DESIGNING ALLOMETRIC EQUATIONS SPECIAL FOR IRANIAN MEN AGED 18 TO 25 YEARS TO ESTIMATE MAXIMUM AEROBIC POWER

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Abstract

Background and objectives: Finding an appropriate method for measuring maximum aerobic power (or maximal oxygen consumption, VO_2max) and replacing this method with conventional maximal exercise tests to obtain VO_2max can be useful in many cases. The measurement of cardiorespiratory functional capacity has always been of great importance to both normal people and elite athletes. The cardiorespiratory system is one of the determinants of health and should be kept wholesome by people to maintain their well-being. Accordingly, the present study was conducted to design the allometric equations special for Iranian men to assist in the accurate assessment of VO_2max in individuals without the need for maximal exercise tests. Materials and methods: This experimental and correlational research was conducted on 44 Iranian male volunteers aged 18-25 years with mean age of 20.5 ± 1.73 years, mean weight of 71.6 ± 10.84 kg and mean height of 176 ± 6.3 cm. After calculating the anthropometric characteristics of the subjects, their VO_2max index was measured using the direct measurement of respiratory gases for designing the allometric equations with the aid of regression analysis. Results: The findings showed that there is a relatively good relationship between the designed allometric equations ($VO_2max=1.04\times weight^{0.03}$, $VO_2max=-0.55\times$(Body Surface Area) $BSA^{1.84}$, $VO_2max=0.83\times$(Lean Body Mass) $LBM^{0.05}$) and the direct measurement of respiratory gases (SEE=0.31-0.32 R=0.67-0.70), and we can use these equations with great confidence to measure VO_2max. Conclusion: Considering that the VO_2max measurement is of particular importance to individuals, we have been able to assess the VO_2max using allometric equations designed for Iranian men with a fairly good validity and that since the VO_2max measurement of individuals without the need to perform the maximal exercise tests can be useful in many situations, so it is recommended to use our allometric equations designed for Iranian men to measure their VO_2max.

Key words: *allometric equations, VO_2max, exercise test.*

Introduction

The physical health of people depends on various factors, one of the most important of which is cardiorespiratory fitness and the body's ability to deliver oxygen to active tissues and muscles. Therefore, measuring cardiorespiratory fitness of individuals is of particular importance, among which measuring maximal oxygen consumption (VO_2max) can be a reliable and effective criterion for assessing the individual aerobic power. Previous studies have shown that the VO_2max measurement requires extreme and maximal exercise tests that may not be feasible for anyone and may increase the risk of injury in individuals. It therefore seems to be useful to find a solution capable of measuring the VO_2max without executing the exercise tests (1-3). In this regard, many efforts have been made by sports science researchers to measure the VO_2max with simplicity and precision. Among the various innovative methods, the method that seems to be most useful is the use of allometric equations to measure the VO_2max. Using these equations, the researcher can evaluate the VO_2max without any physical activity in accordance with anthropometric variables and only with a mathematical calculation. Therefore, the researchers decided to make it possible to quickly and easily evaluate the performance of various human body systems in a variety of ways and thus assess the performance of athletes in gyms and sport fields rather than laboratory conditions.

One of these ways is the use of mathematical equations in the function of various organs of the human body. Accordingly, the researchers study the relationship between energy cost indices and anthropometric factors in the form of allometric equations (4-6). In other words, it can be said that the allometry is a suitable method for expressing the relationship between physiologic, anatomic or anthropometric variables with a unit of body size (commonly weight) in terms of mathematical appropriateness (7). The allometric analyses or grades are described with this mathematical equation: $Y=aM^b$) in which Y is related to the weight and b is the allometric coefficient or power and a is the constant coefficient. In this equation, the exponent b is the main factor, because it expresses the intensity and direction of the relationship between the physiological or metabolic variable (such as VO2max) and body weight, indicating b=1 means that an increase in Y has a direct relation to body weight, b=0 means that the body weight has no effect on Y (independent of weight), b> 1 means increased physiological variable relative to weight changes, and b<0 means decreasing Y with body weight gain (8-10). Therefore, from the point of view of sport research, health tests and safety issues, it is important to design exercise protocols or clinical trials and to achieve an effective physiological index, through lacking the need for maximal exercise tests and

considering the anthropometric confounding factors, which can exhibit valid and fairly accurate evaluation of cardiorespiratory system performance. Accordingly, the purpose of this study was to evaluate the validity of allometric equations designed to estimate the VO_2max of 18-28 year old Iranian men using the direct measurement method of respiratory gases during an exhaustive ramp incremental task, so that the allometric equations can be designed for Iranian men and an optimal allometric formula will be achieved to evaluate the VO_2max without performing any maximal exercise tests.

Materials and methods

This experimental and correlational research was conducted on 44 Iranian male volunteers aged 18-25 years in Hamadan city. After confirming their physical and mental health, the anthropometric physiologic variables required for this study were measured. Then, VO_2 and VCO_2 and VO_2max variables were evaluated directly by the gas analyzer using modified Bruce maximum treadmill graded exercise test (GXT) (11). The internal validity of the aerobic capacity measured by benchmark method (gas analyzer) was evaluated using the designed allometric equations, meaning the study of the size of congruence and convergence between the true value of the aerobic capacity and its estimation by the designed allometric equations. The intensity of ergometery was estimated based on the heart rate reserve (HRR, %) when modified Bruce test using the Karvonen formula (12). Borg's perceived level of exertion was also recorded (13). The James WPT method was used to calculate the Lean Body Mass (LBM) of the subjects (14, 15).

The body surface area (BSA) was obtained using the Haycock formula and measuring height and weight and placement in this formula (16). The VO_2max was measured with the modified Bruce protocol (11). This standard progressive exercise program has been designed for 21 minutes for young people in accordance with increased training time, speed and incline. To go beyond the lactate threshold, the person continued to run on the electric treadmill equipped with an automatic breath-by-breath respiratory gas analyzer (Ginshuren Co., Germany) until the test completion that has the following indications: (a) respiratory exchange ratio (RER)>1.12 according to checking $\Delta VCO_2/\Delta VO_2$ changes on the device monitor, (b) HR exercise>190bpm, (c) volitional exhaustion (1, 2). The mean values of VO_2 and VCO_2 measurements were recorded in the computer memory every 10 seconds to calculate VO_2max by the direct gas analyzer method, and physiological data in the end 20 seconds of the ergometery were used to determine the functional capacity. The exercise heart rate was measured every second by the Polar T-34 Telemetery strap (made in Germany) until the completion of the modified Bruce protocol and saved in the device memory.

The aerobic capacity was estimated using allometric equations using the general allometric equation of $Y=aM^b$ (1). All cardiorespiratory variables were performed on the Treadmill in the afternoon after 4 hours of light lunch and avoiding the use of sweets and coffee with the light sport shoes and shirt.

For statistical analysis, the normal distribution of data was determined by Shapiro-Wilk test (P=0.22, Z=0.85). The correlation coefficient and regression analysis were used to evaluate the relationship between VO_2max obtained from designed allometric equations and VO_2max obtained from direct measurement of VO_2max. Descriptive statistics of variables were reported based on mean and standard deviation (Mean ± SD). The significance level was considered as $P\leq0.05$.

Results

The anthropometric and physiologic characteristics of the subjects are presented in Tables 1 and 2. Considering the mean HR exercise of 196 ± 8.2 bpm, the mean HRR percentage of 97.52 ± 0.06, the mean Borg's perceived exertion level of 18.66 ± 0.84, the mean RER (VCO_2/VO_2) of 1.27±0.07, it can be said that the subjects performed their maximum physical effort when performing the maximal exercise test using the modified Bruce protocol. The allometric equations were designed for Iranian men using regression analysis and log transformation of $y=ax^b$ equation to Log (y)=Log (a)+bLog (x) equation. The equations obtained in this study are shown in Table 3. Considering Tables 3 and 4 and Figure 1, these allometric equations are valid enough for assessing the VO_2max efficiency in Iranian men aged 18-25 years (SEE=0.31-0.32, R=0.67-0.70, P=0.000).

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	20.50	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(m^2)	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. Descriptive information of physiological characteristics for study subjects.

Variables	Min	Max	Mean	SEM	SD
HR_{rest} (bp/min)	56	92	69.9	1.33	8.82
$HR_{exercise}$ (bp/min)	181	211	196	1.23	8.2
%HRR	0.87	1.11	0.97	0.009	0.06
RER: V_{CO2}/V_{O2}	1.12	1.42	1.27	0.01	0.07
VO2max ($l \cdot min^{-1}$)	1.99	3.88	2.89	0.064	0.43
VO2max ($mil \cdot min^{-1} \cdot kg^{-1}$)	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

Table 3. Design of alometric equations for determining the level of cardiovascular readiness of Iranian men.

design the allometric equations	P value	SEE	R^2	R	Anthropometric factors
$vo2max=1.04\times Weight^{0.03}$	0/000	0.32	0.45	0.67	**Weight**
$vo2max= -0.55\times BSA^{1.84}$	0/000	0.31	0.48	0.69	**BSA**
$vo2max=0.83\times LBM^{0.05}$	0/000	0.32	0.49	0.70	**LBM**

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VO2max is in absolute and relative (weight&LBM kg and BSA m2).

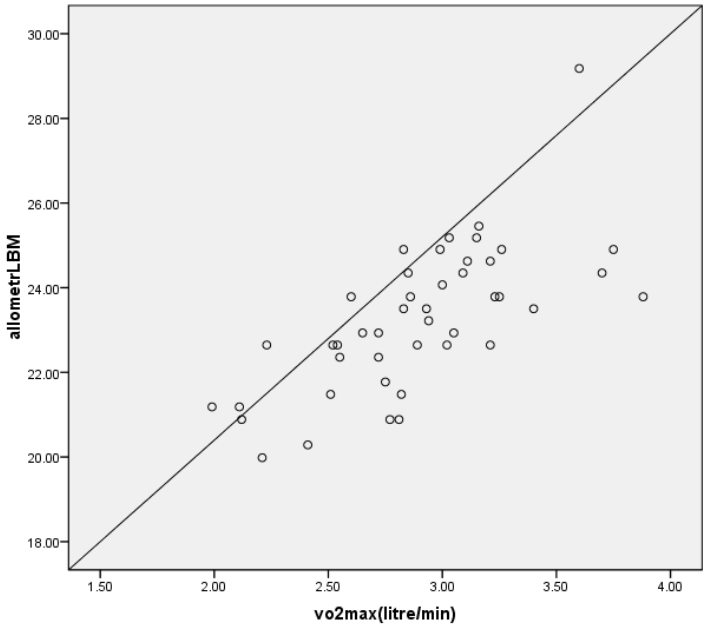

Figure 1. Distribution of the relationship between LBM and VO2max and the allometric optimal equation in Iranian men.

Table 4. Correlation Vo2max and design the allometric equations with Direct method.

P value	SEE	R^2	R	Relative Vo2max and design the allometric equations
0/000	0.33	0.43	0.65	**$vo2max=1.04\times Weight^{0.03}$**
0/000	0.32	0.47	0.68	**$vo2max= -0.55\times BSA^{1.84}$**
0/000	0.31	0.48	0.69	**$vo2max=0.83\times LBM^{0.05}$**

Discussion and conclusion

In the present study, we aimed to design the allometric equations special for Iranian men to measure the VO_2max without performing tedious maximal exercises and the need for precise and expensive equipment, presenting the best allometric equation for this group to provide possibility of fairly accurate evaluation of VO_2max in men aged 18 to 25 years old without the need for exercise tests. The direct measurement of respiratory gases is the best and most accurate measurement method for VO_2max of the subjects. However, because of its expensive equipment and the need for a maximal exercise test, it cannot be used in most cases, so finding an alternative method can be useful in many cases, especially in people with disabilities or in patients with low physical fitness. This research was carried out with the aim of designing the allometric equations special for Iranian men and three allometric equations of $VO_2max=1.04\times Weight^{0.03}$, $VO_2max=-0.55\times BSA^{1.84}$, $VO_2max=0.83\times LBM^{0.05}$) with correlation coefficient (SEE=0.31 -0.32 R=0.67-0.70) was obtained by direct measurement of respiratory gases, which shows the high and good reliability of these equations for measuring the VO_2max. Using these equations, we can measure the VO_2max of the subjects without any exercise test. One of the features of the allometric equations is that the achieved mathematical relationship can be used to measure the respiratory capacity and cardiorespiratory fitness using a measure of anthropometric characteristics such as weight, height and so on. Meanwhile, the weight as an anthropometric variable can play a more significant role in determining the aerobic power, and since the body weight and mass are considered as the main components in the allometric prediction equations, the design of this category of nonlinear equations can more accurately estimate the level of cardiorespiratory fitness.

According to Tables 3 and 4, regarding the correlation between allometric equations designed for specific Iranian men and the direct method for measuring breath-by-breath respiratory gases, the highest correlation was found in the allometric equation of $VO_2max=0.83\times LBM^{0.05}$ with correlation coefficient of R=0.69. Since the VO_2max is usually expressed in terms of body weight and is affected by weight gain or loss, it seems that if the body weight or mass are used in the design of allometric equations, it will be possible to present more precise allometric equations to measure the VO_2max. Other studies have shown that other factors such as body fat mass, in addition to body weight, can be used to measure the VO_2max through the allometric equations.

Regarding studies in Iran on the design of allometric equations special for Iranian men, it should be noted that no research has been conducted so far in order to compare the attained findings. We found only two studies conducted by Saberi (17) and Erfani (18) on adolescent girls in this regard, in which the used method was indirect measurement using European allometric equations, but no research was available on men in this context. However, many international studies have been done regarding the design and validations of allometric equations, which some of them are mentioned below. In a study done by Bionen et al. (19) in 2002 on 73 male athletes using direct measurement of respiratory gases, the exponent b was obtained 0.75, almost the same as our research. Isman et al. (2001) investigated the correlation of body weight between male and female endurance runners using direct allometric equations, which coefficients were calculated to be 0.81 and 0.61, respectively (20), almost in line with the research. Nantumbo et al. (2012) examined the cardiorespiratory function of adolescents using the allometric equation and 1-Mile Walking Test in the rural area of Mozambique and reported that the allometric coefficients were different for estimating aerobic fitness in girls and boys (21). Chamari et al. (2005) measured the aerobic power of young and elite football players using the allometric scale. Their results showed that the oxygen consumed in the maximal and submaximal task positions in terms of body weight was increased with allometric exponents of 0.72 and 0.60, respectively (22). As shown above, the exponent b of allometric equations obtained in these studies are similar to the values obtained in our study. It can be said that the allometric equations designed for Iranian men are similar to those outside of Iran.

Considering that the VO_2max measurement is of particular importance to individuals, and it is also essential to find a method suitable for measuring and evaluating VO_2max without the need for the maximal exercise tests and the use of advanced and expensive laboratory equipment, so the present study designed some allometric equations ($VO_2max=1.04\times weight^{0.03}$, $VO_2max=-0.55\times BSA^{1.84}$, $VO_2max=0.83\times LBM^{0.05}$) special for Iranian men that allow the VO_2max to be evaluated with a relatively good validity (R=0.65-0.69), so that there is no longer any need to run exhaustive exercise tests that may endanger human health.

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