

Exercise and non-exercise aerobic power prediction models using six-minute walk test

Vagner Raso^I, Sandra Marcela Mahecha Matsudo^{II,III}, Marcos Gonçalves de Santana^{IV,V}, Rita Aurélia Boscolo^{IV}, Valter Antônio Rocha Viana^{IV}, Viviane Grassmann^{IV}, Sergio Tufik^{IV,VI}, Marco Túlio de Mello^{IV,VI}

^I Universidade de São Paulo, Faculdade de Medicina, Instituto de Ortopedia e Traumatologia Laboratório de Estudos do Movimento (LEM-IOT-HCFMUSP), São Paulo, Brazil

^{II} Centro de Estudos do Laboratório de Aptidão Física de São Caetano do Sul (CELAFISCS), São Caetano do Sul, Brazil

^{III} Universidad Mayor, Facultad de Ciencias, Escuela de Post Grado, Santiago, Chile

^{IV} Universidade Federal de São Paulo, Centro de Estudos em Psicobiologia e Exercício (CEPE-UNIFESP), São Paulo, Brazil.

^V Universidade Federal de Goiás (UFG), Programa de Ciências Aplicadas a Saúde, Goiânia, Brazil

^{VI} Universidade Federal de São Paulo (UNIFESP), Departamento de Psicobiologia, São Paulo, Brazil

BACKGROUND AND OBJECTIVE: A simple, low-cost approach commonly used to objectively analyze the cardiorespiratory fitness of individuals with different health conditions is the six-minute walk test (6-MWT). Our objective was to develop peak aerobic power prediction using the six-minute walk test in healthy older men.

METHODS: We measured body composition (body mass [BM], body mass index [BMI], fat percentage [FAT]) and peak aerobic power breath-by-breath during cardiopulmonary exercise testing (CPET [velocity, heart rate [HR] and VO_2 at the anaerobic threshold and peak]) and a 6-MWT (distance [D], weight by distance [WxD], HR and oxygen consumption [VO_2] at peak) in 76 healthy older men aged 65 to 80 years (69.1 ± 0.3 yrs-old).

RESULTS: We observed significant correlations for VO_{2peak} during the 6-MWT as a function of WxD ($R = 0.75$, $P < 0.0005$), BM ($R = 0.56$, $P < 0.0005$), D ($R = 0.43$, $P = 0.0004$) and maximum HR ($R = 0.37$, $P = 0.001$). Distance correlated significantly with FAT ($R = -0.43$, $P = 0.005$), BMI ($R = -0.36$, $P = 0.021$) and age ($R = -0.31$, $P < 0.045$), whereas WxD correlated with BM ($R = 0.86$, $P < 0.005$). The inclusion of WxD increased the R^2 from 0.65 to 0.74 and decreased the estimative error while yielding the following equation ($R = 0.86$, standard error of the estimate (SEE) = $182.1 \text{ mL}\cdot\text{min}^{-1}$, $P < 0.0005$) to predict VO_{2peak} : $VO_{2peak} = 962.2 + (0.037 \times \text{WxD}) + (8.565 \times \text{maximum HR})$. A non-exercise model was obtained by univariate regressions but not multiple regressions. The FAT ($R = 0.43$, SEE = 702.2 m , $P < 0.005$) yielded the best model for predicting distance, i.e., distance = $702.2 - (3.067 \times \text{FAT})$.

CONCLUSION: Our prediction model seems to accurately estimate VO_{2peak} in healthy older men primarily when WxD is considered.

KEYWORDS: Aging, Cardiorespiratory Fitness, Male, Maximal Oxygen Uptake.

Raso V, Matsudo SMM, Santana MG, Boscolo RA, Viana VAR, Grassmann V, Tufik S, Mello MT. Exercise and non-exercise aerobic power prediction models using six-minute walk test. MedicalExpress (São Paulo, online). 2016;3(5):M160502

Received for Publication on June 6, 2016; First review on July 13, 2016; Accepted for publication on September 8, 2016; Online on September 30, 2016

E-mail: vagner.raso@gmail.com

INTRODUCTION

The assessment of aerobic power during the aging process has been widely studied for decades not only because of the decline of this important health variable with increasing chronological age but also because regardless of the physical activity level, sedentary subjects, active subjects and athletes exhibit decreased aerobic power as they age. Cardiorespiratory fitness has been extensively analyzed because it represents

an important predictor of functional independence in elderly individuals^{1,2} and of all causes of mortality and cardiovascular events.³

A simple, low-cost approach commonly used to objectively analyze the cardiorespiratory fitness of individuals with different health conditions is the six-minute walk test (6-MWT).⁴ This procedure has been used as a standard reference criterion because the procedure captures a significant portion of the variability in the maximum oxygen consumption (VO_{2max} : 80%) and the maximum heart rate (MHR: 86%) obtained in the cardiopulmonary exercise testing (CPET).⁵ Thus,

DOI: 10.5935/MedicalExpress.2016.05.02

Copyright © 2016 MEDICALEXPRESS. This is an open access article distributed under the terms of the creative commons attribution Non-Commercial License (creativecommons.org/licenses/by-nc/4.0/) which permits unrestricted non commercial use, distribution and reproduction in any medium, provided the original work is properly cited.

the 6-MWT can be used for individuals who are unable to satisfactorily complete a cardiopulmonary CPET in a standard stress test.^{6,7} In addition, the 6-MWT reflects the physiological demands required for daily activities.^{4,8-10} Moreover, in recent years, several studies have analyzed the possible clinical uses of the 6-MWT to measure the functional status and the cardiorespiratory fitness of healthy elderly individuals and of elderly individuals with cardiovascular and pulmonary disease and as a form of aerobic exercise for the elderly.¹¹⁻¹⁴ The 6-MWT test has been used to detect changes in the cardiorespiratory fitness of healthy elderly individuals after training¹⁵ and to predict cardiovascular events in patients with stable coronary heart disease.¹⁶

Thus, there has been an effort to establish standard reference norms that apply to a wide range of individuals.¹⁷ Most studies have sought to develop equations that predict the peak O_2 consumption (VO_{2peak}) or the distance walked during the 6-MWT as a function of variables that are intrinsic to the protocol *per se*, or are associated with clinical and sociodemographic characteristics.^{18,19} These equations seem to explain approximately one- to two-thirds of the variability.^{19,20} Clearly, the selection of the variable to be included in the model is an important factor,^{21,22} because men seem to experience twice the VO_{2max} decline over a ten-year period as compared to women (14% versus 7%)²³, and exhibit a higher mortality risk.²⁴ However, when adjusted to factors known to be involved, such as body mass, the walking distance *per se* may represent a more accurate measure of the cardiorespiratory capacity than the walking distance in elderly men²⁵ and in patients with chronic diseases.²⁶ More recently, a generalized equation has been proposed to predict peak VO_2 from the 6-MWT using data collected from over 1,000 patients with cardiopulmonary disorders.²⁷ No similar proposals for healthy elderly individuals are available. Therefore, the purpose of this study is to develop VO_{2peak} and distance prediction models using body mass (BM), the body mass index (BMI), body fat (FAT), distance (D), the body weight-walking distance product (WxD) and the maximum heart rate (MHR) in healthy elderly men.

METHODS

Volunteers

Elderly male volunteers were recruited from the community. In total, 204 volunteers were contacted by telephone and submitted to a preliminary screening, which consisted of questions regarding past and current health, drug and cigarette use and physical activity. Afterward, to determine the health status of the volunteers more precisely before they were admitted to the study, the volunteers were invited to the hospital for a detailed clinical evaluation and a standard clinical and physical

examination. The evaluation and examination included (i) a detailed assessment of current and past health status, (ii) a 12-lead electrocardiogram, (iii) a check for depression symptoms, (iv) an ascertainment of the ability to self-report and perform basic and instrumental activities of daily living, (v) an evaluation of body composition and (vi) laboratory parameters. The volunteers who were under treatment for acute or chronic cardiovascular, pulmonary or metabolic disease or using medication that influences the cardiovascular and pulmonary system were excluded. The following were additional reasons to exclude a volunteer were: (i) central or peripheral nervous system disorders, (ii) malnourishment or obesity, (iii) smoking, (iv) current or past cancer treatment, (v) surgery of any type during the previous three months, (vi) prescribed bed rest during the previous three months or (vii) any orthopedic disturbances would limit performance during a CPET.

Seventy-six elderly volunteers aged 65 to 80 years were included. The volunteers were cleared for participation and expressed their willingness to submit to the conditions of the experiment. They were informed regarding the procedures and risks before reading and providing written consent. This study was approved by the research ethics committee of our university (#1592/07).

Body composition

We measured height using an electronic scale (Bod Pod®, Life Measurement Inc., USA). The body mass index (BMI) was calculated by dividing the total body mass by the squared height (kg/m^2). The body fat percentage (FAT%) and the fat-free mass were obtained by plethysmography (Bod Pod®, Life Measurement Inc., USA). The measurement procedures followed the criteria described by equipment manuals and literature.²⁸

Cardiopulmonary exercise testing

The peak oxygen consumption (VO_{2peak}) and the anaerobic threshold (AT) were determined using a CPET performed on a treadmill (Life Fitness®, 9700 HR, USA). The treadmill speed was initially set at $1.6 km \cdot h^{-1}$; this was followed by increases of $0.8 km \cdot h^{-1}$ increments in speed and 1% increments in slope every two minutes until voluntary exhaustion.⁵ The expired gas samples were analyzed breath-by-breath at 20-second intervals, using a metabolic portable system (K4b2, Cosmed®, Italy). Before each test, the equipment was calibrated according to the manufacturer's recommendations. The heart rate was recorded simultaneously using a portable system (Polar®, Electro OU, Finland). VO_{2peak} was achieved when the following criteria were satisfied: (i) respiratory exchange ratio (RER) > 1.10, (ii) the age-predicted maximum heart rate (MHR) was reached, (iii) volitional fatigue and (iv) signs of exhaustion toward the test's end (unsteady gait, hyperpnea, sweating, facial flushing and grimacing).²⁹

The anaerobic threshold (AT) was evaluated through the V-slope method, using a computerized regression analysis of the slopes of the CO₂ uptake (VCO₂) versus the O₂ uptake (VO₂) plot, which detects the beginning of the excess CO₂ output generated by the buffering of [H⁺]. The respiratory compensation point (RCP) was detected by examining the minute ventilation per VCO₂ plot.³⁰

Six-minute walk test

The volunteers were instructed to walk at regular speed as far as possible carrying a portable metabolic system (K4b², Cosmed, Italy) for six minutes. Three tests were performed to control for the learning effect and the data reliability.⁵ The first two tests were performed on the same day separated by a one-hour interval. The third test was performed after 24 hours. The 6-MWT was performed in a 20 m corridor that was clear of obstacles. The corridor length was marked every meter, and the volunteers were informed every 60 seconds regarding the remaining test time.^{4,31} The participants were instructed to walk at a self-selected regular pace to cover as much distance as they could during the allotted time. If necessary, slowing and stopping to rest were allowed. At the end of each minute, the participants were provided feedback on the elapsed time and standardized encouragement in the form of statements such as “you are doing well, keep it up” and “do your best”. The VO_{2peak} was established as described in the previous section. The total walked distance was recorded in meters, and the longest distance of the two tests was used. The body weight-walking distance product was calculated by multiplying the body weight by the distance (W x D, kg·m).²⁵

Statistical analysis

The Kolmogorov-Smirnov test was used to analyze the data normality. A one-way analysis of variance with Bonferroni post-hoc compared subjects grouped into quartiles according to the 6-MWT VO_{2peak} (i.e., P₀-P₂₅, P₂₅-P₇₅ and P₇₅-P₁₀₀). The Pearson product-moment correlation coefficient was used to determine the association of VO_{2peak} with BM, BMI, body fat, D, WxD and MHR. Univariate regression analysis was used to investigate the associations of age with all of the other variables and the body weight-walking distance product as a function of VO₂ at the anaerobic threshold and peak. In addition, hierarchical multiple regression analyses were performed to develop exercise (VO_{2peak}) and non-exercise (D and WxD) prediction equation models as a function of BM, BMI, FAT, D, WxD and MHR. All of the analyses were performed using the *Predictive Analytics Software* 17.0 version for Windows package (SPSS, Inc., USA). The data are presented as the mean ± standard error. Significance was set at p < 0.05.

RESULTS

General characteristics

Homogeneity of the population was observed throughout the variables of age and body composition (Table 1). However, VO₂ at the anaerobic threshold and peak (CPET and 6-MWT) were significantly higher in individuals at highest quartile (P₇₅-P₁₀₀). Similar results were observed for distance and the MHR during the 6-MWT (Table 2).

Table 1 - Age and body composition of the elder healthy men

	Mean ± Standard deviation
Age (years)	69.1 ± 3.3 (65.0 - 80.0)
Body mass (kg)	74.0 ± 11.0 (53.1 - 104.8)
Body height (m)	1.69 ± 0.01 (1.52 - 1.85)
Body mass index (kg·m ²)	25.8 ± 3.4 (17.0 - 34.9)
Lean body mass (kg)	53.7 ± 7.3 (39.2 - 74.3)
Body fat (%)	26.8 ± 7.3 (7.6 - 45.3)

Age effects

We observed an age effect on the anaerobic threshold (velocity: β = -0.39, P = 0.010], heart rate ([β = -0.88, P = 0.0005]), MHR during the CPET ([β = -0.38, P = 0.012]) and D during the 6-MWT ([β = -0.31, P = 0.045]) (data not shown).

Body weight-walking distance product

We analyzed the product of body weight and distance (WxD) as a parameter that could reflect the work rate during the 6-MWT. A significant association was observed between WxD vs. the anaerobic threshold (r = 0.63, β = 0.018 ± 0.004 and P < 0.0005) and VO_{2peak} (r = 0.73, β = 0.031 ± 0.005, P < 0.0005) regardless of age (data not shown).

Univariate correlations

Peak oxygen uptake during the CPET correlated significantly with the corresponding peak oxygen uptake during the 6-MWT, as shown in Figure 1.

Figure 2 exhibits the correlation of various parameters of the 6MWT with the respective VO_{2peak}: the best observed correlation is between distance x weight and peak oxygen consumption. However, distance, maximum heart rate and body mass also correlated significantly.

Figure 3 illustrates the expected inverse correlations between body fat, body mass and age with travelled distance.

Multiple regression analysis

We developed exercise and non-exercise models. The first strategy was based on a prediction equation to

Table 2 - Cardiopulmonary exercise parameters according to percentile for VO_{2peak} at 6MWT and entire group*.

	VO_{2peak} ($L \cdot min^{-1}$) at 6MWT			Entire group
	P_0-P_{25} (a)	$P_{25}-P_{75}$ (b)	$P_{75}-P_{100}$ (c)	
CPET at anaerobic threshold				
Velocity ($km \cdot h^{-1}$)	4.1 ± 0.2 (3.2 - 4.8)	4.1 ± 0.2 (2.4 - 5.6)	4.4 ± 0.2 (3.2 - 4.8)	4.2 ± 0.1 (2.4 - 5.6)
Heart rate (bpm)	98.0 ± 3.4 (79.0 - 110.0)	102.1 ± 2.5 (84.0 - 120.0)	98.2 ± 4.9 (75.0 - 118.0)	100.3 ± 1.9 (75.0 - 120.0)
$\dot{V}O_2$ ($L \cdot min^{-1}$)	1.1 ± 0.1 (0.9 - 1.3) ^c	1.1 ± 0.1 (0.83 - 1.3) ^c	1.4 ± 0.1 (0.9 - 1.7)	1.2 ± 0.1 (0.8 - 1.7)
CPET at peak				
Velocity ($km \cdot h^{-1}$)	6.9 ± 0.2 (5.6 - 8.0)	7.2 ± 0.1 (5.6 - 8.0)	7.2 ± 0.0 (7.2 - 7.2)	7.1 ± 0.1 (5.6 - 8.0)
Heart rate (bpm)	148.1 ± 5.6 (112.0 - 171.0)	152.1 ± 3.2 (125.0 - 176.0)	153.9 ± 5.7 (129.0 - 177.0)	151.5 ± 2.5 (112.0 - 177.0)
$\dot{V}O_2$ ($L \cdot min^{-1}$)	1.9 ± 0.1 (1.5 - 2.3) ^c	2.0 ± 0.1 (1.5 - 2.6) ^c	2.5 ± 0.1 (2.1 - 2.7)	2.1 ± 0.1 (1.5 - 2.7)
6MWT at peak				
Distance (m)	589.0 ± 14.8 (532.0 - 675.0) ^c	620.6 ± 9.2 (539.0 - 716.5)	653.8 ± 20.7 (562.0 - 765.0)	620.2 ± 8.1 (532.0 - 765.0)
Body weight by distance (kg·m)	40.2 ± 1.5 (33.4 - 49.4)	44.6 ± 1.1 (35.9 - 53.1)	54.2 ± 2.1 (46.3 - 66.2)	45.6 ± 1.3 (33.4 - 66.3)
Heart rate (bpm)	123.6 ± 4.4 (96.0 - 164.0) ^c	133.4 ± 2.6 (105.0 - 166.0)	141.6 ± 3.1 (109.0 - 170.0)	133.0 ± 2.0 (96.0 - 170.0)
$\dot{V}O_2$ ($L \cdot min^{-1}$)	1.5 ± 0.1 (1.3 - 1.6) ^{bc}	1.8 ± 0.1 (1.6 - 2.1) ^c	2.3 ± 0.1 (2.1 - 2.8)	1.9 ± 0.1 (1.3 - 2.8)

*The dark shading indicates significant differences. CPET: cardiopulmonary exercise testing; AT: anaerobic threshold; 6MWT: six-minute walk test; $\dot{V}O_2$: oxygen uptake

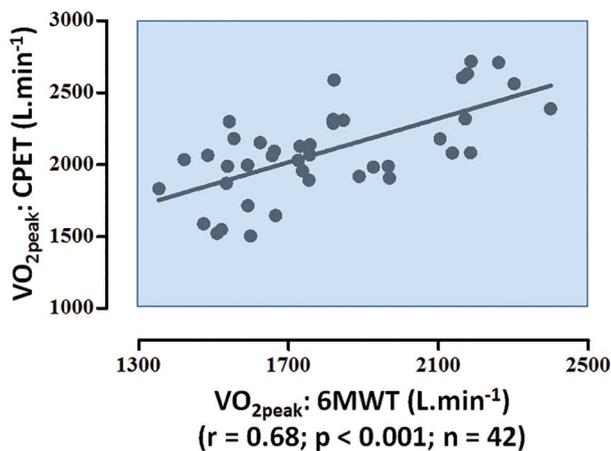


Figure 1 - The high level of correlation between VO_{2peak} during the six-minute walk test and cardiopulmonary exercise test shows that the 6MWT is a reliable predictor of aerobic power.

estimate VO_{2peak} predominantly as a function of the 6-MWT variables. Subsequently, we tested the hypothesis of a non-exercise prediction equation to estimate either distance (D) or the WxD product (Table 3). All of the variables of the respective models independently explained VO_{2peak} . D or WxD. When estimating VO_{2peak} , the inclusion of WxD increased the R^2 from 0.65 to 0.74, which represents a significant 9% increase in the explained variance of VO_{2peak} . Moreover, there was an important decrease in estimative error, which yielded the following equation ($R = 0.86$, $SEE = 182.1 \text{ mL} \cdot \text{min}^{-1}$ and $P < 0.0005$) for predicting VO_{2peak} :

$VO_{2peak} = 962.2 + (0.037 \times WxD) + (8.565 \times MHR)$, where WxD is the body weight-walking distance product in kg·m and MHR is the maximum heart rate in bpm. A non-exercise model was obtained by univariate regressions but not by multiple regressions. Body fat percentage ($R = 0.43$, $SEE = 702.2m$, $P < 0.005$) yielded the best model for predicting distance, i.e., $D = 702.2 - (3.067 \times FAT)$, where FAT represents the percentage of body fat.

DISCUSSION

An obstacle to measuring the aerobic power of elderly individuals (either in groups or clinical care) has been the lack of a practical, safe, low-cost and scientifically valid method to assess functional status, cardiovascular fitness and the impact of comorbidities on such individuals and capable of providing a parameter for the prescription of exercise. The present study proposes a novel model for predicting aerobic power in healthy elderly men. Our results provide normative data related to cardiopulmonary parameters for maximal CPET and for the 6-MWT in clinically healthy and physically inactive elderly men. The data resulting from this study can serve as an important reference standard for this age range because the strict eligibility criteria employed in the present study excluded participants with cardiopulmonary, metabolic or musculoskeletal disorders. In addition, these data support the hypothesis that WxD can be used as an indicator of the submaximal or maximal workload developed during the 6-MWT. Additionally, our data support the hypothesis

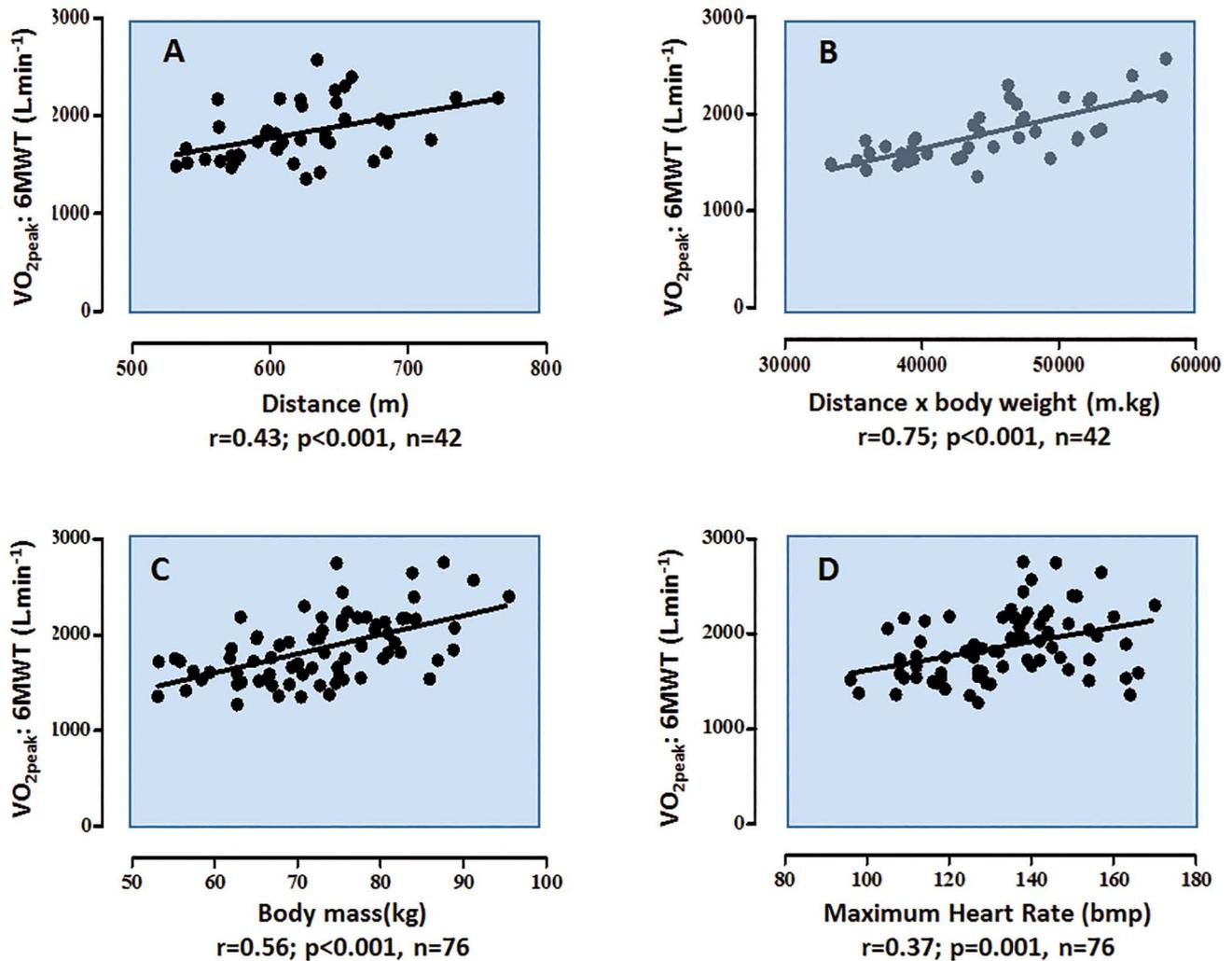


Figure 2 - The four parameters relating to the six-minute walk test correlate significantly with peak O_2 consumption; the best correlation occurred for the distance x weight product.

that the VO_{2peak} achieved during the 6-MWT is significantly associated with the VO_{2peak} recorded in a maximal CPET performance, which facilitated the development of a VO_{2peak} prediction model with satisfactory accuracy. It was also possible to develop other models to estimate distance (based on a non-exercise pattern) but with low accuracy.

The absolute aerobic power (i.e., L·min⁻¹) was considered as the main outcome variable in our models. We tried to avoid potential multicollinearity between the BM and the WxD product in the models which considered the relative aerobic power (i.e., mL·kg⁻¹·min⁻¹). Therefore, the effect of the body mass in our models is not being overestimated by redundancy. Our analyses demonstrate that each of the predictor variables used in this study was independently related to the distance walked in the 6-MWT and the VO_{2peak} . However, the best models were extracted when VO_{2peak} was the main outcome variable.

There are numerous indirect methods to estimate VO_{2peak} in elderly subjects that result in good accuracy with correlations reaching up to 0.97.^{21,22,32,33} These results are similar to the findings of our study for both of the generated exercise models, particularly compared with studies on the 6-MWT.³³ However, some differences in the magnitude of correlations may be partly explained by the type and the number of predictor variables included in the models.^{21,22} Moreover, there seems to be a direct relationship between the severity of the clinical condition and the strength of the correlation in the analysis between the walked distance and the VO_{2peak} .^{4,34,35} A linear mixed-model analysis was used to determine the SEE of the 6-MWT to estimate the peak oxygen uptake; the formula can be useful to compare the peak aerobic capacity without the CPET and can be applied to monitor the course of several cardiovascular and pulmonary diseases and the efficacy of potential treatments.²⁷

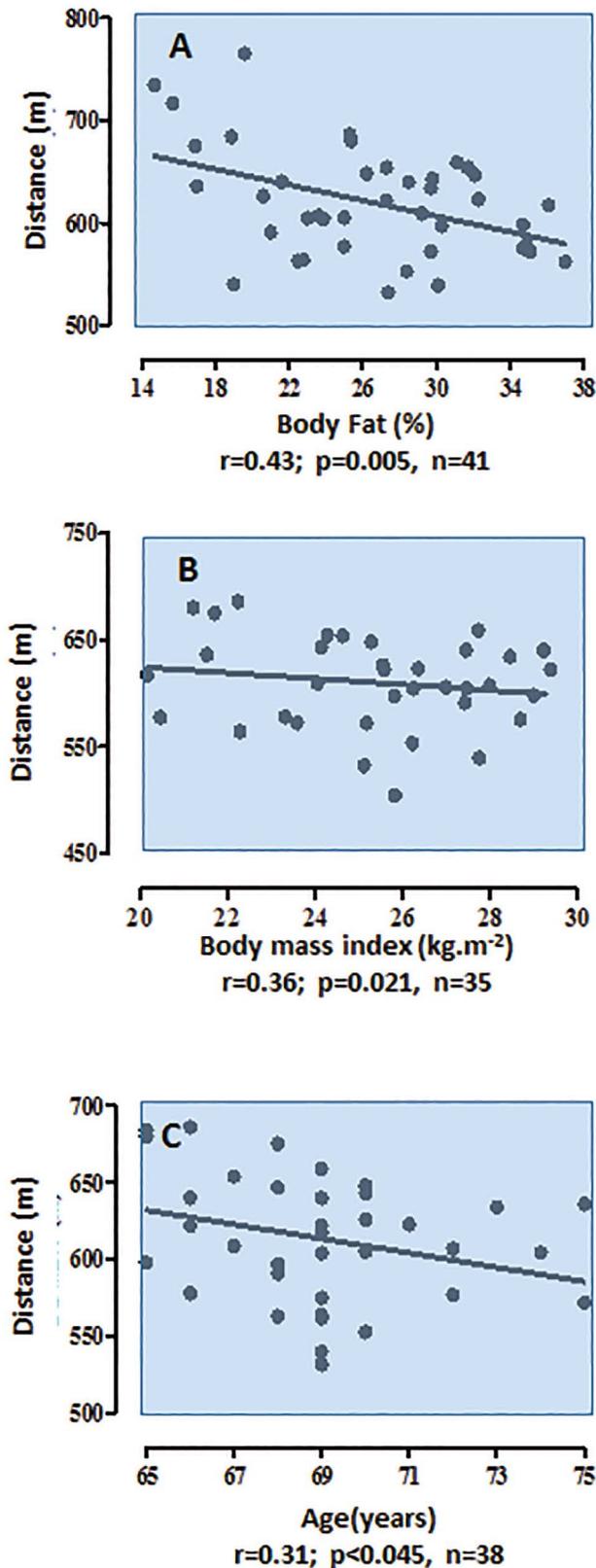


Figure 3 - The percentage of body fat, body mass index and age correlate inversely with travelled distance.

Although the $\text{VO}_{2\text{peak}}$ prediction model developed in the present study has satisfactory accuracy, the extrapolation of the results could be limited because the elderly represent a select group of individuals. Therefore, future studies are required to determine the stability of the proposed model's $\text{VO}_{2\text{peak}}$ prediction for individuals whose characteristics are substantially different from our sample amplitude (e.g., physical activity level and fitness, health condition and disease severity).

The present study is the first to demonstrate that WxD is a more important $\text{VO}_{2\text{peak}}$ predictor in elderly individuals than weight and distance separately. In addition to characterizing the work rate performed during the 6-MWT^{25,26}, this strategy improved the regression model's ability to predict $\text{VO}_{2\text{peak}}$. The WxD parameter more accurately reflects the workload of walking than D and therefore should be used as an evaluation criterion of cardiorespiratory fitness in the absence of gas exchange analysis.²⁵ However, there may be other sociodemographic (e.g., gender) or physiological (e.g., resting heart rate) variables that would facilitate the development of a non-exercise prediction model to satisfactorily predict WxD. For instance, chronological age seems to represent an important discriminatory parameter of cardiopulmonary capacity, especially among elderly individuals.³⁶ Moreover, a significant proportion of the variability of the cardiorespiratory capacity estimate may be explained by anthropometric and sociodemographic variables.²⁶

Therefore, we may conclude that our prediction model seems to be an accurate strategy to estimate $\text{VO}_{2\text{peak}}$ in healthy older men primarily when WxD is considered. The new exercise prediction model derived proposed in this study can be used to estimate $\text{VO}_{2\text{peak}}$ in older men. However, further studies should develop non-exercise models, particularly models based on the WxD parameter.

■ CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest with respect to this project.

■ AUTHOR CONTRIBUTIONS

Study concept and design: Raso V. Acquisition of data: Santana MG, Boscolo RA, Viana VAR and Grassmann V. Analysis and interpretation of data: Raso V. Drafting of the manuscript: Raso V. Critical revision of the manuscript for important intellectual content: Raso V. Statistical analysis: Raso V. Administrative, technical, or material support: Matsudo SMM, Santana MG, Boscolo RA, Viana VAR, Grassmann V, Tufik S and Mello MT. Study supervision: Matsudo SMM, Tufik S and Mello MT.

Table 3 - Exercise and non-exercise prediction models to estimate $\dot{V}O_{2peak}$, distance or body weight-walking distance product as a function of body mass, body mass index, body fat, distance, body weight-walking distance product, and maximum heart rate.

Prediction model	Variable	Coefficients	SE	β	P	Constant	R(R ²)	SEE	P
Exercise model									
$\dot{V}O_{2peak}$ (L·min ⁻¹)	DxW	0.037	0.004	.777	.0005	962.2	0.86(0.74)	182.1 ^a	.0005
	MHR	8.565	1.655	.422	.0005				
	Body mass	20.302	3.084	.642	.0005				
$\dot{V}O_{2peak}$ (L·min ⁻¹)	Distance	2.538	0.689	.383	.001	2064.0	0.80(0.65)	215.8a	.0005
	MHR	6.431	2.115	.317	.004				
Non-exercise model									
Distance	Body fat	-3.067	1.039	-.427	.005	702.2	0.43(0.18)	48.2 ^b	.005
Distance	BMI	-5.581	2.318	-.356	.021	764.4	0.36(0.13)	49.8 ^b	.021
DxW	BMI	1149.9	292.8	.528	.0005	15855.3	0.53(0.28)	6294.7 ^b	.0005

SE: standard error; SEE: standard error of the estimate (a: mL·min⁻¹; b: meters); MHR: maximum heart rate; BMI: body mass index; DxW: body weight-walking distance product.

EQUAÇÕES DE PREDIÇÃO DA POTÊNCIA AERÓBICA USANDO O TESTE DE CAMINHADA DE SEIS MINUTOS

OBJETIVO: O teste de caminhada de seis minutos (TC6M) é uma estratégia simples e de baixo custo operacional que objetivamente mede a aptidão cardiorrespiratória de indivíduos com diferentes condições de saúde. Nosso objetivo foi desenvolver equações de predição da potência aeróbica em homens idosos saudáveis usando o TC6M.

MÉTODOS: Foram medidos a composição corporal (massa corporal [MC], índice de massa corporal [BMI], porcentagem de gordura [%G]) e potência aeróbica de pico através de teste cardiopulmonar de exercício máximo (velocidade, frequência cardíaca [FC] e consumo de oxigênio [$\dot{V}O_2$] no limiar anaeróbico e no pico) e através do TC6M (distância [D], produto massa corporal x distância, FC e $\dot{V}O_2$ de pico) em 76 idosos saudáveis com idade entre 65 e 80 anos (69.1 ± 0.3 anos).

RESULTADOS: Foram observadas correlações significativas para $\dot{V}O_{2pico}$ no TC6M em função do produto MCxD ($R = 0,75, P < 0,0005$), MC ($R = 0,56, P < 0,0005$), D ($R = 0,43, P = 0,0004$) e FC máxima ($R = 0,37, P = 0,001$). A correlacionou-se significativamente com %G ($R = -0,43, P = 0,005$), IMC ($R = -0,36, P = 0,021$) e idade ($R = -0,31, P < 0,045$), enquanto que a MCxD correlacionou-se com MC ($R = 0,86, P < 0,005$). A inclusão da MCxD aumentou o R^2 de 0,65 para 0,74 e diminuiu o erro padrão da estimativa (EPE) gerando a equação ($R = 0,86, EPE = 182,1 \text{ mL}\cdot\text{min}^{-1}, P < 0,0005$) para a predição do $\dot{V}O_{2peak}$: $\dot{V}O_{2peak} = 962,2 + (0,037 \times MCxD) + (8,565 \times FC \text{ máxima})$. Foi também gerado um modelo preditivo não dependente de exercício através de regressão univariada, mas não múltipla. A %G ($R = 0,43, EPE = 702,2 \text{ m}, P < 0,005$) gerou o melhor modelo para a predição da distância, i.e., distância = $702,2 - (3,067 \times \%G)$.

CONCLUSÃO: Nossos modelos de predição parecem estimar precisamente o $\dot{V}O_{2pico}$ de idosos saudáveis, especialmente quando a MCxD é considerada.

PALAVRAS-CHAVE: Aptidão cardiorrespiratória, consumo máximo de oxigênio, envelhecimento, homem.

REFERENCES

- Shephard RJ. Maximal oxygen intake and independence in old age. *Br J Sports Med.* 2009;43:342-6. doi: 10.1136/bjsm.2007.044800.
- Paterson DH, Govindasamy D, Vidmar M, Cunningham DA, Koval JJ. Longitudinal study of determinants of dependence in an elderly population. *J Am Geriatr Soc.* 2004;52:1632-8. DOI: 10.1111/j.1532-5415.2004.52454.x
- Kodama S, Saito K, Tanaka S, Maki M, Yachi Y, Asumi M, et al. Cardio-respiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA.* 2009;301:2024-35. doi: 10.1001/jama.2009.681.
- American Thoracic Society. Guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002ATS Statement: Guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002;166:111-7. DOI: 10.1164/rccm.166/1/111
- Kervio G, Carre F, Ville NS. Reliability and intensity of the six-minute walk test in healthy elderly subjects. *Med Sci Sports Exerc* 2003;35:169-74. DOI: 10.1249/01.MSS.0000043545.02712.A7
- Rostagno C, Boddi V, Gensini GF. 6MWT predicts survival better than CPET in patients with stable cardiomyopathy. *Br J Med Med Res* 2012; 2:386-95.
- Kierkegaard M, Tollbäck A. Reliability and feasibility of the six minute walk test in subjects with myotonic dystrophy. *Neuromuscul Disord* 2007;17:943-9. DOI: 10.1016/j.nmd.2007.08.003
- Braunschweig F, Linde C, Adamson PB, Magalski A, Erdmann E, Kjellstrom B, et al. Continuous central haemodynamic measurements during the six-minute walk test and daily life in patients with chronic heart failure. *Eur J Heart Fail* 2009;11:594-601. DOI: 10.1093/eurjhf/hfp045
- Mudge S, Stott NS. Timed walking tests correlate with daily step activity in persons with stroke. *Arch Phys Med Rehabil* 2009;90:296-301. doi: 10.1016/j.apmr.2008.07.025.
- Witham MD, Argo IS, Johnston DW, Struthers AD, McMurdo ME. Predictors of exercise capacity and everyday activity in older heart failure patients. *Eur J Heart Fail* 2006;8:203-7. DOI: 10.1016/j.ejheart.2005.03.008
- Doutreleau S, Marco P, Talha S, Charloux A, Piquard F, Geny B. Can the six-minute walk test predict peak oxygen uptake in men with heart transplant?. *Arch Phys Med Rehabil* 2009;90:51-7. doi: 10.1016/j.apmr.2008.07.010.

12. Zainuldin M, Knoke D, Mackey M, Luxton N, Alison J. Prescribing cycle training intensity from the six-minute walk test for patients with COPD. *BMC Pulm Med* 2007;7:9-17. DOI: 10.1186/1471-2466-7-9
13. Enright PL, McBurnie MA, Bittner V, Tracy RP, McNamara R, Arnold A, et al. The 6-min walk test. A quick measure of functional status in elderly adults. *Chest* 2003; 123:387-98. DOI: 10.1378/chest.123.2.387
14. Opasich C, Pinna G, Mazza A, Febo O, Riccardi R, Riccardi PG, et al. Six-minute walking performance in patients with moderate-to-severe heart failure. *Eur Heart J* 2001;22:488-96. DOI: 10.1053/euhj.2000.2310
15. Santana M, Lira C, Passos G, Santos C, Silva AH, Yoshida CH, et al. Is the six-minute walk test appropriate for detecting changes in cardiorespiratory fitness in healthy elderly men? *J Sci Med Sport* 2012;15: 259-65. doi: 10.1016/j.jsams.2011.11.249.
16. Beatty A, Schiller N, Whooley M. Six-minute walk test as a prognostic tool in stable coronary heart disease: data from the heart and soul study. *Arch Inter Med.* 2012; 172:1096-102. doi: 10.1001/archintermed.2012.2198.
17. Casanova C, Celli BR, Barria P, Casas A, Cote C, de Torres JP, et al. The 6-min walk distance in healthy subjects: reference standards from seven countries. *Eur Respir J* 2011;37:150-6. doi: 10.1183/09031936.00194909.
18. Jenkins S, Cecins N, Camarri B, Williams C, Thompson P, Eastwood P. Regression equations to predict 6-minute walk distance in middle-aged and elderly adults. *Physiother Theory Pract* 2009;25:516-22. doi: 10.3109/09593980802664711.
19. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. *Am J Resp Crit Care Med* 1998;158(5Pt1):1384-7.
20. Troosters T, Gosselink R, Decramer M. Six minute walking distance in healthy elderly subjects. *Eur Resp J* 1999;14:270-4. DOI: 10.1034/j.1399-3003.1999.14b06.x
21. Cao ZB, Miyatake N, Higuchi M, Ishikawa-Takata K, Miyachi M, Tabata I. Prediction of VO_{2max} with daily step counts for Japanese adult women. *Eur J Appl Physiol* 2009;105:289-96. doi: 10.1007/s00421-008-0902-8.
22. Cao ZB, Miyatake N, Higuchi M, Miyachi M, Ishikawa-Takata K, Tabata I. Predicting VO_{2max} with an objectively measured physical activity in Japanese women. *Med Sci Sports Exerc* 2010;42:179-86. doi: 10.1249/MSS.0b013e3181af238d.
23. Stathokostas L, Jacob-Johnson S, Petrella RJ, Paterson DH. Longitudinal changes in aerobic power in older men and women. *J Appl Physiol* 2004;97:781-9. DOI: 10.1152/jappphysiol.00447.2003
24. Oksuzyan O, Juel K, Vaupel JW, Christensen K. Men: good health and high mortality. Sex differences in health and aging. *Aging Clin Exp Res* 2008;20:91-102.
25. Chuang M-L, Lin I-F, Wasserman K. The body weight-walking distance product as related to lung function, anaerobic threshold and peak VO_2 in COPD patients. *Resp Med* 2001;95:618-26.
26. Iwama AM, Andrade GN, Shima P, Tanni SE, Godoy I, Dourado VZ. The six-minute walk test and body weight-walk distance product in healthy Brazilian subjects. *Braz J Med Biol Res* 2009;42:1080-5. DOI: 10.1590/S0100-879X2009005000032
27. Ross R, Murthy J, Wollak I, Jackson A. The six minute walk test accurately estimates mean peak oxygen uptake. *BMC Pulm Med* 2010;10:31-39. doi: 10.1186/1471-2466-10-31.
28. Fields DA, Hunter GR. Monitoring body fat in the elderly: application of air-displacement plethysmography. *Curr Opin Clin Nutr Metab Care* 2004;7:11-4. DOI: 10.1097/01.mco.0000109597.04238.f7
29. American College of Sports Medicine. General principles of exercise prescription. In: Thompson WR, Gordon NF, Pescatello LS, editors. *ACSM's Guidelines for Exercise Testing and Prescription*. Philadelphia: Williams & Wilkins; 2010.p.152-175
30. Beaver WL, Wasserman K, Whipp BJ. A new method for detecting anaerobic threshold by gas exchange. *J Appl Physiol* 1986;60:2020-7.
31. Enright PL. The six-minute walk test. *Respir Care* 2003;48:783-5.
32. Akalan C, Robergs RA, Kravitz L. Prediction of VO_{2max} from an individualized submaximal cycle ergometer protocol. *J Exerc Physiol Online* 2008;11:1-17.
33. Huggett DL, Connelly DM, Overend TJ. Maximal aerobic capacity testing of older adults: A critical review. *J Gerontol A BiolSci Med Sci* 2005;60:57-66.
34. Solway S, Brooks D, Lacasse Y, Thomas S. A qualitative systematic overview of the measurement properties of functional walk tests used in the cardiorespiratory domain. *Chest* 2001;119:256-70. DOI: 10.1378/chest.119.1.256
35. Guyatt GH, Thompson PJ, Berman LB, Sullivan MJ, Townsend M, Jones NL, et al. How should we measure function in patients with chronic heart and lung disease? *J Chronic Dis* 1985;38:517-24. DOI: 10.1016/0021-9681(85)90035-9
36. Hovington CL, Nadeau S, Leroux A. Comparison of walking parameters and cardiorespiratory changes during the 6-minute walk test in healthy sexagenarians and septuagenarians. *Gerontology* 2009;55:694-701. doi: 10.1159/000240015.