



Validation of the unique OUES scale (ΔV_{O_2} , VE slope) in functional reserve assessment of cardiorespiratory system for Iranian children

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Abstract

The aim of this study was, validation of OUES against the traditional index of VO_{2max} for Iranian children is inevitable. The increasing application of Graded exercise test (GXT) to determine the clinical symptoms or achieve a safe level of physical and metabolic responses in a wide range of healthy or patients individuals is common. On the other hand, the findings a reliable physiologic indicator that can evaluate the practical storage level of cardiorespiratory without the need to perform tests above the lactate threshold is important. 72 healthy young males with a mean age 13.95 ± 1.84 (years) and body mass index of 19.91 ± 3.4 (kg /m²) participated in an aerobic exhaustive test and VO_{2max} value using gas analyzer method (VE, VO_2 , VCO_2 values) were measured with a breath by breath style. Then pattern of the predictor line between OUES and VO_{2max} indexes was determined. Results showed that, OUES index has a high validity for evaluating the performance of children's cardiorespiratory functional reserve ($R^2 = 0.90$, $SEE=292.2$). A Significant relationship between the QUES & VO_{2max} indices at different times of GXT during maximal aerobic test was obtained ($R = 0.81- 0.95$, $p < .001$). In studies of screening and clinical diagnosis of cardiovascular system performance, the supplying of OUES index during the ergometry tests in the lower than lactate threshold conditions is usable for Iranian healthy boys. Application of this sensitive index to compare the performance of the cardiorespiratory system of healthy children with counterpart patients can be also significant in submaximal exercise rather than the exhaustive training protocols.

Keywords: Iranian boys, oxygen uptake efficiency slope (OUES), VO_{2max} .

INTRODUCTION

Graded Exercise Testing (GXT) has been widely used for the purpose of screening studies and clinical evaluation of cardiovascular reserve responses in normal subjects and in patients during performing a standard physical activity. Maximal oxygen uptake (VO_{2max}) is the highest volume of oxygen consumed by the slow-tension myofibrils during an exhaustive exercise protocol (GXT) referred to as a gold standard of measuring the oxygen transport system (15).

According to scientific evidence, from theoretical view, VO_{2max} the point at which oxygen consumption under workload is given to plateau or intracellular physio-metabolic level leading to a two-side balance of "the amount of oxygen required for oxidative metabolism from one hand and the amount of the consumed vo_2 in chemical mitochondrial reactions" is established.

So that even with an increase in the intensity of work, ΔTHR and ΔVO_2 do not changed. Of course, it is possible, in children and some adults, physiological phenomenon real plateau ΔVO_2 during tests of (GXT) on a bicycle ergometer or a treadmill does not occur in that proportion with greater time of implementation, work efficiency (watt / slope and speed) increases. Hence, researchers use VO_{2peak} instead of VO_{2max} (4,19,25).

Maximal oxygen uptake during a maximal aerobic tests is measurable dependent on the maximum effort of individuals and it is possible that subjects especially at children ages, with a high motivation and maximum presentation of their ability don't participate in such tests or some patients with cardiovascular or respiratory failure, high blood pressure, kidney disease and diabetes, which are faced with certain restrictions, selection and implementation of the GXT test is not safe and may be associated with risks.

It appears that access to reliable physiological indicator that without the need to run the GXT, can measure safe levels of cardiorespiratory fitness (ie, healthy or disease conditions, younger adult) and also with the sensitivity to measure cardiorespiratory functional reserve performance at the submaximal level below the lactate threshold ($V_{CO2}/V_{O2} < 1$), will be of great importance. In this regard, the new method of OUES has replaced traditional indicator (V_{O2max}) (5).

What is Oxygen Uptake Efficiency Slope (OUES)?

OUES is a new index to assess cardiorespiratory fitness invented in 1996 by Japanese Dr Baba and opened its place in the scientific community (5,6,7) so that in 2010, a review article by Akkerman was published about the paper in 14 years(1). In 2014, as well as, Roselien Buys developed norm for OUES showing the importance of this style indicator (9).

In terms of terminology, OUES is the slope of the line formed between oxygen cost component V_{O2} and VE magnitudes on the increasing ergometry situation, and it represents an incremental change in response to increased minute ventilation during an incremental exercise by the certain workload and is calculated by a linear relationship: $V_{O2} = a \text{ Log } VE + b$. In this formula, the slope of the line is called Oxygen Uptake Efficiency Slope (OUES). First, Dr BABA took logarithm to calculate OUES index from the minute ventilation, to make diagram changes of VE , V_{O2} linear pattern. Then, slope of the line formed between $\text{Log } VE$ and V_{O2} could be calculated and introduced as a new index to measure cardiorespiratory reserve performance or Oxygen Uptake Efficiency Slope (Figure 1).

In this method, using a submaximal protocol, the correlation of OUES at ratios of 90% and 75% of the run time of an exhaustive test were obtained at $R = 0.96$ and $R = 0.94$.

This means that if a person performs a maximum 20-minute test run, we can replace the sub-maximum test run within 15 minute on standard GXT 20- minute .And thus the level of cardiorespiratory fitness with an emphasis on OUES for a shorter periods will be assessed .In this study, a high correlation between the two indices of OUES and V_{O2max} was achieved in 75% of the maximal exercise test ($R = 0.94$) (5,6) .

Scientific evidence indicates that OUES is of great validity to assess cardiovascular system

performance. In this regard, study of Gademan in (2008) on heart patients showed the high validity of OUES index on cardiorespiratory fitness (17). Also, Akerman's (2010) study on healthy children aged 7-17 showed a high correlation of $R = 0.95$ in both indices OUES and V_{O2max} . Also, no significant difference in the pattern of OUES was not obtained when performing exhaustive and submaximum standard physical labor pattern (2).

On the other hand, Gruet (2010) reported a correlation $R^2 = 0.83$ between the two indexes diagnosis to assess cardiorespiratory fitness: V_{O2max} and OUES in 80% standard GXT exhaustive test time for lung disease (12). Alessandro's clinical report in 2009 on young patients who had undergone the open heart surgery, revealed from physiological findings of subjects in the second half of the time GXT meaning in of 50%test ergometer protocol execution time, the evaluation of cardiac-respiratory function can be done .In this study, the correlation between the V_{O2max} index and OUES scale was reported to be $R = 0.71$, (3).

In this background, further scientific evidences on the obese children (11,18) or healthy controls group(21,26) also shows that from OUES scale can be utilized to assess cardiorespiratory fitness levels at different ages ranges. The advantage of this index is intended to track changes in system circulation parameters in response to controlled physical activity makes us free from full implementation of GXT exhaustive test.

Hence with a submaximal test in a shorter period, individual's clinical responses can be measured with the same validity and sensitivity at maximal aerobics test, at the safety level from the work intensity on patient, a middle-aged or children without risk of pathological symptoms or estimated from the health status of the individual and the elite athletes.

In the present study, we tried to study the validity of the new index OUES for evaluating the performance of the cardiorespiratory system of Iranian children against the traditional index of V_{O2max} by a standard gas analyzers method. The minimum time required to perform a submaximal test which will help to study, in the shortest time possible with the high sensitivity of exhaustive protocol, the cardiorespiratory efficiency in adolescent boys with a high reliability.

MATERIAL & METHODS

Four schools in education center from Hamedan city randomly selected and 72 healthy adolescent boys 11-17 years old, with written permission from their parents, voluntary participate in this study. First parents of participants became familiar with the objectives of the project and after completing the questionnaire of Health PAR-Q Society for Sports Medicine America (ACSM), anthropometric parameters and BMI percentile chart (13,16) using diagram of Center for Disease control and prevention (CDC) and the body fat percentage for two subcutaneous fat layers of brachial triceps and subscapular was determined according to a Slater's equation(10,23). The ergometry work intensity for each individual was estimated based on heart rate reserve magnitude (%HRR) using a Karvonen's formula (20) during the incremental test of GXT.

GXT protocol was performed on treadmill according to the BABA 1996 design. This standard progressive exercise program for 10 minutes, which is designed for children, workload alterations was increased according to the time of exercise, the increased speed and slope as well, the individual continued running style beyond his lactate threshold on electrical treadmill equipped with automatic gas analyzers of respiratory gases assessment (model Ganshorn of Germany) to the time in terms of signs of:

- A) Respiratory efficiency more than unit (ie, $RER > 1.1$) corresponding to changes of $\Delta VC02 / \Delta V02$ on screen of device.
- B) A heart rate activity over $HR_{exercise} > 185bpm$
- C) declaring individual's intentional exhaustion (2,14).

In this protocol, Time for the first four steps of ergometry, 15 seconds and the next steps 5-7 three min is mentioned and finally the whole time of GXT protocol finished within 10minutes(6). To measure $VO2max$ in direct method of gas analyzers, an average of ten seconds $VCO2, VO2$ measurement was recorded in the computer memory and physiology information in the final 20seconds was used to determine the aerobic capacity. Exercise heart rate per second was evaluated by telemetry Polar T34 model made in Finland until the end of GXT protocol and was kept in device memory. OUES value was calculated from the linear relationship $VO2 = a \log VE + b$ at 40, 60, 80 and

100% of the entire ergometry protocol and also at the time subject got the lactate threshold (5).

All cardiorespiratory variables were tested after 2 to 3 hours after lunch and abstinence from consumption of Sweets and coffee, with a light shirt and sport shoes at 4 pm to 6 pm on the treadmill. GXT test was performed under in physiology laboratory at the University of Bu-Ali Sina under temperature 19 to 21 degrees Celsius and relative humidity of 39 to 43 percentages with 1860 meters above sea level.

Statistical Analyses

The normal distribution of the absolute and relative values of the subject's $VO2max$ was found with a Kolmogorov-Smirnov test ($P = 0.2, Z = 0.09$). With the linear regression model, predicting the index OUES through direct measurement of individual practical capacity at different times of exhaustive protocol was evaluated. Information of descriptive statistics of the variables was determined on the mean and standard deviation (Mean \pm SD). Significance level of $P \leq 0.05$ was selected for the analysis of statistical hypotheses.

RESULTS

Anthropometric and physiological characteristics of healthy adolescent boys are given in Table 1. With respect to the exercise heart rate (199.8 ± 4.6) beats per minute, percentage of heart rate reserve (94.68 ± 3.81) and respiratory exchange ratio ($VCO2 / VO2: 1.26 \pm 0.08$), it can be said that the subjects have done maximal physical effort in the implementation of the Protocol GXT in BABA method and the mean value of relative peak oxygen consumption (37.12 ± 10 ml.min⁻¹.kg⁻¹) could indicate the actual maximum cardiovascular performance. As a result, this criterion can be used to predict children's OUES in the different proportions of ergometry run time. According to the results of the study, participants had reached lactate threshold in averagely 56% of the total time of the maximal test.

In Table 2 and Figure 2, the high correlation can be seen between physiological indices of OUES and $VO2max$ in 40, 60, 80 and 100% of maximal aerobic test execution time and the time to reach the lactate threshold ($R2 = 0.71, R2 = 0.83, R2 = 0.88, R2 = 0.90, R2 = 0.74$).

DISCUSSION

In this applied research, the linear correlation pattern between physiological criteria of OUES and

VO₂max in estimating cardiorespiratory reserve function in Iranian adolescent boys was reviewed with emphasis on validating new index OUES so that using it during submaximal ergometry and below the lactate threshold (Time 56%) OUES, children's capacity can be assessed with a high degree of accuracy.

Based on the findings in Table 2, the correlation index of OUES and an indicator of oxygen transfer system efficiency (VO₂max) was R² = 0.90, SEE=292.2 in total run time of exhaustive protocol, which is consistent with the result of a report of Japanese researcher presenting the correlation (R = 0.96) for both indices OUES and VO₂max in Japanese healthy men and women aged 8-52 on treadmill in BABA method (5).

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

Variables	Mean	SD	SEM
Weight(kg)	51.64	13.15	1.55
Age(year)	13.95	1.8	0.21
RPE(20)	18.6	0.9	0.1
% body fat	20.7	10.3	1.2
%BMI	40.7	2.55	3
HRexercise (bp/min)	199.8	4.6	0.55
%HRR: (work intensity index)	94.7	3.8	0.45
RER: VCO ₂ / VO ₂	1.26	0.08	.009
VO ₂ max (ml · min ⁻¹ · kg ⁻¹)	37.12	10	1.18
OUES max : (VO ₂ ml· min ⁻¹) / log ₁₀ VE (L·min ⁻¹)	1663.2	893.7	105.3

Table 2. Pattern of correlation between OUES and VO₂max during different times exercise test.

Physiological index: Practical capacity during ergometer		R ²	R	Sig	SEE	Regression equation
OUES(Time 40 %) : 945	VO ₂ max (L.min-1)	0.71	0.84	0.000	449	OUES 40 % =836.9 VO ₂ max - 697.5
	VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	0.61	0.78	0.000	516.1	OUES40 % = 64.48 VO ₂ max – 1448.4
OUES(Time 60 %) : 1353	VO ₂ max (L.min-1)	0.83	0.91	0.000	394.4	OUES 60 % =1050 VO ₂ max – 707.4
	VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	0.69	0.83	0.000	538.3	OUES 60 % =78.9 VO ₂ max – 1575.8
OUES(Time 80 %) : 1567	VO ₂ max (L.min-1)	0.88	0.94	0.000	319.9	OUES 80 % = 1053.4 VO ₂ max – 500.3
	VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	0.67	0.82	0.000	533.1	OUES 80 % =76.2 VO ₂ max – 1261.6
OUES(Time 100 %) : 1663	VO ₂ max (L.min-1)	0.9	0.95	0.000	292.2	OUES 100% =1020.2 VO ₂ max – 339.2
	VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	0.65	0.81	0.000	529.5	OUES 100% =72.16 VO ₂ max – 1015.5
OUES in (AT) : 1289 or in Time 56%	VO ₂ max (L.min-1)	0.74	0.86	0.000	449.1	OUES in AT = 909.2 VO ₂ max – 494.7
	VO ₂ max (ml·min ⁻¹ ·kg ⁻¹)	0.61	0.78	0.000	550.6	OUES in AT = 68.27 VO ₂ max – 1244.4

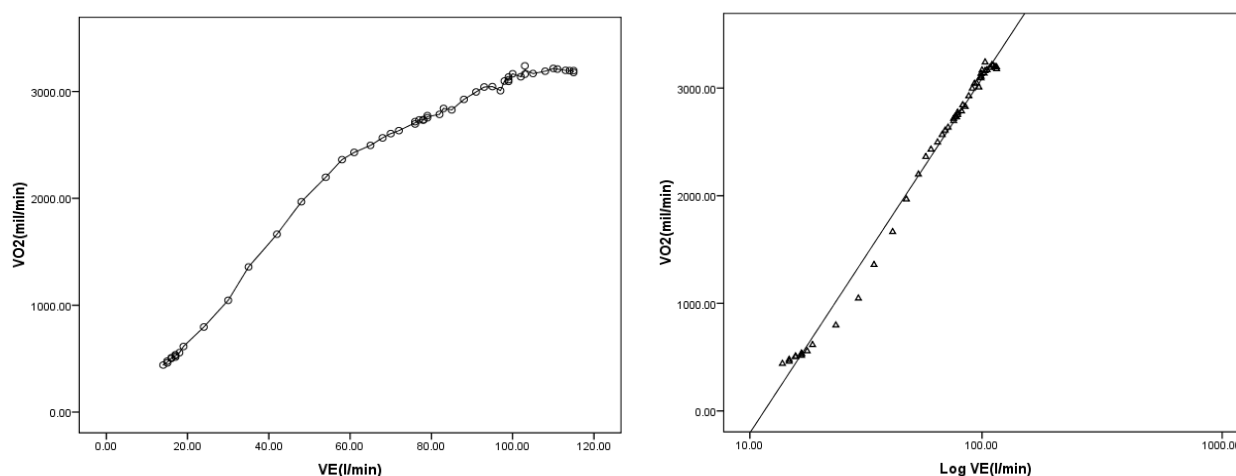


Figure 1. The relationship between VO₂ and VE in a 16-year-old boy during a maximal treadmill test (On the left Diagram, the horizontal axis is logarithmic for OUES to be calculated).

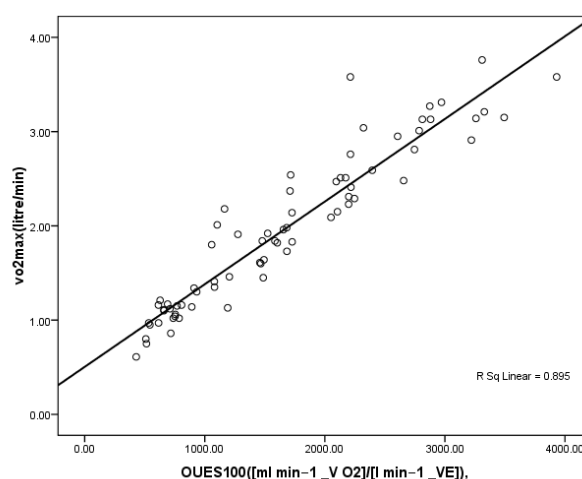


Figure 2. Dependence OUES regression model with VO2max index at the different time of maximal protocol (minutes) in Iranian children.

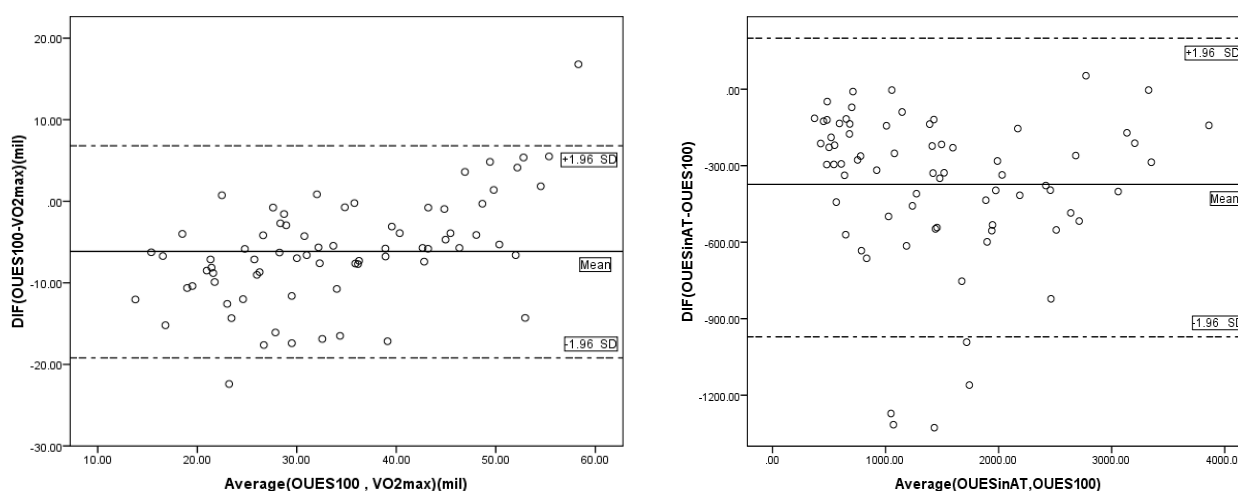


Figure 3. Diagram Bland-Altman agreement for OUES and VO2max in adolescent boys.

Results of this study are consistent with the report of correlation between the two indices ($R = 0.95$) in the study of Akkerman (2010) during ergometer test among 46 Dutch healthy children 7-17 years old (2). These scientific reports detected that the validity of OUES scale in determining the level of cardiorespiratory efficiency among Iranian children follows the same model as their foreign counterparts.

In our study, after normalizing the VO2max index based on weight variable, level of correlation with OUES index reached lower at $R = 0.81$, which corresponds to the study of Xing-Guo Sun et al (2012). They reported the drop of correlation of these two physiological variables after being normalized with the weight the healthy subjects 17-78 years from $R=0.95$ to $R=0.76$ that shows, the role of the components of body weight on OUES (26).

In clarifying the question of whether we can use OUES index under submaximal ergometry ($VCO_2 / VO_2 < 1$) in parallel with the maximal aerobic exhaustive test capability to determine the actual size of cardiorespiratory fitness?

According to an agreement plot Bland-Altman (figure 3), between the indexes of VO2max and OUES scale in Iranian boys at the moment of reaching the threshold Lactat (OUESin(AT)), it was equivalent to 56% (range: %46 - %57) of the total time of exhaustive testing standard ($R^2=0.61$, $SEE=449.1$). (table 2)

As well, the high correlation in the proportion time on a treadmill ergometer, including 40, 60, 80 and 100% of the total execution time, $R^2=0.71$, $R^2=0.83$, $R^2=0.88$ and $R^2=0.90$ were obtained respectively.

It is suggested that for cardiovascular system performance measurement of boys, they do not need to exercise as high as 100% of the time of exhaustive protocol, OUES (Time100%). Because with having gas analyzer physiological information on the maximal ergometry at 50% maximum, or the level of submaximal ergometer, with good accuracy and safety, cardiorespiratory fitness of the subjects can be studied to assess the epidemiological or clinical aims.

In this regard, Akkerman's study on healthy children 7-17 years, showed that the submaximal values of OUES and maximum values of OUES are not significantly difference but are highly correlated ($R = 0.88$) with VO_{2max} so that OUES scale is stronger than VO_{2max} index even in estimating cardiorespiratory performance(2).

In research of Silvia Pogliaghi et al (2007) on the healthy individuals, there were obtained VO_{2max} and OUES correlation $R^2=0.70$ in 60% of heart rate reserve (22). Alessandro Giardini et al, studied the validity of the OUES scale from clinical aspects on heart disease patients and showed that the physiological data during exercise stress to measure the effectiveness of cardiorespiratory system of these patients, is applicable at 50% of the total execution time of ergometry ($R = 0.71$), (3).

In a similar study in 2012 by Sophie on the heart patients, a correlation between index OUES and VO_{2max} at lactate threshold was reported to be $R = 0.87$, (24). The findings of Bongers et al. 2011 on the cardiac disease children with a mean age of 13.2 years, during ergometry at a moment of reaching the lactate threshold, showed that a VO_{2peak} and OUES correlation at $R = 0.55$. But the low correlation, compared to the previous study and the present study, is probably due to heart disease in children with low cardiorespiratory reserve performance (8).

In conclusion; based on the findings of our study and the scientific backgrounds available, it can be noted that the application of OUES scale as a new index of cardiorespiratory efficiency in healthy children is significant. On the other hand, this indicator is a valid and appropriate criterion for assessing the moderate performance of cardiorespiratory reserve in Iranian adolescent boys at the times lower than the maximum test so that our findings in 50% of the exercise stress test, with a high correlation showed that the new index can be used to determine the subjects' cardiovascular fitness.

This means the application of submaximal ergometer test (50% of the total time of maximum exhaustive test) for healthy and probable patient children in the age range of youth and adolescence without the ability or incentive to perform maximal standard tests which are usually performed in specialized health & Cardiology centers would be beneficial.

Limitations of this study include the motivational level of children to run exhaustive protocols, lack of measurement of arterial blood oxygen saturation during ergometry test and of the application of the method to determine the maturation level of subjects and the possibly the sample size studied and selection style of voluntarily subjects.

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