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Metabolic and clinical comparative analysis of treadmill six-minute walking test and cardiopulmonary exercise testing in obese and eutrophic women*

Análise clínica e metabólica comparativa entre o teste de caminhada de seis minutos e o teste de exercício cardiopulmonar em mulheres obesas e eutróficas

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Abstract

Background: Impaired exercise tolerance is directly linked to decreased functional capacity as a consequence of obesity. **Objectives:** To analyze and compare the cardiopulmonary, metabolic, and perceptual responses during a cardiopulmonary exercise test (CPX) and a treadmill six-minute walking test (tread6MWT) in obese and eutrophic women. **Methods**: Twenty-nine female participants, aged 20–45 years were included. Fourteen were allocated to the obese group and 15 to the eutrophic group. Anthropometric measurements and body composition assessment were performed. **Results:** In both tests, obese women presented with significantly higher absolute oxygen uptake, minute ventilation, and systolic and diastolic blood pressure; they also presented with lower speed, distance walked, and oxygen uptake corrected by the weight compared to eutrophics. During the maximal exercise test, perceived dyspnea was greater and the respiratory exchange ratio was lower in obese subjects compared to eutrophics. During the submaximal test, carbon dioxide production, tidal volume, and heart rate were higher in obese subjects compared to eutrophic women. When analyzing possible correlations between the CPX and the tread6MWT at peak, there was a strong correlation for the variable heart rate and a moderate correlation for the variable oxygen uptake. The heart rate obtained in the submaximal test was able to predict the one obtained in the maximal test. Bland-Altman plots demonstrated the agreement between both tests to identify metabolic and physiological parameters at peak exercise. **Conclusions:** The six-minute walking test induced ventilatory, metabolic, and cardiovascular responses in agreement with the maximal testing. Thus, the six-minute walking test proves to be important for functional evaluation in the physical therapy routine.

Keywords: obesity; exercise test; physical fitness; physical therapy.

Resumo

Contextualização: A reduzida tolerância ao exercício está relacionada à diminuída capacidade funcional consequente da obesidade. **Objetivos:** Analisar e comparar respostas cardiopulmonares, metabólicas e subjetivas durante um teste de esforço cardiopulmonar e um teste de caminhada de seis minutos na esteira em mulheres obesas e eutróficas. **Métodos:** Foram incluídas 29 mulheres com idades entre 20 e 45 anos. Catorze voluntárias foram alocadas no grupo de obesas e 15, no grupo de eutróficas. Foram realizadas medidas antropométricas e de composição corporal. **Resultados:** Em ambos os testes, as obesas apresentaram maiores valores de consumo absoluto de oxigênio, ventilação-minuto e pressão arterial sistólica e diastólica; ainda apresentaram menor velocidade de caminhada, distância percorrida e consumo de oxigênio relativo, quando comparadas com as eutróficas. Durante o teste máximo de exercício, a dispneia percebida foi maior e o quociente respiratório menor nas obesas em relação às eutróficas. Durante o teste submáximo, produção de dióxido de carbono, volume corrente e frequência cardíaca foram maiores nas obesas, comparadas às eutróficas. Houve forte correlação entre a frequência cardíaca e moderada correlação entre o consumo de oxigênio no pico dos testes. A frequência cardíaca obtida no teste submáximo aplicado foi capaz de predizer a frequência cardíaca obtida no teste máximo.

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Os gráficos de Bland-Altman demonstraram concordância entre os testes para identificar parâmetros metabólicos e fisiológicos no pico do exercício. Conclusão: O teste de caminhada de seis minutos induziu respostas ventilatórias, metabólicas e cardiovasculares concordantes com as do teste máximo, provando ser importante na rotina de avaliação funcional fisioterápica de mulheres obesas.

Palavras-chave: obesidade; teste de esforço; aptidão física; fisioterapia.

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Introduction

Obesity-induced limitations of the cardiopulmonary and metabolic systems, commonly resulting in exertional dyspnea, collectively contribute to the limitations in functional capacity frequently observed in obese individuals[1]. In addition, the sedentary lifestyle often adopted by these individuals further compounds and contributes to impaired exercise tolerance.

Cardiopulmonary exercise testing (CPX) is considered the "gold standard" method for comprehensively assessing the response to aerobic exercise. The value of CPX data is manifold, including evaluation of exercise tolerance, quantification of impairment and disability levels, determination of the physiological mechanism(s) for exercise intolerance, and exercise prescription[2]. However, given the increasing recognition of the value of functional capacity assessments in numerous populations in conjunction with acknowledgement of the difficulty in broadly applying CPX, there is a need for valid and reliable exercise testing assessments that can be implemented in a time- and cost-efficient manner[3]. The six-minute walking test (6MWT) is a well-established functional assessment[4] that may provide a reasonable estimation of functional capacity in obese patients[5,6], even with associated diseases[7]. However, more work is needed in this area to validate initial findings.

Some authors have found a significant correlation between 6MWT distance and peak oxygen uptake (VO_2) measured by CPX in patients with advanced heart failure[8]. However, no previous study has evaluated the clinical significance of the 6MWT exercise measures comparable to CPX results in obese women. As VO_2 peak is the "gold standard" measure of aerobic capacity, it seems worthwhile to determine if cardiopulmonary, metabolic, and perceptual responses to the 6MWT are in concordance with CPX outcomes in obese women. When the population undergoing functional assessment requires closer monitoring of physiological variables, performing the 6MWT on a treadmill (tread6MWT) may be particularly attractive. This approach has been previously applied in healthy subjects and in certain patient populations[9-11], not including female obese patients. Therefore, the aim of this study was to analyze and compare the cardiopulmonary, metabolic, and perceptual responses to CPX and tread6MWT in obese and eutrophic women. The ultimate goal was to apply a submaximal test that could be easily used in a physical therapy clinical setting as part of the routine evaluation of obese women. We hypothesized that the tread6MWT is related to CPX in obese women and that it would elicit cardiopulmonary and metabolic responses in agreement with CPX responses.

Method

Design and study population

The current investigation is an observational, cross-sectional, comparative study. Subjects were sedentary females, from 20 to 45 years of age, allocated to an obese group (OG): BMI≥30 kg.m^{-2} and weight stable for the past one year; or eutrophic group (EG): 18.5≤BMI≤24.9 kg.m^{-2}. Exclusion criteria were: pregnancy; currently smoking or abstinence from smoking less than one year prior to study initiation; alcohol or drug addiction; presence of diabetes; uncontrolled hypertension; diagnosis of cardiopulmonary disease, such as coronary artery disease; chronic obstructive pulmonary disease or asthma; neurological or orthopedic dysfunctions; and/or the use of β-blockers. The experimental procedures were performed respecting a minimum resting period of 48h: (a) 1st Visit: clinical and physical therapy evaluations (anamnesis, anthropometric measures, regular physical activity pattern investigation, pulmonary function evaluation, bioelectrical impedance analysis); (b) 2nd Visit: CPX on a treadmill; and (c) 3rd Visit: tread6MWT performance. Approval by the institutional Ethics Committee at Universidade Federal de São Carlos (UFSCar), São Carlos, SP, Brazil (Approval 230/2009) and written informed consent from all subjects were obtained before the study initiation.

Measures

Physical therapy evaluations

Anthropometric data (body weight, height, and BMI) was evaluated according to methodology previously described[12]. Regular physical activity patterns were collected by the modified Baecke questionnaire for epidemiological studies, which was previously validated in Portuguese[13]. Occupation, sports activities, and leisure habits were quantified to assess the physical activity patterns.

Foot-to-foot bioelectrical impedance analysis was assessed with the Tanita body composition analyzer (model TBF-310; Tanita Corp., Tokyo, Japan), which calculates fat mass, fat-free mass, percentage of fat. This set has been used previously to assess obese women[14]. Subjects were measured in the morning in bathing suits without shoes or any kind of metal in contact with their bodies. The subjects were advised to be in absolute fast for at least four hours as well as to urinate prior to the assessment of body composition.

Spirometric tests were performed using the ergospirometry system (Oxycon Mobile®, Mijnhardt/Jäger, Würzburg, German) with flow measurement carried out using a calibrated pneumotachograph. The subjects completed at least three acceptable maximal forced and slow expiratory maneuvers according to the recommendations of the American Thoracic Society[15].

Experimental protocols

All of the experimental procedures described above were performed during the afternoon to avoid the influence of circadian changes, in a climate-controlled room with temperature between 22–24ºC and relative air humidity between 40–60%. The subjects received orientation on the experimental protocols and were instructed to abstain from caffeine, stimulants and alcoholic beverages during the 24 h preceding the tests, avoid strenuous physical activities for 24 h before the experiment, to have a good night's sleep, and to ingest a light meal at least 2h prior to the exercise tests. To further standardize the assessment and eliminate potential confounders, the subjects performed the tests during the follicular phase of their menstrual cycle.

Cardiopulmonary exercise testing

Symptom-limited CPX was performed on a treadmill (Master ATL, Inbramed, Porto Alegre, RS, Brazil). The exercise test consisted of: a) 4-min rest at standing position on the treadmill; b) incremental phase according to the Bruce ramp protocol[12]; c) 3-min recovering period. All the subjects were actively encouraged by the investigators in a standardized fashion throughout the test to walk and/or run to the limit of tolerance. Heart rate (HR), arterial blood pressure (ABP) measured using a standard cuff sphygmomanometer (Diasyst®, São Paulo, Brazil) and perceived exertion by Borg scale[16] were measured at each stage of exercise protocol, and throughout the recovering period.

Ventilatory expired gases were continuously measured during CPX and analyzed breath-by-breath using an ergoespirometric system (Oxycon Mobile®, Mijnhardt/Jäger, Würzburg, German), which was calibrated before each test according to manufacturer specifications. Patients were also monitored using a thoracic MC5 lead (cardiac monitor Ecafix TC500, São Paulo, SP, Brazil). Test termination criteria followed American Thoracic Society recommendations[2]. Two qualified physical therapists with physician supervision conducted each exercise test.

Aerobic capacity was evaluated using VO_2 data obtained at the peak of exercise. Metabolic and ventilatory data were processed and calculated in mobile averages, every eight breathing cycles. The average value the last 15 s was defined as the subject's peak VO_2 and peak respiratory exchange ratio (RER). Visual analyses of breathing and metabolic responses were made by three duly trained observers in order to determine ventilatory anaerobic threshold (VAT). The V-slope method was used to determine VAT through consensus of three experienced reviewers[17].

Treadmill Six-Minute Walking Test

The tread6MWT was performed on a treadmill with zero inclination and subject-controlled speed[18]. Subjects began at a speed of 3 $km.h^{-1}$. They were instructed and encouraged to walk as far as possible, according to American Thoracic Society guidelines[4]. In addition, they were allowed to increase or decrease the speed of the treadmill at any time, according to symptoms of fatigue or dyspnea. Heart rate and perceived exertion by the Borg scale[16] were measured every three minutes and at the exercise peak. The subjects' ABP was measured at rest in the standing position on the treadmill as well as at the exercise peak and throughout their recovery period. The treadmill's data panel showing speed and distance covered was not visible to the subject; only the start, stop, and speed up or slow down buttons were accessible to them. The subjects were allowed to interrupt the test if they had symptoms such as tachycardia or any discomfort that would make it impossible for them to continue the test. Two tests were completed with a minimum interval of one hour in order to reduce learning effects. Only the outcomes from the second tread6MWT were considered for statistical analysis.

Statistical analysis

The sample size was calculated using ENE software, version 2.0 (GlaxoSmithKline España S.A., Madrid, Spain, and

Universidad Autónoma de Barcelona, Barcelona, Spain). The target sample size was calculated to be four in each group considering a 5% type I error, a 2-sided test, and an 80% power to detect a significant difference of VO_2=12.9 $mL.kg^{-1}.min^{-1}$ at the maximal metabolic rate in obese and normal weight subjects[19]. The analysis was performed with MedCalc statistical software, Version 11.4.4.0 (MedCalc Software, Mariakerke, Belgium). Data are presented as mean±SD after testing for normal distribution (Shapiro-Wilk test) and as median (minimum, maximum) for categorical variables. The Student unpaired *t*-test was used for the comparison of continuous demographic and anthropometric data, bioelectrical impedance indexes, lung function, symptom data, and CPX and tread6MWT outcomes between the OG and the EG. The Student paired *t*-test was used to compare CPX and tread6MWT outcomes in each studied group. Fisher's exact test was used to compare the medication intake between groups. The relationship between relative VO_2 ($mL.kg^{-1}.min^{-1}$) and BMI in CPX and the tread 6MWT as well as the correlation between HR_{peak} and VO_2 ($mL.min^{-1}$) were assessed using Pearson's correlation. The stepwise regression was analyzed considering HR_{peak} in both tests. Moreover, the absolute limits of agreement between the metabolic and cardiovascular variables assessed by CPX and the tread6MWT were evaluated by the Bland-Altman analysis[20]. The probability of a type I error was set at 5% ($p<0.05$).

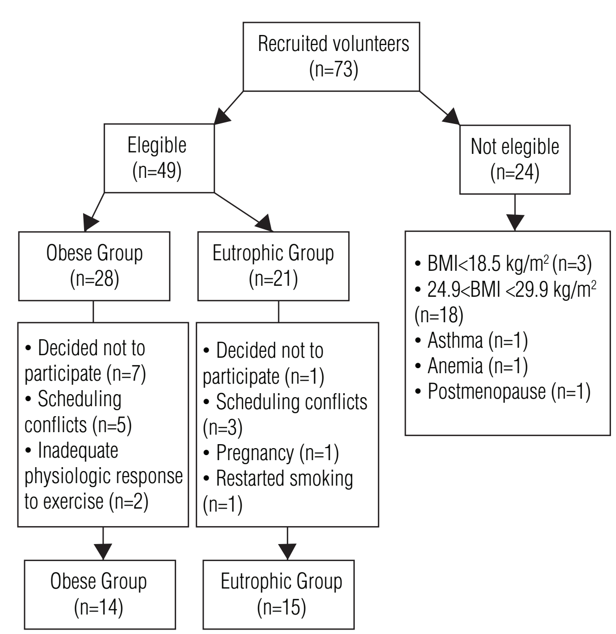


Figure 1. Flowchart – sample loss of each group.

Results

Seventy-three subjects were recruited. Figure 1 illustrates the attrition rate of each group. Table 1 lists demographic and anthropometric data, cardiovascular parameters at rest, bioelectrical impedance indexes, current medications, and lung function of both groups. Significant differences between groups were found regarding weight, BMI, HR, systolic and diastolic ABP (SBP and DBP, respectively), and body composition data. There were no differences in medication intake between groups. Three obese subjects presented with controlled hypertension and two eutrophics presented with controlled hypothyroidism. Data from spirometry confirmed exclusion criteria and no difference was found between the OG and the EG (Table 1). All women were considered to be sedentary according to Baecke questionnaire results, with a total score at or below 8: seven obese women had scores below 6 while the other half had scores between 6 and 8; four eutrophics had scores below 6, and eleven had scores between 6 and 8. Nevertheless, there were no significant differences between groups (p=0.26).

Exercise-related physiological and subjective responses

Table 2 shows CPX and tread6MWT results. All patients were able to successfully complete both tests without complications, except two obese subjects that presented inadequate ABP response to exercise during CPX and were excluded from the final sample. The test duration of CPX as well as the speed reached and the distance covered in both tests were significantly lower in the OG compared to the EG.

As expected, in both tests, obese women had higher absolute values for VO_2 ($p<0.0001$) compared to eutrophics but, when VO_2 were corrected by weight, they were significantly lower (p=0.02) in the OG. Moreover, minute ventilation, SBP, and DBP were higher in the OG. There were no differences in RR, leg fatigue, VE/VO_2 or VE/VCO_2 between groups.

In relation to the maximal test, peak RER was lower and dyspnea symptoms were significantly higher in the OG compared to the EG. There were no differences in percent-predicted peak VO_2, tidal volume, HR, and the percent-predicted HR (%HR) between groups. Regarding the tread6MWT, VCO_2, tidal volume, HR, and %HR were all higher in the OG compared to the EG.

Table 2 also shows the comparison between integrative responses to CPX vs. tread6MWT. CPX induced a higher

Table 1. Demographic, anthropometric, and body composition data; baseline cardiovascular variables; current medications; and lung function of each group.

	Eutrophic Group (n=15)	Obese Group (n=14)	p value
Age, years	30±7	33±8	0.44
Height, m	1.66±7	1.62±7	0.19
Weight, kg	60.5±8	100.4±16	<0.0001
BMI, $kg.m^{-2}$	22±2	38±6	<0.0001
Heart rate, bpm	85±8	93±12	0.04
Fat%	27±5	46±4	<0.0001
Fat mass, kg	17±5	47±11	<0.0001
Fat-free mass, kg	44±3	54±6	0.0002
SBP, mmHg	109±9	119±12	0.01
DBP, mmHg	75±8	86±8	<0.01
Contraceptive	4	6	0.45
Angiotensin II receptor antagonists	0	2	0.22
Diuretic	0	1	0.48
Thyroid-stimulating hormone	2	0	0.22
FVC, L	3.7±0.7	3.4±0.6	0.31
FVC, % pred	93.1±11.9	92.7±12.6	0.93
FEV_1, L	3.3±0.6	2.9±0.5	0.09
FEV_1, % pred	97.8±13.0	94.3±12.5	0.46
FEV_1/FVC	88.8±4.0	85.3±5.4	0.07
FEV_1/FVC, % pred	105.1±4.0	101.7±6.1	0.10

Data presented as mean±SD. BMI: body mass index; Fat%: percentage of total body fat mass; FVC: forced vital capacity; FEV_1: forced expiratory volume in one second. (Student unpaired *t*-test or Fisher's exact test, when appropriate; p<0.05).

increment in the majority of the test outcomes for the OG, except distance walked, VE/VCO_2, DBP, and perceived leg fatigue. In contrast, CPX induced a higher increment in most of the variables of the EG, except walking speed and VE/VO_2 ratio.

At VAT during CPX, markedly lower values were found in the OG compared to the EG for time, treadmill speed, and relative peak VO_2 as were higher absolute values for VO_2, VCO_2, VE, and RR. There were no differences between groups in relation to the other metabolic and ventilatory parameters at VAT.

Considering all the subjects, absolute VO_2 peak ($L.min^{-1}$) during CPX was modestly correlated (r= 0.53) to the same parameter of the tread6MWT (Figure 2A). In addition, a strong positive correlation (r=0.77) was found between HR_{peak} during CPX and the tread6MWT in the OG (Figure 2B). Figure 2C shows a stepwise regression analysis (y=-66.9299+1.2324x) between HR_{peak} in both tests (r^2=0.58; p=0.001).

Agreement between CPX and the tread6MWT

Analysis of agreement between both exercise tests applied to assess functional capacity was carried out by a Bland-Altman plot. Considering the metabolic and ventilatory parameters reached in the CPX as the "gold standard," we chose CPX-peak VO_2 vs. tread6MWT-peak VO_2 and CPX-VE vs. tread6MWT-VE to plot as primary variables of interest.

Two additional secondary variables from CPX were selected as well: CPX-SBP vs. tread6MWT-SBP and CPX-peak HR vs. tread6MWT-peak HR. As reported in Figures 3A and 3B, the mean of the differences to identify the relative VO_2 and the VE by CPX and the tread6MWT was 6.0±5.6 $mL.kg^{-1}.min^{-1}$ and 29.0±16.9 $L.min^{-1}$, respectively. Similarly, the agreement of both tests to identify SBP and HR at the peak of exercise calculated by the Bland-Altman method found a mean difference between the tests of 17.5±19.4 mmHg and 32.9±19.4 beats per minute (Figures 3C and 3D), respectively. Therefore, there was agreement between the tests in all performed analysis.

Discussion

In this study, we demonstrated that the submaximal tread6MWT promoted cardiorespiratory and metabolic responses in agreement with CPX in obese women, thus showing the advantage of lower cardiopulmonary and metabolic stress as well as lower perceived dyspnea during the test. Therefore, it is possible to predict the HR_{peak} of the symptom-limited CPX by means of the HR_{peak} reached in the tread6MWT. Additionally, the exercise tests demonstrated a lower functional capacity in obese women in comparison with eutrophics, expressed by metabolic, ventilatory, and cardiovascular variables and dyspnea perception, as well as speed and walking distance.

Table 2. Maximal cardiopulmonary exercise test (CPX) and treadmill six-minute walking test (tread6MWT) data at the peak of the tests and at the anaerobic threshold.

	Eutrophic group (n=15)		Obese group (n=14)	
	CPX	Tread6MWT	CPX	Tread6MWT
Peak Exercise				
Duration, min	10.7±1.6	–	8.5±1.6*	–
Speed, km.h^{-1}	6.7±0.9	6.7±0.7	5.6±1.0*	6.2±0.7*†
Distance, m	812.1±186.7	633.3±61.0†	580.3±145.7*	582.1±71.3*
Metabolic				
VO_2, %pred	91.1±15.5	64.5±13.3†	86.1±10.5	71.0±16.6†
VO_2, mL.min^{-1}	1739.2±255.7	1299±274.2†	2087.6±451.6*	1602.1±334.5*†
VO_2, mL.kg^{-1}.min^{-1}	28.7±4.4	21.4±4.3†	20.7±3.6*	16.0±3.7*†
VCO_2, mL.min^{-1}	2179.8±368.5	1203.9±254.0†	2478.1±566.2	1595.1±365.7*†
RER	1.25±0.10	0.96±0.09†	1.19±0.07*	0.96±0.1†
Ventilatory				
VE, L.min^{-1}	67.1±10.9	38.1±12.5†	80.2±15.7*	51.2±16.0*†
RR, br.min^{-1}	42±7.6	31±9.9†	44±9.0	36±7.1†
Tidal volume, L	1.6±0.3	1.2±0.2†	1.8±0.3	1.4±0.2*†
VE/VO_2	38.0±6.8	28.9±5.2†	37.8±7.9	32.0±7.9†
VE/VCO_2	31±4.3	29.9±3.4	31.8±5.8	33.4±7.1
Cardiovascular				
Heart rate, bpm	182±9	141±20†	181±11	157±18*†
Heart rate, %pred	101±3	78±11†	102±6	88±10*†
SBP, mmHg	159±16	143±10†	182±18*	163±23*†
DBP, mmHg	86±9	78±8†	94±12*	90±10*
Symptoms				
Dispnea	5.0 [2–7]	1.0 [0–5] †	7.0 [3–10]*	1.50 [0–5] †
Leg fatigue	4 [0.5–7]	1.0 [0–3] †	4 [0–10]	1.75 [0–7]
Anaerobic Threshold				
Time, min	4.9±0.9	–	3.5±0.7*	–
Speed, km.h^{-1}	3.9±0.4	–	3.5±0.6*	–
Metabolic				
VO_2, %pred	61.3±8.3	–	67.7±10.0	–
VO_2, mL.min^{-1}	1053.5±139.6	–	1392.9±279.9*	–
VO_2, mL.kg^{-1}.min^{-1}	17.3±1.6	–	13.7±1.8*	–
VCO_2, mL.min^{-1}	933.6±184.7	–	1198.4±275.8*	–
RER	0.88±0.08	–	0.86±0.06	–
Ventilatory				
VE, L.min^{-1}	25.3±5.1	–	33.5±7.3*	–
RR, br.min^{-1}	21±5.3	–	25±5.4*	–
Tidal volume, L	1.3±0.3	–	1.4±0.3	–
VE/VO_2	23.9±3.0	–	24.1±3.2	–
VE/VCO_2	27.3±2.8	–	28.3±3.5	–

Data presented as mean±SD or median ± [minimum, maximum] when appropriate. VO_2: oxygen uptake; VCO_2: carbon dioxide production; RER: respiratory exchange rate; VE: minute ventilation; RR: respiratory rate; SBP: systolic blood pressure; DBP: diastolic blood pressure. *Significant differences comparing obese versus eutrophic volunteers (Student unpaired *t*-test, $p<0.05$); †Significant differences comparing CPX versus tread6MWT (Student paired *t*-test, $p<0.05$).

Comparison between CPX and tread6MWT outcomes

Because the 6MWT is better tolerated than CPX by individuals with disabilities and because it has been used to evaluate functional capacity in several populations[21], we compared exercise responses between tests. It is well known that CPX is considered the "gold standard" to assess the integrative exercise response since it is a progressive exercise to the tolerance limit that combines the assessment of ECG, hemodynamic, subjective symptoms and ventilatory expired gas analysis measures[2]. Another advantage of the CPX is that it is applied on an ergometer, which allows for the collection of the aforementioned variables while controlling for workload titration. However, the time required, the need for specially trained staff, and the cost of the equipment limits the widespread applicability of CPX.

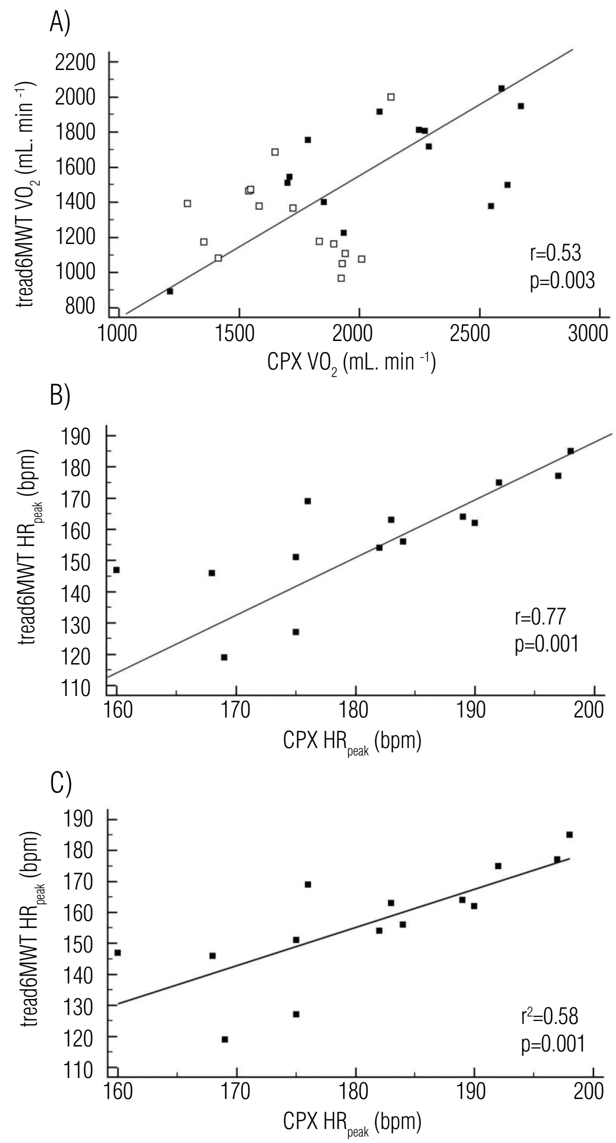
Interestingly, although the 6MWT is usually applied in a corridor to obtain a more secure monitoring of the physiological parameters, it can also be applied on a treadmill[11]. This was one of the reasons for choosing the tread6MWT, the other reason being to collect ventilatory expired gas variables with the same equipment used during CPX for comparative purposes. Guimarães, Carvalho and Bocchi[18] applied the tread6MWT with ventilatory expired gas monitoring in heart failure patients and found it to be a feasible approach to functional assessment in this population. Despite the previous application of the tread6MWT in healthy subjects and certain patient populations, we acknowledge that tread6MWT distance results are not interchangeable with corridor tests[4,11].

Some studies have shown correlation and regression analysis to complement Bland-Altman method-comparison plots of agreement[22]. In this way, besides the demonstrated agreement between CPX and the tread6MWT through Bland-Altman analysis, the linear regression showed the HR_{peak} in CPX could be predicted by means of HR_{peak} reached in the tread6MWT. Thus, although CPX and the tread6MWT measure different aspects of exercise tolerance, the second test becomes an adjunct method in physical therapy evaluation when CPX is not available.

It is well known that obese individuals consume a greater amount of oxygen compared to eutrophics at the same external work load due to their increased body mass[4]. In our results, the OG showed a decreased work capacity compared to the EG since the former reached VAT earlier and had a lower CPX duration with higher VO_2 absolute values. This metabolic behavior may be consequence of a lower tolerability to exercise as a result of the increase in arterial lactate with subsequent metabolic acidosis in obese individuals compared to normal weight individuals.

Hulens et al.[23] applied a maximal exercise test on a cycle ergometer to a large sample of obese and lean women. They demonstrated that exercise capacity in the obese population was decreased as evidenced by lower relative VO_2, VE, HR, and RER compared to the lean subjects. Other authors[24] also demonstrated reduced physical fitness and functional capacity during CPX in obese women compared to normal weight and overweight women. These findings are in accordance with the results of the present study and corroborate the deleterious impact that excess body weight has on physical function and, ultimately, prognosis[25].

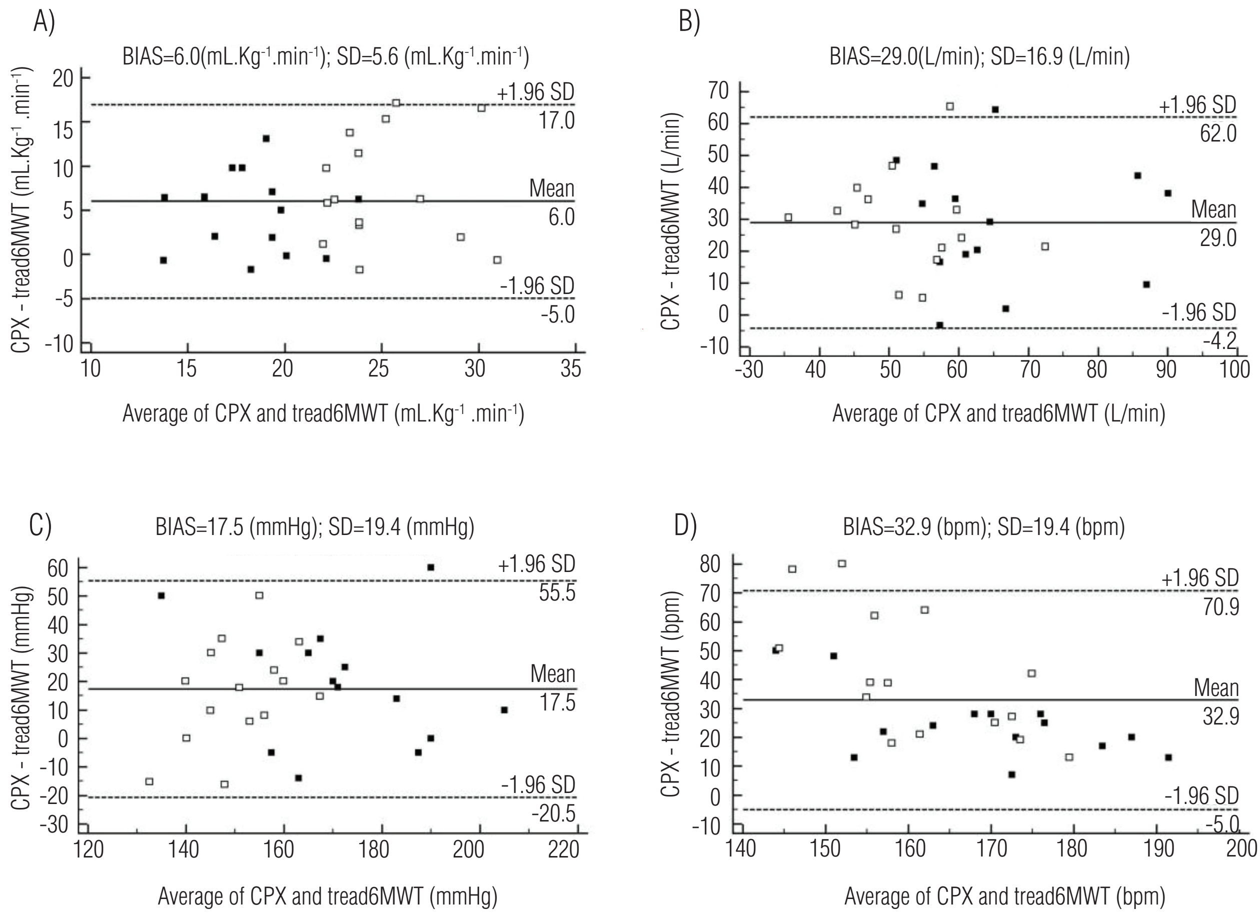
Comparing the walking distance in both tests, the OG covered a shorter distance than the EG. However, the OG covered a greater distance during the tread6MWT compared to the CPX, which may be attributed to the self-selection of walking speed and lower physical requirements. Regarding the submaximal test, several studies have demonstrated shorter 6MWT distances covered by obese individuals, with an increase in distances after weight loss and/or aerobic training[6,12].



Tread6MWT; six-minute walking test on a treadmill; CPX: cardiopulmonary exercise testing; VO_2: oxygen uptake; HR: heart rate. Obese group (black squares) and eutrophic group (white squares).

Figure 2. (A) Correlation between peak VO_2 in both tests in studied groups; (B) Correlation between Peak HR in both tests – tread6MWT and CPX – in obese women; (C) Linear regression considering HR_{peak} in both tests in obese women.

Although pulmonary function evaluated by spirometry remains relatively normal compared to predicted values and no relevant impairment in pulmonary gas exchange occurs in obese women during exercise[1], they present with a blunted hyperventilation response during intense exercise[25,26]. Our results confirmed these previous findings since our obese women did not elevate their respiratory rate proportionally to the significantly higher absolute VO_2 peak compared to the EG as demonstrated in Table 2. This inadequate behavior could be related to the perceived dyspnea by the OG during CPX exercise peak and to the oxygen cost of breathing in



BIAS: mean of the differences between the means; ±1.96 SD = agreement limit of 95%; VO_2: oxygen uptake; VE: minute ventilation; SBP: systolic blood pressure; HR_{peak}: peak of heart rate.

Figure 3. Bland-Altman plots show agreement of means difference: (A) VO_2 (mL.kg^{-1}.min^{-1}); (B) VE (L.min^{-1}); (C) SBP (mmHg); (D) HR_{peak} (bpm).

obese individuals, which can be almost threefold higher (at 3.45 mL of oxygen per liter of ventilation) than eutrophics[27]. VE/VCO_2 ratio reflects the ventilatory efficiency but we found no difference between groups. In contrast with our findings, others authors[28] have described a decreased mean ventilatory efficiency, which increased after a 12-week functional exercise program in obese women, although not to sedentary healthy levels. Future studies are necessary to better investigate ventilatory efficiency in obesity, even at different levels of this disease, including VE/VO_2 slope during maximal and submaximal exercise tests.

In our study, obese women had higher SBP and DBP compared to eutrophics at rest and during both exercise tests. However, the consequences of obesity on cardiac function remain unclear. Some authors have described alterations in systolic or diastolic function[29], with diastolic abnormalities representative of the early cardiac consequences of obesity[30], while other researchers have pointed out normal cardiac function in obese individuals[31]. Similarly to our results, Séres et al.[32] found higher ABP values in morbidly obese individuals than in controls at rest and during a symptom-limited CPX.

Clinical implications

The high energy output required to move total body mass leads obese women to have reduced exercise capacity[32]. Moreover, dyspnea during exercise is a common complaint in this population[1] which could limit their performance in a maximal symptom-limited exercise test. For this reason, we decided to comprehensively assess the response to exercise to confirm a submaximal test (i.e. tread6MWT) could be used as a reasonable method to evaluate functional capacity with ventilatory, metabolic, cardiovascular, and perceptual responses in agreement with CPX. In addition, HR responses of the tread6MWT applied in the present study can predict maximal HR responses. That result is very important given that the submaximal test allows the physical therapist to prescribe the intensity of rehabilitation programs in the obese population without submitting those patients to maximal stress testing.

Thus, ABP and HR measures are variables easily assessed during the tread6MWT and, as the Bland-Altman plot has shown, they have a good level of agreement between CPX and the submaximal test, a finding which supports the clinical utility of the 6MWT in this patient population.

Study limitations

Some limitations of this study should be mentioned. We evaluated only the female obese population due to their adherence to the protocol and their availability to schedule visits. However, more studies are necessary to assess obese men. Although the 6MWT is usually applied in a corridor, we reproduced it on a treadmill to apply the same ergometer used in CPX.

Conclusions

The tread6MWT promoted ventilatory, metabolic, and cardiovascular responses in agreement with CPX. Additionally, it may prove to be an adequate submaximal exercise test for functional evaluation of obese women in the physical therapy routine without imposing maximal stress or a perceived dyspnea level as high as the one imposed by symptom-limited CPX.

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