Peak oxygen uptake prediction in overweight and obese adults

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Summary

Peak oxygen uptake ($\dot{V}O_{2peak}$) is an important risk predictor for cardiovascular mortality and morbidity. The main aim of this study was to develop equations for estimating $\dot{V}O_{2peak}$ in sedentary and active overweight and obese subjects. The second objective was to compare the newly created equations with the standard equations that are widely used. One hundred and twenty-nine overweight and obese subjects (57 males), aged 18-50 years, were randomized into two groups: development group (n = 94) and validation group (n = 35). Individuals performed a modified Bruce protocol before (sedentary) and after (active) a 24-week weight loss program. Body composition was measured by bioelectrical impedance analysis. Stepwise multiple regression models were performed; the following factors: age, body weight (BW), lean body mass percentage (%LBM), and time of effort test (TIME) were included in the model. Four equations were developed: with and without effort test data for sedentary and active subjects. In the validation group, equations with and without TIME underestimated $\dot{V}O_{2peak}$ values in sedentary ($p = 0.002$ and $p = 0.008$, respectively), but not in active subjects. Furthermore, the equations derived from this study presented the greatest determination coefficients and the lowest values for the standard errors of estimate, for both development and validation groups. The following equation presented the highest determination coefficient, using effort test data for active subjects: $\dot{V}O_{2peak}$ (L/min) = -5.017 + (0.040×BW) + (0.127×TIME) + (0.046×%LBM) + (-0.010×AGE). The predicted $\dot{V}O_{2peak}$ values using the Bruce equation were significantly lower than the measured values in active participants ($p = 0.046$); whereas those predicted by ACSM's equation were significantly higher in comparison to the measured $\dot{V}O_{2peak}$ levels in sedentary and active subjects ($p < 0.001$), for both groups. In conclusion, equations developed in this study were adequate to predict $\dot{V}O_{2peak}$ in overweight and obese subjects, whilst the most commonly used equations in the literature, ACSM and Bruce, reported an inaccurate estimation of $\dot{V}O_{2peak}$.

Key words:
Oxygen consumption. Sedentary. Active. Prediction equations.

Predicción del consumo pico de oxígeno en adultos con sobrepeso y obesidad

Resumen

El consumo de oxígeno pico ($\dot{V}O_{2peak}$) es un predictor importante de riesgo cardiovascular. El principal objetivo de este estudio fue desarrollar ecuaciones para estimar el $\dot{V}O_{2peak}$ en sujetos con sobrepeso y obesidad, tanto sedentarios como activos. El objetivo secundario fue comparar las ecuaciones desarrolladas con ecuaciones ampliamente utilizadas. Ciento veintinueve sujetos con sobrepeso y obesidad (57 varones), de entre 18 y 50 años, fueron aleatoriamente divididos en dos grupos: de desarrollo (n=94) y de validación (n=35). Los sujetos realizaron un protocolo de Bruce modificado antes (sedentario) y tras un programa de pérdida de peso de 24 semanas (activo). La composición corporal se midió con impedancia bioeléctrica. Se realizaron modelos de regresión múltiple por pasos y los siguientes factores fueron incluidos en el modelo: edad, peso corporal (PC), porcentaje de masa magra (%MM) y tiempo máximo en la prueba de esfuerzo (TIEMPO). Fueron desarrolladas cuatro ecuaciones: con y sin dato de prueba de esfuerzo para sedentarios y activos. En el grupo de validación, las ecuaciones con y sin TIEMPO subestimaron los valores de $\dot{V}O_{2peak}$ en sedentarios (p = 0,002 y p = 0,008, respectivamente), pero no en sujetos activos. Por otra parte, nuestras ecuaciones presentaron los mayores coeficientes de determinación y los valores más bajos en errores estándar de estimación, tanto para el grupo de desarrollo como para el grupo de validación. La ecuación con el coeficiente de determinación más alto fue la desarrollada para los sujetos activos con datos de prueba de esfuerzo: $\dot{V}O_{2peak}$ (L/min) = -5,017 + (0,040×PC) + (0,127×TIEMPO) + (0,046×%MM) + (-0,010×EDAD). La ecuación de Bruce calculó valores de $\dot{V}O_{2peak}$ significativamente menores que los valores medidos en sujetos activos (p = 0,046); mientras que los valores predichos por la ecuación de ACSM fueron significativamente mayores en comparación con los valores de $\dot{V}O_{2peak}$ medidos, tanto en sedentarios como en activos (p <0,001), para ambos grupos. En conclusión, las ecuaciones desarrolladas en este estudio fueron adecuadas para predecir $\dot{V}O_{2peak}$ en sujetos con sobrepeso y obesidad, mostrando una mayor precisión que otras ecuaciones utilizadas en la literatura.

Palabras clave:
Consumo de oxígeno. Sedentario. Activo. Ecuaciones de predicción.

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Introduction

Peak or maximum oxygen consumption ($\dot{V}O_{2peak}$) represents cardiovascular fitness and is recognized as an important predictor for cardiovascular mortality and morbidity[1]. Moreover, $\dot{V}O_2$ is an important factor for exercise prescription and control[2]. $\dot{V}O_{2peak}$ measured by indirect calorimetry was used to assess cardiorespiratory fitness, using a variety of ergometers until the highest level of physiologic exertion is reached. Although $\dot{V}O_{2peak}$ testing is considered the "gold standard" for assessing aerobic capacity, it is often unfeasible and challenging to achieve a true value as its practice may be influenced by variables such as fatigue, motivation, injuries and physical limitations[3,4]. Therefore, a wide variety of equations to predict $\dot{V}O_{2peak}$ have been developed and published over the last 10 years[3]. Notwithstanding this, most of equations were developed for subjects within a normal weight range[5]. As a result, errors may occur when applying these equations to an overweight/obese population because obese individuals have lower cardiovascular fitness than lean subjects[6]. Therefore, specific equations for the overweight and obese population should be created. Cycle ergometer testing is a popular mode for assessing $\dot{V}O_{2peak}$ in overweight and obese individuals[7,8]. Cycle ergometer testing is influenced by peripheral fatigue and often do not reflect the actual consumption of oxygen[9-11]. Body composition, particularly lean body mass (LBM) may influence $\dot{V}O_{2peak}$. Since LBM is a reflection of metabolically active tissues, it should be considered when predicting $\dot{V}O_{2peak}$[12]. In addition, walking and running are more familiar and habitual modes of exercise for the average individual, thus it would be beneficial to develop equations for treadmill-specific tests[13]. Moreover, another factor that influences oxygen consumption is the level of physical activity; hence equations estimating $\dot{V}O_{2peak}$ should continue to include this variable[14,15]. Therefore, the aim of this study was two-fold. Firstly, to develop equations for estimating $\dot{V}O_{2peak}$ in sedentary and active overweight and obese subjects. Secondly, to compare the equations developed with other widely used equations. A cross-validation study with an independent sample was conducted to determine the accuracy of the new equations.

Material and method

Participants

The present study was part of a randomized clinical trial by *Nutrition and Physical Activity Programs for Obesity Treatments* (PRONAF according to its Spanish initials); the aim of which was to assess the usefulness of different types of physical activity and nutrition programs for the treatment of adult obesity. The inclusion criteria included subjects living in the region of Madrid, aged 18 to 50 years, overweight (Body Mass Index (BMI): ≥25 ≤29.9 kg/m^2) or obese (BMI: ≥30 ≤34.9 kg/m^2), sedentary (<30 min physical activity/day), normoglycaemic and non-smoker. In agreement with the guidelines of the Declaration of Helsinki[16], regarding research on human subjects, all participants were carefully informed about the possible risks and benefits of the present study and signed an institutionally approved document of informed consent. The PRONAF study was approved by the Human Research Review Committee of the University Hospital La Paz (HULP) (PI-643).

Study design

The intervention consisted of a 6-month diet and exercise-based program, with a particular focus on creating a behavior change. Participants entered the study in two sample waves (overweight and obese phase) they were then split into four randomly assigned groups, stratified by age and sex. The following groups were: strength, endurance, combined strength and endurance, and the control group, adhering to physical activity recommendations. All participants were measured pre- and post-intervention, in week 1 and week 24, respectively. Physical activity was assessed by a SenseWear Pro3 Armband™ accelerometer (Body Media, Pittsburgh, PA). Participants wore the monitor continuously for 5 days following general recommendations[17]. Daily energy expenditure was calculated using the Body Media propriety algorithm (Interview Research Software Version 6.0). Additionally, participants were asked to report physical activity habits and chronicle their food consumption during the intervention through a personal diary. From a total of 180 participants, who concluded the PRONAF study, 129 participants (57 males and 72 females) completed all the tests and were included in this study. Individuals of the control group were excluded from the analyzes because their physical activities were not supervised. Individuals were randomized into two groups: development group (n=94) and validation group (n=35), both groups included the same ratio of men to women and a proportional representation of training groups (strength, endurance and combined). With the development and validation groups representing 73% and 27% of the total sample, respectively. The data of development group were used to create the equations, while the data of validation group were used to validate these equations. According to classifications of physical activity level used elsewhere[13], individuals on baseline and post-intervention were considered sedentary and active, respectively. For both classifications, sedentary and active, two equations with the same variables were created; however, one considered the effort test, whilst the other did not. Moreover, measured $\dot{V}O_{2peak}$ was compared to predicted values by American College of Sport Medicine[18] and Bruce[19] equations (Table 1).

Diet intervention

Before initiating the intervention, negative energy balance was calculated for all participants; taking into account their own daily energy expenditure based on accelerometry data and the 3-day food log. As a result, they followed an individualized hypo-caloric diet with a 25-30% caloric restriction. Macronutrient distribution was set according to the Spanish Society of Community Nutrition recommendations[20].

Table 1. ACSM and Bruce equations utilized.

ACSM Equation
$\dot{V}O_{2peak}$ (L/min) = (((Speed×0.1)+(Speed×Grade×1.8)+3.5)/1000)×BW
Bruce Equation
$\dot{V}O_{2peak}$ (L/min) = ((85.42 - (13.73×Sex) - (0.409×Age) - (3.24×PAS) - (0.114×BW))/1000)×BW

$\dot{V}O_{2peak}$: peak oxygen uptake; speed in miles; grade in decimal percentage (10% = 0.1); BW: body weight (in kilograms); sex (1 = male, 2 = female); age in years; PAS: physical activity status (active = 1; sedentary = 2).

Exercise intervention

All exercise training groups followed an individualized training program; which consisted of three exercise sessions per week, for 22-weeks. All exercise sessions were carefully supervised by certified personal trainers. Details of the different protocols developed by the groups are described elsewhere[21].

Measurements

Cardiovascular fitness

Evaluation of cardiovascular fitness was conducted through a maximal effort test with the modified Bruce protocol, broadly used in overweight and obese populations[22,23], with a computerized treadmill (H/P/COSMOS 3PW 4.0, H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany). During testing, minute ventilation (VE), oxygen uptake ($\dot{V}O_2$), and carbon dioxide expiration ($\dot{V}CO_2$) were constantly measured through indirect calorimetry using the gas analyzer Jaeger Oxycon Pro (Erich Jaeger, Viasys Healthcare, Germany). $\dot{V}O_{2peak}$ was assessed using calculations that evaluated the volume and composition of expired gas using the Haldane transformation. All subjects were asked to refrain from intense exercise/physical activity 24 hours preceding the test. The measurements took place in similar environmental conditions. The analyzer was calibrated using certified gas mixtures before each run. Heart rate, in response to increasing exercise, was continuously monitored with a 12-lead electrocardiographic monitor. The following criteria were used to determine $\dot{V}O_{2peak}$: performance must attain ≥85% of the theoretical maximum heart rate, achieve a superior respiratory exchange ratio (RER) to 1.10 and perform until exhaustion[24]. The mean of the three highest measurements determined $\dot{V}O_{2peak}$[25]. All tests were evaluated by two researchers in a double blind process. The coefficient of variation between the assessments of these two studies and those of a highly-experienced expert was 1.3%. The time of effort test (TIME) was used as the independent variable in the equations, with regards to the effort test.

Body composition

A Tanita BC 418 body composition analyzer (Tanita Corp., Tokyo, Japan) was used for the bioelectrical impedance analysis (BIA). Subjects stood with the ball of their feet and heels in contact with the metallic electrodes. Once weight was recorded, subjects were instructed to grasp the hand grips and hold them down by their sides so that the metallic electrodes were in contact with the palm and thumb. The precision error for BIA measures in our laboratory was 0.52% of body fat percentage. All measurements were done in agreement with the normal protocol at least 3 hours after a meal (including drinks), and subjects were instructed to refrain from strenuous exercise 12 hours prior to the measurements. Subjects were asked to empty their bladder before the measurements. Females were not measured during their menstrual period[26]. Body weight (BW), fat mass percentage (%FM) and lean body mass percentage (% LBM) measures were obtained. Height was measured using a SECA stadiometer (range 80-200 cm, Valencia, Spain). BMI was calculated as: body mass (kg)/height (m)^2.

Statistical Analysis

The arithmetic mean and standard deviation were used as descriptive statistics. Stepwise multiple regression models were performed to verify the influence of certain variables in the $\dot{V}O_{2peak}$. In each case, the dependent variable was $\dot{V}O_{2peak}$ and the independent variables were age, gender, BW, BMI,%FM and %LBM, and TIME. If the slope for an independent variable was not found to be statistically significantly different than zero at $\alpha = 0.05$, that independent variable was excluded from the model. Independent variables selected for the final regressions were age, BW and %LBM and TIME. The validity of the model was assessed through the analysis of colinearity statistics and Q-Q plots of unstandardized residuals. Pearson correlation coefficients (*r*) and determination coefficients (R^2) were calculated. Differences between the coefficients of determination from the validation and elaboration groups would be within 0.075. Standard error of estimate (SEE) was calculated. Bland-Altman plots 95% limits of agreement analysis (LoA) were constructed to determine the level of agreement between the measured and predicted $\dot{V}O_{2peak}$ for each equation. In addition, Lin's concordance correlation coefficients were obtained and classified according McBride[27] where values >0.99 is considered almost perfect, >0.95-0.99 substantial, >0.90-0.95 moderate and ≤ 0.90 poor. Independent samples t test was used to compare characteristics at baseline between development and validation groups. Paired samples t tests were performed to compare measured and predicted $\dot{V}O_{2peak}$ values. The analyzes were conducted using SPSS statistical software (Version 17; SPSS, Inc, Chicago, IL) and MedCalc (Medical Calculator) software (version 12.1.4.0). The statistical significance level was set at 5% ($p < 0.05$).

Results

The characteristics of participants at baseline were similar in the development and validation groups (Table 2). Percentages of men were 43.6 and 45.7 in the development and validation group, respectively. All tests were considered maximum, in accordance to the criteria described in methods. Multiple regression models with exercise included BW, TIME, %LBM and age. Models without exercise included the same variables, except TIME. Equations before (sedentary, 1a and 1b) and after (active, 2a and 2b) the intervention were developed (Table 3).

Table 2. Characteristics at baseline.

	Development Group (n=94)	Validation Group (n=35)
Age	37.3 ± 7.3	39.0 ± 8.9
Body weight (kg)	88.8 ± 13.8	88.0 ± 11.9
Height (cm)	169.1 ± 9.3	168.2 ± 9.5
Body mass index (kg/m^2)	30.9 ± 3.2	31.0 ± 2.6
Percentage fat (%)	35.6 ± 7.0	36.1 ± 7.5
Fat mass (kg)	31.7 ± 8.3	31.8 ± 8.0
Lean body mass (kg)	54.2 ± 10.0	53.4 ± 9.6

Data are presented as mean ± SD. No significant differences were found between development and validation groups for any of the variables.

Table 3. Equations obtained in this study.

Equation 1a (sedentary with effort test)

$$\dot{V}O_{2peak}\ (L/min) = -4.119 + (0.038\times BW) + (0.147\times Time) + (0.027\times \%LBM) + (-0.014\times Age)$$

Equation 1b (sedentary without effort test)

$$\dot{V}O_{2peak}\ (L/min) = -3.519 + (0.045\times BW) + (0.050\times \%LBM) + (-0.020\times Age)$$

Equation 2a (active with effot test)

$$\dot{V}O_{2peak}\ (L/min) = -5.017 + (0.040\times BW) + (0.127\times TIME) + (0.046\times \%LBM) + (-0.010\times Age)$$

Equation 2b (active without effort test)

$$\dot{V}O_{2peak}\ (L/min) = -4.849 + (0.046\times BW) + (0.069\times \%LBM) + (-0.010\times Age)$$

$\dot{V}O_{2peak}$: peak oxygen uptake; BW: body weight (in kilograms); TIME: time of effort test (in minutes); %LBM: lean body mass percentage.

Table 4. Measured and predicted peak oxygen uptake in development group (n=94).

Sedentary	**Measured $\dot{V}O_{2peak}$**	**Equation 1a**	**Equation 1b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	2.830 ± 0.805	2.729 ± 0.707	2.786 ± 0.691	3.630 ± 0.888#	2.876 ± 0.866
95% LoA (L/min)	---	-0.074 ± 0.374	-0.017 ± 0.411	0.826 ± 0.677	0.073 ± 0.483
r	---	0.885*	0.859*	0.684*	0.835*
R^2	---	0.757	0.738	0.468	0.697
SEE (L/min)	---	0.383	0.414	1.077	0.491
CCC	---	0.874	0.849	0.460	0.830
Active	**Measured $\dot{V}O_{2peak}$**	**Equation 2a**	**Equation 2b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	3.038 ± 0.852	3.065 ± 0.782	3.052 ± 0.755	3.625 ± 0.889#	2.941 ± 0.832#
95% LoA (L/min)	---	0.026 ± 0.339	0.013 ± 0.401	0.586 ± 0.520	-0.097 ± 0.464
r	---	0.917*	0.882*	0.825*	0.849*
R^2	---	0.841	0.778	0.681	0.721
SEE (L/min)	---	0.342	0.403	0.790	0.477
CCC	---	0.914	0.876	0.672	0.842

*$p<0.001$; #$p<0.05$ - mean differences between predicted and measured values; analysis of the 95% limits of agreement (LoA) expressed as bias (±1.96 SD diff); SEE: standard error of estimate; CCC: concordance correlation coefficient.

The equations derived from this study reported the greatest determination's coefficients and lowest values of SEE, for both development and validation groups. In the development group, $\dot{V}O_{2peak}$ predicted values, using the Bruce equation, were significantly lower than the measured values after the intervention ($p = 0.046$); whereas those predicted by ACSM's equation were significantly higher compared to the measured $\dot{V}O_{2peak}$ levels before and after the intervention ($p <0.001$) (Table 4). In the validation group, equations 1a and 1b underestimated $\dot{V}O_{2peak}$ values at baseline ($p = 0.002$ and $p = 0.008$, respectively); similarly, Bruce's equation also underestimated these values at post intervention ($p = 0.019$). Equally for the elaboration group, ACSM's equation overestimated $\dot{V}O_{2peak}$ measured values, before and after the intervention ($p <0.001$) (Table 5). Before the intervention, concordance correlation coefficients were considered "poor" for all the equations. However, the highest values were reported by the equations from the present study. After the intervention, concordance correlation coefficients were classified as "moderate" for the equations 2a and 2b in the validation group. ACSM's equation presented the lowest values of concordance correlation coefficients in all the cases.

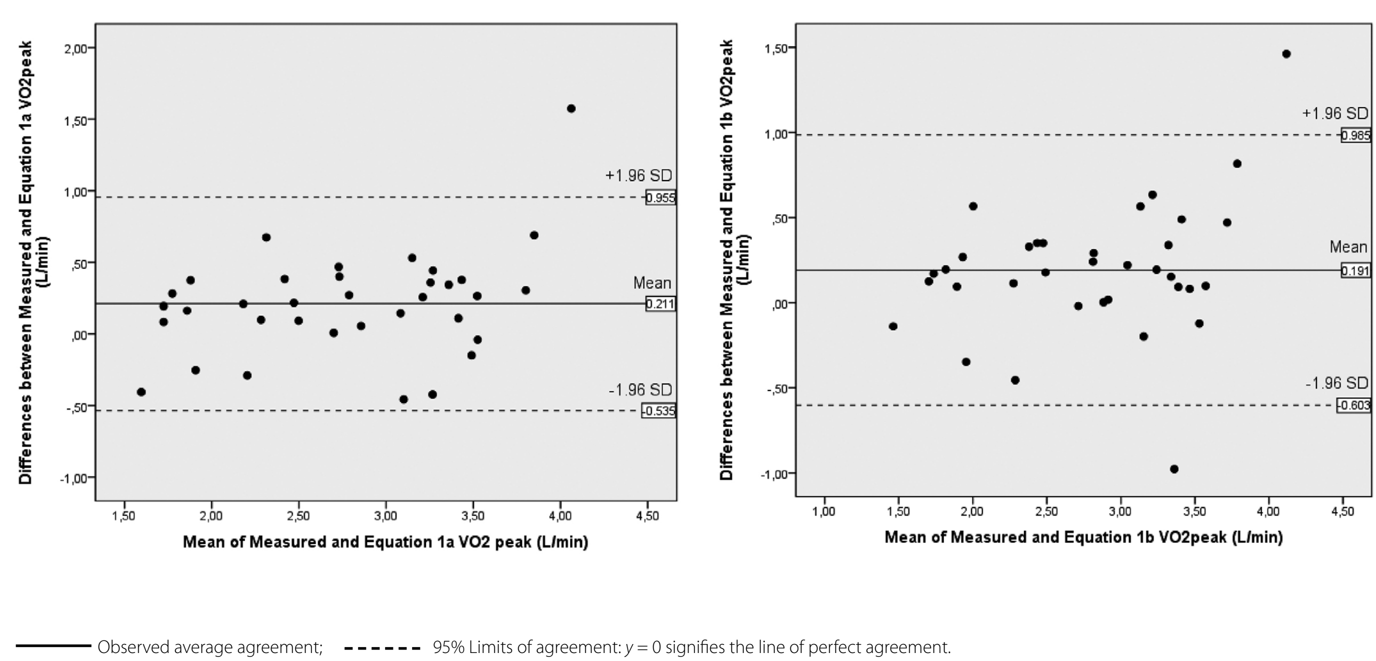
Bland and Altman plots indicated that, on average, the equations of this study in the validation group underestimated $\dot{V}O_{2peak}$ by 0.200L/min (standard errors of mean) in sedentary subjects ($p <0.05$) (Figure 1). However, the standard errors of mean for the same subjects for ACSM and Bruce equations were -0.707 L/min and 0.076 L/min, respectively.

Table 5. Measured and predicted peak oxygen uptake in validation group (n=35).

Sedentary	**Measured $\dot{V}O_{2peak}$**	**Equation 1a**	**Equation 1b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	2.888 ± 0.778	2.678 ± 0.653#	2.698 ± 0.665#	3.596 ± 0.740#	2.813 ± 0.776
95% LoA (L/min)	---	-0.211± 0.373	-0.191 ± 0.396	0.707 ± 0.475	-0.075 ± 0.469
r	---	0.879*	0.860*	0.805*	0.817*
R^2	---	0.772	0.740	0.648	0.667
SEE (L/min)	---	0.436	0.448	0.873	0.483
CCC-	--	0.828	0.821	0.556	0.814
Active	**Measured $\dot{V}O_{2peak}$**	**Equation 2a**	**Equation 2b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	3.019 ± 0.859	3.025 ± 0.759	2.991 ± 0.746	3.516 ± 0.756#	2.846 ± 0.753#
95% LoA (L/min)	---	0.004 ± 0.294	-0.030 ± 0.337	0.494 ± 0.397	-0.176 ± 0.417
r	---	0.941*	0.921*	0.886*	0.874*
R^2	---	0.885	0.848	0.785	0.764
SEE (L/min)	---	0.298	0.343	0.649	0.461
CCC	---	0.934	0.912	0.738	0.846

*$p<0.001$; #$p<0.05$ - mean differences between predicted and measured values; analysis of the 95% limits of agreement (LoA) expressed as bias (±1.96 SD diff); SEE: standard error of estimate; CCC: concordance correlation coefficient.

Figure 1. Bland and Altman's limits-of-agreement plot between measured and estimated $\dot{V}O_{2peak}$; calculated through equations 1a (sedentary with effort test) (left) and (sedentary without effort test) (right) in subjects of the validation group.

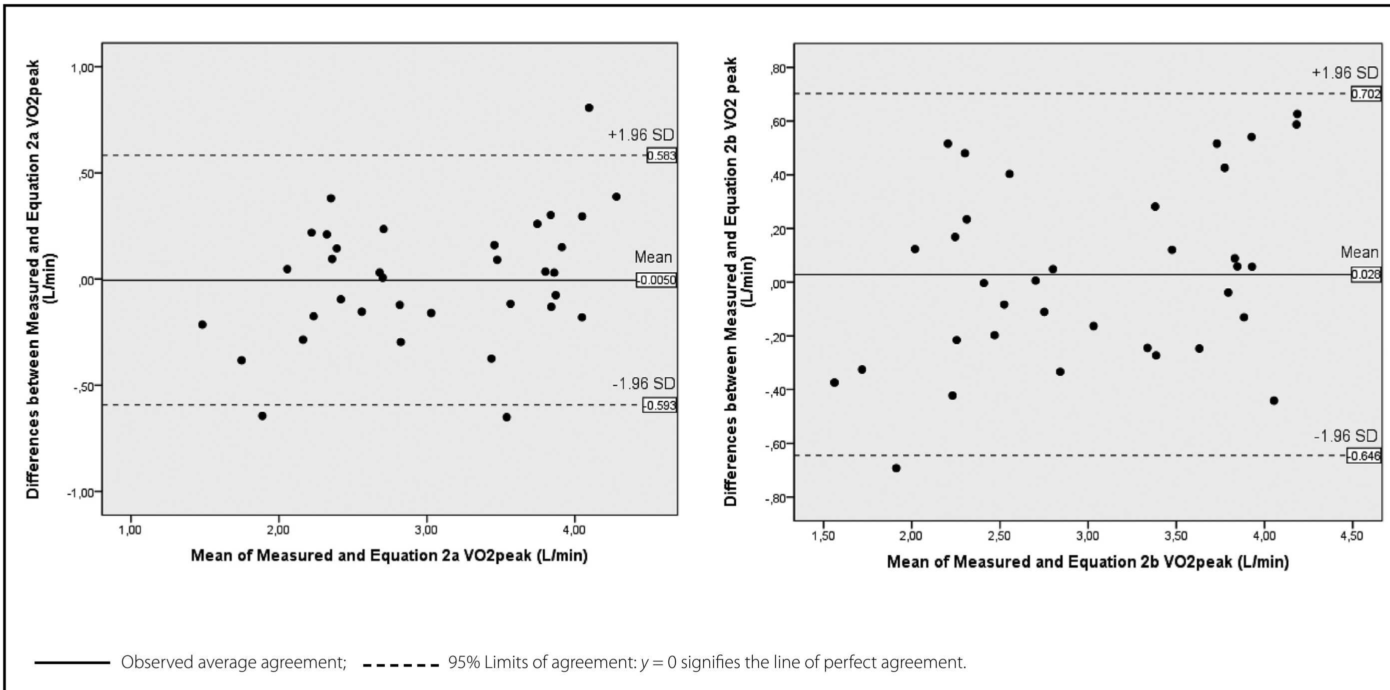


On the other hand, when the subjects were active, the equations predicted $\dot{V}O_{2peak}$ well, with the mean differences close to zero (Figure 2). ACSM and Bruce equations presented standard errors of mean of -0.496 and 0.174, respectively.

Discussion

The purpose of the present study was to develop equations for predicting $\dot{V}O_{2peak}$, with and without effort test data in overweight

Figure 2. Bland and Altman's limits-of-agreement plot between measured and estimated $\dot{V}O_{2peak}$; calculated through equations 2a (active with effort test) (left) and 2b (active without effort test) (right) in subjects of the validation group.



and obese subjects, before and after a weight loss intervention. Our results revealed that BW, %LBM, age and TIME, used in combination, is an adequate method to predict $\dot{V}O_{2peak}$ in this population, explaining almost 80% of the variation in $\dot{V}O_{2peak}$. Moreover, our data showed that equations commonly used in the literature inaccurately estimate $\dot{V}O_{2peak}$.

Several studies found differences between men and women in the oxygen consumption[28,29]. In our data, other variables, such as BW and %LBM, were better predictors than gender. Body composition, particularly muscle mass, seems to have a stronger correlation with the development of some physical capacities than genetic sexual characteristics[30,31]. Furthermore, hormone responses also seem to relate to body size, and greater values of BMI could blunt a sexual dimorphism[32]. It is important to note that many variables influence the muscle mass percentage values obtained by bioimpedance. For this reason, it is recommended that the conditions should be the same, as previously indicated in this study's methodology, to ensure better precision in the equations.

Besides BW and %LBM, age was also included as a predictor of $\dot{V}O_{2peak}$ in the equations of this study. This is in agreement with the results of Loe *et al*[29], which indicated that the oxygen consumption decreases approximately 6% every decade between the second and fifth decade of life in both genders.

Furthermore, TIME was included in the equations instead of velocity, since the Bruce protocol is not graded and time is a simple and easy variable to measure[33].

Although our equations at baseline in the validation group presented significantly different values compared to measured values, equations developed in the present study obtained the best concordance correlation coefficients and greatest determination coefficients compared to ACSM and Bruce equations. Moreover, these equations reported lower values than measured ones. Nonetheless, when working with obese individuals, who commonly have some pathology associated with excess weight, it is better to underestimate than overestimate $\dot{V}O_{2peak}$ predictions. A greater health risk could be incurred if $\dot{V}O_{2peak}$ values were overestimated, and subsequently utilized for the purpose of an intervention program[34]. ACSM's equation overestimated all $\dot{V}O_{2peak}$ values in this study as well as in other studies[35-37]. Also, determination coefficients of this study were higher than coefficients showed in other studies in different populations[8,14,28,38,39]. It is important in the selection of an equation to consider certain factors, such as population, medical conditions or medication, the mode of ergometer in terms of safety, familiarity and availability[4]. Therefore, our equations could be used in other populations with similar characteristics to our sample.

The prediction of $\dot{V}O_{2peak}$ through models without exercise can be a viable alternative for the evaluation of cardiorespiratory fitness in epidemiological studies. It is beneficial for prescribing exercise programs when is not possible to perform an effort test and to estimate $\dot{V}O_2$, and relate it to life expectancy[40]. Bruce and colleagues[19] established prediction equations without exercise, demonstrating that oxygen consumption could be predicted by variables such as gender, age, weight and physical activity habits. These authors were the first to use adults and to consider lifestyle factors such as daily physical activity, in addition to anthropometric characteristics. However, in our study Bruce equation showed significant differences in the estimated oxygen consumption after the intervention. This fact may be due to the sample used by the authors that included elderly individuals which probably altered the regression results, particularly with improving $\dot{V}O_{2peak}$ levels after a training period[19]. Furthermore, Bruce equation did not use the effort test; similar to our equations, specifically those without effort test data presented a satisfactory estimation of $\dot{V}O_{2peak}$.

According to Eston *et al*.[14] sedentary individuals are understandably unfamiliar to the associated signals of exertion emanating from acute cardiorespiratory, thermal, and metabolic changes associated with an increase in exercise intensity. Our results reported improvement in the accuracy of $\dot{V}O_{2peak}$ prediction after the intervention, as suggested by others[15,41].

Duration of the intervention allowed verifying changes in predictive variables due to training, detected by models with and without exercise. Our data contributed to the rectification of the lack of studies in clinical populations, since there are few studies specifically focused on the development of models applied to special groups. And when they are presented, they have a low potential for widespread use due to reduced samples used in their development. In addition, BIA, an easy and low cost instrument, prevents measurement errors of the evaluators and expands its use to different populations. Skinfolds, for example, require well-trained operators to adequately collect data and often use other equations to predict the percentage of fat, which increase errors[42]. In this line, dual X-ray absorptiometry is still an expensive and impractical procedure for general population.

Limitations of this study include the relatively small sample size and joint treatment for females and males. However, the difference between genders for oxygen consumption was reflected in the equations when considering the lean body mass. Additionally, we have to take into account that the predicted $\dot{V}O_{2peak}$ values would be the theoretical value obtained by the subject in a Bruce protocol test on the treadmill with indirect calorimetry.

In conclusion, equations developed in this study including the variables age, BW, %LBM and TIME, were adequate to predict $\dot{V}O_{2peak}$ in overweight and obese subjects. ACSM and Bruce equations, commonly used in the literature, showed inaccurately estimation of $\dot{V}O_{2peak}$.

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