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Comparative analysis of predictive formulas for the evaluation of functional capacity with cardiopulmonary test in professional female soccer players

Análise comparativa de fórmulas preditivas de avaliação da capacidade funcional com o teste cardiopulmonar de jogadoras de futebol profissional

Análisis comparativo de fórmulas predictivas de evaluación de la capacidad funcional con la prueba cardiopulmonar de jugadoras de fútbol profesional

Alexandre Fenley[1,2], Rafael Santiago Floriano[1,3], Tiago de Oliveira Chaves[1,2], Igor Nasser[1,2], Michel Silva Reis[1,2,3]

ABSTRACT | To compare the validity of two oxygen consumption (VO_2) prediction formulas with the values obtained through cardiopulmonary exercise test (CPT) in a treadmill with professional female soccer players. Eighteen professional female soccer players performed CPT in a treadmill with an incremental protocol. The VO_2 of the gas exchange threshold (GET) was determined, as well as at peak exercise. After that, the following formula of VO_2prediction i) VO_2 = (0.2 x velocity) + (0.9 x velocity x incline) + 3.5 – velocity, in mph and %incline); and ii) MET (metabolic equivalent) = 6xHRI-5, where HRI = maximum heart rate/resting heart rate, were applied in the same power for comparison. In the first formula, the values obtained in GET and at peak exercise were below the estimated, indicating that the formula overestimated VO_2 and, consequently, aerobic capacity and power. In the second formula, the values were below the estimated, indicating that the formula also underestimated VO_2 and, consequently, aerobic capacity and power. Given these results, the prediction formulas do not present similarity in determining the functional capacity (FC) of professional female soccer players, indicating they are not suitable for this population.

Keywords | Exercise Test; Women; Soccer.

RESUMO | Comparar a validade de duas fórmulas de predição do consumo de oxigênio (VO_2) com os valores obtidos no teste cardiopulmonar (TCP) em esteira ergométrica de jogadoras de futebol profissional. Dezoito jogadoras de futebol profissional foram submetidas ao TCP em esteira em um protocolo de carga incremental. Na sequência, foi determinado o VO2 da potência do limiar anaeróbio ventilatório (LAV) e no pico do exercício físico. Posteriormente, as fórmulas de predição de VO_2 – i) VO_2 = (0,2 x velocidade) + (0,9 x velocidade x inclinação) + 3,5 – velocidade em mph e inclinação %); e ii) MET (equivalente metabólica) = 6xHRI-5, onde HRI = frequência cardíaca máxima/frequência cardíaca de repouso – foram aplicadas nas mesmas potências para comparação. Para a primeira fórmula foi observado que tanto no LAV como no pico do TCP, os dados obtidos ficaram abaixo do previsto, sugerindo que a fórmula superestima o VO_2 e, consequentemente, a capacidade e a potência aeróbicas. Na segunda fórmula foi observado que os valores ficaram abaixo do obtido, sugerindo que a fórmula subestimou o VO_2 e, consequentemente a potência aeróbica, e mais uma vez a capacidade funcional. Diante disso, as fórmulas de predição não mostraram similaridade na determinação da capacidade funcional (CF) de jogadoras de futebol profissional, sugerindo não serem recomendadas para essa população.

Descritores | Teste de Esforço; Mulheres; Futebol.

RESUMEN | Comparar la validez de dos fórmulas para predecir el consumo de oxígeno (VO2) con los valores obtenidos en la prueba cardiopulmonar (PCP) en una cinta de correr de jugadoras de fútbol profesionales. Dieciocho jugadoras de

Study conducted at the Federal University of Rio de Janeiro (UFRJ)
[1]Research Group for Cardiopulmonary Evaluation and Rehabilitation (Gecare), Federal University of Rio de Janeiro (UFRJ) – Rio de Janeiro (RJ), Brazil
[2]Graduate Program in Physical Education, School of Physical Education and Sports, Federal University of Rio de Janeiro (UFRJ) – Rio de Janeiro (RJ), Brazil
[3]Graduate Program in Cardiology, Federal University of Rio de Janeiro (UFRJ) – Rio de Janeiro (RJ), Brazil

Corresponding address: R. Prof. Rodolpho Paulo Rocco, s/n, Ilha do Fundão – Rio de Janeiro (RJ), Brazil – CEP: 21941-913 – E-mail: msreis@hucff.ufrj.br – Phone: (21) 25622223
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fútbol profesional se sometieron al PCP en cinta de correr en un protocolo de carga incremental. En la secuencia, se determinó el VO_2 de la potencia del Umbral Anaeróbico Ventilatorio (UAV) y en el pico del ejercicio físico. Posteriormente, las fórmulas de predicción de VO_2 –i) VO_2 = (0,2 × velocidad) + (0,9 × velocidad × inclinación) + 3,5 − velocidad en mph e inclinación %); y ii) MET (equivalente metabólico) = 6xHRI−5, donde HRI = frecuencia cardiaca máxima/ frecuencia cardíaca de reposo– se aplicaron en las mismas potencias para comparación. Para la primera fórmula se observó que tanto en la UAV como en el pico del PCP, los datos obtenidos quedaron por debajo de lo previsto, sugiriendo que la fórmula sobrestima el VO_2 y, consecuentemente, la capacidad y la potencia aeróbica. En la segunda fórmula se observó que los valores quedaron por debajo de lo obtenido, sugiriendo que la fórmula subestimó el VO_2 y, consecuentemente, la potencia aeróbica, y una vez más la capacidad funcional. Por lo tanto, las fórmulas de predicción no mostraron semejanza en la determinación de la capacidad funcional (CF) de las jugadoras de fútbol profesional, sugiriendo que no son recomendadas para esa población.

Palabras clave | Prueba de Esfuerzo; Mujeres; Fútbol.

INTRODUCTION

Functional capacity (FC) is the ability to perform daily routine activities independently. This component has been used for disease diagnosis, risk stratification and prescription of exercises[1]. Given this scenario, strategies have been proposed for the implementation of assessment methods and for obtaining FC.

Among these various strategies, cardiopulmonary exercise testing (CPET) is considered the gold standard for determining FC, aerobic capacity, and aerobic power. The variables obtained allow for the identification of peak VO_2 and/or maximum, as well as metabolic thresholds (ventilatory anaerobic threshold – VAT), and respiratory compensation point – RCP), as well as the understanding of limited effort[2]. However, the equipment required for the conducting CPET are expensive and require trained staff. In addition, the environment requires specific care such as: control of temperature, humidity, barometric pressure and noise, in order to carry out the protocol in the most appropriate way possible. Given this, there are few places that specialize in this kind of exam and have all the technological tools necessary to perform the CPET[3].

On the other hand, there are already described formulas for the prediction of VO_2 during exercise in different ergometer and field tests[4,5]. However, little is known about the application of these formulas in specific populations, and the available data do not allow to extrapolate their validity for different groups. Thus, the objective of this study is to compare two formulas for the prediction of VO_2, using the VO_2 obtained through CPET during VAT and at peak exercise in professional soccer players.

METHODOLOGY

Sample

Prospective, observational and cross-sectional study A convenience sample of 18 professional female soccer players was selected. The athletes should meet the following inclusion criteria: age older than 18 years, healthy according to clinical evaluation and, finally, training regularly with their team with minimum frequency of five times per week. The clinical evaluation was performed by the doctor responsible for the team, and routine exams were conducted to assist in the exclusion of diseases, such as: laboratory tests (complete blood count, biochemistry, electrolytes) and electrocardiogram. Players with a history of cardiovascular, respiratory, neurological, orthopedic, muscular, immune or metabolic disease were excluded. This study was approved by the Ethics Committee of the Clementino Fraga Filho University Hospital, in accordance with Resolution No. 466/2012 (CAAE: 43656115.8.0000.5257). All volunteers signed the Informed Consent Form to participate in this study.

Maximum or symptom-limited cardiopulmonary exercise test

The test was performed in an air-conditioned laboratory with temperature between 22° C and 24° C and relative humidity between 50% and 60%, at the same period in the morning. The volunteers were familiar with the experimental environment and the experimenters. The CPET associated with the ergometric system aimed to evaluate the functional capacity of the athletes and identify possible electrocardiographic and hemodynamic changes caused by exercise that may contraindicate their participation in the study. In addition, the protocol adopted for conducting CPET was of type ramp on ergometric treadmill (Inbrasport Master Super ATL, Porto Alegre, RS, Brazil). Initially, the volunteers stayed two minutes at rest on the treadmill; afterwards began a warm-up period for three minutes, walking at 2 km/h and without incline. After this step, the exercise protocol was initiated with increments of 1 km/h per minute and set 1% slope, according to prior study protocol[6] until physical exhaustion — that is, the impossibility of the volunteer to run the load imposed by the ergometric treadmill. Load distribution was controlled through the measurement system of ventilatory and metabolic variables (VO_{2000} – Portable Medical Graphics Corporation, USA). Finally, the post-test recovery period consisted of three minutes at submaximal speed (3 km/h) without inclination, followed by two minutes of rest and sitting after interruption of the load.

Ventilatory and metabolic variables as well as heart rate (HR) were captured and recorded throughout the whole test period, as described below. The peripheral oxygen saturation – SpO_2 (Onyx 9500®, Uberlândia, MG, Brazil) – and the electrocardiogram – ECG (Wincardio USB, Micromed, Brasília, DF, Brazil) – in the derivations MC5, DII, DIII, aVR, aVL, and aVF modified as well as in V1 to V6 were continuously monitored during the whole experimental procedure. Blood pressure was verified in certain periods of the protocol, taking care to avoid interference in the collection of variables. It is worth mentioning that all tests were conducted by a research team composed of physiotherapists and doctors, who were attentive to the signs and/or symptoms of inadequate response to exercise. In addition, the ventilatory and metabolic variables were obtained by means of computerized system of ergospirometric analysis (VO_{2000} – Portable Medical Graphics Corporation, USA). Current volume was obtained through a Pitot pneumotachometer connected to the VO_{2000} system and attached to a face mask – selected according to the face size of the volunteer in order to be properly adjusted, preventing air leaks. After fitting the mask, a few minutes passed until the ventilation of the volunteers stabilized. The equipment provided VO_2 respiration, carbon dioxide elimination (VCO_2), pulmonary ventilation (VE), HR and SpO_2 values in real time. The values of ventilatory equivalents of oxygen (O_2) (VE/VO_2) and ventilatory equivalents of VCO_2 (VE/VCO_2), as well as the ratio of respiratory exchanges (R), the final expired fraction of O_2 (FEO_2), the final expired fraction of CO_2 ($FECO_2$), current volume (CV) and respiratory rate (RR) were also calculated and stored.

Data analysis: determining VAT and peak VO_2

For determining VAT, the V-slope method was adopted, using the curves of the correlation between VO_2 and VCO_2. Subsequently, the relationship between VO_2 and VE/FEO_2 plotted as a function of time was also used for determining VAT. For this, three independent observers conducted VAT determination in the following situations[6]: 1) VE/VO_2: lowest value of this relationship, ensuring that, from it, systematic increase occurs (point of highest ventilatory efficiency); 2) FEO_2: lowest value of this variable, from which begins a systematic increase.

The analysis section selected was based on the responses of cardiorespiratory variables, that is, from the moment they start responding to the increased intensity up to the interruption of the exercise. The qualitative control of the experiment was conducted by means of various criteria: presence or not of equilibrium in the heating stage; whether the beginning of HR responses and ventilatory variables coincided with the increase in intensity; and whether ventilatory variables showed linear behavior at the beginning of the ramp. This method was used as gold standard in the comparisons with other methods for determining VAT. Finally, to identify peak VO_2, an average of the last 30 seconds of the ramp protocol during CPET was calculated.

Prediction of VO_2

For indirect determination of VO_2, two formulas were used for prediction. The first was described as VO_2 = (0.2 x speed) + (0.9 x speed + incline) + 3.5 – speed in mph and incline in %. This strategy for prediction of functional capacity was proposed by the American College Of Sports Medicine (ACSM)[7], and has been a reference for the prescription and interpretation of the most frequently used exercise test results. The second strategy for determining FC was derived from a meta-analysis of 60 studies about direct determination of oxygen consumption in ergometric treadmill at peak exercise. The equation was described as: MET (metabolic equivalent) = 6x heart rate index (HRI), – 5, where HRI=Maximum HR/resting HR[8].

Statistical analysis

Initially, the data were submitted to a normality test (Kolmogorov-Smirnov test) and a homogeneity test (Levene test). When appropriate, the paired Student's t test was applied for parametric variables. General characteristics and those of CPET were expressed as mean ± standard deviation. The significance level was $p<0.05$ and the analyses were performed with the software SigmaPlot for Windows, version 11.0 (copyright© 2008 Systat Software, Inc).

RESULTS

Table 1 presents the characteristics of the study population. The volunteers were young and eutrophic.

Table 1. General characteristics of the volunteers studied

	Volunteers (n=18)
Age (years)	26.07 ± 4.35
Anthropometry	
Height (m)	1.63 ± 0.08
Body mass (kg)	63.37 ± 7.45
BMI* (kg/m^2)	23.84 ± 3.06
Skin folds	
Tricipital (mm)	12.6 ± 3.7
Thoracic (mm)	16.50 ± 5.73
Suprailiac (mm)	15.7 ± 5.4
Thigh (mm)	17.3 ± 5.8

Average data ± SD. *BMI: body mass index.

Table 2 presents the respiratory and metabolic variables obtained from the CPET at peak and in VAT. The HR that was obtained of dyspnea and lower limbs at peak exercise (102% of maximum HR, as stated in the Karvonen formula), according to the Brazilian Society of Cardiology[9] and the rating of perceived exertion, the Borg Scale[10], was compatible with that of high intensity exercises, indicating that the test lead to the exhaustion of the volunteers. According to the value of the relative peak VO_2, the volunteers presented regular aerobic capacity that was in accordance with the classification of the American Heart Association (AHA)[6].

Table 2. Respiratory and metabolic variables obtained from maximum and/or symptom-limited cardiopulmonary exercise testing at peak exercise.

	Volunteers (n=18)
Resting	
HR* (bpm)	72 ± 9
SBP* (mmHg)	119 ± 9
DBP* (mmHg)	70 ± 8
VO_2*(L/min)	-*
VO_2 (mL/kg.min)	-
Ventilatory anaerobic threshold	
HR (bpm)	161 ± 12
PA (mmHg)	-
VO_2 (L/min)	2.0 ± 0.4
VO_2 (mL/kg.min)	32.3 ± 5.8
Speed (km/h)	9.4 ± 1.5
Peak	
HR (bpm)	189 ± 7
PA (mmHg)	-
VO_2 (L/min)	2.9 ± 0.4
VO_2 (mL/kg.min)	45.4 ± 7.3
MET*	13 ± 2.08
Speed (km/h)	14.6 ± 1.4
Borg (0-10) – Dyspnea	8.5 ± 1.3
Borg (0-10) – LL*	8.1 ± 1.8

Average data ± SD. *HR: heart rate; SBP: systolic blood pressure; DBP: diastolic blood pressure; VO_2: maximum oxygen consumption; MET[8]: metabolic equivalent; LL: lower limbs; (-): not measured.

Figure 1 presents the relative VO_2 obtained through CPET and the expected through the ACSM[7] formula. Both with the VAT and peak of CPET, the data obtained were below the expected, suggesting that the formula overestimates VO_2 and, consequently, aerobic capacity and power.

Figure 2 presents the MET[8] prediction formula, when compared with the MET corresponding to the VO_2 obtained at peak exercise. It was observed that the prediction formula was below the result obtained, suggesting that it underestimated VO_2 and, consequently, aerobic power.

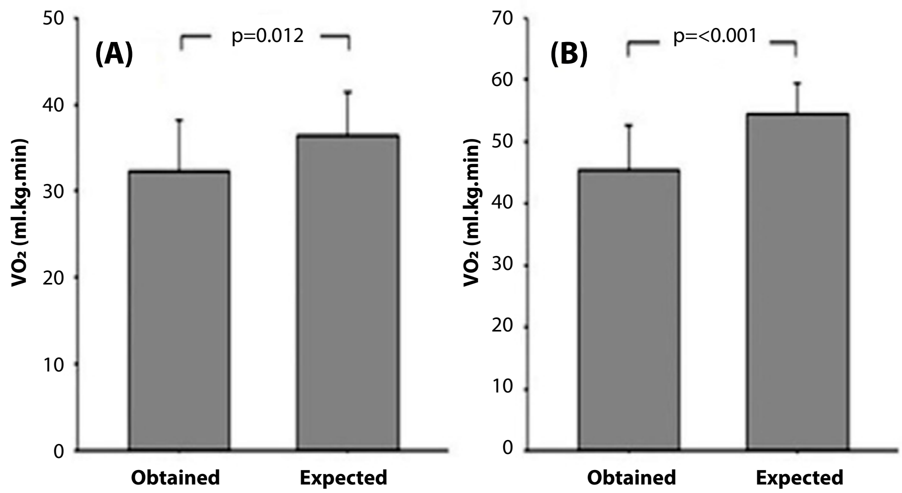

Figure 1. Obtained and expected oxygen consumption (VO_2) according to the American Heart Association[6] (AHA) for the volunteers analyzed. (A): ventilatory anaerobic threshold; (B): peak of cardiopulmonary exercise testing. Paired Student's t-test with $p<0.05$.

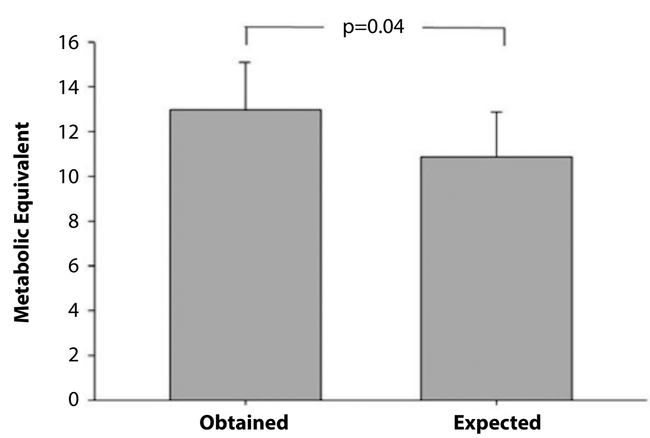

Figure 2. Obtained and expected metabolic equivalent by the formula MET[8] at peak exercise of the volunteers. Paired Student's t-test with $p<0.05$.

DISCUSSION

The main findings of our study were: i) for the ACSM[7] formula, both in VAT and at the peak CPET the data overestimated VO_2 and, consequently, aerobic capacity and power; ii) for the MET formula at peak CPET, the data underestimated VO_2 and, consequently, aerobic power. Given this scenario, the relevance of our study is in testing two stratification formulas of aerobic power and capacity, where that of ACSM[7] was the most widely adopted and the MET[8] formula the most current proposal for physical fitness assessment and prescription of physical exercises.

The volunteers were young, eutrophic, healthy and had a training routine that combined physical and tactical preparation. In addition, they participated annually from two professional championships (*Campeonato Brasileiro de Futebol and Campeonato Carioca de Futebol*). However, interestingly, the players presented an obtained VO_2 peak at peak CPET below the estimated for high performance athletes, which classified them as having regular physical fitness[7]. Such findings seem to suggest that the peak VO_2 response of the athletes may be related to two factors: i) position in the field, as defenders and strikers travel, during a 90 minute game, a distance lower than that traveled by midfielders and left back[11], justifying lower VO_2 values;

and ii) tactical training and physical preparation specific to each position[12].

During pre-season, usually professional players are subjected to cardiorespiratory and performance assessments[13]. Among these tests, obtaining VO_2 has been of particular importance for the stratification of fitness and physical preparation, as it is a factor for determining aerobic capacity. In this way, the use of formulas for VO_2 prediction has been attractive as a substitute to CPET, as CPETs are restricted to elite clubs.

In this study, the ACSM7 formula was shown not to be adequate to reflect the aerobic capacity and power of athletes. Some factors may have compromised the sensitivity of this tool. The first aspect to be considered is the application of only two variables, which may be little sensitive to reflect the population studied (speed and incline of the treadmill). The second aspect refers to mechanical efficiency, since, depending on the population studied, the pass may be influenced by height and body mass, leading the volunteers to adapt their center of mass at the imposed speed (adopting short or long passes)[14] Another aspect that must be considered is that, as it is developed for patients with cardiovascular disease, central dysfunction and, potentially, the presence of peripheral muscle dysfunction (common in heart conditions)[15], the level of these dysfunctions may have influenced in the performance of patients evaluated for the elaboration of the ACSM7 formula.

Another noteworthy consideration is the type of protocol used, since faster incrementing protocols – ramp type – can determine higher speed and inclination values when compared to slower protocols – step type[16]. Finally, another doable and relevant aspect is the presence of arm support on the treadmill. It has been shown that performing an exercise Protocol with frontal or lateral support can change metabolic demand and adaptation to the treadmill. This also occurs for the evaluated executing the protocol with free arms[17].

Regarding the MET[8] formula, in spite of the systematic review that considered using maximal and resting HR an advantage as opposed to formulas that apply speed and incline on the treadmill (such as ACSM), this study showed that the aerobic power of the athletes was underestimated. Two aspects should be considered for the application of the index: i) as most studies developing the formula were developed based on cardiac patients, the effect of the medication used (for example, β-blocker) may have influenced in the obtaining of resting HR[18]; and ii) it is logic to think, as has been established in the literature, that HR is lower in athletes with regular physical training routine[19]. Given these aspects, and the fact that the players selected for this study are of professional level, we can assume that resting HR may have been the variable that explains the underestimation of aerobic power.

On the above, it is worth reflecting on the possibility of elaborating a formula that involves more variables, taking into account the expected FC of the population studied. In this respect, it is possible to assume that variables showing the individual skills of the players could be more suitable for VO_2 differentiation with regards to field position. This way, it would be possible to evaluate in-field movement of professionals in official games or training through devices of type pedometer, global position system (GPS) or laser cameras[20], which could provide prediction equations with data. Another commonly used strategy in physical training of athletes are field tests. They are able to provide more individualized information on performance of players and could subsidize new formulas for FC prediction. A very applied test in the football world has been the YoYo test, which is able to determine VO_2[21] using the distance traveled.

According to another research[22], when comparing predictive models with formulas already described in the literature, such as ACSM[7] or the formulas advocated by other authors[3], it was shown that VO_2 could be accurately predicted using body mass index, age and workload as independent variables, when the volunteers are seemingly healthy and not athletes. In another study[23], the authors developed an equation for the Brazilian population that takes into account the following variables: gender, age, BMI and physical activity level, comparing it with formulas used in the prediction of VO_2, as that of previous studies[6,7,24]. The results indicated that both formulas overestimated the VO_2 when compared to the equation presented by them. In addition, the authors cite BMI as an imprecise variable, however, better applied to the formula than body weight and height, separately. This fact may have implications on the overestimation in VO_2 prediction.

It is worth noting some limitations of the study: i) little cooperation of athletes, making it impossible to present field test data; ii) lack of appropriate formulas for the population studied; iii) small number of volunteers, which may have influenced VO_2 values.

CONCLUSION

The FC prediction formulas showed no similarity in determining the aerobic power and capacity of professional female soccer players. In this sense, the ACSM[7] formula was shown to overestimate VO_2 in VAT and at peak exercise, compared to CPET. On the other hand, the prediction formula based on MET[8] was shown to underestimate VO_2.

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