Reliability of Cardiorespiratory and Metabolic Responses During Incremental Shuttle Walk Test in Adult Subjects With Asthma

Ivana Gonçalves Labadessa, Audrey Borghi-Silva, Adriana Sanches Garcia de Araujo, Fabiola Paula Galhardo Rizzatti, and Valéria Amorim P Di Lorenzo

BACKGROUND: The incremental shuttle walk test (ISWT) has been widely used to assess exercise capacity of subjects with COPD. However, to date, no studies have assessed its reliability in the asthmatic population. This study aimed to assess the test-retest reliability of ISWT for the distance walked (ISWD) and cardiorespiratory and metabolic responses in adult subjects with asthma. METHODS: This was a cross-sectional observational study. Thirty-four subjects of both genders, 18–45 y old, with a diagnosis of controlled asthma, were recruited from March 2012 to December 2015. The subjects performed 3 ISWTs on different days, with a minimum interval of 48 h and a maximum of 1 week between the second and third ISWT. For the reliability analysis, the values of the second and third ISWTs were used, eliminating the influence of any learning effect from the first test. RESULTS: The intraclass correlation coefficients were > 0.75 ($P < .001$) for ISWD (m), speed (km/h),oxygen uptake ($\dot{V}_{O_2}$), ventilatory equivalent carbon dioxide ($\dot{V}_E/\dot{V}_{CO_2}$), and minute ventilation ($\dot{V}_E$) at the ISWT peak. The Bland-Altman plot presented a mean error close to zero, and measurement distribution was within acceptable limits of variation. CONCLUSION: The ISWT presented excellent reliability for the ISWD and metabolic responses. The cardiorespiratory responses in the ISWTs presented good reliability. We concluded that the ISWT was reliable for young adult subjects with controlled asthma. *Key words: asthma; metabolic stress response; physiotherapy; exercise test; walking; test-retest reliability.* [Respir Care 2019;64(1):55–62. © 2019 Daedalus Enterprises]

Introduction

Asthma is a common respiratory disease characterized by chronic or recurrent airway inflammation associated with variable expiratory flow limitation and bronchial hyper-responsiveness.[1] Patients with chronic lung diseases are more likely to present with lower exercise tolerance, explained not only by the air-flow limitation, but also by peripheral muscle dysfunction.[2] As a consequence, many patients adopt a sedentary lifestyle, predisposing them to early fatigue and exercise intolerance.[1]

Regular physical training seems to counteract the consequences of the disease and is a cornerstone in the rehabilitation process. It has been suggested that increased exercise capacity may play an important modulatory role in reducing the degree of systemic inflammation in asthma,[3] along with the use of corticosteroids.[4] Regular exercise training may also act beneficially by improving asthma-related psychosocial factors[5] and reducing the risks of exacerbation in asthmatic patients.[6]

Assessment of exercise capacity is fundamental to determine the systemic consequences in patients with asthma, as well as to propose personalized intervention strategies to promote improved exercise capacity. The cardiopulmonary exercise test is considered the standard method to determine the presence and etiology of exercise intoler-

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The authors disclose relationships with the Fundação de Amparo a Pesquisa do Estado de São Paulo and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior.

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DOI: 10.4187/respcare.06112

ance; however, this test is expensive, requires skilled staff, is not widely available, and is associated with risks inherent to its implementation.[7]

Field tests, on the other hand, have been widely used to evaluate exercise capacity because they are less expensive, require minimal staff for execution, and are considered safer in that only submaximal stress is induced during the tests.[8] The incremental shuttle walk test (ISWT)[9] is an externally paced walk test widely used for the evaluation of exercise capacity. This test is considered to be a reliable, valid, and safe instrument for assessing exercise capacity in subjects with COPD.[10]

Some studies of the ISWT have shown that the peak oxygen uptake ($\dot{V}_{O_2}$) presented moderate to strong correlation with measurements of maximal exercise performance in the cardiopulmonary exercise test.[11] Thus, the reliability of physiologic variables during the ISWT is important because it provides information about exercise capacity and allows elaboration of a more specific therapeutic strategy in a physical training program. However, although the ISWT is described as able to evaluate the exercise capacity of patients with cardiorespiratory diseases, there is less clinical evidence regarding the application of ISWT in asthmatic patients. For example, Dyer and colleagues[12] studied a small sample of elderly subjects with asthma and verified that the reliability for the distance walked in the ISWT was weak. Another study recently conducted by Costa and colleagues[13] showed that the ISWT was reliable to assess the functional capacity of subjects with difficult-to-control asthma.

In addition to the low cost and easy application of the ISWT, it is also safe for assessing exercise capacity in patients with asthma. The test is controlled by symptoms, and the progressive increase in walking speed allows important information about physiological responses during physical exercise, including the possibility of triggering exercise-induced bronchospasm, which is an inherent condition in many asthma patients, to be collected.

Therefore, the aim of our study was to analyze the test-retest reliability of the distance walked in the ISWT (ISWD) and the cardiorespiratory and metabolic responses in young adults with controlled asthma. We hypothesized that the ISWT would present good reliability for the distance walked and the cardiorespiratory and metabolic responses in a sample of subjects with asthma.

QUICK LOOK

Current knowledge

Air-flow limitation and peripheral muscle dysfunction are responsible for reducing exercise tolerance in patients with chronic respiratory diseases, inducing adoption of a more sedentary lifestyle, predisposing them to early fatigue and exercise intolerance. It is important to evaluate exercise capacity to determine the systemic consequences in patients with asthma and to propose personalized intervention strategies to promote improvement in exercise capacity.

What this paper contributes to our knowledge

The distance walked and cardiorespiratory and metabolic variables measured with the incremental shuttle walk test (ISWT) were shown to be reliable for the assessment of the exercise capacity of adult subjects with controlled asthma. In addition, the ISWT can be considered as a low-cost and safe instrument to assess the exercise capacity in this population.

Methods

Study Design and Participants

This was an observational cross-sectional study (the reporting of this study was guided by the STROBE statements)[14] conducted by the Spirometry and Respiratory Physiotherapy Laboratory and Cardiopulmonary Physiotherapy Laboratory at the Federal University of São Carlos. The study included 34 subjects with asthma of both genders, 18–45 y old, recruited from March 2012 to December 2015. Dissemination of the study proposal was performed through posters placed on the university campus, local radio, television, and newspapers advertisements, or after physician evaluation and referral. Subjects were contacted by telephone and email, and they were invited to participate in the study if they met the inclusion criteria.

Subjects with a clinical and functional diagnosis compatible with asthma were eligible to participate in the study. Inclusion criteria involved subjects $\geq$ 18 y with a previous asthma diagnosis. Asthmatic subjects with different disease severities could be engaged in the study, with the exception of individuals who presented with severe asthma, regardless of whether it was controlled. Subjects were required to have been evaluated by the physician in charge and to have the disease classified as controlled according to the criteria established by the Global Initiative for Asthma.[3] Individuals with a medical history of asthma exacerbation $<$ 3 weeks before the scheduled tests were excluded from the study.

Individuals presenting with other respiratory, metabolic, or cardiovascular diseases that could cause or aggravate the sensation of dyspnea during efforts were not eligible for the study. Other exclusion criteria included any other contraindications to perform the cardiopulmonary exercise test[7] such as musculoskeletal, neurological, arterial, rheumatological, renal or liver disorders; diabetes mellitus with diabetic neuropathy; difficulty understanding and/or ad-

hering to the study procedures; illegal drug addiction; and pregnancy.

All subjects were informed about all experimental procedures and signed a consent form of a broader study, which included all evaluations and analyzes used in this study. The study was approved by the university human ethics committee (decision number 018/2012).

Experimental Procedures

Subjects with asthma were evaluated on 3 different days with a minimum interval of 48 h between the first and second days. All procedures were carried out during the afternoon. On the first day of the protocol, subjects underwent clinical and physiotherapeutic evaluations as well as pre- and post-bronchodilator pulmonary function tests. Additionally, on the same day, they underwent the first ISWT to become familiar with the test. Subjects received the following recommendations prior to the test execution: avoid consumption of stimulating beverages (caffeine) for 48 h before the test, do not perform physical activity for 24 h before the test, consume light meals on the day of the test, and sleep properly the night before the test (ie, at least 8 h). In this study, short-acting bronchodilators were suspended for at least 6 h and long-acting bronchodilators for 12 h before all assessments because heart rate variability was included in the evaluations. Previous results regarding heart rate variability in asthmatic subjects have already been published by our group.[15] However, $ß_2$-agonist bronchodilators could be administered at any time, under a previous medical prescription (investigator and pulmonologist linked to the study), to revert the bronchoconstriction response after exercise if the volunteer presented significant dyspnea or if FEV_1 had not returned to within 10% of baseline when the subject was ready to leave the laboratory.[16] On the second day of the protocol, the second ISWT was conducted and, after a minimum of 48 h and a maximum of 1 week, subjects performed the third ISWT. All tests were conducted by the same assessor in a level corridor. The portable cardiopulmonary exercise testing system (Oxycon Mobile, Mijnhardt/Jäger, Würzburg, Germany) was used to capture breath-by-breath ventilatory, cardiorespiratory, and metabolic variables. Furthermore, subject responses were assessed at rest, during exercise, and in the recovery period. To eliminate the learning effect that might influence the first test, only the data from the second and third ISWTs were used in the reliability analysis.

Spirometry

The pulmonary function test was performed with a portable ergospirometry system (Oxycon Mobile), with an oro-nasal mask used as an interface. Technical procedures, acceptability, and reliability criteria followed the American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines.[17] Spirometric indices were presented in absolute values and as a percentage of the reference values obtained for the Brazilian population.[18]

ISWT

The ISWT consists of walking along a 10-m corridor in a space delimited by 2 cones. Walking was performed at a progressive speed, which increased by 0.17 m/s every minute after a sonorous beep. Subjects were instructed, every minute, to increase their walking speed during the 12 stages of the test to reach maximum effort. The test was ended when subjects reported to the examiner an intense sensation of dyspnea, pain, lower limb fatigue,[19] or any other symptoms that could prevent them from continuing the tests. In addition, the test was also interrupted if the subject could no longer maintain the required speed for 2 consecutive laps, considered as being $>$ 0.5 m away from the cone when the beep sounded.[9] If subjects reached the cone before the beep, they were instructed to remain close to the cone and wait for the signal.

Subjects were monitored at rest, immediately after the test, and in the fourth minute of passive recovery. Heart rate was monitored with a cardiofrequencimeter (RS800CX, Polar Electro Co. Ltd., Kempele, Oulu, Finland), blood pressure (mm Hg) was assessed via auscultation, peripheral oxygen saturation was evaluated with a portable oximeter (Nonin 8500A, Hand Held Pulse Oximeter, Plymouth, Minnesota), and the subjective sensation of dyspnea and lower limb fatigue were monitored according to the Borg dyspnea scale.[19] In addition, the following cardiorespiratory and metabolic variables were recorded at rest, during the test, and during the recovery period: expiratory minute volume ($\dot{V}_E$), $\dot{V}_{O_2}$; absolute value and corrected by the body mass, and carbon dioxide production ($\dot{V}_E/\dot{V}_{CO_2}$). The highest values recorded in the final 6 s of the peak of all tests were selected for further analysis. The percentage of predicted distance walked for the ISWT was calculated as previously published.[20]

Statistical Analysis

Statistical analysis was performed with the Statistical Package for Social Sciences (SPSS) software for Windows, version 17.0 (IBM, Armonk, New York). Normality of the data was verified with the Shapiro-Wilk test. Data are organized in tables and graphs. Results are presented as mean± SD or median (interquartile range) for parametric and nonparametric variables, respectively. The significance level was assumed at $P < .05$.

The sample size was estimated as at least 19 asthmatic subjects with the objective of performing the proposed

Table 1. Demographic, Anthropometric and Spirometric Characteristics of the Subjects With Asthma

Characteristics	Values
Age, y	27 (24.0–38.3)
Height, cm	1.69 (1.62–1.77)
Body mass, kg	72.7 ± 14.7
Body mass index, kg/m^2	25.0 (21.7–29.4)
ISWD predicted, m	762.0 ± 102.8
FEV_1 pre-bronchodilator, L	3.3 ± 0.9
FEV_1 pre-bronchodilator, % predicted	92.5 ± 19.2
FEV_1 post-bronchodilator, L	3.5 ± 0.9
FEV_1 post-bronchodilator, % predicted	97.4 ± 16.6
FVC pre-bronchodilator, L	5.1 ± 1.4
FVC pre-bronchodilator, % predicted	116.4 (95.1–127.1)
FEV_1/FVC pre-bronchodilator, % predicted	71.8 ± 18.5
FEV_1/FVC post-bronchodilator, % predicted	91.4 (83.2–100.6)
Maximum voluntary ventilation, L	102.0 (84.4–148.8)
Maximum voluntary ventilation, % predicted	71.8 ± 18.5

N = 34 asthmatic subjects. Results are expressed as mean ± SD or median (interquartile range).
ISWD = incremental shuttle walk test distance

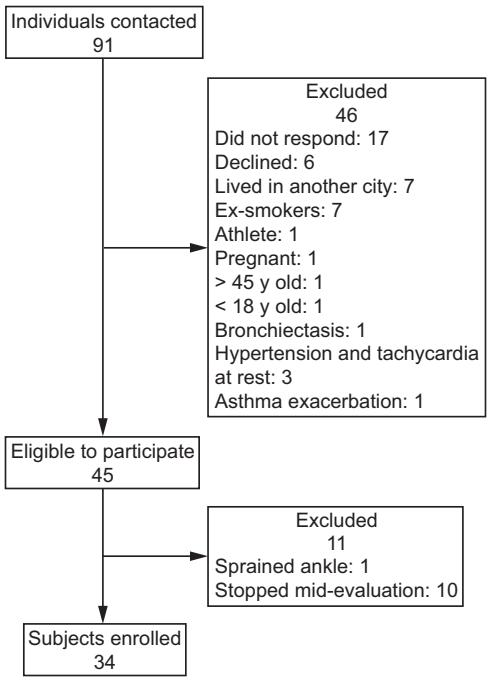

Fig. 1. Flow chart.

reliability analysis,[21] considering $\alpha < 0.05$ and $\beta < 0.2$, a number of repetitions of 2 tests, the null hypothesis of intraclass correlation coefficient (ICC) < 0.7, and the expected hypothesis of ICC > 0.9. A sample size of 30 subjects was considered moderate and acceptable according to the Consensus-Based Standards for the Selection of Health Status Measurement Instruments checklist.[22] The expected ICC was consistent with the mean ICC for the ISWD as verified in 7 previous studies that tested its reliability (range 0.80–0.99).[13,23-28]

Variance analysis comparing the ISWD and the cardiorespiratory and metabolic responses between the second and third ISWT was performed with a paired t test or its corresponding nonparametric test, the Wilcoxon test.

To test reliability, we used the ICC, also known as the reproducibility coefficient, which is an estimate of the fraction of the total variability of the measure due to individual variations. Reliability was analyzed using the ICC, classifying the values as low (ICC < 0.4), good (ICC > 0.4 and < 0.75), and excellent (ICC > 0.75).[29] Furthermore, we calculated the coefficient of variation, which is the SD expressed as a percentage of the mean (coefficient of variation = ISWD/mean). The error analysis between the second and third test was conducted using the mean error and its 95% limits of agreement presented in a Bland-Altman plot.

Results

Demographic and pulmonary function data were obtained on 34 subjects (Table 1). Ninety-one people were initially contacted, of whom 46 were ineligible for various reasons, leaving 45 subjects in the sample. During the study, 11 subjects were excluded, resulting in the 34 subjects who participated in the study (Fig. 1). Medications being taken included short-acting β_2-adrenergics (n = 13), long-acting β_2-adrenergics (n = 8), anticholinergic (n = 2), inhaled corticosteroids (n = 16), oral corticosteroids (n = 1), nasal corticosteroids (n = 3), antihistamines (n = 1), and theophylline (n = 1). Nine subjects were not taking any medication.

Thus, ISWD (ICC = 0.85), speed, $\dot{V}_{O_2}$ (ICC = 0.86) (absolute value (ICC = 0.95) and corrected for body mass (ICC = 0.88), $\dot{V}_E/\dot{V}_{CO_2}$ (ICC = 0.84) and $\dot{V}_E$ = 0.88) presented excellent reproducibility, with ICC values > 0.75 and heart rate (ICC = 0.68), being considered a good reproducibility, presenting a value of 0.4 < ICC < 0.75 (Table 2).

Considering other reliability aspects, no statistically significant differences were observed between the ISWDs in second (ISWT-2) and third (ISTW-3) ISWTs (P = .864) and between the percentage of predicted ISWD for ISWT-2 and ISWT-3 (P = .880). A statistically significant difference in the heart rate at rest was verified between ISWT-2 and ISWT-3, although this result was not clinically relevant (Table 3).

Subjects walked an average distance of 541.7 m (95% CI 432.8–650.6) in the ISWT-2 and 540.0 m (95% CI 431.1–648.9) in the ISWT-3. The Bland-Altman plot for the ISWD showed a mean error in the test-retest comparison of 0.69 m, with limits of agreement of −117.9 m to 119.3 m. This

indicates that in the retest, 95% of subjects should be able to walk a distance ranging from −117.9 m to 119.3 m of the mean ISWT-2 (Fig. 2).

The heart rate at ISWT peak was an average of 151.9 beats/min (95% CI 116.6–187.2) in the ISWT-2 and 148.2 beats/min (95% CI 113.0–183.5) in the ISWT-3. In the Bland-Altman analysis, a mean error of −4.4 beats/min with agreement limits of −41.9 to 33.1 beats/min between the ISWT-2 and ISWT-3 (Fig. 3) was found for peak heart rate. This indicates that in the retest, 95% of subjects who underwent ISWT are expected to present a heart rate variation ranging from −41.9 to 33.1 beats/min of the mean ISWT-2 heart rate.

Peak $\dot{V}_{O_2}$ presented a mean value of 25.9 mL/kg/min (95% CI 19.7–32.1) in the ISWT-2 and 25.3 mL kg/min (95% CI 19.1–31.5) in the ISWT-3. In the Bland-Altman analysis, a mean error of −0.67 mL/kg/min was observed for peak $\dot{V}_{O_2}$, with limits of agreement of −7.2 to 5.9 mL/kg/min between the ISWT-2 and ISWT-3 (Fig. 3). This indicates that in the retest, 95% of subjects who underwent ISWT are expected to present a $\dot{V}_{O_2}$ value in the range of −7.2 to 5.9 mL/kg/min of the mean ISWT-2 $\dot{V}_{O_2}$.

Table 2. Reliability Analysis for ISWD, Cardiorespiratory and Metabolic Responses Between the Second and Third ISWT

Variables	Intraclass Correlation Coefficient (95% CI)	Coefficient of Variation
ISWD	0.85 (0.72–0.82)	0.08
Speed	0.86 (0.74–0.93)	0.04
$\dot{V}_{O_2}$	0.95 (0.89–0.97)	0.08
$\dot{V}_E/\dot{V}_{CO_2}$	0.84 (0.71–0.92)	0.06
$\dot{V}_{O_2}$	0.88 (0.76–0.94)	0.09
$\dot{V}_E$	0.88 (0.77–0.94)	0.12
Heart rate	0.68 (0.45–0.83)	0.12

ICC = intra-class correlation coefficient
ISWT = incremental shuttle walk test
ISWD = incremental shuttle walk distance
$\dot{V}_{O_2}$ = oxygen uptake
$\dot{V}_E/\dot{V}_{CO_2}$ = ventilatory equivalent carbon dioxide
$\dot{V}_E$ = minute ventilation

Discussion

The main outcomes of this study were that the ISWT presented excellent reliability for the ISWD, speed, $\dot{V}_{O_2}$, $\dot{V}_E/\dot{V}_{CO_2}$, and $\dot{V}_E$; the only exception was heart rate, which presented good reliability. Therefore, the ISWT can be considered a safe and reliable instrument to evaluate the exercise capacity of patients with asthma; however, evidence of the validity of the ISWT for the evaluation of cardiorespiratory and metabolic responses, mainly peak $\dot{V}_{O_2}$, in subjects with asthma is scarce and this topic requires further investigation.

In the study of Dyer and colleagues[12] the reliability of the ISWT was evaluated in a small sample of elderly subjects with asthma who performed 2 ISWTs within 2 weeks. However, all of the subjects evaluated in this study completed the tests, contrary to the study by Dyer and colleagues,[12] where 12% of the subjects who were evaluated did not complete the tests; nonetheless, the investigators concluded that the ISWT is feasible and reliable to evaluate elderly patients with or without air flow obstruction.

Costa and colleagues[13] evaluated the reliability of the ISWT in 45 subjects with difficult-to-control asthma and performed 2 ISWTs on the same day with a 20-min rest period between tests. The investigators concluded that the ISWT is reliable and can be used to evaluate the exercise capacity of patients with difficult-to-control asthma.

The ISWT test-retest reliability performed in our study resulted in ICC > 0.75 for distance walked, indicating that

Table 3. Comparative Assessment of the Second and Third ISWT for ISWD, Cardiorespiratory, and Metabolic Responses

Variables	ISWT-2	ISWT-3	*P*
ISWD, m	541.7 ± 102.5	540.0 ± 101.9	.90
ISWD, % predicted	71.0 ± 10.1	70.8 ± 8.9	.88
Speed, km/h	6.1 (5.5–6.7)	6.1 (5.5–6.7)	.51
$\dot{V}_{O_2}$, mL/min	1,870.8 ± 552.9	1,849.3 ± 556.4	.50
$\dot{V}_E/\dot{V}_{CO_2}$	30.3 ± 4.5	30.5 ± 4.2	.57
$\dot{V}_{O_2}$, mL/kg/min	25.9 ± 5.9	25.3 ± 7.0	.28
$\dot{V}_E$, L/min	61.1 ± 17.5	61.6 ± 21.9	.97
Heart rate at rest, beats/min	86.2 ± 12.1	82.4 ± 12.0*	.047
Heart rate peak, beats/min	151.9 ± 21.2	148.2 ± 23.8	.24
Heart rate maximum, predicted, %	83.9 ± 10.7	81.1 ± 1	.13

Results are expressed as mean ± SD or median (interquartile range).
* Different compared to the mean value of the ISWT-2 by the paired Student *t* test ($P < .05$).
ISWD = incremental shuttle walking test distance
$\dot{V}_{O_2}$ = oxygen uptake
$\dot{V}_E/\dot{V}_{CO_2}$ = ventilatory equivalent carbon dioxide
$\dot{V}_E$ = minute ventilation

the ISWD in the ISWT is reliable. Seven previous studies tested the test-retest reliability for the ISWD, with ICCs ranging from 0.80 to 0.99.[13,23-28] These results are consistent with study findings in other chronically ill populations.

Considering the coefficient of variation results of the ISWD, the observed values were low (0.08, or 8.0%), indicating homogeneous variability between means and a dependence on the application method over time. One study verified the ISWT reliability in subjects with chronic heart failure[30] and found coefficient of variation values similar to those found in our study (6.9); however, the sample size was considered small.

Costa and colleagues[13] conducted a study with subjects with difficult-to-control asthma and found a mean error of −12.7 m with limits of agreement of 37.8 to −63.2 m, whereas the mean error value of our study was close to zero (0.69 m). Although the limits of agreement of our study were higher, the distributions were within acceptable limits, unlike the findings of the study in question, which presented 5 points below the acceptable lower limit.

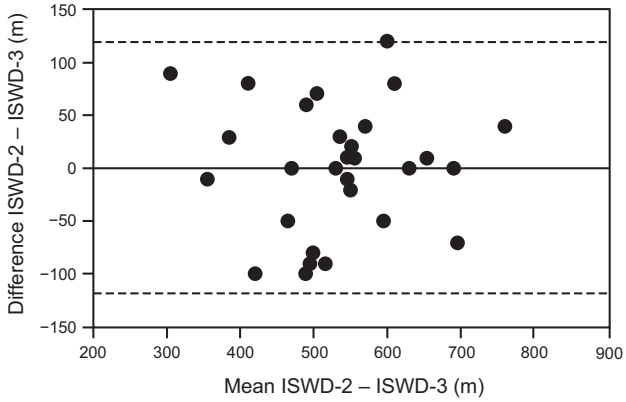

Fig. 2. Reliability by Bland-Altman plot for subjects with asthma. Performance between the second and third incremental shuttle walk test (ISWD). Mean error = 0.69.

Pepera and colleagues,[26] when studying subjects with clinically stable cardiovascular disease, found a mean error of −7 m with limits of agreement (Bland-Altman) of −203 to 189 m. Hence, the magnitude of these values (386 m) was higher than that found in our study, which was 241.4 m. Jürgensen and colleagues[28] conducted a study with obese women, finding a mean error of −5.9 with limits of agreement of −82.0 to 70.2 m, and the magnitude of these values was 148.2 m, lower than the value obtained in our study (241.4 m).

Another study[27] conducted with subjects with bronchiectasis without cystic fibrosis found a mean error of −4.4 m and limits of agreement between −57 and 48 m, which were lower values than those found in our study. The tests were performed on the same day with a 30-min interval between tests. van Bloemendaal and colleagues[31] conducted a study with subjects after a stroke and they found a mean error of 27.4 and limits of agreement of −272.3 to 327.0 m; however, the authors did not clearly state the time interval between tests.

For ISWT speed we found an ICC of 0.86, similar to the results observed by Jürgensen and colleagues[28] (ICC = 0.84). The coefficient of variation observed in our analysis was low (0.04, or 4.0%), indicating homogeneity between the measurements.

In the analysis of cardiorespiratory responses obtained during the ISWT, the heart rate in the test retest presented an ICC of 0.68. de Camargo and colleagues[27] and Costa and collegues[13] found ICCs of 0.92 and 0.97 in the post-exercise, respectively; however their experimental procedures differed from our study. The coefficient of variation value of the heart rate in this study was low (0.12, or 12.0%), indicating homogeneity of our results, which is similar to that found by Green and colleagues.[30]

We found a heart rate mean error value of −4.4 beats/min, which is close to zero, and limits of agreement ranging

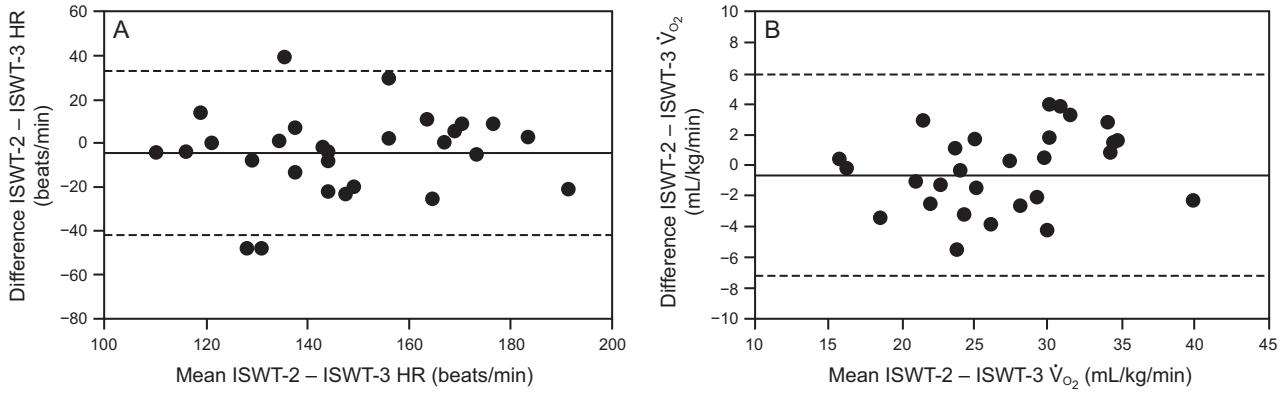

Fig. 3. Reliability by Bland-Altman plot for subjects with asthma. A: Peak heart rate (HR), mean error −4.4. B: Peak oxygen uptake ($\dot{V}_{O_2}$), mean error −067.

from −41.9 to 33.1 beats/min. These values were similar to the results obtained by Jürgensen and colleagues[28] and by Booth and Adams.[32] The expected heart rate was in the range of 110–190 beats/min, which is similar to that found by Jürgensen and colleagues[28] (ie, 120–180 beats/min), but different from the one obtained by Booth and Adams[32] (ie, 80–140 beats/min). In this study, the distributions of the heart rate occurred within acceptable limits of variation.

Regarding the metabolic variables, we found an ICC of 0.88 for the test-retest for $\dot{V}_{O_2}$ (mL/kg/min); the coefficient of variation was low (0.09, or 9.0%), and there was no significant difference ($P = .28$) between the $\dot{V}_{O_2}$ in the ISWT-2 and ISWT-3. The mean error was close to zero (−0.67), and the limits of agreement were between −7.2 and 5.9. The distributions occurred within acceptable limits of variation, thus the 2 measurements had similar results. These finding are in accordance with Jürgensen and colleagues,[28] except for the limits of variation of their results.

For $\dot{V}_{O_2}$ (mL/min), we found an ICC of 0.95 in the test-retest comparison, and the coefficient of variation was low (0.08, or 8.0%), indicating homogeneity between the measurements. We found an ICC of 0.84 for $\dot{V}_E/\dot{V}_{CO_2}$ and 0.88 for $\dot{V}_E$ (L/min) in the test-retest comparison, with the coefficients of variation (0.06, or 6.0%) and (0.12, or 12.0%), respectively, indicating good homogeneity. Thus, our results for the variables above mentioned (except $\dot{V}_E/\dot{V}_{CO_2}$) were in accordance with the findings of Jürgensen and colleagues.[28]

We consider the difficulty of comparing our findings with those of other studies to be a limitation of our study, because we found experimental procedures that varied regarding the intervals (time and days) between tests. In this study, we determined that the ISWT-2 and ISWT-3 should be conducted on different days with a maximum interval of 7 d because we could not predict whether the ISWT would provoke exercise-induced bronchospasm.

Our results are clinically relevant because the distance walked and the cardiorespiratory and metabolic responses were reliable during ISWT in the test-retest analysis. According to Singh and colleagues,[11] there is a significant learning effect between the first 2 ISWTs, with a mean difference of 9–25 m, and this magnitude is sufficient to recommend that 2 tests could be performed on the first exposure, attenuating the learning effect over subsequent repetitions of the test. However, Dyer and colleagues[33] suggested that after longer periods (> 8 weeks) the learning effect may return to a level similar to that recorded in the first exposure to the test. In our study, we assumed that the tests could be compared if performed after a 1-week interval.

Conclusion

ISWT presented excellent reliability for the ISWD and metabolic responses. The cardiorespiratory responses in ISWT presented good reliability. We conclude that ISWT was reliable for the assessment of the exercise capacity of young adults with controlled asthma.

ACKNOWLEDGMENTS

The authors are grateful for the contributions made by Juliano Ferreira Arcuri.

REFERENCES

1. Reimberg MM, Castro RA, Selman JP, Meneses AS, Politti F, Mallozi MC, et al. Effects of a pulmonary rehabilitation program on physical capacity, peripheral muscle function and inflammatory markers in asthmatic children and adolescents: study protocol for a randomized controlled trial. Trials 2015;16:346-352.
2. Del Giacco SR, Firinu D, Bjermer L, Carlsen KH. Exercise and asthma: an overview. Eur Clin Respir J 2015;2(1):27984.
3. Global Strategy for Asthma Management and Prevention, Global Initiative for Asthma (GINA) 2016. Available at www.ginasthma.org. *Accessed July 10, 2018.*
4. Mendes FAR, Almeida FA, Cukier A, Stelmach R, Jacob-Filho W, Martins MA, Carvalho CR. Effects of aerobic training on airway inflammation in asthmatic subjects. Med Sci Sports Exerc 2011; 43(2):197-203.
5. Mendes FA, Gonçalves RC, Nunes MP, Saraiva-Romanholo BM, Cukier A, Stelmach R, et al. Effects of aerobic training on psychosocial morbidity and symptoms in subjects with asthma: a randomized clinical trial. Chest 2010;138(2):331-337.
6. Garcia-Aymerich J, Varraso R, Antó JM, Camargo CA Jr. Prospective study of physical activity and risk of asthma exacerbations in older women. Am J Respir Crit Care Med 2009;179(11):999-1003.
7. Neder JA, Nery LE. Teste de exercício cardiopulmonar. J Pneumol 2002;28(1):166-206.
8. Hill K1, Dolmage TE, Woon L, Coutts D, Goldstein R, Brooks D. Comparing peak and submaximal cardiorespiratory responses during field walking tests with incremental cycle ergometry in COPD. Respirology 2012;17(2):278-284.
9. Singh SJ, Morgan MDL, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in subjects with chronic airways obstruction. Thorax 1992;47(12):1019-1024.
10. Parreira VF, Janaudis-Ferreira T, Evans RA, Mathur S, Goldstein RS, Brooks D. Measurement properties of the incremental shuttle walked test: a systematic review. Chest 2014;145(6):1357-1369.
11. Singh SJ, Puhan MA, Andrianopoulos V, Hernandes NA, Mitchell KE, Hill CJ, et al. An official systematic review of the European Respiratory Society/American Thoracic Society: measurement properties of field walking tests in chronic respiratory disease. Eur Respir J 2014;44(6):1447-1478.
12. 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(1):34-38.
13. Costa IP, Dal Corso S, Borghi-Silva A, Peixoto F, Stirbulov R, Arena R, et al. Reliability of the shuttle walk test with controlled incremental velocity in patients with difficult-to-control asthma. J Cardiopulmon Rehabil Prev 2017;38(1):54-57.
14. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational

Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol 2008;61(4):344-349.
15. Garcia-Araújo AS, Pires Di Lorenzo VA, Labadessa IG, Jürgensen SP, Di Thommazo-Luporini L, Garbim CL, Borghi-Silva A. Increased sympathetic modulation and decreased response of the heart rate variability in controlled asthma. J Asthma 2015;52(3):246-253.
16. Crapo RO, Casaburi R, Coates AL, Enright PL, Hankinson JL, Irvin CG, et al. Guidelines for methacholine and exercise challenge testing-1999. This official statement of the American Thoracic Society was adopted by the ATS Board of Directors, July 1999. Am J Respir Crit Care Med 2000;161(1):309-329.
17. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J 2005;26(2):319-338.
18. Pereira CAC, Sato T, Rodrigues SC. Novos valores de referência para espirometria forçada em brasileiros adultos de raça branca. J Bras Pneumol 2007;33(4):397-406.
19. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982;14(5):377-381.
20. Dourado VZ, Guerra RL, Tanni SE, Antunes LC, Godoy I. Reference values for the incremental shuttle walked test in healthy subjects: from the distance walked to physiological responses. J Bras Pneumol 2013;39(2):190-197.
21. Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med 1998;17(1):101-110.
22. Mokkinki LB, Terwee CB, Knol D, Stratford PW, Alonso J, Patrick DL, et al. The COSMIN checklist for evaluating the methodological quality of studies on measurement properties: a clarification of its content. BMC Med Res Methodol 2010;10:22.
23. Fowler SJ, Singh SJ, Revill S. Reproducibility and validity of the incremental shuttle walking test in subjects following coronary artery bypass surgery. Physiotherapy 2005;91(1):22-27.
24. Campo LA, Chilingaryan G, Berg K, Paradis B, Mazer B. Validity and reliability of the modified shuttle walk test in subjects with chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2006; 87(7):918-922.
25. da Cunha-Filho IT, Pereira DAG, de Carvalho AMB, Campedeli L, Soares M, de Sousa Freitas J. The reliability of walking tests in people with claudication. Am J Phys Med Rehabil 2007;86(7):574-582.
26. Pepera G, McAllister J, Sandercock G. Long-term reliability of the incremental shuttle walking test in clinically stable cardiovascular disease subjects. Physiotherapy 2010;96(3):222-227.
27. de Camargo AA, Amaral TS, Rached SZ, Athanazio RA, Lanza FC, Sampaio LM, et al. Incremental shuttle walking test: a reproducible and valid test to evaluate exercise tolerance in adults with noncystic fibrosis bronchiectasis. Arch Phys Med Rehabil 2014;95(5):892-899.
28. Jürgensen SP, Trimer R, Dourado VZ, Di Thommazo-Luporini L, Bonjorno-Junior JC, Oliveira CR, et al. Shuttle walking test in obese women: test retest reliability and concurrent validity with peak oxygen uptake. Clin Physiol Funct Imaging 2015;35(2):120-126.
29. Fleiss JL. The design and analysis of clinical experiments. New York: John Wiley; 1986.
30. 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 subjects with heart failure. J Sci Med Sport 2001; 4(3):292-300.
31. van Bloemendaal M, Kokkeler AM, van de Port IG. The shuttle walk test: a new approach to functional walking capacity measurements for subjects after stroke? Arch Phys Med Rehabil 2012;93(1):163-166.
32. Booth S, Adams L. The shuttle walking test: a reproducible method for evaluating the impact of shortness of breath on functional capacity in subjects with advanced cancer. Thorax 2001;56(2):146-150.
33. Dyer F, Marriner P, Cheema K, Bott J. Is a practice incremental shuttle walk test really necessary? Chron Respir Dis 2011;8(3):201-205.