The Incremental Shuttle Walk Test in Older Brazilian Adults

Soraia Pilon Jürgensen^a Letícia Cláudia de Oliveira Antunes^b
Suzana Erico Tanni^c Marcos Carraro Banov^b Paulo Adolfo Lucheta^c
Alessandra Freire Bucceroni^b Irma Godoy^c Victor Zuniga Dourado^a

^aDepartment of Health Sciences, Laboratory of Human Motricity, Federal University of São Paulo, Santos,

^bRehabilitation Department, and ^cDepartment of Internal Medicine, Pulmonology Division, Botucatu Medical School, São Paulo State University, Botucatu, Brazil

Key Words

Shuttle walk • Exercise testing • Reference values

Abstract

Background: Despite widespread use of the incremental shuttle walk distance (ISWD), there are no reference equations for predicting it. **Objectives:** We aimed to evaluate ISWD in healthy subjects and to establish a reference equation for its prediction. **Methods:** 131 Brazilian individuals (61 males; 59 ± 10 years) performed 2 walk tests in a 10-m long corridor. We assessed height, weight, body mass index, forced expiratory volume in 1 s, forced vital capacity and self-reported physical activity. **Results:** Mean ISWD was greater in males than in females (606 ± 167 vs. 443 ± 117 m; $p < 0.001$). ISWD correlated significantly ($p < 0.05$) with age ($r = -0.51$), height ($r = 0.54$) and weight ($r = 0.20$). A predictive model including age, height, weight and gender explained 50.3% of the ISWD variance. In an additional group of 20 subjects prospectively studied, the difference between measured and predicted ISWD was not statistically significant (534 ± 84 vs. 552 ± 87 m, respectively), representing $97 \pm 12\%$ of the predicted value calculated with our reference equation for ISWD. **Conclusions:** This reference equation in-

cluding demographic and anthropomorphic attributes could be useful for interpreting the walking performance of patients with chronic diseases that affect exercise capacity.

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Introduction

In the mid-1960s, walking tests for use in the field were created as a means of evaluating exercise capacity by measuring the distance walked during a predetermined period of time [1]. These 'field' walking tests were originally developed to evaluate functional exercise capacity in patients with cardiopulmonary diseases [2, 3]. However, they have since been validated for use in patients with other chronic diseases [4].

The 6-min walk test (6MWT) is the most popular of the field walking tests, its principal advantages being its operational simplicity and low cost [4, 5]. However, the main disadvantage of the 6MWT is its very simplicity, as it allows the patient to set the walking speed. As an alternative to self-paced tests and in an attempt to improve standardization and reproducibility, the incremental shuttle walk test (ISWT) was developed by Singh et al. [3].

In this test, the individual is guided to walk at a progressively faster pace imposed by prerecorded signals. The greatest advantage of the ISWT is that, due to this difference, the incremental shuttle walk distance (ISWD) correlates more strongly with maximal oxygen uptake than the 6-min walk distance (6MWD) does [4, 6, 7].

The ISWT is a simple and reliable test that evaluates domains of exercise capacity other than those evaluated by the 6MWT [8]. The ISWT has become an established and widely used measure of exercise capacity in patients with cardiopulmonary disease. However, there are no reference equations designed to predict the ISWD in healthy subjects. Therefore, the present study was designed to evaluate ISWD in healthy individuals and to establish reference equations for its prediction based on demographic and anthropometric variables. As a secondary objective, we evaluated exercise intensity during the ISWT and the need for a practice walk in order to familiarize subjects with the test.

Subjects and Methods

Individuals

We studied a sample of 131 healthy Brazilian subjects (61 males), ranging in age from 40 to 84 years. Volunteers were recruited from among postgraduate students and employees of the Federal University of São Paulo and employees of the Santa Casa da Misericórdia Hospital, both institutions located in the city of Santos, Brazil, as well as from among residents of the surrounding community. Reported physical activity (RPA) scores were collected from the subjects by means of the Baecke questionnaire [9] and were classified as sedentary (total score <8) or physically more active but still untrained (total score ≥8). Based on body mass index (BMI), the volunteers were stratified into the following categories: underweight (<18.5), normal weight (18.5–24.9), overweight (25–29.9) and obese (≥30). Due to the high prevalence of overweight and obesity in the Brazilian population, subjects with BMI <40 were included so that the sample could be more representative. Clinical stability, defined as the absence of any acute disease during the 6 weeks before the study measurements, was an inclusion criterion. Subjects with abnormal post-bronchodilator lung function, i.e. forced expiratory volume in 1 s (FEV₁) <80% of the predicted value or forced vital capacity (FVC)/FEV₁ ratio <70%, were excluded, as were those with a current diagnosis of cardiovascular/respiratory disease, those with any health problem that might interfere with the ability to undertake physical exercise and those regularly using medications for chronic diseases. However, those subjects with controlled hypertension and former smokers without tobacco-related diseases were included in the study.

To verify the reliability of our ISWD reference equation, we prospectively measured ISWD in a second group of 20 additional healthy adults (13 women). These volunteers were recruited from among students and employees from the University and the surrounding community. They met the inclusion criteria and had not participated in the first part of the study.

Body weight and height were measured, and BMI was calculated. Pulmonary function and reversibility tests were performed using a spirometer (Spirodoc, MIR, Italy), according to the criteria established by the American Thoracic Society [10]. Values of FEV₁ are expressed as percentages of reference values [11]. All subjects gave written informed consent to participate in the study, and the study design was approved by the Ethics in Human Research Committee of the Federal University of São Paulo.

Incremental Shuttle Walk Test

Each subject was instructed to walk around a 10-meter course in an indoor hospital corridor. A second ISWT was performed in the same manner as the first, following a rest of at least 30 min. The course was marked by two traffic cones, as described by Singh et al. [3]. The walking speed was dictated by acoustic signals pre-recorded on a CD, which imposed an increase of 0.17 m/s every minute. Since ISWT was developed to assess functional exercise capacity in patients with respiratory diseases, the original protocol consists of 12 stages (1,020 m). However, to avoid the ceiling effect in healthy subjects, we prolonged the acoustic signals up to 15 stages (1,500 m). The walking speed was controlled by a series of signals indicating the moment at which the subject should be rounding the cone. At the end of every minute, there was an additional signal indicating the moment at which the walking speed should increase. The end of the test was determined either by the subject, for any reason, or by the physical therapist conducting the test, when the individual was unable to maintain the required speed to complete the course (>0.5 m away from the cone). Chest pain, intolerable dyspnea, dizziness, leg cramps, diaphoresis and pallor were carefully observed during the test. The results of the second test were recorded for analysis. Before and after each test, the following data were obtained: pulse rate, respiratory rate, blood pressure, dyspnea and leg effort [12].

Statistical Analysis

The statistical analysis was performed using SigmaStat statistical software, version 2.03 (SPSS Inc., Chicago, Ill., USA). Data are presented as means ± SD. The following tests were carried out: Kolmogorov-Smirnov to evaluate the normality of variable distribution; Pearson's or Spearman's coefficient of correlation to study the correlation between variables; unpaired t test to determine differences in numerical data between groups; paired t test to compare variables before and at the end of the ISWT, and multiple linear regression analysis to evaluate the best predictor variables for ISWD as a dependent variable, including a reference equation. Age, gender, height and weight were identified a priori as predictors of ISWD. Interaction terms for gender were evaluated for age, height and weight. The sample size was estimated based on the relationship between the number of variables (e.g. age, height, weight and gender) entered into the multiple regression analysis and the minimum number of observations required, indicating at least 40 subjects for elaborating a linear model containing these 4 variables. The reliability of our ISWD reference equation was evaluated in the second group of 20 healthy individuals. We compared the measured ISWD with the predicted distance derived from our equation. The predicted maximal heart rate (HR_{max}) was calculated (220 – age in years). Values between 70 and 85% of HR_{max} were considered moderate exercise, and values above 85% were considered high-intensity exercise [13]. The level of statistical significance was set at 5%.

Table 1. General characteristics of the study participants

	Men (n = 61)				Women (n = 70)			
	mean $\pm$ SD	95% CI	max.	min.	mean $\pm$ SD	95% CI	max.	min.
Age, years	58 $\pm$ 11	55–66	81	40	60 $\pm$ 11	57–68	84	40
Weight, kg	78 $\pm$ 12	74–81	107	47	67 $\pm$ 12 ^a	64–71	95	36
Height, cm	171 $\pm$ 6	169–172	183	150	156 $\pm$ 7 ^a	154–158	172	141
BMI, kg/m ²	26 $\pm$ 3	25–27	33	19	27 $\pm$ 5	26–28	39	17
RPA score	8.51 $\pm$ 2.07	7.88–9.13	15.75	4.88	8.24 $\pm$ 2.65	8.12–9.13	14.75	4.25
Baseline pulse rate, bpm	80 $\pm$ 14	75–82	101	52	82 $\pm$ 11	80–85	105	58
Maximal pulse rate, bpm	134 $\pm$ 27 ^b	126–141	187	80	125 $\pm$ 20 ^b	122–132	166	84
%HRmax	80 $\pm$ 14	76–84	109	47	76 $\pm$ 11	74–79	96	49
Baseline dyspnea ¹	0.15 $\pm$ 0.50	0.01–0.29	2	0	0.32 $\pm$ 0.81	0.13–0.55	3	0
Maximal dyspnea ¹	3.00 $\pm$ 1.70 ^b	2.50–3.46	7	0	3.26 $\pm$ 1.43 ^b	3.03–3.72	7	0
Baseline leg effort ¹	0.20 $\pm$ 0.54	0.04–0.35	3	0	0.48 $\pm$ 0.90	0.27–0.73	3	0
Maximal leg effort ¹	2.40 $\pm$ 2.00 ^b	1.82–2.93	8	0	2.20 $\pm$ 1.90 ^b	1.75–2.74	8	0
Second ISWD, m	606 $\pm$ 167	557–652	1,090	300	443 $\pm$ 117 ^a	429–486	866	210

CI = Confidence interval; max. = maximum value; min. = minimum value; %HRmax = percentage of the predicted HRmax (220 – age in years) reached at the end of the walk test. ^a p < 0.05 versus men. ^b p < 0.05 for baseline versus post-test values.

¹ Assessed using the Borg scale.

Results

The characteristics of the 131 subjects are summarized in table 1. All individuals presented normal lung function (FEV₁ 93 $\pm$ 8%; FVC 91 $\pm$ 8%; FEV₁/FVC 90 $\pm$ 12%). The age distribution of our sample was as follows: 40–49 years, n = 37; 50–59 years, n = 34; 60–69 years, n = 30, and $\geq$ 70 years, n = 29. On average, BMI was within the overweight range (27 $\pm$ 4). The mean total RPA score was 8.2 $\pm$ 2.5 (60.36% sedentary). The main differences between male and female subjects can be seen in table 1. Weight, height and ISWD were greater in males than in females. Mean resting and maximum pulse rate, dyspnea and leg effort values were not statistically different between males and females. There was substantial variability in the ISWD for males and females alike. There was a significant difference between the first and the second tests in terms of the ISWD (467 $\pm$ 147 vs. 508 $\pm$ 160 m; p = 0.043). During the ISWT, subjects reached 78 $\pm$ 12% of their HRmax (range 47–109%).

The univariate analysis showed that ISWD correlated significantly (p < 0.05) with age (r = –0.516), height (r = 0.543) and weight (r = 0.201), as well as with FEV₁ (r = 0.578), FVC (r = 0.652), percentage of HRmax (r = 0.376) and RPA score (r = 0.188). There was a tendency toward a statistically significant correlation with BMI (r = –0.170; p = 0.0527). Predictors in the regression analysis jointly

Table 2. Predictive model for ISWD in healthy subjects

Variable	Coefficient	Standard error	p value
R ² = 0.503			
Constant	374.004	282.161	0.187
Age, years	–6.782	1.012	<0.001
Weight, kg	–2.328	0.924	0.013
Height, cm	3.865	1.727	0.027
Gender ^a	115.937	31.237	<0.001

Reference equation: ISWD in meters = 374.004 – (6.782 vs. age) – (2.328 vs. weight) + (3.865 vs. height) + (115.937 vs. gender). Standard error of the estimate = 114.732 m.

^a Factor gender: men = 1; women = 0.

explained 50.3% of the total variance in ISWD (table 2). No interactions with gender were detected.

The mean walking distance prospectively measured in an additional 20 subjects (55 $\pm$ 13 years; height 164 $\pm$ 8 cm; weight 68 $\pm$ 12 kg; BMI 25 $\pm$ 4 kg/m²) was not different from predicted walking distance (534 $\pm$ 84 vs. 552 $\pm$ 87 m, respectively), representing 97 $\pm$ 12% of the predicted value calculated with our reference equation for ISWD.

Discussion

The main objective of the present study was to evaluate normal ISWT values, as well as the demographic and anthropometric predictors of ISWD. A large part (50.3%) of the ISWD variance was explained by age, height, weight and gender. Reference equations are useful tools for evaluating ISWT results obtained from patients with chronic diseases. Since the ISWT is an externally paced walk test, the interference of external factors such as operator encouragement and motivation is lower. Therefore, we believe that the reference equations developed in the present study can be useful in other populations. To our knowledge, the present study is the first to develop reference equations for prediction of the total ISWD.

In our study, the demographic variables selected as independent predictors of ISWD were gender and age. Male subjects walked approximately 115 m farther than did female subjects, as has been described for the 6MWT [14–17]. The influence of gender on the distance walked might be attributable to the greater absolute muscle strength, muscle mass and height of men in comparison with women. We found no data in the literature concerning the correlation between age and ISWD in healthy subjects. However, studies involving healthy controls suggest that there is an influence of age on the ISWD [18, 19]. Our volunteers (mean age 58 ± 10 years) walked, on average, 508 ± 160 m. Lee et al. [18], in a study involving 19 healthy older volunteers (mean age 61 ± 10 years), found the mean ISWD to be 440 m (range 360–520 m). Similarly, Dyer et al. [19] reported a mean ISWD of 243 ± 21 m in a sample of 32 healthy older controls aged 70–85 years. The negative influence of advanced age on the ISWD might be explained by the gradual reduction in muscle mass, muscle strength and maximal oxygen uptake that typically occurs in parallel with aging [20, 21].

In the present study, the anthropometric variables selected as independent predictors of ISWD were height and weight. In fact, the previous correlations found between height and 6MWD lend support to our results ($r = 0.20$ – 0.54) [14, 16, 17, 22]. These strong correlations can be attributed to the greater stride length in taller individuals, stride length being a major predictor of gait speed [23]. In contrast, the correlation between body weight and distance walked on field walk tests is weak or not significant [14, 15, 24, 25]. Our results showed statistically significant positive correlation between body weight and ISWD. On the other hand, results of the multiple regression analysis revealed a negative coefficient for body weight, which can be explained by the nonlinear relation-

ship between body weight and walking performance [24]. Obesity increases the workload of walking, resulting in a shorter distance walked by subjects with a higher body weight or BMI. Similar results were previously described in the literature for patients with chronic obstructive pulmonary disease (COPD) [26]. Our findings reinforce these previous results.

The present study showed substantial variability in the ISWD (range 210–1,090 m). Recently, Tully et al. [27] also observed such variability in the ISWD in a group of healthy subjects aged 40–61 years. However, an important part of the variability in our study was adequately explained by demographic and anthropometric variables such as age, height, body weight and gender ($R^2 = 0.503$). Similar R^2 values have been reported for 6MWD reference equations (0.30–0.66) [17, 24].

The externally paced nature of the ISWT supposedly results in higher cardiovascular stress than that provoked during the 6MWT and, consequently, the potential for cardiovascular complications is thought to be greater during the ISWT [4]. However, we observed that the intensity of exercise during the ISWT was submaximal ($78 \pm 12\%$ of HRmax). In studies evaluating healthy individuals [18, 19, 27, 28], we were unable to find details regarding exercise intensity during the ISWT. The results of percentage of HRmax in the present study showed great variability. This can be attributed to several factors. First, field walk tests depend on the motivation of the subject even when an externally paced walk test such as the ISWT is undertaken. Second, the energy cost of walking is highly dependent on aspects related to the gait strategy such as the size and frequency of strides and the degree of movement of the upper and lower limbs. Third, the metabolic cost of running at low speed (i.e. jogging) is substantially greater than walking at a similar speed, indicating that, especially for the younger participants able to run more easily, it may have resulted in less cardiovascular stress [29]. Moreover, we found it surprising that our results were similar to those previously described for the 6MWT, during which the mean exercise intensity has shown great variability, ranging from 67 ± 10 to $85 \pm 2\%$ in healthy adults and seniors, respectively [15, 30]. These findings might be explained by discrepancies in the standardization observed in several studies, predominantly in terms of the level of encouragement and the number of practice walk tests [4]. In fact, Casas et al. [31] showed that the intensity of exercise during the 6MWT when performed under vehement verbal encouragement can reach the critical walking speed (i.e. critical power), which represents the limit between intense and highly

intense exercise. In addition, Kervio et al. [30] observed that healthy elderly subjects presented 85% of HRmax after five 6MWTs. The supposed greater cardiorespiratory stress related to ISWT is controversial in the literature. Greater cardiorespiratory stress in response to ISWT compared to the 6MWT has been described by some authors [8, 32, 33]. Morales et al. [32] and Green et al. [33] compared the ISWT with the 6MWT in patients with heart failure, and Onorati et al. [8] compared these two tests in patients with COPD. The results showed that the changes from baseline in heart rate, systolic blood pressure and dyspnea index were significantly higher after the ISWT. In contrast, Vagaggini et al. [34] observed that the changes from baseline in systolic blood pressure, heart rate, respiratory rate, oxygen saturation and dyspnea Borg index at the end of the test were similar between the 6MWT and ISWT in patients recovering from acute exacerbation of COPD. Similar results were also described by other authors [31, 35]. Whether the ISWT results in a greater cardiorespiratory response and risk of cardiovascular events should be elucidated in patients and in healthy subjects.

We found a mean difference of 40 ± 51 m between the ISWD achieved on the first ISWT and that achieved on the second. This difference was statistically significant ($p = 0.043$). Woolf-May and Ferrett [28] evaluated 19 healthy elderly control subjects and observed similar results (1st ISWT = 553 ± 93 m; 2nd ISWT = 560 ± 111 m). The small number of healthy individuals typically included in control groups precludes the drawing of conclusions regarding the learning effect on the ISWT [18, 19, 28]. Although Tully et al. [27] applied the ISWT in 106 healthy elderly individuals, the authors did not provide details about the learning effect. The difference between the tests observed in our study is near the minimum clinically significant difference of 47.5 m (95% confidence interval 38.6–58.5 m) recently defined for the ISWT [36], suggesting that there was a modest learning effect. Further studies are needed in order to evaluate the reliability of the ISWT in healthy subjects.

Some potential limitations of our study should be considered. The use of a convenience sample might have introduced a bias. However, this type of sample has often been used in studies evaluating reference values for the total distance walked during field walking tests such as the 6MWT [15, 17, 22, 25, 37, 38]. Moreover, adequate reliability of our equation was established through prospective assessment in a similar sample. Although we evaluated a sufficiently large sample in the present study, our findings should be confirmed in studies involving

larger samples. Potential sources of ISWD variance other than age, gender, height and weight should be considered. One such source is the relationship between psychological status and exercise capacity in healthy subjects and in patients with pulmonary disease [4]. Other potential sources are differences in peripheral muscle conditioning [24] and in pulmonary function [14]. However, these variables are not as easily assessed as are demographic and anthropometric attributes, since dynamometers and spirometers are necessary to quantify muscle and pulmonary function, respectively.

We conclude that ISWD is highly variable in healthy individuals, although a great part of the variance can be explained by demographic and anthropometric attributes such as age, body weight, height and gender. The reference equations created here could be useful for interpreting the walking performance of patients suffering from chronic diseases that affect exercise capacity. However, the ISWT only induced moderate exercise intensity in the healthy subjects evaluated. Our results suggest a modest learning effect related to ISWT. Future studies are necessary to assess the reliability of the ISWT in healthy individuals.

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References

- 1 Balke B, Ware RW: An experimental study of physical fitness of air force personnel. *US Armed Forces Med J* 1959;10:675–688.
- 2 Butland RJ, Pang J, Gross ER, Woodcock AA, Geddes DM: Two-, six-, and 12-minute walking tests in respiratory disease. *Br Med J (Clin Res Ed)* 1982;284:1607–1608.
- 3 Singh SJ, Morgan MD, 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.
- 4 ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories: ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med* 2002;166:111–117.

- 5 Chetta A, Pisi G, Aiello M, Tzani P, Olivieri D: The walking capacity assessment in the respiratory patient. *Respiration* 2009;77:361–367.
- 6 Gayda M, Choquet D, Temfemo A, Ahmaidi S: Cardiorespiratory fitness and functional capacity assessed by the 20-meter shuttle walking test in patients with coronary artery disease. *Arch Phys Med Rehabil* 2003;84:1012–1016.
- 7 Benzo RP, Sciurba FC: Oxygen consumption, shuttle walking test and the evaluation of lung resection. *Respiration* 2010;80:19–23.
- 8 Onorati P, Antonucci R, Valli G, Berton E, De Marco F, Serra P, Palange P: 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.
- 9 Baecke JA, Burema J, Frijters JE: A short questionnaire for the measurement of habitual physical activity in epidemiological studies. *Am J Clin Nutr* 1982;36:936–942.
- 10 Standardization of Spirometry, 1994 Update. American Thoracic Society. *Am J Respir Crit Care Med* 1995;152:1107–1136.
- 11 Pereira CA, Sato T, Rodrigues SC: New reference values for forced spirometry in white adults in Brazil. *J Bras Pneumol* 2007;33:397–406.
- 12 Borg GA: Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* 1982;14:377–381.
- 13 McArdle W, Katch F, Katch V: Fisiologia do exercício: energia, nutrição e desempenho humano, ed 5. Rio de Janeiro, Guanabara Koogan, 2003.
- 14 Camarri B, Eastwood PR, Cecins NM, Thompson PJ, Jenkins S: Six minute walk distance in healthy subjects aged 55–75 years. *Respir Med* 2006;100:658–665.
- 15 Chetta A, Zanini A, Pisi G, Aiello M, Tzani P, Neri M, Olivieri D: Reference values for the 6 min walk test in healthy subjects 20–50 years old. *Respir Med* 2006;100:1573–1578.
- 16 Enright PL, Sherrill DL: Reference equations for the six-minute walk in healthy adults. *Am J Respir Crit Care Med* 1998;158:1384–1387.
- 17 Troosters T, Gosselink R, Decramer M: Six minute walking distance in healthy elderly subjects. *Eur Respir J* 1999;14:270–274.
- 18 Lee KW, Blann AD, Ingram J, Jolly K, Lip GY: Incremental shuttle walking is associated with activation of haemostatic and haemorheological markers in patients with coronary artery disease: the Birmingham rehabilitation uptake maximization study (BRUM). *Heart* 2005;91:1413–1417.
- 19 Dyer CA, Singh SJ, Stockley RA, Sinclair AJ, Hill SL: The incremental shuttle walking test in elderly people with chronic airflow limitation. *Thorax* 2002;57:34–38.
- 20 Fleg JL, Lakatta EG: Role of muscle loss in the age-associated reduction in VO_2 max. *J Appl Physiol* 1988;65:1147–1151.
- 21 Evans WJ, Campbell WW: Sarcopenia and age-related changes in body composition and functional capacity. *J Nutr* 1993;123:465–468.
- 22 Poh H, Eastwood PR, Cecins NM, Ho KT, Jenkins SC: Six-minute walk distance in healthy Singaporean adults cannot be predicted using reference equations derived from Caucasian populations. *Respirology* 2006;11:211–216.
- 23 Callisaya ML, Blizzard L, Schmidt MD, McGinley JL, Srikanth VK: Sex modifies the relationship between age and gait: a population-based study of older adults. *J Gerontol A Biol Sci Med Sci* 2008;63:165–170.
- 24 Enright PL, McBurnie MA, Bittner V, Tracy RP, McNamara R, Arnold A, Newman AB: The 6-min walk test: a quick measure of functional status in elderly adults. *Chest* 2003;123:387–398.
- 25 Gibbons WJ, Fruchter N, Sloan S, Levy RD: Reference values for a multiple repetition 6-minute walk test in healthy adults older than 20 years. *J Cardiopulm Rehabil* 2001;21:87–93.
- 26 Dourado VZ, Antunes LC, Tanni SE, de Paiva SA, Padovani CR, Godoy I: Relationship of upper-limb and thoracic muscle strength to 6-min walk distance in COPD patients. *Chest* 2006;129:551–557.
- 27 Tully MA, Cupples ME, Hart ND, McEneny J, McGlade KJ, Chan WS, Young IS: Randomised controlled trial of home-based walking programmes at and below current recommended levels of exercise in sedentary adults. *J Epidemiol Community Health* 2007;61:778–783.
- 28 Woolf-May K, Ferrett D: Metabolic equivalents during the 10-m shuttle walking test for post-myocardial infarction patients. *Br J Sports Med* 2008;42:36–41, discussion 41.
- 29 Wasserman K, Hansen J, Sue DY, Whipp BJ, Casaburi R: Prova de esforço: princípios e interpretação, ed 3. Rio de Janeiro, Revinter, 2005.
- 30 Kervio G, Carre F, Ville NS: Reliability and intensity of the six-minute walk test in healthy elderly subjects. *Med Sci Sports Exerc* 2003;35:169–174.
- 31 Casas A, Vilario J, Rabinovich R, Mayer A, Barbera JA, Rodriguez-Roisin R, Roca J: Encouraged 6 min walking test indicates maximum sustainable exercise in COPD patients. *Chest* 2005;128:55–61.
- 32 Morales FJ, Montemayor T, Martinez A: Shuttle versus six-minute walk test in the prediction of outcome in chronic heart failure. *Int J Cardiol* 2000;76:101–105.
- 33 Green DJ, Watts K, Rankin S, Wong P, O'Driscoll JG: A comparison of the shuttle and 6 minute walking tests with measured peak oxygen consumption in patients with heart failure. *J Sci Med Sport* 2001;4:292–300.
- 34 Vagaggini B, Taccola M, Severino S, Marcello M, Antonelli S, Brogi S, De Simone C, Giardina A, Paggiaro PL: Shuttle walking test and 6-minute walking test induce a similar cardiorespiratory performance in patients recovering from an acute exacerbation of chronic obstructive pulmonary disease. *Respiration* 2003;70:579–584.
- 35 Turner SE, Eastwood PR, Cecins NM, Hillman DR, Jenkins SC: Physiologic responses to incremental and self-paced exercise in COPD: a comparison of three tests. *Chest* 2004;126:766–773.
- 36 Singh SJ, Jones PW, Evans R, Morgan MD: Minimum clinically important improvement for the incremental shuttle walking test. *Thorax* 2008;63:775–777.
- 37 Geiger R, Strasak A, Treml B, Gasser K, Kleinsasser A, Fischer V, Geiger H, Loeckinger A, Stein JI: Six-minute walk test in children and adolescents. *J Pediatr* 2007;150:395–399, 399.e1–e2.
- 38 Lammers AE, Hislop AA, Flynn Y, Haworth SG: The 6 min walk test: normal values for children of 4–11 years of age. *Arch Dis Child* 2008;93:464–468.