HUMAN MOVEMENT
2014, vol. 15 (1), 56–59

PREDICTION OF VO_2max BASED ON AGE, BODY MASS, AND RESTING HEART RATE

doi: 10.2478/humo-2014-0003

AGRON M. REXHEPI [1] *, BEHLUL BRESTOVCI [2]

[1] Sport Center for Increasing of Morpho-Functional Abilities, Fitness & Nutrition 'Corpore Sano", Prishtina, Kosovo
[2] Faculty of Special Education and Rehabilitation, University of Zagreb, Zagreb, Croatia

ABSTRACT

Purpose. The aim of the present study was to develop a non-exercise regression model for predicting maximal oxygen uptake (VO_2max) using age, body mass, and resting heart rate as predictor variables. **Methods.** The VO_2max of 1502 active football players aged 16–35 years was measured using the Astrand Bike Test. The obtained data were analyzed by calculating basic statistical parameters and performing correlation and regression analysis. **Results.** The results of regression analysis indicated that all three independent variables could significantly ($p = 0.000$) predict the VO_2max of the studied athletes. Measured VO_2max showed significant correlation (0.688) with predicted VO_2max. Student's paired samples *t* test indicated no significant differences between measured VO_2max and predicted VO_2max ($p = 0.782$). **Conclusions.** The results suggest that the non-exercise variables of age, body mass, and resting heart rate, may significantly predict the endurance abilities of athletes (VO_2max).

Key words: oxygen uptake, Astrand bike test, regression analysis, endurance ability

Introduction

Aerobic endurance is the ability of the body's cardio-respiratory system to continue prolonged physical activity and withstand fatigue. Aerobic endurance can be estimated by measuring the volume of oxygen (VO_2max) an athlete consumes while exercising at maximum capacity, as this variable depends on the ability of the lungs and heart to take and transport adequate amounts of oxygen to working muscle. This ability also quantifies the ability of muscle to extract and efficiently use oxygen. A number of factors have been found to affect VO_2max, including: age, sex, the type and mode of exercise practiced, body composition, and heredity [1, 2].

Hill et al. were first to introduce the concept of VO_2max as the maximum amount of oxygen consumed in one minute and tried to explain its physiological mechanisms [3]. Over the years, a number of maximal or submaximal tests have been introduced to accurately measure VO_2max [1, 4–10], although many of these exercise tests (executed on a treadmill or cycle ergometer) require expensive equipment, involve complicated testing procedures, and are difficult to administer or perform.

Hence, for these reasons researchers have attempted to find a more accessible way to predict VO_2max by using more easy-to-measure variables [11–14]. Of considerable interest is the development of non-exercise prediction equations, such as in the case of Akalan et al. [11] using multiple regression analysis to predict VO_2max. Sanada et al. [12] found in young Japanese adults that the use of non-exercise variables such as thigh muscle mass and cardiac dimensions to be a valid method to predict VO_2max. Stahn et al. [13] demonstrated the validity of using bioelectrical impedance for the non-exercise prediction of VO_2max, although Moon et al. [14] concluded that the use of bioelectrical impedance may not be appropriate in predicting VO_2max in healthy men and women.

Oxygen consumption has also been estimated using heart rate, where lower resting heart rate values among well-trained athletes is generally treated as an indicator of higher aerobic performance, thereby signifying higher oxygen consumption rates, higher efficiency in sport, and the ability to perform more physical activity before reaching exhaustion. Southard and Pugh [15] stressed the importance of monitoring hydration status whenever heart rate data are used in an assessment of aerobic fitness. Additionally, even though a decline in VO_2max has been found with age in an endurance-trained population, Fitzgerald et al. [16] did not establish a significant relationship between a decline in aerobic performances and a decline of maximal heart rate.

Given the importance of predicting VO_2max and the fact that there still does not exist a 100% accurate method in estimating VO_2max estimation, the purpose of this study was to continue this line of research and seek to develop an accurate multiple regression equation to predict VO_2max in athletes based on easy to measure non-exercise variables.

Material and methods

Research was conducted as part of larger project called "Testing and applying a new functional test" conducted

* Corresponding author.

at the Center for Sport Medicine and Recreation and the Corpore Sano Center for Sport, Fitness, and Nutrition in Prishtina, Kosovo during 2008–2011. The testing procedures were conducted in accordance with the ethical standards outlined by the Ethics Committee of the University Clinical Center in Pristina, Kosovo.

Morpho-functional measurements were performed on 1502 randomly chosen active football players aged 16–35 years from Kosovo. The athletes were informed about the study's purpose and protocol and provided their written consent for participation. All participants were submitted a medical examination and had body mass measured.

VO_2max (aerobic endurance) was measured by the Astrand Submaximal Bike Test [17]. All general guidelines were followed and the cycle ergometer was adjusted to each athlete [17]. Altogether, the following variables of each participant were measured:

- AG – age (years),
- BM – body mass (kg),
- HR0' – resting heart rate (bpm),
- VO_2maxAST – estimated absolute maximal oxygen uptake estimated using the Astrand Bike Test (L/min),
- VO_2maxPred – predicted absolute maximal oxygen uptake (L/min).

The obtained data were reported in terms of basic statistical parameters, with statistical analysis consisting of correlation and regression analysis. Regression analysis is one of the most commonly used statistical tools to explore the relationships between variables and predict the changes of a dependent variable within a system composed of independent variables. In the present study, age (AG), body mass (BM) and resting heart rate (HR0') were treated as the non-exercise independent variables, whereas VO_2max calculated from the Astrand Bike Test (VO_2maxAST) was treated as the dependent variable. Estimated maximal oxygen uptake (VO_2maxAST) and predicted maximal oxygen uptake (VO_2maxPred) were assessed using Students paired samples *t* test. All statistical procedures were conducted using *SPSS ver.* 15 (IBM, USA).

Results

Descriptive parameters (minimum, maximum, mean, and standard deviation) for the measured variables are shown in Table 1. The low values of standard deviation indicate normal and concentrated dispersion of the measured variables' values.

Based on the correlation analysis presented in Table 2, it can be seen that estimated VO_2maxAST showed poor positive correlation with body mass. Additionally, this variable showed poor correlation, albeit negative, with resting heart rate. No significant correlation was shown with age.

The acquired regression model (Tab. 3), as a whole, was statistically significant (p = 0.000), while the system of independent variables was able to explain 26% of total variability of VO_2maxAST. The Durbin-Watson test was applied and indicated that the predictor errors (residuals) were uncorrelated (d = 1.58) [18]. As autocorrelation correction was not needed, regression analysis was continued.

It was found that all three independent non-exercise variables can significantly predict the aerobic endurance of athletes (VO_2maxAST) as a dependent variable (Tab. 4).

Using the value of the regression's constant (ά) as well as the *B* coefficients of each independent variable, signifying the significant correlations with the dependent

Table 1. Descriptive statistics of the measured variables

	n	Min.	Max.	Mean	*SD*
AG	1502	16.00	35.00	21.28	4.15
BM	1502	47.00	108.20	72.62	8.52
HR0'	1502	46.00	98.00	69.32	9.86
VO_2maxAST	1502	2.60	5.20	3.54	0.31
VO_2maxPred	1502	2.52	4.14	3.54	0.16

AG – age (years)
BM – body mass (kg)
HR0' – resting heart rate (bpm)
VO_2maxAST – estimated absolute maximal oxygen uptake estimated using the Astrand Bike Test (L/min)
VO_2maxPred – predicted absolute maximal oxygen uptake (L/min)

Table 2. Correlation analysis of the analyzed variables

	AG	BM	HR0'	VO_2maxAST
AG	1.00			
BW	0.32**	1.00		
HR0'	–0.17**	–0.06*	1.00	
VO_2maxAST	–0.00	0.36**	–0.34**	1.00

* correlation significant at the 0.05 level (two-tailed)
** correlation significant at the 0.01 level (two-tailed)

Table 3. Summary of the acquired regression model

Model	*R*	R^2	Adjusted R^2	Std. error of estimate	*d*	*p*
1	0.51	0.26	0.26	0.27	1.58	0.000

Table 4. Coefficients of the three non-exercise variables

	B	SE	β	*t*	*p*
(Constant)	3.542	0.084		42.26	0.000
AG	–0.014	0.002	–0.19	–7.91	0.000
BM	0.015	0.001	0.40	17.03	0.000
HR0'	–0.011	0.001	–0.35	–15.40	0.000

AG – age (years), BM – body mass (kg),
HR0' – resting heart rate (bpm)

variable [19], the following regression equation was derived:

$VO_2maxPred$ = 3.542 + (–0.014 × AG) + (0.015 × BM) + (–0.011 × HR0')

In order to clarify the calculated method for predicting VO_2max, an example is provided based on one of the study participants. Athlete #650, 20 years of age (AG), weighing 72.5 kg (BM), with a resting heart rate 52/min (HR0'), and who attained a value of 3.7 L/min (VO_2maxAST) during the Astrand Bike Test, was calculated to have a predicted VO_2max value of:

$VO_2maxPred$ = 3.542 + (–0.014 × 20) + (0.015 × 72.5) + (–0.011 × 52) = 3.78 L/min

Table 5 presents the descriptive parameters of VO_2maxAST (estimated aerobic endurance based on maximal oxygen uptake during the Astrand Bike Test) and VO_2maxPred (predicted aerobic endurance based on maximal oxygen uptake), which were found to be very similar.

Maximal oxygen uptake measured by the Astrand Bike Test (VO_2maxAST) was significantly correlated (0.688) with the predicted value of maximal oxygen uptake (VO_2maxPred) (Tab. 6).

The differences between measured maximal oxygen uptake (VO_2maxAST) and predicted maximal oxygen uptake (VO_2maxPred) were assessed using Student's paired samples *t* test (Tab. 7). This comparative test indicated no significant differences between measured and predicted VO_2max (p = 0.782). Based on the statistical analyses, a high degree of similarity exists between measured VO_2maxAST and predicted VO_2maxPred.

Table 5. Paired samples statistics

		Mean	*n*	*SD*	Std. Error of mean
Pair 1	VO_2maxAST	3.542	1502	0.314	0.0081
	VO_2maxPred	3.544	1502	0.218	0.0056

Table 6. Paired sample correlations

	n	Correlation	*p*
Pair 1: VO_2maxAST & VO_2maxPred	1502	0.688	0.000

Table 7. Paired samples *t* test

	t	*p* (two-tailed)
Pair 1: VO_2maxAST & VO_2maxPred	–0.277	0.782

Discussion and Conclusions

Aerobic endurance (VO_2max) is an important component and indicator of athletic performance. Given that direct or indirect VO_2max measurement requires expensive equipment, a great deal of time, and a sufficiently motivated test participant, many researchers have attempted to find a simpler way of predicting VO_2max based on prediction equations derived in different ways [11–14].

The results from this investigation suggest that using the newly formulated regression equation, based on the non-exercise variables of age, body mass, and resting heart rate, may significantly predict an athlete's aerobic endurance (VO_2maxPred). Therefore, it is suggested that in situations where it is not possible to measure VO_2max using exercise variables (maximal or submaximal tests), coaches and trainers may utilize the abovementioned non-exercise variables to predict the approximate VO_2max values of athletes.

References

1. McArdle W.D., Katch F.I., Katch V.L., Exercise physiology. 4th ed. Lippincott Williams & Wilkins, Baltimore 1996.
2. Rexhepi A.M., Mjekësia Sportive – Sports Medicine [in Albanian]. Mozaiku, Prishtina 2009, 117–134.
3. 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.
4. Assessing Cardiorespiratory Endurance. Available from: URL: http://academic.wsc.edu/faculty/taeveto1/ped470/lecture/ppt/aerobic.ppt#338,1,Assessing Cardiorespiratory Endurance (Accessed: 11/02/2012).
5. Astorino T.A., Robergs R.A., Ghiasvand F., Marks D., Burns S., Incidence of the oxygen plateau at VO_2max during exercise testing to volitional fatigue. *JEPonline*, 2000, 3 (4), 1–12.
6. Liverpool John Moores University. Fitness Testing. Available from: URL: https://www.ljmu.ac.uk/ECL/digital-resources/ 86831.htm (Accessed: 02/02/2012).
7. Wasserman K., Principles of exercise testing and interpretation. 2nd ed. Lea & Febiger, Pennsylvania 1994, 53–61.
8. Powers S.K., Howley E.T., Exercise physiology. 4th ed. McGaw-Hill Comp, New York 2001, 279–292.
9. Rexhepi A., Brestovci B., Comparison of the 3'Bike Test with the Astrand Bike Test by VO_2max. *Hum Mov*, 2011, 12 (4), 348–352, doi: 10.2478/v10038-011-0040-8.
10. 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.
11. Akalan C., Robergs R.A., Kravitz L., Prediction of VO_2max from an individualized submaximal cycle ergometer protocol. *JEPonline*, 2008, 11 (2), 1–17.
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 VO_2max in Healthy Men and Women. *Sport J*, 2011, 14 (1).
15. Southard T.L., Pugh J.W., Effect of hydration state on heart rate-based estimates of VO_2max. *JEPonline*, 2004, 7 (1), 19–25.
16. Fitzgerald M.D., Tanaka H., Tran Z.V., Seals D.R., Age-related declines in maximal aerobic capacity in regularly exercising vs. sedentary women: a meta-analysis. *J Appl Physiol*, 1997, 83 (1), 160–165.
17. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. 6th ed. Williams & Wilkins, Baltimore 2000.
18. NLREG. Understanding the results of an analysis. Available from: URL: http://nlreg.com/results.htm (Accessed: 12/02/2012).
19. Princeton University. Data and statistical services – Interpreting regression output, 2007. Available from: URL: http://dss.princeton.edu/online_help/analysis/interpreting_regression.htm (Accessed: 12/02/2012).

Paper received by the Editors: July 3, 2013
Paper accepted for publication: February 6, 2014

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