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Determining the Validity of Selected Allometric Equations to Estimate VO2max in Iranian Youth Aged 18-25 Years

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ABSTRACT

Objectives: The measurement of VO2max is important for assessing the cardiovascular capacity of the body. Cardiovascular fitness is one of the factors affecting physical fitness and plays a key role in endurance exercise performance. However, measuring VO2max requires maximal exercise tests that may not be feasible to everyone. Hence, it is remarkable to find a method that can contribute to estimate VO2max without the need for physical activity and with the help of allometric equations. The purpose of this study was to determine the validity and reliability of the selected allometric equations for the measurement of VO2max (maximal oxygen uptake) in Iranian youth aged 18-25 years to calculate the maximal aerobic power of individuals.

Methodology: The present study was conducted on 44 young male volunteers aged 18-25 years in Hamadan (Iran). After measuring the anthropometric variables, direct measurement of respiratory gases was used to measure VO2max and then to compare with the value obtained from selected allometric equations.

Results: The current study aimed to determine the validity of three allometric equations for predicting VO2max specific to Iranian youth using the direct measurement of respiratory gases. The findings indicated potent correlation between the three VO2max prediction equations of Neville's, VO2max = 0.244 × m0.699, Weibel's, VO2max = 93 × m0.849 and Beunen's, VO2max = 1.94 × m0.75 (R = 0.66-0.68, sig = 0.000) and direct measurement of aerobic power.

Conclusion: Since easy calculation of VO2max is of great importance and weight can be measured easily in human research, especially in sports and healthcare centers, some of the allometric predictive models of VO2max using weight measurement as an alternative to physical activity may seem to be employed by studies related to epidemiology or cardiovascular health promotion, as well as by sports coaches at talent identification centers for young people. Also, due to the high correlation (R = 0.66-0.68)

obtained from the direct measurement of respiratory gases and selected allometric equations, these can be used to estimate the aerobic power of young people with high validity and no longer need to boring maximal exercise tests.

Keywords: Youth, Selected Allometric Equations, vo2max

INTRODUCTION

Researchers in sport sciences, within the field of health concerns, attach great importance to the assessment and measurement of physiological parameters using anthropometric factors. They have studied the relationship between anthropometric variables and VO2max and proposed several equations for calculating aerobic power using weight and other anthropometric variables based on allometric equations [1]. The cardiovascular fitness is one of the factors that affects physical fitness and plays a key role in endurance exercise performance. In these activities, the aerobic pathway provides a larger share of the energy needed. The maximal oxygen uptake is an appropriate measure for cardiovascular capacity measurement [2]. There are two direct (laboratory) and indirect (field) methods for evaluating the maximal oxygen uptake. The use of direct measurement devices for maximal oxygen uptake due to high cost, impossibility of displacing some devices, and unfamiliarity of all coaches with the operation of devices, the use of this method is not feasible everywhere and for everyone. Therefore, the researchers decided to develop a variety of methods to progress rapidly in assessing the performance of different human body systems, to ease the assessment, and to implement them in sports fields and community level instead of laboratories and facilities of sport sciences. One of these methods is the use of mathematical equations and their application in the function of various organs of the human body. Accordingly, the researchers have examined the physiological indices from the perspective of allometric equations.

The allometric methods are used mainly in the field of biological sciences, so that the allometric relationships have been presented on small and large animals and human specimens. The researchers consider it important to apply the allometric equations as a mathematical model for the relative control of anatomical or physiological confounding factors, such as the role of body composition and weight in the estimation pattern of the maximal oxygen uptake of animals, especially the mammalian species [3-5].

In this regard, the history of scientific studies has shown the validity of mathematical models of allometric equations. For example, the alometric relationship between the two anthropometric and physiological variables in the Huxley model is defined as : $Y= a M b$ [6]. In this linear equation, Y indicates the physiologic or metabolic characteristics that are related to the weight factor (M) and the relative coefficient (a); b is the allometric coefficient that shows the intensity and direction of the relationship between Y and M. In other words, b=1 establishes the direct fit between the size of the physiological component and the weight changes; b=0 means no dependence between M and Y; $1> b> 0$ shows that the metabolic variable does not change as the body size or weight increases; $b>1$ displays that the metabolic profile increases faster than weight changes; and –b expresses that aerobic capacity or metabolic equivalent decreases proportional to weight gain. The allometric coefficient b has been reported in several studies to estimate VO2max in children and adolescents ranging from 0.37 to 1.02. In fact, it can be said that the allometry is a suitable method for expressing the relationship between physiological, anatomical or thermal variables and a unit of body size (usually weight) through mathematical relations [7].

Many studies outside of Iran have tried to estimate the physiological parameters using one of the variables of weight or height through the explanation of the allometric equation. We found only to studies in Iran by Saberi and Erfani to determine the validity

of the allometric equation for measuring VO2max in girls aged 16 years in Mashhad and Hamedan. However, no research in this field has been conducted so far on Iranian boys [8,9].

Outside of Iran, research has tried to estimate VO2max as a very useful variable in cardiorespiratory fitness using the allometric equation and only by measuring the body weight. In one of these studies, Nantumbo et al. in 2012 examined the aerobic power of youth using the allometric equation and one-mile walk test in a rural area in Mozambique and suggested different allometric coefficients for estimating aerobic fitness in girls and boys [10]. In another study, Chamari et al. in 2005 measured the aerobic power of adult, young and professional football players using the allometric scale. The results of this study showed that maximal and submaximal oxygen uptake rates increased proportionally to the weight with the power of 0.72 and 0.60, respectively [11].

In another study, Weibel et al. examined 34 species of mammals weighing 7 grams to 500 kilograms, and concluded that the allometric coefficient is 0.872 for estimating VO2max for all species [12]. Eisenman et al. in 2001 studied the relationship between VO2max and the body weight of young men and women running long distances using the allometric scale. In this study, the allometric coefficients in boys and girls were 0.81 and 0.61, respectively [13].

In another study, Beunen et al. in 2002 studied longitudinally 73 non-athletic boys aged 8 to 16 years. Their results demonstrated that interpersonal allometric coefficient was 0.75 in most age groups of the subjects. These results were obtained by direct measurement of respiratory gases [14].

In a study by Estone et al. in 1997 on 253 males and females with normal weight and 35 obese youths, the allometric coefficient was 0.78. In addition, in a study of Loftin et al. to measure the VO2max of 46 obese girls and 47 normal-weight girls, the allometric coefficient was 0.46 for obese girls and 0.92 for normal-weight girls [3,4].

In the present study, we decided to evaluate validity of the allometric equations of Weibel's (12), $VO2max = 93 \times m0.849$, Brunen's [14], $VO2max = 1.94 \times m0.75$ and Neville's 15, $VO2max = 0.244 \times m0.699$ in estimating the VO2max of Iranian young boys aged 18-25 years using the direct measurement of respiratory gases to provide the best equation for estimating the VO2max in this age group.

METHODOLOGY

The present correlational study was conducted on 44 young male volunteers aged 18-25 years in Hamadan. After assuring the subjects' health, the anthropometric and physiological parameters needed for this study were measured. Then, VO2, VCO2 and VO2max variables were evaluated directly and with the gas analyzer using the incremental exercise test according to modified Bruce protocol on treadmill [2]. Then, the internal validity of the aerobic capacity was investigated using the standard method (gas analyzer) with the estimation method of the selected allometric equations. In other words, the amounts of the convergence between the actual and estimated values of the aerobic capacity of individuals were evaluated using the triple allometric equations. The intensity of the ergometric activity of each person was estimated based on the percent heart rate reserve (%HRR) when performing the incremental exercise test according to the modified Bruce protocol on the treadmill using the Karvonen formula [16]. The Borg's perceived exertion scale was also recorded [17]. The James WPT method was used to calculate LBM, and the lean body mass of the subjects was calculated as well [18,19]. Body surface area (BSA) was determined using Haycock formula and respective measured height and weight [20].

The incremental exercise test according to the modified Bruce protocol on the treadmill was carried out to assess VO2max [2]. This 24-minute progressive standard exercise program developed for young people was intensified in proportion to increased training time, speed and slope. Running on electric treadmill equipped with automatic gas respiratory gas analyzer (Ganshorn Co., Germany) continued to go beyond the threshold of lactate as all out of breath and ended up by observing the following signs: a)

respiratory quotient (RQ) higher than unit (RER> 1.12) as measured by the monitoring of the variation in ΔVCO2/ΔVO2 on the device monitor, b) heart rate> 190 bpm while exercising and c) actual volitional exhaustion [1,2].

To calculate the VO2max by gas analyzer method, the mean VO2 and VCO2 was measured every 10 seconds and recorded in the computer. The physiological data in the last 20 seconds of the ergometric activity were used to determine the practical capacity. The heart rate while exercising was measured every second by the Polar Telemetry (T_{34} model, Germany) until the end of the modified Bruce protocol and data were saved in the device memory. The aerobic capacity was estimated using allometric equations and the general allometric equation of $Y = aM^b$ [1]. All of cardiorespiratory variables were taken after four hours of light lunch meal while avoiding sweets and coffee when exercising on treadmill with sports shirts and shoes in the afternoon. For statistical analysis, the normal distribution of data was determined by Shapiro-Wilk test (P = 0.22, Z = 0.85). The relationship between allometric equations and direct measurements of youth aerobic power was evaluated using correlation coefficient. Descriptive statistics of variables were determined based on mean and standard deviation (Mean ± SD). The significance level was considered as $P \leq 0.05$.

RESULTS

Descriptive anthropometric information for subjects such as mean, standard deviation and variance is presented in Table 1.

Table 1: Descriptive information of anthropometric characteristics for study subjects.

Variables	Min	Max	Mean	SEM	SD
Height(cm)	165	192	176	0.95	6.3
Weight(kg)	54	109	71.6	1.63	10.84
Age(year)	18	25	20.5	0.26	1.73
RPE(20)	17	20	18.66	0.12	0.84
%body fat	12.6	55.6	28.7	1.5	10
LBM(kg)	46	79	57.2	0.91	6
BSA(m2)	1.58	2.43	1.87	0.02	0.16
%BMI	13	93	44	3.58	23.75
BMI	16.8	31.8	23.1	0.52	3.44

Table 2 shows physiological information of the subjects. As seen in this table, considering the mean exercise HR (196 ± 8.1 bpm), % HRR (97.52 ± 0.06), Borg's perceived exertion scale (18.66 ± 0.84), respiratory gas exchange ratio (VCO2/VO2: 1.26 ± 0.07), it can be said that the subjects performed their maximum physical effort in implementing the modified Bruce protocol. Moreover, the mean relative value of VO2max obtained for 44 people (40.89±5 $ml.min^{-1}.kg^{-1}$) can show their maximum cardiorespiratory performance. Accordingly, this index can be used to measure young aerobic capacity for comparing the selected allometric equations.

Table 2: Descriptive information of physiological characteristics for study subjects.

Variables	Min	Max	Mean	SEM	SD
HRrest (bp/min)	56	92	69.9	1.33	8.82
HRexercise (bp/min)	181	211	196	1.23	8.2
%HRR	0.87	1.11	0.97	0.009	0.06

RER: VCO2/VO2	1.12	1.42	1.27	0.01	0.07
VO2max (l · min–1)	1.99	3.88	2.89	0.064	0.43
VO2max (mil · min–1 · kg -1)	33.8	53.8	41	0.76	5.03
Time exercise	16.1	22	18.13	0.23	1.49
HRmax (220-age)	195	202	199	0.26	1.73
VO2max (Weibel)	45.8	50.92	48.9	0.16	1.08
VO2max (Beunen)	38.65	65.44	47.65	0.81	5.37
VO2max (Nevill)	51.64	65.16	59.63	0.44	2.9

Table 3 and Figure 1, presents the results of the mean comparison of aerobic capacity according to direct measurement of respiratory gases and indirect measurement of aerobic power by each of the selected allometric equations using Pearson's correlation coefficient. As can be seen, the direct measurement method has a significant relationship with all three Beunen's, Weibel's and Neville's formulas and the highest correlation is related to Neville formula (R = 0.68, sig = 0.000).

Table 3: Correlation of VO2max obtained from the direct measurement of respiratory gases and the selected allometric equations.

Allometric equations	**R**	**R2**	**sig**
vo2max=1.94×m.75 (Beunen)	0.66	0.44	0
vo2max=93×m.849 (Weibel)	0.67	0.45	0
vo2max=0.244×m.669 (Nevill)	0.68	0.46	0

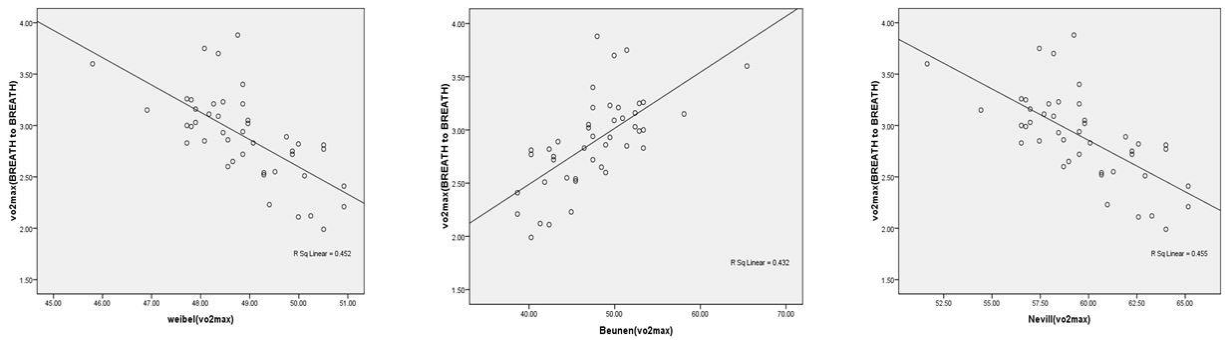

Figure 1: The dispersion graph of relationship between vo_2max (breath to breath) and vo2max of Selected Allometric Equations in Youth.

DISCUSSION

Scientific evidence of accurate measurement of VO2max during maximal aerobic exercise tests suggests that this index depends on the individual's maximum effort, and it is possible that the subject will not be able to participate with high motivation and ability to expose himself in such exercise protocols. As well, the selection and implementation of maximal exercise tests is not safe for patients with cardiovascular and respiratory failure, high blood pressure, renal failure and diabetes, who have certain limitations, and might be associated with risks [21]. Epidemiologically, it seems to be essential to provide the safety of exercise protocols or clinical trials for achieving an effective physiological indicator without the need for maximal exercise tests and with the help of anthropometric confounding factors displaying the valid assessments of the cardiorespiratory system performance.

The current study aimed to determine the validity of three allometric equations for predicting VO2max specific to Iranian youth using the direct measurement of respiratory gases. The findings indicated potent correlation between the three VO2max prediction equations of Neville's, VO2max = $0.244 \times m^{0.699}$, Weibel's, VO2max = $93 \times m^{0.849}$ and Beunen's, VO2max = $1.94 \times m^{0.75}$ (R = 0.66-0.68, sig = 0.000) and direct measurement of aerobic power. Moreover, these equations can be used with high validity to assess the youth's aerobic power without the need for maximal exercise tests; and this method can be valuable in many cases, maximal and submaximal oxygen uptake rates.

In one hand, the cardiovascular fitness is one of the components related to individual health and shows the ability of the cardiorespiratory system to provide oxygen for active muscles during maximal and submaximal exercises [22]; as well the direct measurement of respiratory gas and in vitro determination of VO2max using progressive exercise tests have high validity [23]. On the other hand, the use of these methods in epidemiological studies and extensive human populations is limited due to the high cost and administrative-technical problems. Hence, several scientific endeavors have been made to design field models for predicting VO2max [24]. Furthermore, the VO2max change profile has shown that it is dependent on body size and anatomical growth of the organism, such as an increase in the size of the heart, lungs, blood volume, and muscle mass [5]. Therefore, people who are facing with cardiovascular constraints in supplying their oxygen needs, such as sick youth, cannot continue aerobic exercise until volitional exhaustion. The VO2max is usually expressed in terms of body weight (vo2: ml per kilogram per minute), so the VO2max is affected by weight [3]. Other factors are involved in scaling the power (b) of allometric equations. Some of these factors, such as individual changes, differences in daily activity and physical activity volume, and an increase in the concentration of aerobic muscle enzymes or the quality of contraction of myocardial muscle, are factors that are independent of size. They believe that body weight alone is not significant in VO2max regulation, but in addition to weight, body fat percentage is also considered as the confounding factors [5].

VO_{2max} allometric estimated in 46 obese girls and 47 normal-weight immature girls showed similar absolute size of practical capacity (liters per minute), but this cardiovascular index was 50% lower in weight in obese girls than in normal peers. In a study of Rowland et al., the mean b value for the allometric estimation of the VO2max, corresponding to lean body mass that disappear to somewhat effect of the body composition, was significantly higher in boys (1.04) than in girls (0.81). These findings suggest that other factors other than body weight can be effective in increasing the VO2max in young people [3,5].

In the study of Sabiri et al., the correlation between VO2max obtained from the Beunen's allometric equations and indirect method of modified Bruce protocol on treadmill was R = 0.72, similar to our result with the correlation level of R = 0.66-0.68 using direct measurement of respiratory gases and the selected allometric equations [8]. In the study of Chamari et al. in 2005 aiming to measure the aerobic power of adult, young and professional football players using the allometric scale, the results reveals that maximal and submaximal oxygen uptake rates increased proportionally to the weight with the power of 0.72 and 0.60, respectively [11], which

is similar to that of the selected allometric equations (0.66-0.84) in our study. The highest correlation (R = 0.68) was obtained in the Neville's equation, with the allometric power of b = 0.75. These findings show that we can use the allometric equations designed to measure the aerobic power of Iranian youth.

CONCLUSION

Concerning the application of the results of this study, it can be noted that since easy calculation of VO2max is of great importance and weight can be measured easily in human research, especially in sports and healthcare centers, some of the allometric predictive models of VO2max using weight measurement as an alternative to physical activity may seem to be employed by studies related to epidemiology or cardiovascular health promotion, as well as by sports coaches at talent identification centers for young people. Also, due to the high correlation (R = 0.66-0.68) obtained from the direct measurement of respiratory gases and selected allometric equations, these can be used to estimate the aerobic power of young people with high validity and no longer need to boring maximal exercise tests.

REFERENCES

1. Rowland, TW, Children's exercise physiology, **2005**. 2nd Edition**.**
2. Eston, R., et al. The Kinanthropometry and Exercise Physiology Laboratory Manual, **2009**. Third edition published by Routledge.
3. Loftin, M., et al. Scalin VO2max peak in obese and non-obese girl. *Obes Rev*, **2001**. 9: 290-296.
4. George, JD., et al. Non-exercise VO2max estimation for physically active college students. *Med Sci Sports Exerc*, **1997**. 29: 415-423.
5. Rowland, T., et al. Body Size and the Growth of Maximal Aerobic Power in Children: A Longitudinal Analysis. *Pediatric Exercise Science*, **1997**. 9: 262-274.
6. Huxley, JS., Problems of Relative Growth, **1993**. Baltimore MD: The Johns Hopkins Univ, Press.
7. Alan, MB., et al. George. Nevill's explanation of Kleiber's 0.75 mass exponent: an artifact of collinearity problems in least squares models?. *J Appl Physiol*, **1997.** 82: 693-697.
8. Sabiri noghani, Z., Survey validity of Allometric equation specific evaluation vo2max of girl of students 12-16 old years in Mashhad city. *Olampic*, **2010**. 18(1)(In Persian).
9. Erfani, A., Compare estimation of VO2peak with Allometric equations in girl student adolescent of Overweight and not Overweight. Thesis of Msc. Bu-Ali Sina University of Hamedan. **2012**. (In Persian)
10. Nhantumbo, N., Allometric study of functional fitness of children and adolescents in a rural area of Mozambique. *Rev Bras Cine antropo mesempenho Hum*, **2012**. 14(5): 507-516.
11. Chamari, K., Appropriate interpretation of aerobic capacity: allometric scaling in adult and young soccer players. *Br J Sports Med*, **2005**. 39(2): 97–101.
12. Weibel, ER., et al. Allometric scaling of maximal metabolic rate in mammals: muscle aerobic capacity as determinant factor". *Respir Physiol Neurobiol*, **2004**. 140(2): 115
13. Eisenman, JC., et al. Scaling peak vo2 by body mass in young male and female distance runners. *J Apple physiol*, **2001**. 90(6): 2172- 2180.
14. Beunen, G., et al. Intraindividual allometric development of aerobic power in 8-16 year old boy". *Med sci sport Exerc*, **2002**. 34: 503-510.

15. Nevill, AM., et al. Scaling physiological measurements for individuals of different body size. *Eur J Appl Physiol*, **1992**. 65: 110-117.
16. Myers, J., et al. ACSM's Resources for Clinical Exercise Physiology Musculoskeletal, Neuromuscular, Neoplastic, Immunologic, and Hematologic Conditions.2010, 2nd edition.
17. Borg, GA., category scale with ratio properties for intermodal and interindividual comparisons. In: Geissler HG, Petzold P, eds. Psychophysical judgement and the process of perception. Berlin: VEB DeutscherVerlag der Wissenschaften, **1982**. 25–34.
18. James, WPT., Research on obesity. Group Report .London: Her Majesty's Stationery Office, **1976**.
19. Hallynck, TH., Should clearance be normalised to body surface or to lean body mass? *Br J ClinPharmacol*, **1981**. 11: 523-526.
20. Haycock, G., et al. Geometric method for measuring body surface area: A height weight formula validated in infants, children and adults. *The Journal of Pediatrics*, **1978.** 93(1): 62-66.
21. Thompson, W., et al. ACSM's Guidelines for Exercise Testing and Prescription. 2010. 8th New York. Lippincott Williams & Wilkins.
22. Sanada, K., et al. Development of nonexercise prediction models of maximal oxygen uptake in healthy Japanese young men". *Eur J Appl Physiol*, **2007.** 99: 143-148.
23. George, JD., et al. Non-exercise VO2max estimation for physically active college students. *Med Sci Sports Exerc*, **1997**. 29: 415-423.
24. Cao, ZB., et al. Prediction of VO2max with daily step counts for Japanese adult women. *Eur J Appl Physiol*, **2009**. 105: 289-296.