INVESTIGATING VALIDITY OF SLOPE OF THE LINES BETWEEN SELECTED PHYSIOLOGICAL VARIABLES FOR EVALUATION OFCARDIORESPIRATORY FITNESSINIRANIAN ADOLESCENT BOYS

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Abstract
The aim of this study was, validation of slope of the lines between selected physiological variables (VO2, VCO2, VE, HR) for evaluation of cardio-respiratory fitness in Iranian boys. So we investigate cardio-respiratory fitness without exhaustive protocol and below the lactate threshold, measured. For that purpose, middle and high school students were randomly selected and number of 72 healthy adolescent boys with a mean age 13.95 ± 1.84 (years) and body mass index of 19.91 ± 3.4 (kg/m2), weight 51.64±13.15 (kg) voluntarily participated in an aerobic exhaustive test. Also, VO2max value using gas analyzer method (VE, VO2, VCO2 values) was measured with a breath by breath style. Then its correlation with slope of the line of the physiological parameters (VO2, VCO2, VE, HR) were analyzed. Results showed a high validity evaluating of the performance of children's cardio-respiratory functional reserve exists for OUES (R=0.95, SEE=292.2) and index slope of the lines between selected physiological variables was high too (R=0.74-0.81). Also there are moderate correlation between VO2max and index slope of the lines between selected variables in time %80 of test (R=0.70 – 0.94) and in Lactate threshold (R=0.31–0.86). Overall, results showed that slope of the lines between variables (VO2,VCO2,VE,HR) and OUES can be new indicators to measure of the cardio-respiratory system in Iranian teenage boys respiratory and diseases of screening studies or sports talent, especially when the activity is in lactate threshold (in %56 time test), used ofthis findingaresignificant and outstanding.

Key words: *adolescent boys, Oxygen Uptake Efficiency Slope (OUES), Vo2max*

Intrtoduction

VO2max index is the highest oxygen uptake that slow-twitch myofibrils can use during standard exercise at the sea level, and is known as a valid criterion for assessing the oxygen transfer capacity of the individual (Kraemer and Fleck 2012). Theoretically, VO2max is reached when the pattern of changes in oxygen consumption reaches a plateau by a given work load, so that even by the increase in the amount of work, the intracellular VO2 volume of the myofibrils under the contraction, is not increased. It is also possible that a real plateau of VO2 during maximal exhaustive exercises on treadmill or cycle ergometer in which work efficiency (watt/ belt slope and speed) increases as the physical activity takes longer, does not occur in a group of children or some adults.

Therefore, work physiologists usually use the term VO2peak with caution (Mezzani 2009, Armstrong and Fawkner 2007,Vanhees et al 2005). Standardized laboratory graded exercise testing (GXT), is widely used aiming at clinical assessment of cardiorespiratory functional reserve of healthy individuals or patients or athletic talent discovery. The actual maximum oxygen consumption is measured during aerobic exhaustive testing and it is possible that a range of subjects, such as children and adolescents are not able to perform these tests with high motivation and their highest ability or for some patients with certain restrictions of movement or physio-metabolic complications, GXT testing is not safe and is associated with some risks (Kraemer and Fleck 2012).

It seems that achieving a valid physiological marker being able to accurately measure the cardiorespiratory fitness of an individual (healthy or sick, child or adult) at a safe level without the necessity to perform GXT, and also the cardiorespiratory functional reserve with the same sensitivity, at a submaximal level below the lactate threshold of the individual (VCO2/VO2 <1), is of outstanding importance. In this regard, a new method called oxygen uptake efficiency slope (OUES) has been developed and replaced VO2peak index (Baba et al 1996) for assessing the cardiorespiratory fitness using the slope of the lines between the two variables, oxygen uptake (VO2) and minute ventilation (VE). Theoretically, it can be questioned whether the slope of the lines between physiological variables such as (VO2, VCO2, VE, HR) can be used to assess aerobic fitness of individuals and in addition to the slope between two variables (VO2, VE) that is called OUES, a new slope can be found to measure the cardiorespiratory fitness of subjects.

In fact, OUES is a new index for evaluation of cardiorespiratory fitness invented in 1996 by Baba and quickly opened its place in scientific communities (Baba et al., 1996, 1999, 2000), so that in 2010 a review article was published by Akkerman of the articles written during 14 years on OUES (Akkerman 2010), and in 2014, Bous also began to develop software for OUES during a research, which indicates the importance of the application of this new index (Bous 2014).

OUES is the slope of lines between two variables, VO2 uptake and minute ventilation (VE) which shows the increase in oxygen uptake in response to the increase in minute ventilation. It is calculated using the regression equation VO2 = aLog VE + b (Baba et al 1996,1999,2000), where the slope is the gradient index of oxygen consumption or OUES. To calculate OUES, Dr. Baba first used the logarithm of minute ventilation to VE-VO2 regression graph become linear and then calculated the slope between the lines of VO2, Log VE and introduced it as a new index to measure cardiorespiratory fitness called Oxygen Uptake Efficiency Slope (OUES) (Figure 1). In this method, using a maximal testing, he was able to obtain the correlation between OUES and VO2max at 90 and 75% of the time of maximal testing as R = 0.96 and R = 0.94, respectively showing that we can, for example, if a 20-minute maximal testing is run, instead of performing a 20-minute maximal testing, complete the testing in 15 minutes which is considered sub-maximal in this case, and calculate OUES for 15 minutes, and use it as the new validated index for the assessment of cardiorespiratory fitness (Baba et al 1996,1999). Scientific evidence implies the high validity of the slope of the lines between the two variables (VO2, VE) or the OUES to measure cardiorespiratory function of different individuals during ergometry. In this regard, report by Maaikein 2008, showed the high validity of OUES for the evaluation of cardiorespratory performance of patients (Maaike , 2008). On one hand, in 2010 the study by Akkerman on healthy children between ages (baba 2000, Maaike 2008) years revealed a high correlation between the two physiological indices OUES and VO2max (R = 0.95), but no significant difference was observed in OUES during ergometry at standard exhaustive and submaximal conditions (Akkerman 2010). The experimental study by Gruet (2010) on pulmonary patients also showed a high correlation (R2 = 0.83) between VO2max and OUES in 80% of the entire exhaustive testing.

Report by Giardini et al in 2009 on young patients with open heart surgery, showed that the physiological findings in the second half of the stress exercise testing can be used to assess cardiorespiratory fitness of the patients, so that they reported the correlation between OUES and VO2max of the patients in 50% of the time of ergometry on the treadmill equal to R = 0.71 for the assessment of cardiorespiratory function (Alessandro 2009). These clinical findings and other studies on obese children or healthy individuals (Pichon 2009, Xing-Guo 2012) support the hypothesis that the new OUES index for evaluating the performance of the oxygen transfer system of different people in different age groups can be used so that with the help of the physiological parameter, there is no need for subjects (patients or healthy) to undergo a maximal stress test. This means that submaximal aerobic testing (below the lactate threshold) also can be used to study the cardiorespiratory function with high accuracy and reliability.

Regarding the history of the scientific evidence available, the question arises as to whether in the study of evaluating the efficiency of oxygen transfer system during ergometry using the slope of lines between other physiological variables such as (VO2, VCO2, VE, HR), a similar pattern of the slope of the lines between the two variables VO2 and VE to that found by Japanese researcher Baba can be achieved? The purpose of this study was to introduce a new index for evaluating the cardiorespiratory fitness and comparing it with VO2max obtained by the direct method of gas analyzer, in healthy adolescent boys, in order to assess the validity of the slope of lines between selected physiological variables (VO2, VCO2, VE, HR), in addition to the accuracy of OUES in Iranian children, to evaluate the cardiopulmonary functional reserve, in order to establish a new indicator to assess cardiorespiratory fitness to examine cardiorespiratory fitness in adolescent boys with high validity in a shorter time than that of a maximal testing and in fact, using submaximal testing.

Material and methods

Four primary and high schools were randomly selected and 72 boys 11 to 17-year-oldhealthy, with written permission from their parents, voluntarily participated in this study. First, the anthropometric characteristics of subjects such as body mass index, height, weight, subcutaneous fat at two scapular and triceps areas and the resting heart rate were measured then BMI percentage was obtained using US Center for Disease Control and Prevention (CDC), (Guo 2000, Kuczmarski 2002). Subcutaneous fat content of subjects was calculated using Slaughter equation (1988) (Dezenberg 0999, Guo 2000). To determine the size of the work pressure in terms of heart rate reserve, the Karvonen Formula was used in terms of changes in the heart rate at the resting state and during activity (Myers 2010). Maximal exercise testing was performed using Dr. Baba's RIS protocol. In the seven-step protocol, as the exercise duration increases, speed and slop also increase, duration of the first four stages was considered 15 seconds and of steps 5 to 7 three minutes and the total duration of maximal aerobic test is completed within 10 minutes (baba 1999). For the calculation of VO2max, the Ganshorn gas analyzer made in Germany and the breath-to-breath method was used and a mean measurement was recorded every ten seconds. And to determine VO2max, exercise data of the last 20 seconds was used. Data of the first 40 seconds of measurement of respiratory gas analysis was not used and the test was finished for the subjects when the following conditions were provided (Akkerman 2010 b, Hollenberg 2000): a) RER> 1.1, b) HRexercise> 185, C) inability to continue working, Exercise heart rate per second was measured by Polar telemetry model T34 to the end of the test and was recorded in the device memory. To calculate OUES, Dr Baba's equation VO2 = aLog VE + b was used and OUES was calculated at 40,60,80 and 100% of the test duration as well as when the participants reached the lactate threshold (baba 1996). Also, the slope of lines between the physiological variables (VO2, VCO2, VE, HR), were obtained at 80 and 100% of the test duration and also when the participants reached the lactate threshold to examine its relationship with VO2max. For statistical analysis, SPSS version 16 was used and first using Kolmogorov-Smirnov test, normalization of VO2max data of subjects was evaluated (P = 0.2, Z = 0.09). Then, using a linear regression model, the pattern of relationship between VO2max and slope of lines between physiological variables (VO2, VCO2, VE, HR) and OUES at various times of ergometry was assessed. Descriptive data of variables was expressed in mean values and standard deviation. Significant level for evaluating statistical hypothesis was selected P≤0.05.

Results

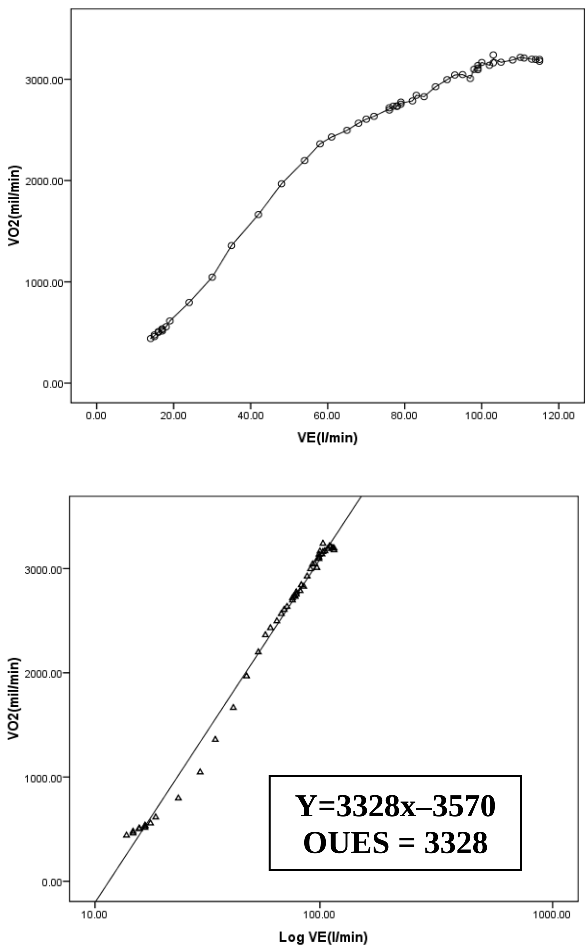

Figure 1.The relationship between VO2 and VE in a 16 year-old boy during a maximal treadmill test. (On the bottom Diagram, the horizontal axis is logarithmic for OUES to be calculated.)

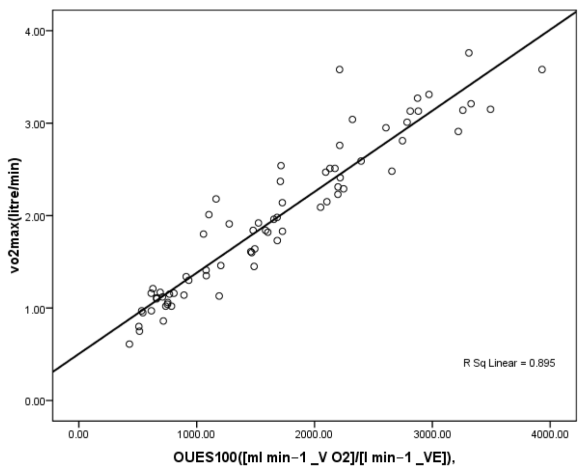

Figure 2.Dependence OUES regression model with different VO2max protocol At total the time of maximal test (minutes) in children

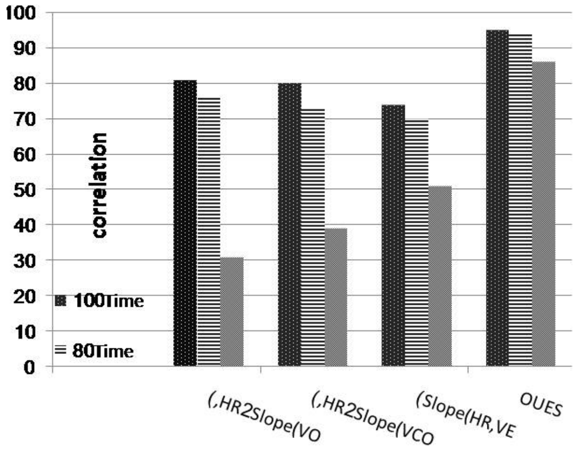

Figure3. The relationship between VO2max with different slope of lines and OUES

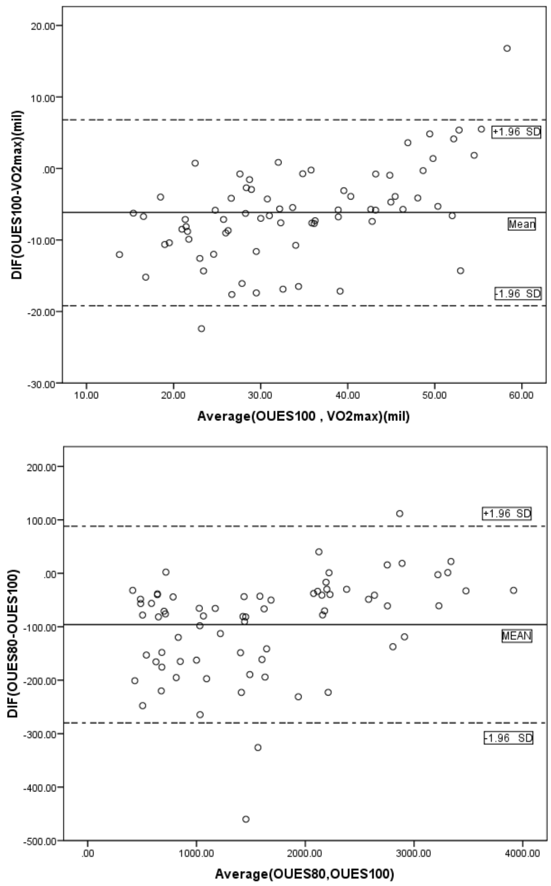

Figure.4 Bland Altman plot for OUES and VO2max during exhaustive test

Table 1 Anthropometric and physiological characteristics during increasing ergometry in adolescent boys

Variables	Mean	SD	SEM
Weight(kg)	51.64	13.15	1.55
Age(year)	13.95	1.80	0.21
RPE(20)	18.60	0.90	0.10
% body fat	20.70	10.30	1.20
%BMI	40.70	2.55	3.00
HRexercise(bp/min)	199.80	4.60	0.55
%HRR	94.70	3.80	0.45
RER: VCO2/VO2	1.26	0.08	0.09
VO2max (mil · min–1 · kg -1)	37.12	10.00	1.18
OUESmax: (VO2mil·min-1) / log10VE(L·min-1)	1663.20	893.70	105.30
OUES: (VO2mil·kg-1·min-1)/ log10 (VEmL·kg-1·min- 1)	30.91	13.46	1.58

Table 2 Correlation between OUES and VO2max during different times of exhaustive testing

Physiological index:Practical capacity during ergometer		R2	R	Sig	SEE	Regression equation
OUES(Time 40 %):945	VO2max (L.min-1)	0.71	0.84	0.000	449.0	OUES40=836.9 VO2max - 697.5
	VO2max (mil·min–1 ·kg -1)	0.61	0.78	0.000	516.1	OUES40=64.48 VO2max – 1448.4
OUES(Time 60 %):1353	VO2max (L.min-1)	0.83	0.91	0.000	394.4	OUES60=1050 VO2max – 707.4
	VO2max (mil·min–1 ·kg -1)	0.69	0.83	0.000	538.3	OUES60=78.9 VO2max – 1575.8
OUES(Time 80 %):1567	VO2max (L.min-1)	0.88	0.94	0.000	319.9	OUES80=1053.4 VO2max – 500.3
	VO2max (mil·min–1 ·kg -1)	0.67	0.82	0.000	533.1	OUES80=76.2 VO2max – 1261.6
OUES(Time 100 %) =1663	VO2max (L.min-1)	0.90	0.95	0.000	292.2	OUES100=1020.2 VO2max – 339.2
	VO2max (mil·min–1 ·kg -1)	0.65	0.81	0.000	529.5	OUES100=72.16 VO2max – 1015.5
OUES in (AT):1289 or in Time 56%	VO2max (L.min-1)	0.74	0.86	0.000	449.1	OUESin AT =909.2 VO2max – 494.7
	VO2max (mil·min–1 ·kg -1)	0.61	0.78	0.000	550.6	OUESin AT =68.27 VO2max – 1244.4

Table 3 The relationship betweenVO2max and the slope of lines between the physiological variables (VO2, VCO2, VE, HR) during different times of exhaustive testing

TIME	Relation between two Variables		R	R2	Sig
In total time	VO2max	Slope(VO2 , HR)	-0.81	0.66	0.000
		Slope(VCO2 , HR)	-0.80	0.64	0.000
		Slope(VE , HR)	-0.74	0.55	0.000
In %80 total time	VO2max	Slope(VO2 , HR)	-0.76	0.58	0.000
		Slope(VCO2 , HR)	-0.73	0.53	0.000
		Slope(VE , HR)	-0.70	0.49	0.000
In Anaerobic threshold or in Time 56%	VO2max	Slope(VO2 , HR)	-0.31	0.09	0.000
		Slope(VCO2 , HR)	-0.39	0.15	0.000
		Slope(VE , HR)	-0.51	0.26	0.000

Table 4 Correlation between VO2max and the slope of lines between physiological variables selected by anthropometric factors

Relation between two Variables		R	R2	SEE	Sig
Height	Slope(VO2 , HR)	0.72	0.51	8.60	0.000
	Slope(VCO2 , HR)	0.70	0.49	8.80	0.000
	Slope(VE , HR)	0.63	0.40	9.60	0.000
	VO2max	0.83	0.68	6.73	0.000
	OUES	0.78	0.61	7.47	0.000
Weight(kg)	Slope(VO2 , HR)	0.62	0.38	10.50	0.000
	Slope(VCO2 , HR)	0.59	0.35	10.70	0.000
	Slope(VE , HR)	0.52	0.27	11.20	0.000
	VO2max	0.65	0.42	10.10	0.000
	OUES	0.63	0.40	10.31	0.000
Age	Slope(VO2 , HR)	0.63	0.40	1.40	0.000
	Slope(VCO2 , HR)	0.61	0.38	1.50	0.000
	Slope(VE , HR)	0.56	0.31	1.50	0.000
	VO2max	0.71	0.51	1.30	0.000
	OUES	0.72	0.52	1.29	0.000

Anthropometric and physiological characteristics of healthy adolescent boys are given in Table 1. Taking the mean values of exercise heart rate (199.8 ±4.6) beats per minute, the percentage of heart rate reserve (94.68±3.81), working pressure (18.6 ± 0.9), respiratory exchange ratio (1.26 ± 0.08) it can be suggested that participants did their best in RIS maximal exercise testing and their mean relative value of practical capacity was (37.12 ± 10 mil • min-1• kg-1). According to Table 2 and Figure 2, there was a high correlation between physiological indices, OUES and VO2max at 80 and 100% of the time of the testing and at the time of reaching lactate threshold, (R = 0.94, R = 0.95, R = 0.86, respectively), that in the present study, the subjects averagely passed lactate threshold in 56% of the time of maximal testing.

Table 3 and Fig 3 show the relationship between VO2max and slope of lines between selected physiological variables (VO, VCO2, VE, HR) during different times of maximal testing in adolescent boys. This means that there is a high correlation between the dependent variable VO2max and the slope of lines between the variables; [R = -0.81 (VO2, HR)]; [, R = -0.80 (VCO2, HR)]; [and, R = -0.74 (VE, HR)] in total maximal testing time. This correlation can also be observed in eighty percent of the maximal testing time (R = -0.70 - -0.76), but the correlation was lower at time of reaching the lactate threshold (R = -0.31 --0.51).

Table 4 shows the correlation between OUES, VO2max and slope of lines between physiological variables (VO2, VCO2, VE, HR) and anthropometric characteristics such as weight, height and age that the correlation with height was the highest among all indicators of age and weight and the highest correlation between VO2max and height of the subjects (R= 0.83) was obtained by the regression equation (VO2max = 0.06 Height -7.08).

Discussion and conclusion

In this study, the pattern of relationship between two measures of cardio-respiratory function, OUES and VO2max and also the slope of lines between variables (VO2, VCO2, VE, HR) during different times of ergometry to evaluate the cardiorespiratory functional reserve of adolescent Iranian boys and also validation of new index OUES and the slope of lines between variables (VO2, VCO2, VE, HR) were measured. Using selected regression models, during safe submaximal ergometry and at the lactate threshold, children's practical capacity can be evaluated with high validity. According to Table 2 and Bland Altman plot(Fig 4), the correlation between OUES index and the marker of oxygen transport system function (VO2max), at the total time of the aerobic protocol was (R = 0.95, SEE = 292.2) which is consistent with the correlation (R = 0.96) obtained by Japanese researcher "Baba" for the two indices VO2max and OUES in healthy men and women from 8 to 52 years old on treadmill by exhaustive RIS method (baba 1996).

Our results are also consistent with the correlation between the two indices mentioned in the report by Marino in 2003 on 60 healthy Bulgarian children aged from 6 to 17 on treadmill (R = 0.91) (Marinov 2003). The evidence indicates that the reliability of OUES index for measuring cardiorespiratory fitness of Iranian children follows the same pattern of non-Iranian indices. On the relationship between VO2max and slope of the lines between physiological variables (VO2, VCO2, VE, HR) at different times of maximal aerobic testing, as described in Table 3, a high correlation can be seen for total maximal testing time between the dependent variable VO2max and the slope of lines between variables; [R = -0.81 (VO2, HR)]; [R = -0.80 (VCO2, HR)]; [and, R = -0.74 (VE, HR)].The high correlation is also visible in eighty percent of the maximal testing time (R = -0.70, -0.76), but at the lactate threshold it is much lower (R = -0.31 -- 0.51). Correlation of slope of lines between the two variables (VE and VCO2) with VO2max was obtained R2 = 0.36 which is consistent with the findings of the Research by Baba in 1996 and Maaike in 2008. They also reported a weak correlation between pulmonary ventilation line VE and VCO2 during graded ergometry. About the relationship between VO2max presented in Table 3, no related scientific background was found. But as can be seen in Table 3, the slope of the line between heart rate and variables (VO2, VCO2, and VE) enjoys a high validity to assess cardiorespiratory fitness in adolescent boys. And the new slope can be used to measure children's cardiorespiratory function. On the other hand, the correlation between VO2max and OUES index was lower (R = 0.81) after normalization based on body weight, which was consistent with the findings of the study by Xing-Gua sun et al in 2012. They reported a lower correlation between the two physiological indices after normalization with weight of 17-78-year old healthy subjects from R = 0.95 to R = 0.76, it may how the prominent influence of body weight on OUES component (Xing-Guo 2012). In the present study, of which the results are presented in Table 4, there was an obvious relationship between variables such as height, weight, age and absolute value of OUES (without normalization) that the size of the correlation were R = 0.78, R = 0.63 and R = 0.72, respectively. The relationship between absolute VO2max (without normalization with weight) and variables (height, weight, age), were R = 0.83, R = 0.65 and R = 0.71, respectively, which probably shows the effects of anthropometric factors on both VO2max and OUES indices. In the meantime, the variable height showed a closer relationship with the two indices that is consistent with the report by Marino in 2003 (R = 0.88), (Marinov 2003). Also according to Table 4, the correlation (R = 0.52-0.72) between the variables height, weight and age and the slope of the lines between variables (VO2, HR), (VCO2, HR), (VE, HR) can be observed, so that the maximum correlation is observed between the height and the slope of lines between (VO2, HR) (R = 0.72). In this context, there is not suitable scientific evidence for comparison between the findings. It seems that the slope of the line between two variables, heart rate and oxygen consumption, given its high correlation with anthropometric variables and VO2max, has a better performance over other variables to assess cardiorespiratory fitness. In examining the question whether it is possible to use indices OUES and slope of lines between variables (VO2, HR), (VCO2, HR) and (VE, HR) under submaximal protocol (VCO2/VO2 <1) equivalent to the ability to measure the exhaustive maximal aerobic testing for determining the actual amount of cardiorespiratory fitness in children?

According to Table 3, it must be said "there is a high correlation between VO2max and the slope of lines between the variables; [R = -0.81 (VO2, HR)]; [R = 0.80 (VCO2, HR)]; [and; R = -0.74 (VE, HR)] at total maximal testing time. A similar pattern of correlation was also obtained in eighty percent of the maximal testing time (R = -0.70 - 0.76). Also according to Table 2, based on the high correlation between the two indices OUES and VO2max in time ratios of ergometry on a treadmill including "80, 100"% of total time of testing that were R = 0.94 and R = 0.95 respectively between variables, they concluded that there is a significant correlation between these two cardiac indices. on the other hand, considering the significant correlation (R = 0.86, SEE = 449.1) between OUES and VO2max when the lactate threshold is reached in Iranian boys which is equivalent to 56% of the total exhaustive testing time, it can be suggested the to assess cardiorespiratory fitness in boys, there is no need for their physiological responses to be evaluated as high as 100% of the maximal testing time. Given the physiological information of the gas analyzer available in 56% of the maximal ergometry time equivalent to submaximal ergometery, efficiency of the oxygen transfer system of the children can be evaluated from epidemiological, clinical, health promotion and screening aspects with a high degree of validity. In this regard, Akkerman in its 2010 report on healthy children aged from 7 to 17 years old pointed out that OUES values during submaximal work were not significantly different from those at maximum level, they have a high correlation (R = 0.88) with VO2max in other words, OUES index is even more powerful than VO2max in estimating cardio-respiratory fitness (Akkerman 2010b). In the clinical study by Bongers et al in 2011 on children with a mean age of 13.2 years with heart disease during ergometry when reaching the lactate threshold, correlation between VO2peak and OUES was equal to R = 0.55. However, the low correlation, compared to that of the present study probably is because of the fact that heart patients may yield low cardio-respiratory reserve (Bongers 2011). In the research by Silvia Pogliaghi et al (2007) on healthy elderly, the correlation between OUES and VO2max in 60% of heart rate reserve was obtained R2 = 0.70 (Pogliaghi 2007). Study by Alessandro (2009) on heart patients, pointed out that the physiological data can be used for clinical assessment of cardio-respiratory system of subjects in 50% of the time of exercise stress testing. They reported the correlation in the second 50% of the total testing time as R = 0.71 . Sophie (2012) in a similar study on heart patients, obtained the correlation between the two indices OUES and VO2max when reaching lactate threshold as (correlation) R = 0.87.

Generally, according to the findings of this study and the available background it can be noted that the application of OUES index and the slope of lines between variables (VO2, HR), (VCO2, HR) and (VE, HR) as new indicators of evaluating cardio-respiratory fitness in children should be considered. On the other hand, the indices are valid and appropriate criteria for assessing the performance of cardiac reserve in Iranian adolescent boys at times shorter than the total time of maximal aerobic testing, so that our findings at the lactate threshold level with a high correlation (R = 0.86) showed OUES index can be used to determine cardiovascular fitness in children. This means that the application of submaximal ergometry testing is equivalent to 56% of the maximal exhaustive testing time for healthy children not having the ability or motivation to perform standard maximal tests at health or specialized cardiovascular centers. Moreover, the application of these indicators in the assessment of cardio-respiratory function of heart or respiratory patients during exercise testing can be considerable. Limitations of this study include the child's motivation to perform exhaustive protocols, lack of measurement of arterial blood oxygen saturation during ergometry, non-application of Tanner direct method for determining biological maturity (however, an independent paper shows lack of influence of maturity on slope of lines between selected physiological variables), sample size and voluntary method of subject selection.

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ISTRAŽIVANJE VALJANOSTI NAGIBA LINIJE IZMEĐU ODABRANIH FIZIOLOŠKIH VARIJABLI ZA OCJENU KARDIORESPIRATORNOG FITNESA KOD IRANSKIH ADOLESCENATA

Sažetak

Cilj ovog istraživanja bio je vrednovanje nagiba linije između odabranih fizioloških varijabli (VO2, VCO2, VE, h) za procjenu kardio-respiratornog fitness u iranskih dječaka. Tako smo istražiti kardio-respiratorni fitness bez iscrpljujućeg protokola i mjereno ispod laktatnog praga. U tu svrhu, učenici osnovne i srednje škole su nasumce odabrani i 72 zdravih adolescenata dječaka sa prosječnom dobi 13.95 ± 1.84 (godina) i indeksom tjelesne mase 19.91 ± 3,4 (kg/m2), težine 51.64 ± 13,15 (kg) dobrovoljno je sudjelovao u aerobnim iscrpnom ispitivanju. Također, VO2max vrijednost metodom analizatora plinova (VE, VO2, VCO2 vrijednosti) mjerena je na način "breath by breath". Zatim je analizirana korelacija nagiba linije s fiziološkim parametrima (VO2, VCO2, VE, HR). Rezultati su pokazali visoku valjanost ocjenjivanja izvedbe kardio-respiratornog testa i postojanje dječje funkcionalne rezerve OUES (r = 0,95, SEE = 292,2) a indeks nagiba linije između odabranih fizioloških varijabli bila je jako visoka (R = 0,74 do 0,81). Također postoje umjerene korelacije između VO2max i indeksa nagiba linije između odabranih varijabli u vremenu% 80 ispitivanja (R = 0,70 - 0,94), te na laktatnom pragu (R = 0,31-0,86). Sveukupno, rezultati su pokazali postojanje očekivanih vrijednosti i da nagib linije između varijabli (VO2, VCO2, VE, HR) i OUES može biti novi indikator mjere kardio-respiratornog sustava u iranskih tinejdžera i kod analize izbora studija ili sportske pripreme, posebno jer su nalazi aktivnosti na laktatnom pragu (u% 56 vremena testa) značajne i izvanredne.

Ključne riječi*: adolescenti, primitak kisika, efikasnost nagiba (OUES), Vo2max*

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