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Ventilatory and metabolic responses during field tests and cpx in obese adults

Respostas ventilatórias e metabólicas durante testes de campo e o TECP em obesos adultos

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RESUMO: The 6-minute walk test (6MWT) and the incremental shuttle walking test (ISWT) have been used as alternatives to the Cardiopulmonary Exercise Test (CPX) for functional evaluation, as well as after rehabilitation programs. The objective was to analyse the cardiorespiratory and metabolic demands among the ISWT, 6MWT, and CPX in the obese, and the contribution of adiposity markers to this response. An observational and cross sectional study was conducted with fifteen obese subjects (10 women and 5 men; 39.4±10.1years) submitted to CPX, 6MWT, and ISWT. The subjects were part of a rehabilitation program and bariatric surgery at the University Hospital. Metabolic and ventilatory variables were recorded by a telemetry system during all tests. Peak oxygen uptake, VO_2peak was similar between CPX (18.6±4.0ml/kg/min) and ISWT (15.4±2.9ml/kg/min), and different from 6MWT (13.2±2.5ml/kg/min). There was agreement (3.2ml/kg/min; 95%; IC-3.0-9.4) between VO_2peak of CPX and ISWT. CPX duration (R2=0.61; p=0.001) was best-fit by waist circumference (WC) and body adiposity index (BAI) that reduced CPX duration by 4.7% and 3.2%, respectively. Forced vital capacity and WC predicts an increase of carbon dioxide production for CPX (R2=0.95; p=0.001) and ISWT (R2=0.67; p=0.001). In conclusion, the obese individuals performed the ISWT and CPX test with similar physiological responses. It is suggested that ISWT could be an alternative to CPX, and that metabolic monitoring of ISWT by telemetry can be useful for the clinical assessment of the functional capacity of obese. Clinical Trial Number RBR-6dwy85.

Palavras-chave: Obesity; oxygen consumption; incremental shuttle walk test; cardiopulmonary exercise test.

***ABSTRACT*:** The 6-minute walk test (6MWT) and the incremental shuttle walking test (ISWT) have been used as alternatives to the Cardiopulmonary Exercise Test (CPX) for functional evaluation, as well as after rehabilitation programs. The objective was to analyse the cardiorespiratory and metabolic demands among the ISWT, 6MWT, and CPX in the obese, and the contribution of adiposity markers to this response. An observational and cross sectional study was conducted with fifteen obese subjects (10 women and 5 men; 39.4±10.1years) submitted to CPX, 6MWT, and ISWT. The subjects were part of a rehabilitation program and bariatric surgery at the University Hospital. Metabolic and ventilatory variables were recorded by a telemetry system during all tests. Peak oxygen uptake, VO_2peak was similar between CPX (18.6±4.0ml/kg/min) and ISWT (15.4±2.9ml/kg/min), and different from 6MWT (13.2±2.5ml/kg/min). There was agreement (3.2ml/kg/min; 95%; IC-3.0-9.4) between VO_2peak of CPX and ISWT. CPX duration (R2=0.61; p=0.001) was best-fit by waist circumference (WC) and body adiposity index (BAI) that reduced CPX duration by 4.7% and 3.2%, respectively. Forced vital capacity and WC predicts an increase of carbon dioxide production for CPX (R2=0.95; p=0.001) and ISWT (R2=0.67; p=0.001). In conclusion, the obese individuals performed the ISWT and CPX test with similar physiological responses. It is suggested that ISWT could be an alternative to CPX, and that metabolic monitoring of ISWT by telemetry can be useful for the clinical assessment of the functional capacity of obese. Clinical Trial Number RBR-6dwy85.

Key Words: Obesity; oxygen consumption; incremental shuttle walk test; cardiopulmonary exercise test.

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Introduction

Peak oxygen uptake (VO_2peak) is the best variable to express the fitness and efficiency of the cardiovascular system during maximal Cardiopulmonary Exercise Testing (CPX), and it can be considered a key variable in rehabilitation programs for exercise prescription and training intensity. However, in some specific situations either by clinical reasons and/or factors regarding economic viability, equipment availability and a lack of trained professionals, it was not possible to perform CPX. As such, this field test has deserved special attention in recent years [(1-6)] because it is practical, economical, reliable [(7,8)], and especially used in a clinical/rehabilitation setting. VO^2peak is found before maximal oxygen uptake (VO_2max), along with determining the beginning of symptoms such as fatigue and dyspnea [(9)]. VO^2peak from CPX is strongly correlated with VO_2 of Incremental Shuttle Walking Test (ISWT) rather than the 6-minute Walk Test (6MWT) [(3,10-12)], and produces more similar physiologic responses to maximal effort [(1,13)]. VO^2 measurement is used to establish the appropriate level of exercise intensity during a rehabilitation program [(14,15)] independently from the test.

ISWT was initially developed [(8)] in order to assess the cardiorespiratory capacity in patients with chronic obstructive pulmonary disease (COPD). However, its use today is extended to several diseases [(9,16-19)] including adolescent obesity, to estimate physical activity level and then physical fitness [(11,20)]. However, the behavior of cardiovascular stress variables during the incremental field test in obese adults is unknown. Due to the cardiovascular overload required to move large body weight, it is possible to also present similar physiological responses to CPX in the field test, as shown in other diseases. Moreover, we believe that biomechanical impairment makes the maximal effort test harmful and arduous to sedentary, obese individuals, making them stop CPX early before becoming exhausted. Given the physiological evidence and operational simplicity, the ISWT seems to be a better choice than CPX, and becomes more applicable in clinical environments and less physically exhausting for obese people, making it a useful tool for early evaluation before instituting a rehabilitation program.

Using ISWT with real-time monitoring of respiratory gases by a telemetry system could help elucidate these questions and increases the accuracy in diagnosing ISWT for this population. The main objective of this study is to analyze and compare oxygen uptake (VO_2) and carbon dioxide production (VCO_2) achieved during the walking and incremental tests (6MWT and ISWT) along with CPX in obese adults, and agreement of metabolic and ventilatory variables among these tests. As its secondary aim, we also analyzed the impact of different adiposity markers on cardiovascular test response.

Material and method

Individuals

This was an observational and cross-sectional study design performed with subjects as an initial part of the bariatric surgery program at the local University Hospital. Subjects included in the study were obese individuals (body mass index-BMI>30 kg/m²) of both genders, age>18<60years, sedentary, physically able to perform the tests with preserved spirometric function (>80%-predicted) or absence of limiting cardiopulmonary disease (angina or functional class 4(NYHA) diagnosed by the cardiologist team) who signed free and informed consent forms (Resolution No. 466/12 of the National Health Council - NHC). The local ethics committee (98.314; 31/08/2012) approved the study. We excluded obese who did not complete the protocol. The sample size was defined based on our pilot study, where α and β were respectively 0.05 and 0.20, thus 15 obese were defined in the final sample.

Baseline Evaluation

Clinical (presence of hypertension, tobacco use), spirometric (Datospir, 120, Sibelmed, Spain) and anthropometric (weight, height, BMI, body adiposity index-BAI, and waist, hip circumferences – WC, HC) measurements were taken in all subjects. A Spirometric test (FVC, FEV1, MVV) was performed [14] to establish the inclusion criteria and to compare the respiratory interest variable with the cardiovascular test.

Cardiopulmonary Exercise Testing-CPX

All obese individuals underwent a symptom-limited exercise test performed on a treadmill (Micromed-Centurion 300). A complete ergoespirometric system by telemetry was used for respiratory gas analyzer (Cortex, Biophysik, Metamax 3B®™ and ErgoPCElite, Leipzig, Germany). When performing a test, the obese individuals wore a nasal mask and data were collected breath-by-breath. A volume transducer and gas line (to measure O_2 and CO_2) wer connected to the nasal mask. The gas concentration cellule was calibrated with ambient air, as well as flow and volume prior to all tests. VO_2, VCO_2, Ventilation-VE, cardiac variables (blood pressure-BP; heart rate-HR; and continuous ECG-12 channels) and peripheral oxyhemoglobin saturation-SpO2%- determined by pulse oximetry (Nonin, Plymouth, MN) were recorded throughout the testing. Subjective final exertion perception was measured before and after the tests (Borg 6-20). The test started after 2 minutes of rest and familiarization using a ramp protocol. Interruption criteria were in accordance with ATS [14].

Measurement of VO2 during field walking tests

A telemetry system was connected to the obese individuals during both tests to collect breath-by-breath ventilatory and metabolic variables, as well as data from the CPX. The 6MWT was performed and the patients then underwent the ISWT after 30 minutes. During the 6MWT, the subjects were instructed to walk as fast as possible along a corridor (30 meters) for 6 minutes [7]. During the ISWT, the subjects had to walk between two cones placed 10 meters away from each other, with their velocity being determined by sound signals (participants were required to increase their pace according to the signals). The ISWT started with a slower speed and was increased after 1 minute [8]. The tests were interrupted by a sound signal if participants felt exhausted and/or breathless to complete the shuttle in a determined time, or if they showed any discomfort or failed to reach a SpO_2 above 80%.

Maximal VO_2 reached during exercise (VO_2peak) was used as a measure of aerobic capacity at the end of each test. Ventilatory threshold (VT) was automatically by the V-Slope method and it was visually confirmed by an experienced researcher [21]. Equations of prediction [22] were used to define the predicted values of cardiopulmonary and respiratory variables.

Statistical analysis

The hypothesis of data distribution normality was accepted. All data were expressed as mean and standard deviation (+SD). Analysis of variance (One-way ANOVA) was used to test the hypothesis of difference between the variance of interest variables among the three cardiovascular tests. A factorial ANOVA was added to certify difference in terms of the gender factor. The level of agreement between VO_2peak achieved during the tests was analyzed using a Band Altman plot. The possibility of association and the influence of factors (anthropometric, spirometric and effort perception) on metabolic and aerobic capacity response in all tests was tested with Pearson's correlation and the linearity between data was confirmed using univariate linear regression. The magnitude of predicting the power of multiple variables was tested on a multiple linear regression model (stepwise) to explain what real contribution the anthropometric and respiratory result had on VO_2peak, VCO_2, and VE. All analyses were performed with Statistic 10.0, assuming 5% of error type I error.

Results

Twenty-nine obese individuals were recruited; however, 14 dropped out. Table 1 illustrates the baseline values of the respiratory function and anthropometric measurements from the 15 obese individuals (66.7% - obesity III; 20.0% - obesity II; 13.3% - obesity I).

	OBESE (n=15)	WOMEN (n=10)	MEN (n=5)
Age, years	39.4±10.1	33.1±10.5	36.8±9.5
Weight, kg	118.0±27.2	105.8±15.9	142.5±30.1*
Height, cm	164.0±12.2	158.1±8.9	176.0±8.7*
BMI, Kg/m²	43.5±6.8	42.4±6.7	45.6±7.1
BAI	49.6±12.3	50.0±10.5	48.8±16.9
WHR	0.94±0.09	0.91±0.1	1.0±0.04
HC, cm	135.7±13.1	134.7±18.3	137.8±12.3
WC, cm	127.0±16.6	121.1±8.9	139.0±12.4*
FVC, L	3.5±0.9	3.0±0.5	4.5±0.7*
FVC%	93.7±9.7	89.8±5.3	101.3±11.2
FEV_1, L	3.0±0.8	2.5±0.4	3.8±0.7*
FEV_1%	95.8±10.2	92.9±6.0	101.5±15.0
MVV, l/min	115.4±31.6	102.7±18.8	140.8±38.5
%MVV	89.7±11.0	90.7±7.9	87.5±16.7

Table 1. Variable distribution of baseline measures of anthropometry and lung function among obese.

Physiological responses

The values of CPX and those from the field test are illustrated in Table 2. Exercise intensity assessed by %HR and $\%VO_2$ on CPX was higher than in the other two tests with a difference between variance.

There is a test type effect on cardiovascular performance (VO_2) at peak of activity ($F(2,42)=10.8$ $p=0.0001$), with a range of 18.6±4.0ml/kg/min on CPX, 15.4±2.9 during the ISWT, and 13.2±2.5 during the 6MWT. However, the factorial analysis showed a difference of VO_2ml/kg/min and $\%VO_2$ only for CPX and the 6MWT in both genders ($\%VO_2$ $p=0.008$ in women and $p=0.01$ in men). The exercise intensity during the ISWT seems to be similar to CPX in women and men ($p>0.05$). This intensity was confirmed by %HR only between CPX and the 6MWT in both genders ($p=0.0002$, women, and $p=0.003$ for men). Even though the ISWT is considered a submaximal test, the subjects performed it at an intensity that was slightly high (82.7%-HRmax) compared to maximal effort. The respiratory quotient (RER) at peak of exercise confirmed the exercise intensity, however, there was a difference in the women's group (CPX and ISWT $p=0.02$; CPX and 6MWT $p= 0.005$) (Table 2).

	CPX			ISWT			6MWT		
	Women(n=10)	Men (n=5)	Both (n=15)	Women(n=10)	Men (n=5)	Both (n=15)	Women(n=10)	Men (n=5)	Both (n=15)
VO_2,ml/kg/min	16.8±3.4 ^{b}	22.8±2.1 ^{c}	18.6±4.0	14.3±2.1 *	17.8±3.1	15.4±2.9*	12.5±2.6 ^{b}	14.6±1.6 ^{c}	13.2±2.5 *
%VO_2	99.9±20.6 ^{b}	95.9±6.9 ^{c}	98.5±17.0	85.3±14.6 *	76.3±13.5	82.3±14.5 *	74.3±15.7 ^{b}	62.8±9.0 ^{c}	70.5±14.6 *
VE,l/min	52.1±15.4	104.0±24.2 ^{c,d}	69.4±9.6	39.5±11.7 *	75.1±15.1 ^{d}	51.4±21.3 *	33.4±15.0	56.6±4.0 ^{c}	41.2±16.6 *
VCO_2,l/min	1.79±14.8	3.5±0.7	2.3±1.0	1.3±0.3 *	2.6±0.5	1.7±0.7	1.1±0.4	2.1±0.4	1.4±0.6*
RER	1.04±0.14 ^{a,b}	1.1±0.09	1.06±0.1	0.8±0.1 ^{a}	1.0±0.1	0.95±0.1 *	0.8±0.06 ^{b}	0.9±0.08	0.89±0.09 *
HR,bpm	172.8±14.1 ^{a,b}	172.2±13.2 ^{c}	172.6±13.5 *	145.9±12.0 ^{a}	155.8±25.4	149.2±17.3 *	135.6±15.6 ^{b}	130.6±26.7 ^{c}	133.9±19.1 *
%HR	96.3±4.9 ^{a,b}	94.1±7.6 ^{c}	95.6±5.8*	81.4±5.6 ^{a}	85.3±14.9	82.7±9.3 *	75.5±6.4 ^{b}	71.5±15.8 ^{c}	74.2±10.0 *
Duration,s	466.7±119.1	411.0±81.5	448.1±108.4	-	-	408.5±68.5	-	-	-
Distance,m	-	-	-	360.0±96.6	500.0±38.7	406.6±105.3	439.1±49.8	531.8±44.7	74.2±10.0 *

Table 2. Description of metabolic and respiratory variables during the peak of activity in the maximal exercise test and submaximal, distributed by gender and difference between the performance measures between tests.

Values expressed as mean and standard deviation-SD, during peak activity in both genders. VO_2=oxygen uptake; VE=minute ventilation; VCO_2=carbon dioxide production; RER=respiratory exchange ratio; VE/VCO_2= ventilatory equivalent carbon dioxide; HR=heart rate. Post-Hoc Tukey (a,difference between CPX e ISWT, women; b,difference between CPX e 6MWT, women; c,difference between CPX e 6MWT, men; d,difference between CPX e ISWT,men).

In general, there was a negative correlation between CPX duration, BMI (r=-0.75;p=0.001) and WC (r=-0.70;p=0.003). Table 3 shows the linear regression for metabolic and ventilatory variables in all tests. The WC negatively impacted VO_2 and positively impacted VCO_2 in all tests, and seems to affect the performance of obese individuals more during the test than on weight and isolated BMI. These factors lost strength and significance in the multiple regression analysis model. In this obese group, the BMI and WC alone justify 56% and 48% of CPX testing duration, and it decreases 11.93 seconds for each 1kg/m^2 increased in BMI and 5.77 seconds for each centimeter at the waist of obese (Table 3). However, when we included other anthropometric variables, the model explained 61% variance of the duration of CPX, and was defined by the association of WC and BAI. Then, the best-fit regression used to predict duration showed that for each centimeter increase in WC, whether adjusted or independent of other variables such as BAI, there was a decrease of 4.7seconds during CPX. Also, independent of WC, there was a decreased duration of 3.2 seconds during the CPX for each 1% of body fat (Table 3).

Even without any correlation among VO_2peak for the three tests, we noted agreement using a Bland-Altman plot of

Test		R^2	Intercept	β^1	Estimated Error	P	$F_{(1,13)}$	Multiple Regression (Final model)
CPX								
Duration,s	BMI	0.56	968.07	-11.93	74.31	0.001	16.81	y= 1203.33-4.7(WC)-3.2(BAI) R^2=0.61
	WC	0.48	1182.10	-5.77	80.48	0.003	12.41	
	Weight	0.38	738.00	-2.45	88.49	0.01	8.02	
	BAI	0.32	697.42	-5.02	92.13	0.02	6.39	
VE,l/min	WC	0.52	-147.73	1.70	22.21	0.002	14.27	
VCO_2,l/min	WC	0.62	-5.33	0.06	0.64	0.000	21.48	y= -3.34+0.02(WC)+0.81(FVC) R^2=0.95
	FVC	0.90	-1.21	1.01	0.32	0.000	121.89	
	Weight	0.77	-1.47	0.03	0.49	0.000	46.02	
ISWT								
VCO_2,l/min	WC	0.51	-3.66	0.04	0.56	0.002	13.78	y= -2.57+0.02(WC)+0.44(FVC) R^2=0.67
	FVC	0.59	-0.48	0.64	0.51	0.000	19.34	
	Weight	0.56	-0.76	0.02	0.53	0.001	16.87	
VE,l/min	Weight	0.48	-12.78	0.54	15.95	0.004	12.12	y= -40.29 + 12.7(FVC)+1.09(NC) R^2=0.54
	FVC	0.50	-5.36	16.06	15.61	0.003	13.22	
	NC	0.33	-5.76	2.55	18.08	0.02	6.55	
	WC	0.43	-85.63	1.07	16.61	0.007	10.16	
6MWT								
VO_2,ml/kg/min	Weight	0.32	7.04	0.05	2.14	0.02	6.13	y= 6.82+0.002(Weight)+1.70(FVC) R^2=0.44
	FVC	0.44	6.91	1.44	1.94	0.006	10.45	
VE,l/min	WC	0.38	-59.42	0.79	13.52	0.01	8.26	y= -27.67 + 12.91(FVC) + 0.18 (WC) R^2=0.69
	Weight	0.58	-13.91	0.46	11.15	0.000	18.26	
	FVC	0.68	-10.35	14.57	9.74	0.000	27.98	

Table 3. Univariate analysis and multiple linear regression of the three tests (CPX, ISWT, 6MWT) among metabolic, ventilatory and performance with anthropometric and general adiposity

CPX=cardiopulmonary exercise testing; ISWT=incremental shuttle walking test; 6MWT=six minute walking test; VO_2=oxygen uptake; VE=volume expiratory; VCO_2=carbon dioxide production; WC=waist circumference; BMI=body mass index BAI= body adiposity index.

3.2ml/kg/min (95%; CI: 3.0 - 9.4) of 16.4% on VO_2peak only between ISWT and CPX (Figure 1).

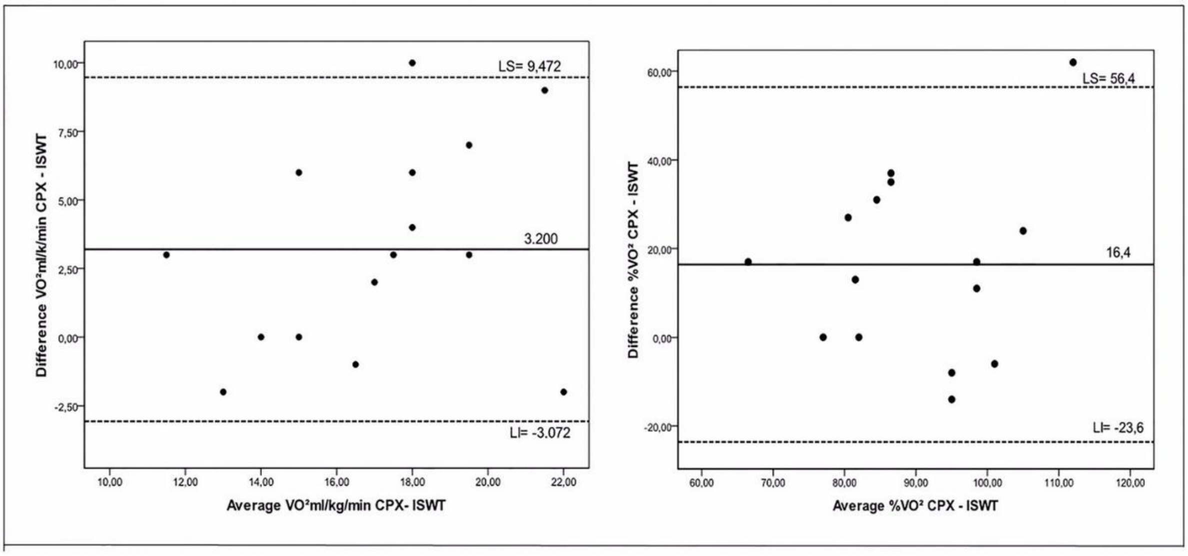

Figure 1: Bland-Altman plot between CPX and ISWT between measures VO_2 and percentage of VO_2. CPX=cardiopulmonary exercise testing; ISWT=incremental shuttle walking test; VO_2= oxygen uptake.

Discussion

The limitations of this study were inherent to the equipment used (problems changing the O_2 cell) and some dropouts by patients. Thus, the study had a small number of participants. Although being small, the sample showed a homogeneous nature with narrow confidence intervals.

Our main results support the hypothesis that obese individuals perform ISWT with a similar physical effort intensity as they perform during the CPX. This behavior is not exhibited when compared to the 6MWT. Interesting results are shown considering the impact of adiposity and anthropometric markers on VO_2peak, VCO_2, and ventilation during the tests. For this level of obesity, we also show that WC and BAI impact more negatively on CPX duration than BMI and/or weight separately (Table 3).

We did not demonstrate any difference between VO_2peak of exercise during ISWT and CPX, which suggests that physical response can be considered similar in both tests for this population. Even though it is considered a submaximal test, we confirm a higher heart effort during the ISWT on %VO_2 (82.3%) and %HR (82.7). Dourado et al. (1,10) previously suggested that ISWT could be an acceptable choice when measuring physical performance of healthy individuals based on their achieved intensity. We also support this hypothesis with a posterior agreement analysis (Bland-Altman plot). A previous study of Thommazzo-Luporini et al. (23) in evaluating the cardiorespiratory fitness of obese by the six-minute step test concluded that the intensity of effort for this population approaches the maximum capacity observed through the %VO_2 and HR (89% and 87% of predicted, respectively).

The intensity of exercise training is regarded as an important determinant of training response and is usually prescribed as a percentage of full capacity to the measured effort by VO_2peak. Recently, Evans et al. (24) reported that 16 obese people with obstructive apnea with VO_2peak <16 ml/kg/min walked less than 400 meters in the ISWT. In our study, we observed a VO_2peak of 15.4ml/kg/min and a distance of 406.6 meters, confirming the above data. We propose that the different results (VO_2peak) in our study could be a result of the higher BMI of our patients (BMI=33.2 kg/m^2 - Evans et al.).

In addition, we demonstrate that VCO_2 during incremental and maximal effort has a direct correlation with WC in obese individuals; and with a possibility of 95% explication in the multiple model linear model, being independently adjusted by pulmonary capacity, the VCO_2 is 0.02 higher for each centimeter increase on the waists of obese individuals during CPX and the ISWT. We also defend the similarity of effort between the incremental and maximal test for obesity using this aspect.

When jointly analyzed, these results show that cardiovascular response seems to be similar and comparative between the ISWT and CPX, which also happens in patients with COPD or heart failure. Lewis et al. (17) demonstrated that VO_2 during ISWT and CPX strongly correlate, and suggest that it is viable and reproducible to test exercise tolerance in individuals with severe heart failure. COPD patients also initially showed (8) that maximal VO_2 after ISWT and 6MWT correlates with results found during CPX. Casas et al. (25) reported higher levels of VCO_2, respiratory quotient and effort perception at peak exercise during incremental cycling testing in COPD patients than during ISWT; however, the VO_2 values were similar in both tests. Also, Zainuldin et al. (6) concluded that a prescription of walking exercise at 70% of the peak ISWT speed provided an appropriate intensity for achieving physiologic training responses in COPD patients.

Metabolic and respiratory variables during a 6MWT seem to be completely different from CPX. However, Thomazzo-Luporini et al. (5) recently showed a moderate correlation in VO_2peak (l/min) for both tests in obese individuals. In previous studies (16,26) there seemed to be no doubt regarding the close relationship between VO_2peak from 6MWT and CPX for individuals with limited oxygen transport capacity (heart failure and lung disease). However, according to our findings in obese individuals, it is difficult to cite this similarity. Firstly, the Bland-Altman analysis did not demonstrate acceptable agreement on both tests. Secondly, the supposition of a previous study [5] was made for a 6MWT on a treadmill, which may have had a different physical cardiovascular impact from a 6MWT test performed in the field. Furthermore, the BMI of our study is higher (35.7-50.3kg/m2) than those previously shown (32-44kg/m2) [5]. Thomazzo-Luporini et al. [23] also noted in another study with obese that there was a satisfactory concurrent validity between CPX and six-minute step test to identify VO_2peak and HR, and the Bland-Altman analyses found a mean difference between the tests of 5.1+3.6ml/kg/min and 23+13bpm respectively. In this way, concurrent validity between both methods was found to evaluate cardiorespiratory fitness by means of VO_2peak and HR.

Assessment by telemetry defines the cardiopulmonary and metabolic impact in real time through walking, incremental or maximal tests in obese individuals. It potentially increases the diagnosing power of field testing, can elucidate physiological responses, and be useful for functional rehabilitation programs. The ISWT assessment by telemetry can be especially useful in patients who are not able to perform a test that reaches maximal physical effort given their extreme obesity, ventilatory or cardiac output limitation. Tueller et al. [27] showed a high applicability and reliability of telemetry in a large group of patients (heart, restrictive, obstructive disease, and pulmonary hypertension). In our study, it was possible to define one safe and accurate way for this level of adiposity that the ISWT is similar to the CPX from a physiological and functional point of view.

Another important aspect was that we found a strong correlation between respiratory and anthropometric variables which best predict the final results of the three tests. Part of this was justified by the homogeneity between these variables in our study group. As had been shown in lean health [28,29], BMI negatively influences the final distance during the ISWT. Our linear regression analysis demonstrated that solely BMI, weight, body adiposity index and waist circumference predicts CPX duration. However, by using a multiple linear regression analysis, BAI and WC remain as being able to predict the best-fit on the regression line for the CPX duration. Even considering control of WC above the duration of the test, the duration decreased 4.7seconds for each centimeter of WC. Waist circumference is a good predictor of cardiovascular risk [30], but until now, there has been no association of cardiovascular test response.

Conclusions

Data from this study show that among the walking tests, the ISWT presents similar ventilatory and metabolic response to those produced in a maximal exercise test in obese individuals. The ISWT could be a useful and alternative choice for measuring cardiovascular stress, especially with higher levels of obesity. Therefore, we suggest that ISWT can be a useful assessment tool for individualized exercise prescription for weight loss programs, as well as functional rehabilitation in obese adults. However, we need to conduct more randomized clinical trials to prove this theory with greater reliability. By combining field tests to metabolic and cardiovascular measurements using a sophisticated telemetry system, walking tests become particularly strong for making a functional diagnosis. Additionally, WC and adiposity percentage are the best predicting factors for VO_2 and VCO_2 during ISWT and CPX in obese individuals.

Reference

1. Dourado VZ, Guerra RLF. Valores de referência para o teste de caminhada com carga progressiva em indivíduos saudáveis: da distância percorrida às respostas fisiológicas. J Bras Pneumol. 2013; 39: 190-197.

2. Guazzi M, Dickstein K, Vicenzi M, Arena R. Six-Minute Walk Test and Cardiopulmonary Exercise Testing in Patients With Chronic Heart Failure. Circ Heart Fail. 2009; 2:549-555.

3. Jürgensen SP, Antunes LCO, Tanni SE, Banov MC, Lucheta PA, Bucceroni AF, et al. The Incremental Shuttle Walk Test in Older Brazilian Adults. Respiration. 2011; 81:223–228.

4. Pulz C, et al. Incremental shuttle and six-minute walking tests in the assessment of functional capacity in chronic heart failure. Can J Cardiol. 2008; 24: 2.

5. Thommazo-Luporini L, Jürgensen SP, Castello-Simões V, Catai AM, Arena R, Borghi-Silva A. Metabolic and clinical comparative analysis of treadmill six-minute walking test and cardiopulmonary exercise testing in obese and eutrophic women. Rev. Bras Fisioter. 2012; 38(55): 862-863.

6. Zainuldin R, Mackey MG, Alison JA. Prescription of walking exercise intensity from the incremental shuttle walk test in people with chronic obstructive pulmonary disease. Am J Phys Med Rehabil. 2012;91:592-600.

7. ATS - American Thoracic Society. Statement: guideline for six-minute walk test. Am J Respir Crit Care Med. 2002; 166:11-117.

8. Singh SJ, Morgan MDL, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in patients with chronic airways obstruction. Thorax. 1992; 47: 1019-1024.

9. Woolf-may K, Meadows S. Exploring adaptations to the modified shuttle walking test. BMJ Open. 2013; 2.

10. Dourado VZ, Banov MC, Marino MC, Souza VL, Antunes LCO, McBurnie MA. A Simple Approach to Assess VT During a Field Walk Test. Int J Sports Med. 2010; 31: 698-703.

11. Klijn PHC, Baan-slootweg OH, Stel HF. Aerobic exercise in adolescents with obesity: preliminary evaluation of a modular training program and the modified shuttle test. BMC Pediatrics. 2007; 7:19.

12. Luxton N, Alison JA, Judy WU, Mackey MG. The relationship between field walking tests and incremental cycle ergometry in COPD. respirology. 2008; 13: 856–862.

13. Onorati P, et al. Non-invasive evaluation of gas exchange during a shuttle walking test vs. a 6-min walking test to assess exercise tolerance in COPD patients. Eur J Appl Physiol. 2003; 89: 331–336.

14. ATS/ACCP - American Thoracic Society/American College of Chest Physicians. Statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med. 2003; 167:211-77.

15. Balady GJ, et al. Clinician's Guide to Cardiopulmonary Exercise Testing in Adults: A Scientific Statement From the American Heart Association. Circulation. 2010; 122:191-225.

16. Benzo RP, Sciurba FC. Oxygen Consumption, Shuttle Walking Test and the Evaluation of Lung Resection. Respiration. 2010; 80:19–23.

17. Lewis ME, Newall C, Townend JN, Hill SL, Bonser, RS. Incremental shuttle walk test in the assessment of patients for heart transplantation. Heart. 2001; 86:183–187.

18. Parreira VF, Ferreira TJ, Evans RA, Mathur S, Goldstein RS, Brooks D. Measurement Properties of the Incremental Shuttle Walk Test A Systematic Review. Chest. 2014; 145(6): 1357–1369.

19. Ringbaek T, Martinez G, Brøndum E, Thøgersen J, Morgan M, Lange P. Shuttle walking test as predictor of survival in chronic obstructive pulmonary disease patients enrolled in a rehabilitation program. J Cardiopulm Rehabil Prev. 2010; 30(6): 409-14.

20. Castro-piñero J, Padilla-moledo C, Ortega FB, Moliner-urdiales D, Keating X, Ruiz JR. Cardiorespiratory fitness and fatness are associated with health complaints and health risk behaviors in youth. J Physic Activity Health. 2012; 9: 642-9.

21. Santos EL, Neto AG. Comparison of computerized methods for detecting the ventilatory thresholds. Eur J Appl Physiol. 2004; 93: 315–324.

22. Neder JA, Nery LE, Peres C, Whipp BJ. Reference Values for Dynamic Responses to Incremental Cycle Ergometry in Males and Females Aged 20 to 80. Am J Respir Crit Care Med. 2001; 164:481–1486.

23. Thommazzo-Luporini L, et al. The six-minute step test as a predictor of cardiorespiratory fitness in obese woman. Eur J Phys Rehabil Med. 2015; 51:793-802.

24. Evans RA, Dolmage TE, Robles PG, Goldstein RS, Brooks D. Do field walking tests produce similar cardiopulmonary demands to an incremental treadmill test in obese individuals with treated obstructive sleep apnea? Chest. 2014; 146:13-2060.

25. Casas A, et al. Patients Maximum Sustainable Exercise in COPD Encouraged 6-min Walking Test Indicates. Chest. 2005; 128:55-61.

26. Carvalho EEV, et al. Insuficiência Cardíaca: Comparação entre o Teste de Caminhada de seis Minutos e o Teste Cardiopulmonar. Arq Bras Cardiol. 2011; 97:59-64.

27. Tueller C, et al. Six-Minute Walk Test Enhanced by Mobile Telemetric Cardiopulmonary Monitoring. Respiration. 2010; 80: 410–418.

28. Dourado VZ, Vidotto MC, Guerra RLF. Equações de referência para os testes de caminhada de campo em adultos saudáveis. J Bras Pneumol. 2011; 37:607-614.

29. Probst VS, Hernandes NA, Teixeira DC, Felcar JM, Mesquita RB, Gonçalves CG, et al. Reference values for the incremental shuttle walking test. Respiratory Medicine. 2012; 106: 243-248.

30. McAuley PA, et al. The Obesity Paradox, Cardiorespiratory Fitness, and Coronary Heart Disease. Mayo Clin Proc. 2012; 87(5): 443-451.

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