



## ESTIMATION OF VO<sub>2</sub>MAX ACCORDING TO THE 3'BIKE TEST

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### ABSTRACT

**Purpose.** The aim of this study was to derive the regression equation for predicting VO<sub>2</sub>max 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 VO<sub>2</sub>maxAST. According to the regression coefficients that had been derived, a regression equation that could predict VO<sub>2</sub>max was created. A significant high correlation ( $r = 0.688$ ) and a non-significant paired  $t$ -test ( $p = 0.782$ ) found between the measured VO<sub>2</sub>max (Astrand test) and the predicted VO<sub>2</sub>max (3'Bike Test) indicates a large similarity between the predicted and measured VO<sub>2</sub>max 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 VO<sub>2</sub>max.

**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. VO<sub>2</sub>max, 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 VO<sub>2</sub>max 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 VO<sub>2</sub>max 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 VO<sub>2</sub>max score in order to evaluate fitness levels [2–8]. However, maximal exercise tests (executed on an ergocycle or treadmill) measuring VO<sub>2</sub>max 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 VO<sub>2</sub>max as well as reducing the need for directly measuring VO<sub>2</sub>max by proposing numerous submaximal and non-exercise predictive methods [11–14]. As there is no precise method of estimating VO<sub>2</sub>max by only mathematic reasoning, most research has aimed at providing a simple method of determining VO<sub>2</sub>max 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 VO<sub>2</sub>max 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-

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exercise prediction of VO<sub>2</sub>max using thigh muscle mass and a cardiac dimension was a valid method of predicting VO<sub>2</sub>max in young Japanese adults.

Stahn et al. [13] have also demonstrated the viability of using bioelectrical impedance for the non-exercise prediction of VO<sub>2</sub>max. However, according to Moon et al. [14], the use of bioelectrical impedance in a non-exercise-based VO<sub>2</sub>max 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<sub>2</sub>max 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<sub>2</sub>max" [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<sub>2</sub>max) 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<sub>2</sub>max, has already been published [9]. This study found that the heart rate during the third minute of the 3'Bike Test (HR3') is better predictor of VO<sub>2</sub>max 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);
- HR0' – Heart rate during rest;
- HR1' – Heart rate in the 1<sup>st</sup> minute of the 3'Bike Test;
- HR2' – Heart rate in the 2<sup>nd</sup> minute of the 3'Bike Test;
- HR3' – Heart rate in the 3<sup>rd</sup> minute of the 3'Bike Test;
- VO<sub>2</sub>maxAST – Absolute maximal oxygen uptake (L/min) estimated according to the Astrand Bike Test;
- VO<sub>2</sub>max3'BT – Absolute maximal oxygen uptake (L/min) predicted according to the 3'Bike Test;
- WL – Workload during the 3<sup>rd</sup> 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 <sub>2</sub> max3'AST	2.60	5.20	3.54	0.31
VO <sub>2</sub> 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 VO<sub>2</sub>max 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 VO<sub>2</sub>max calculated from the Astrand Bike Test (VO<sub>2</sub>maxAST) 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 VO<sub>2</sub>maxAST. 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 (VO<sub>2</sub>maxAST), 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 VO<sub>2</sub>maxAST (estimated aerobic endurance) and VO<sub>2</sub>max3'BT (predicted aerobic endurance). VO<sub>2</sub>max measured by the Astrand Bike Test (VO<sub>2</sub>maxAST) correlated significantly (0.688) with the values of VO<sub>2</sub>max predicted by the 3'Bike Test (VO<sub>2</sub>max3'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 VO<sub>2</sub>max3'BT is highly similar to estimated VO<sub>2</sub>maxAST.

## Discussion

Aerobic endurance is an important component of athletic performance and is commonly measured by VO<sub>2</sub>max. Due to the fact that the direct measurement of VO<sub>2</sub>max testing requires expensive equipment and is quite lengthy in nature, many researchers have devel-

Table 2. Regression model summary VO<sub>2</sub>maxAST (WL, AG, HR0', HR3')

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

Predictors: WL, AG, HR0', HR3' (Constant); Dependent variable: VO<sub>2</sub>maxAST; R – correlation; R<sup>2</sup> – multiple correlation; Adjusted R<sup>2</sup> – adjusted multiple correlation based on the number of subjects; DW – Durbin-Watson statistic

Table 3. Regression coefficients VO<sub>2</sub>maxAST (WL, AG, HR0', HR3')

	B	SE	Beta	t	p-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: VO<sub>2</sub>maxAST; 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 <sub>2</sub> maxAST	3.5425	0.31442	0.00811
	VO <sub>2</sub> 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 <sub>2</sub> maxAST & VO <sub>2</sub> max3'BT	0.688	0.000

R – correlation

Table 6. Paired sample test

		t	p-value
Pair 1	VO <sub>2</sub> maxAST – VO <sub>2</sub> max3'BT	-0.277	0.782

t – t-value

oped different tests and formulas for predicting VO<sub>2</sub>max 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 VO<sub>2</sub>max 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, VO<sub>2</sub>max, 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:

$$\text{VO}_2\text{max3'BT} = \hat{a} + (\text{Bi} \times \text{AGi}) + (\text{Bi} \times \text{HR0'i}) + (\text{Bi} \times \text{WLi}) + (\text{Bi} \times \text{HR3'i})$$

To clarify the calculation method for predicting VO<sub>2</sub>max, 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 VO<sub>2</sub>max during the Astrand Bike Test was found to be 4.10 L/min. Based on the above equation, predicted VO<sub>2</sub>max could be calculated by:

$$\begin{aligned} \text{Predicted VO}_2\text{max3'BT} &= 5.387 + (-0.0206 \times 18) + \\ &+ (-0.0044 \times 60) + (0.007 \times 200) + (-0.0147 \times 142) \\ &= 4.065 \text{ L/min (based on Table 3)} \end{aligned}$$

As such, and based on the data in Tables 4, 5 and 6, the results verify the similarity between VO<sub>2</sub>max measured by the Astrand Bike Test and the predicted value of VO<sub>2</sub>max by the 3'Bike Test and confirm this test's reliability and validity for measuring VO<sub>2</sub>max.

## 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 VO<sub>2</sub>max.

Therefore, it may be suggested that researchers who do not possess the required cardiopulmonary equipment to accurately measure VO<sub>2</sub>max can utilize this submaximal test in predicting athletes' VO<sub>2</sub>max.

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