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Evaluation of pulmonary function for estimation of peak oxygen consumption through the respiratory gas analysis and allometric equation in boy student

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ABSTRACT:

Purpose: Allometry is a method of expressing the relationship between physiological and anatomical variables, which can be used in order to measure the vital capacity through mathematical equations. This study investigated the evaluating lung function indices in order to estimate the maximal aerobic power by respiratory gas analysis device and the allometric equation. Methods: This study is a descriptive from correlation type, 80 subjects were chosen by convenience sampling. Anthropometric characteristics and dimensions of chest circumference (diameter and depth of the chest) were measured, and Bruce Test was used in order to measure maximal aerobic power. Pearson correlation coefficient and multivariate regression analysis were performed using SPSS version 16. Results: There is a positive significant relationship between vital capacity and maximal aerobic power (r=0.229 and P=0.041) and between the amounts of the device vital capacity and formula vital capacity(r=1.00 and P=0.00). Accordingly, the following model was developed (chest circumference × 0.284) + (age × 0.319) + (vital capacity × 1.761) + incline = Maximal Oxygen Consumption. Conclusion: According to the results of this study, there is a significant correlation between device vital capacity and formula vital capacity. Thus, it can be concluded that in order to gain predict of the maximal oxygen consumption, in the absence of accessibility to other experimental methods, allometric equation can be used.

KEY WORDS: Pulmonary Function, Peak Oxygen Consumption, Allometric Equation

INTRODUCTION

Increasing the frequency and depth of breathing are among the physiological changes in the body which happen at the beginning of sporting activities in a way that at the start of sporting activities, these two factors are used in order to provide the body's supply of oxygen needed by active muscles and to minimize lack of oxygen. Ventilation rate should increase parallel to the cardiac output in order that the volume of air in the lungs reach to the extent that oxygen is delivered to the blood and carbon dioxide is excreted from it [1]. In order to do so, while doing physical activities and sport, the amount of oxygen consumption in different organs of the body increases, and the volume and velocity (speed) of blood flow also increase in order to deliver nutrients and oxygen to various organs and tissues [2]. Therefore, participating in aerobic activity increases the number of breaths and heart beats and put a considerable strain on the cardio-respiratory system; therefore, its effect on lung capacity and volumes not

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unexpected. Measurement of respiratory indices will provide useful information about the effect of aerobic exercise on the strength of respiratory muscles, airway resistance, and lung function. Dynamic respiratory indices such as forced vital capacity (FVC) and forced expiratory volume in first second (FEV1) depend on the factors such as age, level of physical activity, body composition, and health condition of people[3].

In this regard, some studies by comparing the lung volume and capacity of the athletes and non-athletes were seeking to study the effects of exercise on these volumes and capacities [4-5]. According to the studies having been done on these parameters, FVC values increase by exercise and sport [6]. Regarding this, George et al., (2014) in a study examining the comparison of pulmonary function in 60 athletes and non-athletes have concluded that implementation of physical exercise leads to the lack of significant difference between the variables of body weight, body surface area, and FVC at the end of the period; however, significant changes in FEV1, the FEV1 / FVC ratio, and MVV, which are higher in athletes compared with non-athletes are observed [7]. Hajinia et al., (2014) investigated the relationship between aerobic power to physical activity levels and anthropometric factors among 12-16 years old boys have concluded that there was significant positive correlation between aerobic power and Physical activity levels (PAL). Aerobic power was significantly higher in subjects with high level PAL than subjects with moderate and low PAL. The Rates aerobic power and level of physical activity was significantly decreased with increasing age [8]. There are different methods to estimate the lung volume and capacity, one of which is spirometry. In this method, much effort has been made in order to standardize the methods of performing and interpreting spirometry tests [4, 9-10], to the extent that due to the importance of this issue, The American Thoracic Society (ATS) has started many studies in order to solve this problem [11-12].

Most formulas derived from studies based on linear regression, using age and height as independent variables; however, on-linear equations also have been used in some studies [13].The problem threatening the interpretation of spirometry results is the fact that the expected values in different studies are different from each other up to 20% [14], and because of the same reason, the individual spirometry values compared with the values obtained from a study might be lower than normal yet higher than normal in comparison with the values obtained from another study. Therefore, because of the same reason, it is necessary to investigate and determine the normal values for each society. In this case, however, the most common method to determine the vital capacity is using the spirometry device, but utilizing this method requires expertise and is very time-consuming. In addition, other methods to evaluate pulmonary function are utilizing direct and indirect methods. Due to the high prices of the devices, the fact of not being able to move some devices, and unfamiliarity of some coaches with the operation of the devices, utilizing special devices to measure maximum oxygen consumptions not possible everywhere and for everyone. Therefore, in order to progress rapidly in evaluating the performance of different systems of the human body and facilitate the measurement, the researchers decided to make it possible in different ways and to transfer the evaluation of the athletes' performance from the physical education laboratory and the use of their facilities and equipment to sport fields. In order to do so, one way is to use mathematical equations and its application in functions of various organs of the human body. Accordingly, researchers evaluated physiological indices from the perspective of allometric equations [15-16].

Allometry is a method to express the relationship between physiological and anatomical variables with a unit of body size (usually weight) while increasing the size through mathematical equations [16].

In this regard, a researcher, named Dismoth could achieve a formula based on allometric equations and by using height index, via which one can measure vital capacity of girls and boys. Regarding this, due to the differences of race, climate, and different characteristics of people of different societies, every country should evaluate Dismoth equation based on the specific characteristics of its society because all the aforementioned factors can influence the level of vital capacity. Overall, in order to estimate the exact maximal aerobic power in activities, we require a valid device with high precision so as to calculate the increase of function and coordination of cardiopulmonary systems. Therefore, assuming the fact that by utilizing the respiratory gas analysis device, one would be able to have an exact estimation of the lung volume and capacity, the researcher decided to suggest a model based on the evaluation of lung volume and capacity in order to estimate the maximum aerobic power by respiratory gas devices as well as mathematical equations and their application in lung function on students to answer this question that whether or not it is possible to estimate individual maximal aerobic power through respiratory gas analysis test, and whether or not it is possible to use Bonin formula in order to estimate the maximal aerobic power through allometric equation.

METHODS

Subjects

This study is a descriptive from correlation type, which has been conducted on a group of subjects. The data collection procedure was in a way that after selecting the subjects, their anthropometric sizes and cardio respiratory fitness index was collected. The population of the subjects under the study of this research included the male students (20 to 25 years old), which were selected by convenience sampling. In this study, 80 individuals were selected among the available subjects. In this study, the subjects' health status was controlled by self-reported health status questionnaire and medical history. After completing the consent form for participation and cooperation in research, in the first stage, some information about the nature and method of cooperation in research along with following essential tips on how to hold the Bruce test were given to the subjects.

Anthropometric Measurements

During the second stage, their heights were measured by using an electronic balance with stadiometer (SECA-Germany) to the nearest 0.1 cm and their weight was recorded using a digital scale produced by a German company called Beurer (PS07-PS06). Then, the waist-hip ratio was determined. Body fat percentage was calculated using InBody-720 (Biospace, Dogok-dong, South Korea) to study the fat mass (FM), muscle mass (MM) and total body water (TBW). All of these measurements were carried out while the volunteers had stopped eating or drinking four hours before their test, and their bladder, stomach, and bowels were empty.

Diameter of the chest

In this study, in order to estimate the diameter of the chest, after the exhale, it was measured by placing the two ends of sliding caliper on the second or third ribs (2.5 cm. above the bust line) in the underarm area of the subjects. However, in order to determine the depth of the chest, after the exhale, it was measured by putting one end of the sliding caliper on the tip of the dagger appendage of the sternum and the other end on the twelfth rib.

Peak oxygen consumption

In addition, in order to evaluate the maximal aerobic power, Bruce test for respiratory gas analysis on the treadmill h/p /cosmos was used. Before performing the test, Polar watch was used to determine the intensity of training. The carrying out process will include: 1.wet the electrode areas of the strap well under running water. 2. Attach the connector to the strap. Adjust the strap length to fit it tightly but comfortably. 3. Tie the strap around chest, just below the chest muscles, and attach the hook to the other end of the strap. 4. Check that the wet electrode areas are firmly against your skin and that the Polar logo of the connector is in a central and upright position. This 10-step method starts with the speed of 2.74 kilometers per hour and the in cline of 10% and the speed and the incline increasingly increase and continue until the subject gets exhausted and is not able to perform the tests anymore.

$$VO2max\ (ml/kg/min) = 14.76 - (1.379 \times T) + (0.451 \times T^2) - (0.012 \times T^3)$$

Analysis or allometry ranking is described by this equation: Y = aMb, where Y is a variable which is associated with weight, and “a” is the coefficient of proportionality (proportionality constant). The index b is the allometry coefficient and the main element because this element is expressing the intensity and direction of the relationship between the variable b and the body weight. If Y increase has a direct relationship with body weight, then b equals 1 (b=1). If b=0, the body mass does not have any effects on Y and is a variable independent of weight. If Y increases with weight gain but to a lesser degree, in a way that the increase of the variable is less than the weight gain, b will be greater than zero and smaller than 1. If the value of B is higher than 1, it means that the variable increase is more than weight gain. If Y decreases by the weight gain, as a result, B will be negative [16]. After data collection, the subjects’ maximal oxygen consumption was calculated via allometric equation by using weight replacement in Bonin et al.’s formula [15] (Vo2max=1.94M 0/75).

Data Analysis

At the end, the data were analyzed by SPSS version 16. After ensuring the normality of the theoretical distribution of the data by Shapiro-Wilk statistical test, the analysis of variance was used for homogeneity. In order to predict the values of a variable according to two or more other variables, a multivariate regression model (stepwise method) was used, then using Pearson correlation coefficient, the rate of the correlation of the measured values Vo2maxwas determined by two methods of Bruce test and allometric equation. The simplest and the most common model, used for multivariate correlation, is multiple linear models. This model is defined by the following linear relationship: Y = a + b1x1 + b2x2 + b3x3 + ..., where y is a dependent variable, representing the scores of the variable which is measured; X1’s are the independent variables, representing the scores used to estimate y; β1’s are the regression coefficients, representing the amount of changes happening in y and in relationship with every change unit in x, and β 0 is a fixed number, which must be obtained by replacing x and y in the equation. In this equation, vital capacity, age, and the chests of the subjects were entered as independent or predictor variables. P-value of the tests was considered $p<0.05$.

STATISTICAL RESULTS

The Characteristics of the subjects in this study have been shown in Table 1. According to the findings of Table 2, there is a significant positive relationship (P=0.041 and r=0.229) between the maximal aerobic power with the values of inspiratory reserve volume (P=0.03 and r=0.231), expiratory reserve volume (P=0/042 and r=0.228), inspiratory capacity (P=0.048 and r=-0.221), and vital capacity with maximal aerobic power in male university students. Furthermore, there is a significant positive relationship (P=0.00 and r=1.00) between the device vital capacity and formula vital capacity for male university students. According to the results of Table 3, the following model was developed on the basis of the data obtained from the study: (chest circumference × 0.284) + (age × 0.319) + (vital capacity × 1.761) + incline = maximal oxygen consumption which for every unit change in the independent variables such as vital capacity, age, and chest circumference, the unit change in the maximal oxygen consumption would be 1.761, 0.319, and 0.284 respectively.

Table 1
The characteristics of the subjects

Group	Variations (M±SD)				
	Age (year)	Height (cm)	Weight (kg)	BMI (kg/m2)	VO2max (ml/kg/min)
Subjects (n=80)	23.73±1.33	1.73±6.34	73.39±1.16	23.27±3.68	42.20±5.05

Table 2
The correlation between pulmonary function indices with Peak oxygen consumption in boy students

variables	pulmonary function indices							
	Inspiratory reserve volume (L)		Expiratory reserve volume (L)		Inspiratory capacity (L)		Forced vital capacity (L)	
Peak oxygen consumption	r	P	r	P	r	P	r	P
	0.231	0.03†	0.221	0.04†	0.221	0.04†	0.229	0.041†

† A significant level P<0.05 *Data presented as mean ± standard deviation

Table 3
Results of multivariate regression analysis

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	7.055	15.254		0.463	0.645
Age	0.319	0.414	0.085	0.772	0.442
Forced vital capacity	1.761	0.929	0.208	1.896	0.062
Chest circumference	0.284	0.167	0.188	1.703	0.093

† A significant level P<0.05

DISCUSSION

The aim of this study was to evaluation of pulmonary function for estimation of peak oxygen consumption through the respiratory gas analysis and allometric equation in boy student. The result of this study shows that between amounts of FVC with peak oxygen consumption has a positive significant correlation. The findings from the present study are consistent Fatemi et al.[3] and Rabiee et al.[17]and inconsistent Haji Nia et al.[8] with those reported in the literature. Fatemi et al.[3] reported that a significant correlation among the three independent variables of FEV1, FVC, FEV1/FVC and projected VO2max values in 50 healthy males with range of age, 22.1 ± 2.47 years. Rabiee et al. [17] investigated the Relationship between body composition and maximum oxygen consumption with pulmonary function in 20 subjects show that there was a significant positive correlation between Cardio respiratory fitness and respiratory parameters in light weight in the FEV1 and FVC and heavy weight groups in the FEV1 and FVC. There was also a significant negative relationship between weight and respiratory parameters in heavy weight group FEV1, FVC. But, we didn't observe any significant relationship between the weight and respiratory parameters in the FEV1 in light group. Haji Nia et al [8]investigated the relationship between aerobic power to physical activity levels and anthropometric factors among 12-16 years old boys concluded that there was significant inverse relationship between aerobic power and indicators of age, weight, fat percent, BMI, WHR, and body surface area. There was not significant correlation between aerobic power and Height. There was significant positive correlation between aerobic power and physical activity levels (PAL). Aerobic power was significantly higher in subjects with high level PAL than subjects with moderate and low PAL. Haines, and Wilby [18]examined the relationship between lung function and physical fitness from 605 boys and 566 girls, aged 9-15 years reported that there is a significant corrlation between aerobic power with each of FVC and FEV1 and there was not a relationship between FEV1 to FVC ratio. According to the results, between pulmonary function index is directly related to the amount of cardiorespiratory fitness and with increases of cardiovascular fitness the pulmonary function also increase [19]. The mechanism by which physical activity may affect vital capacity and FEV1is unclear, but between pulmonary function and exercise capacity and hemodynamic parameters to be observed that amount of vital capacity and FEV1 in pulmonary function at rest situation can be used as independent variables significantly correlated with the amount of peak aerobic power [20].

According to this research, between amount of FVC with height has a positive significant correlation.This finding was supported by Palka et al. [21]. Palka et al. [21] reported that Coincided with an increase age and maturity in boys, especially the vital capacity of the lung volume increases. In this regard, with increasing of age and body size, The size of the lungs also increases, but the airway resistance is reduced[22].In fact, with increasing age along with puberty and height increase in boys, the volume and size of organs, especially the heart and lungs and the chest size increases. This factor in this age lead to the increase of the vital capacity and total lung capacity, Therefore, predicted vital capacity is based on height are possible In this context, it can be stated that the height factor could be the best predictor of lung function has been confirmed [23-24]Generally, it seems that with increasing height, the trunk is equally increases. The consequence of this increase, expanding the size of the chest and consequently lung volumes that can affect the vital capacity. On the other hand, with increasing age and height, the muscles involved in the inhaling, inhaling deeply and exhaling deep (during exercise), especially the diaphragm, are more powerful, and to receive more oxygen, allowing vital capacity expansion [25]. In this context, coinciding with the increase in height, and the breathing muscles become stronger, ventilatory responses will be increase[26]. Based on studies, height and body weight equations together, are a better predictor of lung function[27-28].

The results of the present study reveal that there is a significant correlation between peak oxygen consumption and chest circumference, and there is a positive correlation between amounts of FVC of respiratory gas analysis system with FVC of formula significantly. This finding was supported by Shakerin et al. [29] and Beunen et al. [15]. The findings from the present study are inconsistent with those reported in the literature [16]. Shakerin et al. [29] determined the correlation of vital capacity of 11 to 17-year-old girl students measured by spirometry and allometry equation on 311 girl students with average of age 14±3 years showed that allometric equation enjoys high validity in determining the vital capacity of 11 to 17 years old girl students. ($r=0.83$ and $\alpha=0.86$). And there is no difference between vital capacity's mean of athlete group and non-athlete. There for the result of this research shows that allometric equation can be used for determining the vital capacity of girl students in the conditions when exercise laboratory and spirometer are not available. Beunen et al. [15]analyze intra individual allometric development of aerobic power of 73 boys followed at annual intervals from 8 to 16 yr show that, inter individual allometry coefficients for body mass exceed $k = 0.750$. Intra individual coefficients of peak VO2 by body mass vary widely and range from $k' = 0.555$ to $k' = 1.178$. Gaeini et al. [16] determine the reliability of allometric equation in measuring the vo2max of 12 to 16 years old girl students reported that allometric equation enjoys high reliability in determining vo2max, when vo2max was absolute (1/min). But when vo2max is relative vo2max (ml/kg/min), the reliability between vo2max by allometric equation and vo2max by Bruce protocol is $r=-.362$, $P=.01$. Therefore, according to the results obtained, allometric equation can be used. In the field due to an increase in chest size the pulmonary ventilation increased and these changes can lead to an increase in the supply of oxygen better and suitable release oxygen to all body parts. That by implementing appropriate physical activity, endurance of the respiratory muscle is increases which increases chest expansion and lung volume is increased [30-31]. Increase in maximal oxygen uptake, pprobably due to increased oxidative capacity of muscle, increased the total amount of hemoglobin; arterial-venous oxygen difference increased end-diastolic volume and chemistry of biological processes [1]. It also shows that Vo2max Increases proportional to the weight, but the increase in the rate of Vo2max is less than weight. This is largely the result of increasing the size-dependent organs to vo2 during the physical activity. At the same time, with increased in growth of body weight, these organs also grow. But its growth rate is lower than the growth of the whole body. According to the results of this study showed significant positive correlation between amounts of FVC of respiratory gas analysis system with FVC of formula. According to this result the following model was developed: $Vo2max = \text{incline} + (1.761\times FVC)+(0.319\times age)+(0.284\times \text{chest circumference})$. Thus it can suggested that in order to earn awareness of maximal oxygen uptake male students, In the absence of other methods, This method is very easy to carry out, and the possibility of implementing it in any place can be used allometric equation. The limitations of this study include lack of control over their life style (the amount of sleep, rest and extra-curricular activities), and the small number of subjects that cancellation to take part in this study.

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