Reference Equation for the Incremental Shuttle Walk Test in Children and Adolescents

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Objective To determine a prediction equation for distance walked of incremental shuttle walk test (ISWT) and test its reliability in children and adolescents.

Study design Cross-sectional study, which included 108 healthy volunteers between 6 and 18 years old. Those who had an abnormal spirometry or had a history of chronic disease were excluded. Two ISWT were performed. Heart rate and peripheral capillary oxygen saturation (SpO_2) were continuously measured during the test. Dyspnea and lower limb fatigue were assessed by Borg scale before and after the tests.

Results Boys walked longer distances compared with girls (1066.4 ± 254.1 m vs 889.7 ± 159.6 m, respectively, $P < .0001$). Except for dyspnea, there were no significant differences in the other outcomes measured (heart rate, lower limb fatigue, SpO_2, and distance walked) at the peak of the two ISWT. The variables included in the predicted equation were age, body mass index, and sex. The predicted equation is: $ISWT_{pred} = 845.559 + (sex * 193.265) + (age * 47.850) - (body\ mass\ index * 26.179)$. The distance walked had an excellent reliability between the two ISWT, 0.98 (95% CI 0.97-0.99). The Bland–Altman plot shows agreement between tests (range from −40 to 45 m).

Conclusions We established a prediction equation for ISWT. It can be used as a reference to evaluate exercise capacity for children and adolescents. ISWT has excellent repeatability and it is a maximal-effort field test for this age group. *(J Pediatr 2015;167:1057-61)*.

Walk tests have been widely used in clinical practice to evaluate physical capacity. These tests do not require expensive equipment, as does a cardiopulmonary exercise test,[1,2] and it is easy to perform them. The incremental shuttle walk test (ISWT) was a simple walk test that was described by Singh et al,[3] which evaluates maximal exercise capacity based on the distance walked.

The ISWT was designed primarily for adult patients with chronic obstructive pulmonary disease,[3] but since then, it has been used for other lung diseases[4,5] and health conditions.[6-8] Prediction equations for use with the ISWT have been established for adults.[9,10] Probst et al[9] and Jürgensen et al[10] evaluated Brazilian adult volunteers to determine a predictive equation for the ISWT.

The ISWT has been less thoroughly explored in children and adolescents. The few studies of the use of the ISWT in children and adolescents describe its feasibility and reproducibility.[11-13] Some studies determined the reduction of physical capacity in patients with asthma[14] and preterm newborns by ISWT.[15,16] Considering that there is no reference equation with which to determine the predicted distance walked in ISWT for children and adolescents, those authors could only observe the reduction of physical capacity because they used a control group to compare the results. Currently, to evaluate whether reduced functional capacity is present by ISWT, we must compare them by a control group.

Owing to the very important measurement properties of the ISWT, the aim of this study was to determine a prediction equation for distance walked in the ISWT and also to test its reliability in children and adolescents.

Methods

This was a cross-sectional study that included 108 healthy subjects. They were recruited from among students at private and public schools in São Paulo, Brazil. The protocol was approved by the Research

6MWT	6-minute walk test
BMI	Body mass index
FEV_1	Forced expiratory volume in 1 second
FVC	Forced vital capacity
HR	Heart rate
ICC	Intraclass correlation coefficient
ISWT	Incremental shuttle walk test

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Ethics Committee of the University (483692). The protocol began in April 2013 and ended in May 2014. All measurements were obtained in the school or in the physiology laboratory of our university (Nove de Julho University) by trained investigators.

The inclusion criteria were as follows: both sexes, ages 6-18 years old, absence of chronic or acute diseases, and normal lung function (forced vital capacity [FVC] and forced expiratory volume in 1 second [FEV_1] > 80% pred, FEV_1/FVC > 80%). The volunteers were excluded if they were unable to understand the test, had premature birth, practiced physical activity more than twice a week, or if the parents did not sign the consent form. A questionnaire was given to the parents in order to determine the health status of the subject, including medication use, acute, or chronic disease.

Weight was measured to the nearest 0.1 kg using a calibrated balance (110F; Welmy, São Paulo, Brazil), and height was determined to the nearest 0.5 cm using a stadiometer. Body mass index (BMI) was calculated as weight/height^2.

To determine whether the volunteer's lung function was normal, spirometry was performed with a calibrated pneumotachograph (CPFS/D USB; Medical Graphics, St. Paul, Minnesota), as recommended by the American Thoracic Society/European Respiratory Society.[17] We recorded FVC, FEV_1, and FEV_1/FVC. The measurements were then compared with those predicted for the Brazilian population.[18]

Two ISWT were performed with at least 30 minutes of rest between them. The test was performed in a 10 m corridor that was identified by 2 cones at the endpoints.[3] The best test, (ie, the longest distance walked) was considered for analysis. Participants should walk (or run) around the course at the speed dictated by an audio signal. The initial walking speed was 0.5 m/s, and this increased by 0.17 m/s each minute; the speed increment was always indicated by a triple bleep. The test was composed of 15 levels. A trained professional conducted the tests. The maximum difference between the tests should be 40 m.[19] A third test was performed when the difference was greater than this. The ISWT was interrupted if the volunteer presented 1 of the following conditions: could not maintain the required speed due to dyspnea or fatigue or if he or she failed to complete a shuttle in the time allowed for the second time. Heart rate (HR) and peripheral capillary oxygen saturation (SpO_2) were continuously measured during the test, and perceived dyspnea and leg fatigue (modified Borg scale)[20] were assessed before and after the test. The maximum predicted HR was calculated as 208 − (0.7 * age).[21]

Statistical Analyses

The normality of the data was analyzed via the Shapiro–Wilk test. The data showed a parametric distribution and was expressed as mean ± SD. The Borg scale was expressed as median (25-75). The difference in distance walked between males and females, and between children (≤12 years old) and adolescents (≥13 years old), were analyzed using an unpaired *t*-test. The test with the greatest distance walked was selected for the next analysis. Pearson correlation coefficient was used between the independent variables (age, weight, height, and BMI), and the dependent variable (distance walked) in order to select independent variables for the multiple regression analysis (stepwise) and develop the predictive equation. The interactions (multicollinearity) between independent variables were tested in this model; the conditional (interaction) between age and sex, and height and weight was tested. The intraclass correlation coefficient (ICC) and Bland–Altman analysis[22] were used to assess the reproducibility of the two ISWT. The ICC was characterized as follows: good reliability 0.80-1.0; fair reliability 0.60-0.79; and poor reliability <0.60.[23]

The sample size was calculated based on the follow equation[24]:

$$N > 50 + (8 * m)$$

where: m = number of independent variables included in the analysis.

The minimal sample was 82 participants, for α 0.05, and β 0.2, but considering that other correlations were evaluated, we included more participants. The probability of a type I error was established as 0.05 for all tests. The SPSS statistical package, ver. 22 (Chicago, Illinois) was used.

Results

A total of 173 subjects were selected, but 46 of the volunteers had chronic lung disease, 12 had abnormal lung function, and the parents of 7 volunteers did not sign the consent form. The final sample was 108 subjects; 52 (48%) of whom were male. The subjects' characteristics are described in **Table I**.

As expected, boys walked longer distances during the ISWT compared with girls (1064.4 ± 254.1 vs 889.7 ± 159.6, respectively, $P < .0001$; **Table I**). We divided the volunteers into children (≤12 years old) and adolescents (≥13 years old), and we observed shorter distances walked for the youngest compared with the oldest (899.4 ± 176.3 m vs 1047.1 ± 248.7 m, respectively), $P < .0001$ (**Figure 1**).

Only 25 (23%) volunteers performed 3 tests because their distances walked for the first and second tests were more than 40 m different. For them, the 2 tests with the greater distance walked were used for analysis. Fifty percent (n = 54) of the volunteers provided their best performance (ie, they had a greater distance walked) in the first ISWT, 44 (41%) volunteer walked farther in the second test, and only 10 volunteers (9%) walked farther in the third test. There was no significant difference in distance walked in the 2 selected ISWT (968.5 m ± 225.1 vs 954.3 m ± 217.9, respectively; $P = .86$). Except for dyspnea, there were no significant differences in the other outcomes measured at the peak of the 2 ISWT (**Table II**).