Original Article

Comparative analysis and reproducibility of the modified shuttle walk test in normal children and in children with cystic fibrosis*

Cristiane Cenachi Coelho[1], Evanirso da Silva Aquino[2], Dorcas Costa de Almeida[3], Gisele Caroline Oliveira[3], Roberta de Castro Pinto[3], Ivana Mara Oliveira Rezende[4], Cíntia Passos[5]

Abstract

Objective: To analyze the shuttle walk test, and its respective retest, comparing children with cystic fibrosis (CF) to normal children. **Methods:** The children were divided into two groups: the CF group, composed of children in whom the diagnosis had been confirmed through sweat testing; and the control group, composed of normal children with no history of pulmonary diseases and no alterations in respiratory function. The children were submitted to at least two consecutive tests, 30 min apart. We evaluated distance walked, cardiac overload, peripheral oxygen saturation (SpO_2) and subjective perception of exertion (dyspnea at rest scale and Borg dyspnea scale). **Results:** A total of 28 children were evaluated. Ages ranged from 7 to 15 years (11.57 ± 2.50 and 11.28 ± 1.85 years for the CF and control groups, respectively). The Borg scale scores were significantly higher in the controls ($p = 0.007$). No differences were found regarding cardiac overload and SpO_2. In relation to the intergroup retest, the controls presented significant improvements on the second test, both in the distance walked and in dyspnea at rest ($p = 0.014$ and $p = 0.036$, respectively). The CF group presented a significant improvement only in the dyspnea at rest score ($p = 0.168$ and $p = 0.042$, respectively). **Conclusion:** The cardiac overload imposed by the test did not differ between the groups. The greater fatigue at the beginning of the second test suggests that the 30 min rest between the tests was insufficient.

Keywords: Cystic fibrosis; Exercise test; Heart rate.

* Study carried out at the *Universitário de Belo Horizonte* – Uni-BH, Belo Horizonte University – Center, Belo Horizonte (MG) Brazil.
1. Masters in Bioengineering from the *Universidade do Vale do Paraíba* – UNIVAP, Vale do Paraíba University – São José dos Campos (SP) Brazil.
2. Masters student in Physical Therapy at the *Universidade Cidade de São Paulo* – UNICID, Cidade de São Paulo University – São Paulo (SP) Brazil.
3. Degree in Physical Therapy from the *Centro Universitário de Belo Horizonte* (Uni-BH, Belo Horizonte University Center) – Belo Horizonte (MG) Brazil.
4. Masters in Rehabilitation Sciences from the *Universidade Federal de Minas Gerais* – UFMG, Federal University of Minas Gerais – Belo Horizonte (MG) Brazil.
5. Nutritionist at the Minas Gerais Association for the Treatment of Mucoviscidosis, Belo Horizonte (MG) Brazil.
Correspondence to: Cristiane Cenachi Coelho. Avenida Professor Mario Werneck, 2368, apto. 703, Buritis, CEP 30575-180, Belo Horizonte, MG, Brasil.
Phone 55 31 3226-2997. E-mail: cccoelho@terra.com.br
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Introduction

Cystic fibrosis, also known as mucoviscidosis, is a genetic, systemic, monogenic disease, with an autosomal recessive inheritance pattern. The disease is characterized by generalized dysfunction of the exocrine glands, with chronic progressive evolution, which affects the function of practically all organs and systems. Cystic fibrosis affects all exocrine organs that excrete their products. The cystic fibrosis gene is located in the region of the long arm of chromosome 7, locus q 31, exon 10. It is unique and is responsible for encoding a protein of the chloride channel known as the cystic fibrosis transmembrane conductance regulator (CFTR). For the formation of the chloride channel, this protein is displayed in two transmembrane domains and contains phosphorylation sites; therefore, this channel is regulated by cyclic adenosine monophosphate.[1]

The alterations found in the disease are due to mutations in the cystic fibrosis gene in the CFTR protein and in the chloride channels, generating abnormalities in ion transport. Over 800 such mutations have been described in the literature. However, the most common is the deletion of three specific nucleotides (ATT), which causes the deletion of phenylalanine at position 508 of the CFTR protein. This genetic aberration is known as mutation ΔF508 and is present in approximately 70% of the chromosomes of patients with cystic fibrosis in North America and Europe.[1]

Its diagnosis is based on the clinical manifestations associated with the altered sweat test. The DNA test might or might not identify the cystic fibrosis mutation.[1]

Typical clinical manifestations are cough, chronic diarrhea, and malnutrition. However, the disease can manifest in other ways, depending on the systems or organs affected.[1]

Respiratory impairment is progressive, of varying severity, and occurs in over 95% of the patients. Pulmonary impairment determines the final prognosis. Alterations in the absorption of lipids can also be observed, reflecting the nutritional status of the patient and generating hypodevelopment of the organism as a whole, including the muscle system. Therefore, the exercise tolerance of these patients can be limited.[1]

The evaluation of exercise tolerance and exercise aptitude in children with cystic fibrosis is a useful measurement of the impact of the disease in the patient, particularly when the disease has reached an advanced stage. In addition, measuring the activity level of the exercise and exercise tolerance of an individual can be used to identify functional limitations, as well as quantifying the effects of the disease on their daily life activities and consequent quality of life. It is also useful in order to predict the prognosis of the disease, allowing safe prescription of the exercise and the evaluation of various treatments.[2]

The clinical exercise test is aimed at diagnosing the disease, determining disease severity, assessing cardiorespiratory function, and evaluating the role of physical therapy in rehabilitation.[3-6]

Therefore, the objective of this study was to conduct a comparative analysis between children with cystic fibrosis and normal children in terms of their performance on the modified shuttle walk test (MSWT) and to determine the reproducibility of this test in the two populations studied.

Methods

This study was approved by the Ethics in Human Research Committee of the Belo Horizonte University, and the legal guardians of the children selected all gave written informed consent. A total of 28 children were evaluated. They were divided into two groups: those with cystic fibrosis and those without (control group).

In the two groups, ages ranged from 7 to 15 years. In the cystic fibrosis group, the diagnosis of the disease was confirmed using the sweat test. In the control group, spirometry revealed no alterations, and none of the children had any history of pulmonary disease. The children who presented hemodynamic instability, such as significant alterations in arterial blood pressure and heart rate, were excluded from the study, as were those presenting attacks/exacerbation of the respiratory symptoms of cystic fibrosis, or osteomuscular and cognitive alterations that impaired their performance of the tests.

Evaluation methods

All of the children selected were submitted to respiratory evaluation, anamnesis and measurement of vital signs, as well as static and dynamic inspection previously standardized by the Pulmonary Rehabilitation Center. They were also submitted to

spirometry. The equipment used in this study was the Microlab 3500 spirometer (Micro Medical, Ltd, Kent, UK), which allowed us to outline forced expiratory curves and basal respiratory cycles, based on which the values of the pulmonary function parameters were determined. Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and the Tiffeneau index (FEV_1/FVC ratio) were determined following the norms established in the American Thoracic Society pulmonary function test guidelines, and the values found were calculated using equations previously established.[7]

The age, weight, and height of the children were measured in order to evaluate their nutritional status. For children aged ≤ 9 years, the anthropometric indices weight/age (W/A) and height/age (H/A) were used. We referred to the anthropometric indices of the National Center for Health Statistics, recommended by the World Health Organization and adopted by the Brazilian Ministry of Health. The children presenting a W/A or weight/height index lower than -2 standard deviations were classified as malnourished (underweight), and those with H/A lower than -2 standard deviations as height deficient. In order to increase the sensitivity of the evaluation process and minimize the number of false negatives, children presenting a Z score that was 1 standard deviation or more below the National Center for Health Statistics reference mean were considered to be at nutritional risk. Children presenting a W/A index above 2 standard deviations were classified as being overweight. The ratio of body mass index to age (BMI/A) was used in order to analyze the children between 10 and 15 years of age. According to the anthropometric reference of the Centers for Disease Control, underweight status was assigned to children with BMI/A indices below the 5th percentile, and overweight status to those with BMI/A indices above the 85th percentile.[8]

The MSWT has a standardized protocol, which was used in our study.[9] The test has 15 levels, the patients must walk rapidly, at increasing velocities, on a 10-m course delimited by two 2 cones (one at each end of the course), which must be rounded by the patient. An audio signal is part of the test, indicating each change in level, as well as the increases in velocity during the test. In this study, the children were accompanied by the physical therapist during the first minute to help them adapt to the rhythm of the audio signal. At the end of each level, they were given strong verbal encouragement. The children were also encouraged to walk faster and to continue for the full duration of the test. The children continued walking until the end of the test period, until they could walk no longer, or until they could no longer keep pace with the audio signal. Dyspnea upon exertion and dyspnea at rest were measured using, respectively, the Borg scale[10] and the numeric rating scale developed by Gift & Narsavage.[11]. Peripheral oxygen saturation (SpO_2) and heart rate were measured at 15-s intervals[12] using a pulse oximeter and a heart rate monitor, respectively. The test ended when the children felt they were no longer capable of maintaining the required speed.[13]

The criteria for interruption of the test were as follows: SpO_2 lower than 75%; arterial blood pressure higher than 180/115 mmHg; heart rate higher than the maximum stipulated.[14]

Experimental protocol

All of the children evaluated performed the tests on the same days. Each child performed at least two tests per day. The two most reproducible tests, that is, those between which the difference in the distance walked was 10% or less, were included in the analysis. The children had 30-min rest breaks between the tests. The tests were carried out in a quiet environment, without interferences and by the same physical therapist. The test was performed in a straight line and on level ground. Arterial blood pressure, heart rate, and SpO_2 were measured before and after each test. The dyspnea at rest scale was applied before the test, and the Borg scale was applied after the test.

Verbal stimulation was given at regular intervals. Supplemental oxygen was available for patients presenting hypoxemia.

Statistical analysis

Statistical analysis was performed using the Minitab version 13 software.

The two groups were characterized on the basis of anthropometric variables (age, weight, and height) and pulmonary function (FVC, FEV_1, and the Tiffeneau index) using the nonparametric Mann-Whitney test. The comparison of the tests between the groups was also performed using the Mann-Whitney test. The variables analyzed were: heart

rate, cardiac overload, expressed as the percentage of the maximum heart rate (MHR), SpO_2, distance walked and subjective perception of exertion on the Borg scale.

The Wilcoxon test was used in order to compare the reproducibility of the MSWT in each of the groups studied. The variables analyzed were the same as those used in the comparison between the groups, plus the dyspnea at rest scale.

The level of significance was set at 5% ($p < 0.05$).

Results

A total of 28 children were evaluated (10 females and 18 males), 14 in each group. In the cystic fibrosis group, the mean age was 11.57 ± 2.50 years, ranging from 8 to 15 years, and 9 of the children were above the age of 10. In the control group, the mean age was 11.28 ± 1.85 years, ranging from 9 to 14 years, and 9 of the children were above the age of 10. There were no differences between the groups regarding the anthropometric data (Table 1).

The children were classified, by age, according to their nutritional status. For the children ≤ 9 years of age, the W/A and H/A Z scores were used. For the children from 10 to 15 years of age, the BMI/A ratio was used. In the cystic fibrosis group, 64.28% of the children were classified as healthy, 7.14% as malnourished (underweight), 14.30% as being at nutritional risk, and 14.28% as overweight. Of the children in the control group, 78.58% were classified as healthy, 7.14% as malnourished (underweight), and 14.28% as overweight (Table 1).

Mean FVC was lower in the cystic fibrosis group than in the control group, and this difference was statistically significant ($p = 0.03$). However, mean values were within the limits of normality (Table 2).

Regarding the MSWT, there were no significant differences between the groups in terms of MHR, % MHR, or SpO_2. The only variable for which there was a significant difference between the groups was the subjective perception of exertion, evaluated through the Borg scale, which was significantly higher ($p = 0.007$) in the control group (Table 3).

In comparing the first and second MSWTs, we found that, in the control group, the pre-test dyspnea at rest scale score was higher (greater perceived fatigue) prior to the second test ($p = 0.014$). However, on average, the control group children walked a greater distance in the second test than in the first test, and this difference was statistically significant ($p = 0.036$). In both groups, the only statistically significant difference between the first and the second test was in the dyspnea at rest scale score, which was significantly higher for the second test ($p = 0.042$) in the cystic fibrosis group and in the control group (Tables 4 and 5, respectively).

Discussion

The fact that FVC values in the cystic fibrosis group (although, on average, within the limits of normality) were significantly lower than in the control group is probably attributable to the pulmonary impairment seen in approximately 30% of the children with cystic fibrosis evaluated in the present study. This impairment, according to some authors, is responsible for the symptomatology of these children, which can be characterized as mild to moderate.[13]

Regarding the MSWT, in the comparison between the groups, the only significant difference was in the perception of exertion scale score, which was higher in the control group. This probably occurred because these children walked more than the children with cystic fibrosis, although this difference was not statistically significant. In terms of the distance walked, the cystic fibrosis group presented a performance similar to that of the control group. This could have happened because the children in

Table 1 - Anthropometric data of the two groups studied.

Variable	Control group (n = 14)		Cystic fibrosis group (n = 14)	
	Mean	sd	Mean	sd
Age (years)	11.28	1.85	11.57	2.50
W/A (Z score)	-0.05	1.19	-0.66	1.62
H/A (Z score)	0.11	0.87	-0.05	2.09
BMI (percentile)	48.09	33.00	45.95	34.20

Table 2 - Pulmonary function of the two groups studied.

Variables (% of predicted)	Control group (n = 14)		Cystic fibrosis group (n = 14)		p
	Mean	sd	Mean	sd	
FVC	100.99	8.90	94.85	25.19	0.03
FEV_1	112.26	15.56	86.34	27.11	0.10
FEV_1/FVC	91.99	10.54	90.30	9.14	0.53

The p values in the table refer to the Mann-Whitney test. FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; FEV_1/FVC: Tiffeneau index.

the cystic fibrosis group, in this study, presented little pulmonary impairment. Hence the need to stimulate physical activity in these patients, monitored according to the level of pulmonary impairment.

According to some reports in the literature, individuals with cystic fibrosis who present altered pulmonary function or altered nutritional status also present decreased aerobic performance, and subsequently walk shorter distances on walk tests.[15] Regarding the subjective perception of exertion, we should also consider the hypothesis that children with cystic fibrosis adapt to pulmonary alterations, since their respiratory impairment is progressive and their exercise tolerance limited. Therefore, these children might have been desensitized, in terms of the subjective perception of exertion, in comparison with normal children.[16,17]

Although all of the children evaluated in the present study presented normal pulmonary function, some authors report that the parameters of respiratory function tests are not suited to predicting exercise tolerance.[1,2] In the present study, the children with cystic fibrosis, despite presenting normal pulmonary function test results, were classified as presenting mild to moderate symptomatology.[13]

In the comparison between the first and second MSWTs, the control group children presented values of distance walked and dyspnea at rest scale scores that were significantly higher for the second test than for the first. However, in the cystic fibrosis group, only the dyspnea at rest scale score was significantly higher for the second test. Therefore, the children in the control group presented a greater learning effect on the MSWT than did those in the cystic fibrosis group, as evidenced by the fact that the control group children walked significantly longer distances in the second test. This difference might be related to the fact that, in the first test, the control group children did not adapt well to the audio signal, which was too slow for them at the beginning, and they had to slow the initial pace in order to follow the signal, which created a certain difficulty during the first levels of the test. The same did not occur in the cystic fibrosis group, since the children already presented altered exercise tolerance, and the slower initial audio signal facilitated the beginning of the test for them. In the second test, the children in the control group were already more adapted to the audio signal and therefore presented significantly better performance in relation to the distance walked.

Regarding the pre-test, at-rest subjective perception of fatigue, these scores were higher, in both groups, before the second test, demonstrating that 30-min breaks between tests were not sufficient for

Table 3 - Modified shuttle walk test parameters.

Variable	Control group (n = 14)		Cystic fibrosis group (n = 14)		p
	Mean	sd	Mean	sd	
MHR (bpm)	151.57	25.53	144.50	21.45	0.46
% MHR (bpm)	72.63	12.25	69.35	10.44	0.47
SpO_2 (%)	96.28	2.49	93.71	4.54	0.06
Distance walked (m)	544.28	131.13	484.28	78.61	0.20
Borg scale score	13.14	1.65	10.35	2.64	0.007
Duration (min)	8.85	1.16	8.14	0.66	0.06

The p values in the table refer to the Mann-Whitney test. MHR: maximum heart rate; % MHR: cardiac overload; SpO_2: peripheral oxygen saturation.

Table 4 - Comparison between the first and second modified shuttle walk test in the control group.

Variable	Control group (n = 14)				
	Test 1		Test 2		p
	Mean	sd	Mean	sd	
Initial heart rate (bpm)	85.35	7.61	89.71	10.95	0.05
SpO_2 (%)	96.5	2.47	96.92	1.43	0.756
Distance walked (m)	491.42	133.86	539.28	140.51	0.014
DRS score	0.85	1.35	1.43	1.55	0.036
Borg scale score	12.28	2.19	13.0	2.07	0.19

The p values in the table refer to the Wilcoxon test. SpO_2: peripheral oxygen saturation; DRS: dyspnea at rest scale.

the children to rest, despite the great subjectivity of the scale in question.

In order to determine the reproducibility of the MSWT in the present study, we referred to the American Thoracic Society Guidelines for the 6-min walk test.[18] The tests were considered reproducible both in the control group and in the cystic fibrosis group, since the difference between the first and the second test was lower than 10% in both groups, although this distance was significantly greater in the second test of the control group.

The 30-min rest break between the tests was chosen because some previous studies in the literature had already used 15-min breaks between 6-min and 2-min walk tests in patients with cystic fibrosis.[4,19] However, for the MSWT used in the present study, this period proved insufficient for either group to rest.

Previous studies reported the good reproducibility of the MSWT for adults and children (10-19 years of age) with cystic fibrosis, confirming the findings of the present study.[11,12] The validation of the test for children at an advanced stage of the disease, who are incapable of performing other tests, has also been described in the literature.[5] However, the present study demonstrated that the MSWT can be applied with accuracy in normal children as well as in children with cystic fibrosis in whom the disease has not advanced to the stage in which there is significant pulmonary impairment.

The children with cystic fibrosis learned the MSWT more easily than did the normal children, as evidenced by the difference between the distance walked in the first and second test in the two groups. The 30-min rest break was apparently insufficient for the children in either group to rest.

These findings suggest that the MSWT is a good exercise test to be applied in normal children and children with cystic fibrosis, since there were no differences between the two groups in terms of cardiac load. The MSWT can be used to determine the effectiveness of physical rehabilitation programs for children with cystic fibrosis, as well as that of physical activity programs for normal children. However, since we found that normal children have greater difficulty in learning this test than do those with cystic fibrosis, it is fundamental that, in either population, the test be applied at least twice.

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Table 5 - Comparison between the first and second modified shuttle walk test in the cystic fibrosis group.

Variable	Cystic fibrosis group (n = 14)				
	Test 1		Test 2		p
	Mean	sd	Mean	sd	
Initial heart rate (bpm)	96.14	14.58	94.07	11.67	0.168
SpO_2 (%)	94.28	4.66	93.92	4.39	0.624
Distance walked (m)	461.4	58.8	477.85	83.49	0.168
DRS score	0.92	1.07	1.71	1.32	0.042
Borg scale score	10.28	2.33	10.57	2.73	0.55

The p values in the table refer to the Wilcoxon test. SpO_2: peripheral oxygen saturation; DRS: dyspnea at rest scale.

Association for the Treatment of Mucoviscidosis for referring the children with cystic fibrosis to us.

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