EXERCISE AND SPORTS SCIENCES

ORIGINAL ARTICLE

Comparison Between Direct and Indirect Methods for the Determination of the Maximal Oxygen Uptake in Female Runners

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ABSTRACT

The aim of this study was to compare the values of $\dot{V}O_{2max}$ directly determined by an ergospirometry system, with values indirectly predicted by the ErgoPC system during maximal exercise test underwent by female runners. Twenty trained female runners participated in the study (42.7 ± 6.4 years-old, height 1.64 ± 0.04m, body mass 58.3 ± 5.8kg, body mass index (BMI) 21.7 ± 1.9kg/m^2 and body fat percentage 22.3 ± 3.5. The subjects were evaluated for body composition and underwent a progressive exercise test on treadmill (Inbrasport, Porto Alegre, RS, Brazil) to measure the aerobic fitness ($\dot{V}O_{2max}$). The initial speed was 7km/h with increments of 1km/h every three minutes and constant inclination of 1% was kept throughout the test. The participants were encouraged to remain in the test as long as possible until voluntary exhaustion. The gas analyzer VO2000 Inbrasport Spirometer, Porto Alegre, Brazil was used for the direct measurement of $\dot{V}O_{2max}$, while for the indirect measurement of $\dot{V}O_{2max}$ the ErgoPC program with the prediction formula from Foster (1996) was used. Statistical analysis was performed by Student's t test for the comparison of the values of $\dot{V}O_{2max}$ obtained in the direct and indirect test, and Pearson's correlation was applied to correlate these two variables. Direct measurement of $\dot{V}O_{2max}$ showed a value of 51.8 ± 6.8ml/kg/min and indirect one of 42.8 ± 3.7ml/kg/min. The comparison between both results was significantly different. The correlation between the values of $\dot{V}O_{2max}$ was r = 0.67. Thus, the results show that the obtained $\dot{V}O_{2max}$ by an indirect way underestimates the value of the direct measurement.

Keywords: aerobic fitness, ergoespirometry, ErgoPC.

INTRODUCTION

The maximal oxygen uptake ($\dot{V}O_{2max}$) is an important predicting parameter of aerobic performance which us used in the training control and prescription; it is a widely used index for the determination and classification of the cardiorespiratory functional capacity, especially for athletes who perform efforts of long and medium duration and prioritarily depend on the oxidative metabolic way[1,2].

This measurement is the best representation of the quantitative as well as qualitative of the functional capacity of the cardiorespiratory system integrated with the muscular system during physical exercise and the ability to regulate the energetic demand from each intensity for the performance of activities, since there is a perfect congruency of the body in uptaking, transporting and using oxygen for the aerobic processes of energy production during physical exertion[3,4].

The $\dot{V}O_{2max}$ may be influenced, according to Fernandes et al.[5], by factors such as: gender, age, presence of pathologies or use of some kinds of medication, the manner of exercising and body composition. According to Barros et al.[6], the $\dot{V}O_{2max}$ decreases with age progression, both in men and women, regardless of the training status or level of physical activity.

Concerning gender, due to the differences in body composition, it is expected that the men present higher $\dot{V}O_{2max}$ values than women since the former have more muscle mass and less body fat. Moreover, since men have higher concentrations of hemoglobin, which enables the transport of more oxygen by the blood during exercise, the $\dot{V}O_{2max}$ index is higher in the male gender[7].

$\dot{V}O_{2max}$ measuring and determination can be done through two methods: direct and indirect, both present advantages and disadvantages which should be taken into consideration.

The direct measurement is considered gold standard for being the most reliable and it is performed through the ergospirometric test in which the individual is submitted to increasing effort loads and the oxygen expired (O_2) and carbon dioxide (CO_2) fractions are measured during exercise and pulmonary ventilation, precisely assessing hence the cardiorespiratory and metabolic capacity[8,9].

Nonetheless, the ergospirometric test presents high cost, the equipment is sophisticated and needs skilled labor to operate it, longer time for evaluation of each individual as well as higher motivation since the tests are usually performed in laboratory; these are the reasons why methods for $\dot{V}O_{2max}$ indirect determination have been proposed[10,11].

Indirect determination is performed during submaximal or maximal exertion tests, in which some physiological variables are used and whose values are inserted in mathematical equations and many individuals can be concomitantly assessed, the cost is low and the test conditions may be closer to the modality's specificities[7,8].

However, reliability is many times questioned, both by the used equations and the specific groups to which it was designed and by the significant differences found in the comparison of the direct and indirect measurements; many studies have shown that the indirect method tends to overestimate values[12-14].

Thus, the present study had as aim to compare the $\dot{V}O_{2max}$ values directly determined by an ergospirometry system, with values indirectly predicted by the ErgoPC system during maximal exertion test performed by female runners.

METHODS

Sample

Twenty female runners, mean age of 42.7 ± 6.4 years, running practitioners submitted to systematized training with weekly volume of approximately 25km and competitive experience in rustic events of the modality participated in the study. Each subject after having received information on the work procedures and goals signed a Free and Clarified Consent Form for participation in the study, which was approved by the Local Ethics in Research Committee.

Data collection

All athletes replied to an anamnesis form containing specific and individual information on their health and training prior to the tests. Anthropometric measures concerning body mass, height, and skinfolds were taken for subsequent determination of the body fat percentage. Body weight was checked on a digital scale brand name Tanita and height was checked with a stadiometer brand name Seca® with 0.1cm precision and skinfolds were measured with adipometer brand name Harpender. Body density was calculated with equation by Jackson et al.[15] and for determination of fat percentage the Siri formula was used[16]. Body mass index (BMI kg/m^2) was calculated from the formula: body mass (kg)/height^2 (m^2).

A rest electrocardiogram (ECG) was performed before the beginning of the exertion test and during the test performance the heart rate (HR) was constantly checked. Blood pressure (BP) was checked before and at the end of the each stage of the test. All procedures were followed by a cardiologist.

Determination of the aerobic parameters

Incremental treadmill tests were performed (Inbrasport, Porto Alegre, RS, Brazil) in a acclimatized laboratory, during the morning shift with mean temperature kept at 24°C. Initial speed was 7km/h, with increments of 1km/h at every three minutes and constant inclination of 1% was kept during the entire test. The participants were strongly encouraged to stay in the test for as long as possible, until voluntary exhaustion. The tests were monitored with electromyographic records at the end of each stage as well as at recovery.

A gas analyzer (Spirometer VO2000, Inbrasport, Porto Alegre, Brazil), in which the gas samples are collected and directly measured during the test was used for determination of the $\dot{V}O_{2max}$. Additionally to the spirometry system, the ErgoPC program (Micromed, Brasília, Brazil) was used. Besides recording the cardiac behavior, it also indirectly predicts the

$\dot{V}O_{2max}$ through a formula proposed by Foster et al.[17], which consider the intensity increase in each of the stages: $\dot{V}O_{2max}$ (ml/kg/min) = [0.869] x [0.2 x Speed (m/min) + 0.9 x Speed x Elevation (%/100) + 3.5] + [–0.070].

STATISTICAL ANALYSIS

Data were analysed with descriptive statistics with mean ± standard deviation (SD), Student's t test for mean comparisons and significance level was of $p < 0.05$. Pearson correlation test was used to correlate the variables related to $\dot{V}O_{2max}$.

RESULTS

Table 1 presents mean ± SD values of the variables concerning the sample's anthropometric characteristics (age, body mass, stature, BMI, % fat).

Table 2 shows the mean values of $\dot{V}O_{2max}$ (ml/kg/min) directly obtained (ergospirometry) and indirectly obtained. Statistically significant difference was observed between the $\dot{V}O_{2max}$ values directly determined by the ergospirometry system as well as $\dot{V}O_{2max}$ predicted by the ErgoPC system. Despite of that, moderate correlation was identified direct and indirect $\dot{V}O_{2max}$ ($r = 0.67$).

Table 3 represents the cardiorespiratory fitness classification of the women according to the American College of Sports Medicine[18]. There was difference in the classification between the two methods for all age groups.

Table 1. Descriptive characteristics of the sample (mean ± SD).

Variables	Women (n = 20)
Age (years)	42.7 ± 6.4
Body mass (kg)	58.3 ± 5.8
Stature (m)	1.64 ± 0.04
BMI (kg/m^2)	21.7 ± 1.9
% fat	22.3 ± 3.5

Table 2. Comparison of the $\dot{V}O_{2max}$ (ml/kg/min) determined by the direct and indirect methods.

Variables	Women (n = 20)
$\dot{V}O_{2máx}$ (indirect)	42.8 ± 3.7
$\dot{V}O_{2máx}$ (direct)	51.8 ± 6.8*

* $p < 0.05$ in relation to the indirect method.

Table 3. Classification of the cardiorespiratory fitness according to the American College of Sports Medicine(18).

Method	30-39 years (n = 6)	40-49 years (n = 11)	50-59 years (n = 3)
$\dot{V}O_{2máx}$ (indirect)	Good	Excellent	Excellent
$\dot{V}O_{2máx}$ (direct)	Excellent	Excellent	Excellent

ACSM, 1980.

DISCUSSION

The aim of this study was to compare the $\dot{V}O_{2max}$ values directly determined by an ergospirometry system with values indirectly predicted by the ErgoPC system during a maximal exertion test performed by female runners.

It is known that ergospirometry is the gold standard for evaluation of cardiorespiratory fitness, especially for scientific studies or evaluations which require greater accuracy[8,11,19,20]. In order to indirectly measure the $\dot{V}O_{2max,}$ measurement instruments such as cycle ergometers and treadmills, wooden benches as well as application of field tests (run or gait) have been used[21].

Higher practicality justifies the cost/benefit ratio of the application of indirect measurements, since they present higher associated error[22]. The ACSM[23] reported an approximate error of 7% in the O_2 estimation with their equations as a starting point.

The main finding of this study was that the indirect $\dot{V}O_{2max}$ measurement underestimated the direct measurement, as shown in table 2.

Conversely, further studies found opposite results, as the study by Santos[13] and Rondon et al.[9], who assessed in the conventional ergometry the $\dot{V}O_{2max}$ estimated by regression, in which the indirect measurement overestimated the direct measurement regardless of the protocol and ergometer used. Brum et al.[24], Filardo et al.[25] and Costa et al.[14] assessed, respectively, the run and gait equations by the ACSM[11,26,27] for estimation of the O_2 and also found results which overestimated the direct measurement, pointing to the need to specify the study of the indirect methods by gender, age and physical status.

In a field test, Costa et al.[28] compared ergospirometry values with the ones predicted by the 12-minute Cooper's test[29] and similarly to the present study, found underestimation of the indirect method compared to the direct method.

Therefore, it can be observed that extent to which the protocol and formula used influence on the $\dot{V}O_{2max}$ prediction and are able to increase or decrease the real values. According to Rondon et al.[9] and Santos[13], the final results obtained ($\dot{V}O_{2max}$) with the indirect measurement are influenced by the level of cardiorespiratory fitness of the studied subjects. In their studies, these authors observed that the $\dot{V}O_{2max}$ estimated by the formula by the ACSM was higher in individuals with low physical fitness than in the ones with moderate fitness.

Table 3 presents the classification of the level of cardiorespiratory fitness when the $\dot{V}O_{2max}$ values are used for prediction of this fitness[26]; from this point, the individuals are classified regarding fitness as: very low; low; average; good or excellent, according to the American College of Sports Medicine[18], taking the age group into consideration.

The difference found in table 2 between the two measurements (direct and indirect), it is important to highlight the usefulness as well as influence that the $\dot{V}O_{2max}$ measurement represents to training and its prescription. According to Laurentino and Pellegrinoti[3], the $\dot{V}O_{2max}$ is an index of great validity of application and prescription in sports modalities which individualizes the exercise intensity for improvement of cardiorespiratory fitness of each subject[11].

According to the ACSM[27], a physical conditioning program which aims to improve cardiorespiratory fitness should be applied with training loads suitable concerning intensity, duration, frequency and modality. Amongst the cited factors, intensity is the one which has the greatest influence on the reached results.

Thus, it is implied that athletes who present excellent fitness (table 3), if use parameters obtained through the indirect test (good fitness), may be within a lower target zone of aerobic training, inadequate to physical fitness improvement and their performance.

Therefore, it is important to highlight that the $\dot{V}O_{2max}$ underestimated by the indirect measurement, when used as parameter for a population of athletes, will be able to determine lower cardiorespiratory adaptations and, consequently, lower improvement as a consequence of training. Nevertheless, when populations with any coronary risk are considered, the intensity underestimation in comparison with protocols which are able to overestimate the $\dot{V}O_{2max}$ variable guarantees higher safety of training application, not representing hence higher risks.

CONCLUSION

Based on the data presented here, it was observed that the $\dot{V}O_{2max}$, indirectly obtained, underestimates the value of direct measurement, at least through the systems and protocols used in this investigation. Therefore, the conventional ergometric test presented substantial limitations for the real functional capacity of the studied individuals; however, since the indirect method is more practical, it is more present in the sports routine.

Thus, the use of indirect methods of cardiorespiratory evaluation should not be used as the only parameter in the training prescription, since it can represent aerobic fitness lower or higher than the reality and can be applied together with other physiological variables. Nonetheless, if the goal is to determine the $\dot{V}O_{2max}$ for the physiological use for athletes or general training, it is suggested that ergometric tests which determine this variable by the direct method are performed.

All authors have declared there is not any potential conflict of interests concerning this article.

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