20:739-754
8. Laplaud D., F.Hug, R.Menier (2004) Training-induced changes in aerobic aptitudes of professional basketball players. *Int.J.Sports Med.* 25:103–108
9. Kobayashi Y., T.Takeuchi, T.Hosoi, Y.Arai, J.Loeppki (2006) Comparison of aerobic and anaerobic power and leg strength between young distance runners and basketball/soccer players. *Biol.Sport* .23:211-224
10. Prampero (di) E.P. (2003) Factors limiting maximal performance in humans. *Eur.J.Appl.Physiol.* 90:420–429
11. Wasserman K., J.E.Hansen, D.Y.Sue, R.Casaburi, B.J.Whipp (1999) Principles of Exercise Testing and Interpretation. 3rd Ed. Lippincott Williams & Wilkins, Philadelphia, 550 pp.

Accepted for publication 9.11.2006