



ESTIMATION OF VO₂MAX ACCORDING TO THE 3'BIKE TEST

doi: 10.2478/v10038-012-0044-z

AGRON M. REXHEPI^{1, 2, 3 *}, BEHLUL BRESTOVCI^{1, 4}

¹ Institute of Sports Anthropology, Pristina, Kosovo

² Sport Center for Increasing of Morpho-functional Abilities, Fitness & Nutrition “Corpore Sano”, Pristina, Kosovo

³ University College for Sport Education – Universi, Pristina, Kosovo

⁴ Faculty of Special Education and Rehabilitation, University of Zagreb, Zagreb, Croatia

ABSTRACT

Purpose. The aim of this study was to derive the regression equation for predicting VO₂max of athletes by the relatively new submaximal 3'Bike Test. **Methods.** This test was conducted on 1501 active football male players, aged 16÷35 years. A medical anamnesis was administered and then the athletes' weight was measured. Afterwards, the athletes performed the 3'Bike Test followed by the Astrand Bike Test for comparison reasons. **Results.** Linear regression of the data indicated that the produced regression model, as a whole, is statistically significant. In addition, the system of predictive variables was able to explain for 48% of total variability of the criterion variable VO₂maxAST. According to the regression coefficients that had been derived, a regression equation that could predict VO₂max was created. A significant high correlation ($r = 0.688$) and a non-significant paired t -test ($p = 0.782$) found between the measured VO₂max (Astrand test) and the predicted VO₂max (3'Bike Test) indicates a large similarity between the predicted and measured VO₂max values. **Conclusions.** The 3'Bike Test was found to be a capable measurement tool of aerobic endurance, more reliable and valid than the Astrand submaximal test, as well as being shorter, more easily executed and a better predictor of VO₂max.

Key words: aerobic endurance, prediction, Astrand Bike Test, regression coefficients

Introduction

Cardio-respiratory endurance, also known as aerobic capacity, is the ability of the cardiovascular and respiratory system to supply the body's muscles with needed fuel and oxygen. It is also used as a valuable tool for assessing health. This ability can be estimated by the volume of oxygen that one can consume while exercising at maximum capacity. VO₂max, or maximal oxygen uptake, is the maximum amount of oxygen that one can use in one minute, and has been found as one of the most applicable parameters that can measure the aerobic capacity of an individual. The measurement of VO₂max originates from Hill and Lupton, who introduced this concept and attempted to explain its physiological mechanisms [1]. It was concluded that athletes, who are better trained, reach higher VO₂max values as well as being able to exercise more intensely than non-trained individuals.

A number of maximal or submaximal tests are currently in use to measure an individual's VO₂max score in order to evaluate fitness levels [2–8]. However, maximal exercise tests (executed on an ergocycle or treadmill) measuring VO₂max have criticized as being more expensive, complicated, unsuitable and less “pleasant” than submaximal tests, which are less costly, less time con-

suming and less risky [9, 10]. As a result, researchers have placed more focus on finding less taxing methods of predicting VO₂max as well as reducing the need for directly measuring VO₂max by proposing numerous submaximal and non-exercise predictive methods [11–14]. As there is no precise method of estimating VO₂max by only mathematic reasoning, most research has aimed at providing a simple method of determining VO₂max by using variables that are easily measurable [11]. These tests are based on the principle that such functional tests ought to be widely used, reliable, valid and economically affordable [9]. Researchers have suggested that such functional tests should be multi-staged and feature stepped intensity, meaning that the participant should perform physical exertion at gradually increasing submaximal workloads [15].

The most commonly used approach of submaximal workload testing has been based on predicting VO₂max by the relationship between heart rate and oxygen consumption [11, 16]. According to the American College of Sports Medicine [17], the physiological rationale for this type of predictive method is due to the linear relationship between workload, oxygen consumption and submaximal exercise heart rates [18]. Akalan et al. [11] suggested that the accuracy of this predictive method could be considerably improved if the estimate of maximal heart rate could be replaced by an individualized assessments of heart rate response to incremental exercise. Sanada et al. [12] have also found that the non-

* Corresponding author.

exercise prediction of VO_2max using thigh muscle mass and a cardiac dimension was a valid method of predicting VO_2max in young Japanese adults.

Stahn et al. [13] have also demonstrated the viability of using bioelectrical impedance for the non-exercise prediction of VO_2max . However, according to Moon et al. [14], the use of bioelectrical impedance in a non-exercise-based VO_2max assessment may not be appropriate and valid in healthy men and women. Verma [19] attempted to construct two nomograms for predicting maximal aerobic endurance: the first nomogram was based on cardio-respiratory strain and the second based on body weight and time to complete a 2–3 km run. However, both nomograms were found to have limited validity.

The purpose of this study was to add to the discussion of using submaximal tests for VO_2max assessment by continuing this author's research found in a study entitled "Comparison of the 3'Bike Test with the Astrand Bike Test by VO_2max " [9], which compared two submaximal ergocycle exercises tests, the 3'Bike Test, which had not been previously used as a functional test, and the Astrand Submaximal Bike Test. The aim was to derive the regression equation for predicting the aerobic endurance (VO_2max) of athletes by using the 3'Bike Test.

Materials and methods

This study was part of a project named "Testing and applying a new functional test", being implemented at the Center for Sport Medicine and Recreation and at the "Corpore Sano" Center for Sport, Fitness and Nutrition located in Pristina, Kosovo during 2008–2011. A part of this project, comparing the 3'Bike Test with the Astrand Bike Test by VO_2max , has already been published [9]. This study found that the heart rate during the third minute of the 3'Bike Test (HR_3') is better predictor of VO_2max than the heart rate during the fifth minute of the Astrand Bike Test.

The two functional tests were performed on 1501 athletes aged 16–35 years from Kosovo. All of the athletes had been active football players for more than two years. The equipment used in the study was an ergocycle (fitness bike), a chronometer and a heart rate monitor. All testing procedures were in accordance with the ethical standards of the Ethics Committee of the University Clinical Center in Pristina. The athletes were first informed about the purpose and nature of the study and read and signed an informed consent form. All athletes were then subjected to a medical anamnesis to measure body weight and detect any health conditions that could limit their participation in the submaximal workload of the test. The ergocycle was adjusted to each subject prior to completing the 3'Bike Test and, afterwards, the Astrand Bike Test.

The procedure of the 3'Bike Test, depending on the age of the athletes, was as follows:

- **First minute of the test** – ergocycle set to a workload of 100 Watts for 16–17-year olds and individuals above 30; 125–150 Watts (W) for individuals 18–30 years old; pedal frequency was 60 revolutions per minute (60 rev/min);
- **Second minute of the test** – workload was the same as above whereas pedal frequency was increased to 100 revolutions per minute (100 rev/min);
- **Third minute of the test** – workload was increased by 50 W more than in the first minute of the test; pedal frequency stayed constant at 100 revolutions per minute (100 rev/minute).

The workload was also adjusted during the test depending on the subject's physical capabilities. Individuals whose heart rate did not rise above 100 bpm at the end of first minute had their workload increased by an additional 50 W. The Astrand Bike Test was performed in accordance to the general guidelines of the test.

The following variables were measured:

- AG – Age of the tested individual;
- BW – Body weight (kg);
- HR_0' – Heart rate during rest;
- HR_1' – Heart rate in the 1st minute of the 3'Bike Test;
- HR_2' – Heart rate in the 2nd minute of the 3'Bike Test;
- HR_3' – Heart rate in the 3rd minute of the 3'Bike Test;
- VO_2maxAST – Absolute maximal oxygen uptake (L/min) estimated according to the Astrand Bike Test;
- $\text{VO}_2\text{max3'BT}$ – Absolute maximal oxygen uptake (L/min) predicted according to the 3'Bike Test;
- WL – Workload during the 3rd minute of the 3'Bike Test.

The data was analyzed using basic statistical parameters and by regression analysis, a paired correlation and paired *t*-test. All statistical procedures were conducted with SPSS ver. 15 (IBM, USA). Significance level was set at $p \leq 0.05$.

Results

Table 1 contains the descriptive statistics (minimum, maximum, mean and standard deviation values) calculated for the measured variables. Low values of standard deviation indicate that the measured variables have normal and concentrated dispersion near their mean values.

Based on the mean values of age and the heart rate at the third minute of the 3'Bike Test test, the average percentage of maximal heart rate (MHR) was estimated by the formula:

$$\begin{aligned} \% \text{ MHR } 3' \text{ Bike Test} &= \text{HR}_3' / (220 - \text{Age}) = \\ &= 148 / (220 - 21) = 74\% \end{aligned}$$

Table 1. Descriptive statistics of the measured variables

Variables	Min	Max	M	SD
AG	16.00	35.00	21.27	4.15
BW	47.00	108.20	72.63	8.51
HR0'	46.00	98.00	69.33	9.85
WL	150.00	200.00	153.33	12.47
HR1''	84.00	160.00	117.09	12.91
HR2'	104.00	184.00	135.60	14.48
HR3'	106.00	196.00	147.86	14.73
VO ₂ max3'AST	2.60	5.20	3.54	0.31
VO ₂ max3'BT	2.87	4.37	3.54	0.22

Min – minimal value; Max – maximal value;
M – mean (average) value; SD – standard deviation

Therefore, the percentage of MHR that the athletes reached (74%) at the end of the test confirms the sub-maximal nature of the 3'Bike Test [5–8].

Regression analysis was used to explore the possibility of the dependent variable's predictive influence within a system of independent variables. Due to the fact that the aim of our study was to predict VO₂max according to such variables as: heart rate during the third minute of the 3'Bike Test (HR3'), workload during the third minute of the 3'Bike Test (WL), body weight (BW) and age (AG), all of these variables were treated as predictor (independent) variables, whereas VO₂max calculated from the Astrand Bike Test (VO₂maxAST) was treated as a dependent variable.

The results of regression analysis are presented in Table 2 and indicate that the regression model as a whole is statistically significant: in addition, the system of predictive variables was able to explain for 48% of total variability of the variable VO₂maxAST. The statistic of the Durbin-Watson test, DW = 1.793 (Tab. 2), indicated that no autocorrelation of errors (residuals) was observed

and that, therefore, the predictor errors are uncorrelated [20]. Thus, autocorrelation correction was not needed and regression analysis could be continued (Tab. 3). Based on the analysis, it can be concluded that all four independent variables can significantly predict the aerobic endurance of athletes (VO₂maxAST), as the variable criterion.

Based on the value of the regression constant (\hat{a}) as shown in Table 3, as well as the B-coefficients of each independent variable that had significant correlation with the criterion variable [21], the goal of predicting aerobic endurance according to the significant independent formulas produced the following regression equation:

$$\text{VO}_{2\text{max}3'\text{BT}} = \hat{a} + (\text{Bi} \times \text{AGi}) + (\text{Bi} \times \text{HR0'i}) + (\text{Bi} \times \text{WLi}) + (\text{Bi} \times \text{HR3'i})$$

Table 4 contains the descriptive parameters of VO₂maxAST (estimated aerobic endurance) and VO₂max3'BT (predicted aerobic endurance). VO₂max measured by the Astrand Bike Test (VO₂maxAST) correlated significantly (0.688) with the values of VO₂max predicted by the 3'Bike Test (VO₂max3'BT) (Tab. 5). The differences between these two variables were assessed using a paired *t*-test (Tab. 6), which indicated no significant differences. Therefore, it can be surmised that predicted VO₂max3'BT is highly similar to estimated VO₂maxAST.

Discussion

Aerobic endurance is an important component of athletic performance and is commonly measured by VO₂max. Due to the fact that the direct measurement of VO₂max testing requires expensive equipment and is quite lengthy in nature, many researchers have devel-

Table 2. Regression model summary VO₂maxAST (WL, AG, HR0', HR3')

Model	R	R ²	Adjusted R ²	Std. error of the estimate	DW	<i>p</i> -value
1	0.693	0.480	0.478	0.227	1.793	0.000

Predictors: WL, AG, HR0', HR3' (Constant); Dependent variable: VO₂maxAST; R – correlation; R² – multiple correlation; Adjusted R² – adjusted multiple correlation based on the number of subjects; DW – Durbin-Watson statistic

Table 3. Regression coefficients VO₂maxAST (WL, AG, HR0', HR3')

	B	SE	Beta	<i>t</i>	<i>p</i> -value
(Constant)	5.3876	0.1001		53.821	0.000
AG	-0.0206	0.0015	-0.272	-13.512	0.000
HR0'	-0.0044	0.0007	-0.138	-6.726	0.000
WL	0.0070	0.0005	0.278	14.437	0.000
HR3'	-0.0147	0.0005	-0.692	-31.271	0.000

Dependent variable: VO₂maxAST; B – unstandardized coefficients; SE – standard error; Beta – standardized coefficients; *t* – *t*-value

Table 4. Descriptive parameters for the paired samples

		M	SD	SEM
Pair 1	VO ₂ maxAST	3.5425	0.31442	0.00811
	VO ₂ max3'BT	3.5442	0.21768	0.00562

M – mean (average) values; SD – standard deviation;
SEM – Standard Error Mean

Table 5. Paired sample correlation

		R	p-value
Pair 1	VO ₂ maxAST & VO ₂ max3'BT	0.688	0.000

R – correlation

Table 6. Paired sample test

		t	p-value
Pair 1	VO ₂ maxAST – VO ₂ max3'BT	-0.277	0.782

t – t-value

oped different tests and formulas for predicting VO₂max values.

The main aim of this study was to continue research comparing the Astrand Bike Test with the 3'Bike Test in order to derive a regression equation that could be used to predict the VO₂max values of athletes. The results of the test provided a number of interesting observations. First, the submaximal nature of the 3'Bike Test was confirmed by the percentage of maximal heart rate that the athletes reached (74%) at the end of the test. Descriptive statistics also confirmed the normal dispersion of the mean values of the measured variables.

Regression analysis was used to find if any of the predictive variables can predict the criterion variable, VO₂max, and could therefore be used to indicate the aerobic endurance of athletes. Based on the performed calculations (Tab. 2 and 3), it was found that the system of predictive variables was able to explain for 48% of total variability. This allowed the creation of a regression equation where all four independent variables are able to significantly predict the aerobic endurance of athletes:

$$\text{VO}_{2\text{max}3'\text{BT}} = \dot{a} + (\text{Bi} \times \text{AGi}) + (\text{Bi} \times \text{HR0'i}) + (\text{Bi} \times \text{WLi}) + (\text{Bi} \times \text{HR3'i})$$

To clarify the calculation method for predicting VO₂max, the following example can be provided: an athlete 18 years of age (AG), with a heart rate at rest of 60 bpm (HR0'), performing at a workload of 200 W (WL), is measured with a heart rate in the third minute of the 3'Bike Test at 142 bpm (HR3'). For comparison reasons, the athlete's VO₂max during the Astrand Bike Test was found to be 4.10 L/min. Based on the above equation, predicted VO₂max could be calculated by:

$$\begin{aligned} \text{Predicted VO}_{2\text{max}3'\text{BT}} &= 5.387 + (-0.0206 \times 18) + \\ &+ (-0.0044 \times 60) + (0.007 \times 200) + (-0.0147 \times 142) \\ &= 4.065 \text{ L/min (based on Table 3)} \end{aligned}$$

As such, and based on the data in Tables 4, 5 and 6, the results verify the similarity between VO₂max measured by the Astrand Bike Test and the predicted value of VO₂max by the 3'Bike Test and confirm this test's reliability and validity for measuring VO₂max.

Conclusion

The relatively new 3'Bike Test has been shown to be more reliable and valid than the Astrand submaximal test, as well as being shorter, more easily executed and a better predictor of VO₂max.

Therefore, it may be suggested that researchers who do not possess the required cardiopulmonary equipment to accurately measure VO₂max can utilize this submaximal test in predicting athletes' VO₂max.

References

- Hill A.V., Lupton H., Muscular exercise, lactic acid, and the supply and utilization of oxygen. *QJM*, 1923, 16 (62), 135–171, doi: 10.1093/qjmed/os-16.62.135.
- Assessing Cardiorespiratory Endurance. Available from: <http://academic.wsc.edu/faculty/taeveto1/ped470/lecture/ppt/aerobic.ppt#338,1>, Assessing Cardiorespiratory Endurance [Accessed: 11.02.2012].
- Astorino T.A., Robergs R.A., Ghiasvand F., Marks D., Burns S., Incidence of the oxygen plateau at VO₂max during exercise testing to volitional fatigue. *JEPonline*, 2000, 3 (4), 1–12. Available from: <http://faculty.css.edu/tboone2/asep/Astorino.pdf> [Accessed: 25.10.2012].
- Liverpool John Moores University. Fitness Testing. Available from: URL: <https://www.ljmu.ac.uk/ECL/digitalresources/86831.htm>
- Foss M.L., Keteyian S.J., Fox's Physiological Basis for Exercise and Sport. 6th ed. McGraw-Hill International, New York 1998.
- McArdle W.D., Katch F.I., Katch V.L., Exercise physiology. 4th ed., Lippincott Williams & Wilkins, Baltimore, 1996.
- Powers S.K., Howley E.T., Exercise physiology. International edition. McGraw-Hill International, New York 2001, 279–292.
- Rexhepi A.M., Mjekësia Sportive – Sports Medicine [in Albanian]. Mozaiku, Prishtina 2009.
- Rexhepi A., Brestovci B., Comparison of the 3'Bike Test with the Astrand Bike Test by VO₂max. *Hum Mov*, 2011, 12 (4), 348–352, doi: 10.2478/v10038-011-0040-8. Available from: <http://www.degruyter.com/view/j/humo.2011.12.issue-4/v10038-011-0040-8/v10038-011-0040-8.xml?format=INT> [Accessed: 28.12.2011].
- Stykes K., Roberts A., The Chester step test – a simple yet effective tool for the prediction of aerobic capacity. *Physiother*, 2004, 90 (4), 183–188, doi: 10.1016/j.physio.2004.03.008.
- Akalan C., Robergs R.A., Kravitz L., Prediction of VO₂max from an individualized submaximal cycle ergometer protocol. *JEPonline*, 2008, 11 (2). Available from: <http://fac>

- ulty.css.edu/tboone2/asep/AkalanJEPonlineApril2008.pdf [Accessed: 11.02.2012].
12. Sanada K., Midorikawa T., Yasuda T., Kearns C.F., Abe T., Development of non-exercise prediction models of maximal oxygen uptake in healthy Japanese young men. *Eur J Appl Physiol*, 2007, 99 (2), 143–148, doi: 10.1007/s00421-006-0325-3.
 13. Stahn A., Terblanche E., Grunert S., Strobel G., Estimation of maximal oxygen uptake by bioelectrical impedance analysis. *Eur J Appl Physiol*, 2006, 96 (3), 265–273, doi: 10.1007/s00421-005-0025-4.
 14. Moon J.R., Dalbo V.J., Roberts M.D., Kerksick Ch.M., Stout J.R., Usefulness of bioelectrical impedance in the prediction of VO₂max in healthy men and women. *Sport J*, 2011, 14. Available from: <http://www.thesportjournal.org/article/usefulness-bioelectrical-impedance-prediction-vo2max-healthy-men-and-women> [Accessed: 15.02.2012].
 15. Heyward V.H., Advanced fitness assessment and exercise prescription. 5th ed. Human Kinetics, Champaign 2006, 57–58.
 16. Southard T.L., Pugh J.W., Effect of hydration state on heart rate-based estimates of VO₂max. *JEPonline*, 2004, 7 (1), 19–25. Available from: <http://www.asep.org/files/SouthardV2.pdf> [Accessed: 05.11.2011].
 17. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 6th ed. Williams & Wilkins, Baltimore 2000.
 18. George J.D., Vehrs P.R., Babcock G.J., Etchie M.P., Chilver T.D., Fellingham G.W., A modified submaximal cycle ergometer test designed to predict treadmill VO₂max. *Meas Phys Educ Exerc Sci*, 2000, 4 (4), 229–243. Available from: http://www.informaworld.com/smpp/content-db=all?content=10.1207/S15327841MPPE0404_3 [Accessed: 05.05.2010].
 19. Verma S.S., Prediction of maximal aerobic power in man: a nomographic approach. *Ergonomics*, 1994, 37 (9), 1491–1494, doi:10.1080/00140139408964928.
 20. NLREG. Understanding the results of an analysis. Available from: <http://nlreg.com/results.htm> [Accessed: 12.02.2012].
 21. Princeton University. Data and statistical services – Interpreting regression output, 2007. Available from: http://dss.princeton.edu/online_help/analysis/interpreting_regression.htm [Accessed: 12.02.2012].

Paper received by the Editors: March 22, 2012

Paper accepted for publication: October 9, 2012

Correspondence address

Agron M. Rexhepi
Str. "Sali Butka" Nr.31/D
10000 Prishtina, Kosovo
e-mail: agronmrexhepi@gmail.com