

Success rate of preschool and school children with/without respiratory symptoms in pulmonary function tests

Frequência de sucesso de pré-escolares e escolares com e sem sintomas respiratórios nos testes de função pulmonares

Frecuencia de éxito de los preescolares y escolares con y sin síntomas respiratorios en pruebas de función pulmonar

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ABSTRACT | The aim of this study was to evaluate the success rate of preschool and school children with/without respiratory symptoms in pulmonary function tests. Children and adolescents, aged 4 to 12 years, with/without respiratory symptoms based on the questionnaire of respiratory diseases were included. Participants were recruited from two schools and classified according to their age group in preschool children (4-6 years) and school children (7-12 years). We collected demographic and anthropometric data, and the variables of the manovacuometry test (MIP and MEP) and spirometry test (FEV₁, FVC, FEV₁/FVC, and FEF_{25-75%}). Pulmonary function tests were considered successful when the participants reached acceptability and reproducibility criteria established by national and international guidelines. In the statistical analysis, we used the chi-square test and Pearson correlation test. We included 148 participants, mean age of 8.1±1.7 years, being 51.4% female and 85.1% healthy. The success rate for the manovacuometry test and spirometry was 91.9% and 91.2%, respectively. There was a significantly lower success rate in the preschool group, compared to school children for both manovacuometry (p=0.044) and spirometry (p=0.015) tests. We found positive correlations between the MIP and FEV₁ and MEP and FEF_{25-75%}. The findings demonstrated a significantly lower success rate in

preschool age group, compared to pre-school subjects in both pulmonary function tests evaluated.

Keywords | Muscle Strength; Respiratory Muscles; Respiratory Function Tests; Feasibility Studies; Child, Preschool; Child

RESUMO | O objetivo deste estudo foi avaliar a frequência de sucesso de pré-escolares e escolares com e sem sintomas respiratórios nos testes de função pulmonar. Foram incluídas crianças e adolescentes com idade entre quatro e 12 anos com e sem sintomas respiratórios, baseados no questionário de doenças respiratórias. Os participantes foram recrutados em duas escolas e classificados, de acordo com sua faixa etária, em pré-escolares (4-6 anos) e escolares (7-12 anos). Foram coletados dados demográficos e antropométricos, além das variáveis dos testes de manovacuometria (PIMAX e PEMAX) e de espirometria (VEF₁, CVF, VEF₁/CVF e FEF_{25-75%}). Os testes de função pulmonar foram considerados bem-sucedidos quando os participantes preenchem os critérios de aceitabilidade e reprodutibilidade das diretrizes nacionais e internacionais. Para fins estatísticos, utilizou-se o teste de qui-quadrado e correlação de Pearson. Foram incluídos 148 participantes, com média

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de idade de 8,1±1,7 anos, sendo 51,4% do sexo feminino e 85,1% saudáveis. A taxa de sucesso no teste de manovacuometria e de espirometria foi de 91,9% e 91,2%, respectivamente. Houve uma taxa de sucesso significativamente menor no grupo de pré-escolares em comparação aos escolares, tanto para o teste de manovacuometria ($p=0,044$) como para o exame espirométrico ($p=0,015$). As correlações entre as variáveis do teste de manovacuometria e do exame espirométrico mostraram-se positivas e moderadas entre a PIMAX e a CVF, e a PEMAX e o VEF_1 e $FEF_{25-75\%}$. Os achados demonstram uma frequência de sucesso significativamente menor no grupo etário pré-escolar em comparação com os sujeitos escolares em ambos os testes de função pulmonar avaliados.

Descritores | Força Muscular; Músculos Respiratórios; Testes de Função Respiratória; Estudo de Viabilidade; Pré-Escolar; Criança.

RESUMEN | Este estudio tiene por objeto evaluar la frecuencia de éxito en los preescolares y escolares con y sin síntomas respiratorios en pruebas de función pulmonar. Del estudio, participaron niños y adolescentes de 4 a 12 años de edad con y sin síntomas respiratorios, con base en el cuestionario de enfermedades respiratorias. Se les invitaron a los participantes de dos escuelas, y se los clasificaron según el rango etario en preescolares (4-6 años) y escolares (7-12 años). Se recolectaron datos demográficos y antropométricos, además de las variables

de la prueba de presión inspiratoria y presión espiratoria máximas ($P_{Imáx}$ y $P_{Emáx}$) y espirometría (VEF_1 , CVF, VEF_1/CVF y $FEF_{25-75\%}$). Se consideraron las pruebas de función pulmonar exitosas cuando los participantes rellenaban los criterios de aceptación y reproducción de las directrices nacional e internacional. Para análisis estadístico, se empleó la prueba Chi-cuadrado y la correlación de Pearson. Se incluyeron 148 participantes, con promedio de edad de 8,1±1,7 años, siendo el 51,4% del género femenino y el 85,1% saludables. Las tasas de éxito en la prueba de presión inspiratoria y presión espiratoria máximas y de espirometría fueron de 91,9% y 91,2%, respectivamente. Hubo una tasa de éxito significativamente menor en el grupo preescolar en comparación con el escolar, tanto en la prueba de presión inspiratoria y presión espiratoria máximas ($p=0,044$) como para la de espirometría ($p=0,015$). Las correlaciones entre las variables de la prueba de presión inspiratoria y presión espiratoria máximas y la de la espirometría presentaron valores positivos y moderados entre la $P_{Imáx}$ y la CVF, y la $P_{Emáx}$ y VEF_1 y $FEF_{25-75\%}$. Los resultados mostraron una frecuencia de éxito significativamente menor para el grupo preescolar en comparación con el escolar en ambas pruebas de función pulmonar evaluadas.

Palabras clave | Fuerza Muscular; Músculos Respiratorios; Pruebas de Función Respiratoria; Estudios de Viabilidad; Preescolar; Niños.

INTRODUCTION

Nowadays, technological advances, development of new software, and increased interest and efforts of the multidisciplinary staff to evaluate the pulmonary system have enabled the evaluation of the respiratory system through pulmonary function tests in children and adolescents¹⁻³. These methods are important tools not only as clinical parameters at the time of evaluation, but also as objective instruments for the long-term monitoring of lung growth from childhood to adulthood^{4,5}. In clinical practice, they are commonly used in subjects with a predisposition to the development of respiratory disorders, neuromuscular disorders, and in patients with lung diseases, such as asthma and cystic fibrosis^{3,6}.

Among the pulmonary function tests, spirometry is characterized as one of the most widely used methods of pulmonary assessment in clinical practice.

This resource aims to evaluate the obstruction of air flow by measuring respiratory capacity, volumes, and flows^{7,8}. In addition, another instrument often used for ventilatory muscle function evaluation is manovacuometry test^{9,10}. The latter has the objective of quantifying the inspiratory and expiratory muscle strength, responsible for the functioning of ventilatory mechanics¹⁰.

Several studies have been published with the aim of generating reference values for the spirometry and manovacuometry tests in children and adolescents^{9,11-14}, to standardize and facilitate the interpretation of ventilatory findings obtained in these tests. Although studies report that the age factor has direct influence on the success of these methods and that the quality of the tests can be compromised in children under 12 years of age, information on the success rate of these resources in the pediatric age group are still scarce, especially for the manovacuometry test. In addition, there are few data on

the possible association between the manovacuometry test and the spirometry test in this age group.

Therefore, considering the relevance of these methods to evaluate the pulmonary system in children and adolescents, as well as the scarcity of information about the viability of these methods in early age groups, there is evident necessity for a greater understanding of the topic. Thus, the objective of this study was to evaluate the success rate of preschool and school children with/without respiratory symptoms in pulmonary function tests.

METHODOLOGY

This is an observational study, of the transversal type. It included children and adolescents, aged 4 to 12 years, with/without respiratory symptoms based on analysis of the respiratory disease questionnaire validated by the American Thoracic Society and Division of Lung Diseases (ATS-DLD-78-C)¹⁵. This questionnaire served for pulmonary characterization of this sample and for exclusion of possible comorbidities that could influence the outcomes investigated. Thus, individuals with comorbidities, including heart disease, neurological disease, muscular disease, bone disease, and cognitive deficit, reported by the parents and/or guardians, were excluded.

Individuals were classified according to their age group into preschool children (≥ 4 and < 7 years) or school children (≥ 7 and ≤ 12 years). All participants were recruited in two schools (one public and one private) in the city of São Luiz Gonzaga, state of Rio Grande do Sul, Brazil. Data collection was carried out from March to July 2014.

This study was approved by the Ethics Committee of the Integrated Regional University of Alto Uruguai and Missões (URI), Campus de Santiago, Rio Grande do Sul, Brazil, under number 310,204, and the legal guardians signed the informed consent form and children signed the term of permission.

First, we handed the questionnaire of respiratory symptoms and the TFCC. After the filling in and returning of these instruments, the children and adolescents were invited to participate in the study. We conducted anthropometric measurements (weight and height), followed by manovacuometry and spirometry tests. All tests were conducted in schools in the period of classes.

Anthropometric measures were obtained by assessing weight and height in duplicate or until two identical measures were obtained. Weight measures were obtained by means of a digital scale (Glicomed®, Rio de Janeiro, Brazil) with 100 gram precision. Height was measured by means of a portable stadiometer (Altuxexata®, Belo Horizonte, Brazil) with precision of one millimeter^{16,17}. All anthropometric measurements were performed according to the Anthropometric Standardization Reference Manual.

Pulmonary function tests were conducted by two trained assessors with prior experience, and each one was responsible for carrying out a method proposed (manovacuometry or spirometry). No participant evaluated was familiar with the tests prior to inclusion in the study.

Measurement of the manovacuometry test was performed through an analog manovacuometer (model M120, Globalmed, São Paulo, Brazil), which had been previously calibrated, with a variation of -120 to $+120$ cmH_2O and intervals of 4 cmH_2O between measures. The equipment was connected to a hose, attached to an isolator filter and to a piece with inner diameter of 2.5 cm, which connected to a mouthpiece. The semi-rigid and flat mouthpiece had an orifice of approximately 1 millimeter. To avoid air leaking, individuals were asked to keep the mouthpiece firm around the lips^{1,9}.

The test was conducted in a sitting position, with the feet on the ground, and using a nasal clip^{1,12}. Before measuring the maximum respiratory pressure, evaluators demonstrated in detail the execution of the maneuvers. Measures of MIP were obtained from residual volume, with individuals instructed to perform a full expiration, followed by a fast and maximum inspiratory effort¹. MEP was obtained from total lung capacity, with individuals instructed to perform a full inspiration before the fast/maximum expiratory effort^{1,9}. All maneuvers were performed with maximum respiratory efforts, with intervals of approximately 1 minute between measurements and sustained for at least 1 second¹². Five satisfactory respiratory maneuvers were performed in each assessment (MEP or MIP). The test was finished and considered satisfactory (success) when it obtained technically correct maneuvers, including three acceptable measures (without air leak through mouth or nose) and two reproducible measures (variation lower than 5% between the two highest measures)^{1,9}. The last value registered could not be higher than the previous ones and the highest value obtained in each test was

used as the final result^{18,19}. For better visualization of the results, the data were normalized and presented as percentage of the expected⁹. Failure in the test was considered when participants did not meet the criteria of acceptability and reproducibility described above.

Spirometry measurements were performed by means of portable spirometer, KOKO® (Louisville, CO, USA), calibrated, validated by the ATS and with a system of the open type⁸. This is a flow-based spirometer, which has an animation program to aid the extension of the expiration and also enables the visualization of volume-time and flow-volume curves, so forced expiratory maneuvers can be analyzed^{7,20}.

Spirometry was performed in standing position and with no use of nasal clip²¹. The technique consists in a deep inhalation, followed by a rapid and forced expiration with minimum duration of 1 second, with the aid of computerized incentive and standardized verbal stimuli from the technician. Before undergoing the test, the children received a previous training to become familiar with the technique. All participants performed at least three forced expiration maneuvers and the choice of the best curve was performed by the software or by the evaluator when pertinent. Spirometry parameters evaluated included forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), and forced expiratory flow 25% and 75% (FEF_{25-75%})⁸.

Spirometry test was considered satisfactory (success) when it met the criteria for acceptability and reproducibility of ATS according to age group (preschool or school children)^{8,22,23}. Test was considered acceptable for both age groups when individuals obtained a rapid start of peak expiratory flow, with gentle descent and without early termination and noises that could interfere with the interpretation of the test. In addition, participants should conduct a sustained expiration for at least one second or present a plateau in the volume-time curve^{8,22}. As for reproducibility criteria, for preschool children²³, two spirometric curves were considered, with variation lower than or equal to 10% between the values of FEV₁ and FVC. For school children, three acceptable curves were requested, with a variation equal to or less than 5% for the same variables⁸. The highest values of FEV₁, FVC, and FEF_{25-75%} were used for data analysis. Spirometry results were normalized through an international equation and expressed as percentage of the expected²⁴. Spirometry

test was considered a failure when the subjects evaluated did not meet the criteria for acceptability and reproducibility described above.

Sample size was estimated to detect a failure rate of approximately 10%, with a power of 90% and a maximum acceptable difference of 5%⁹. Thus, we estimated the inclusion of approximately 140 individuals. Normality of data was assessed using the Kolmogorov-Smirnov test. All data showed normal distribution and were expressed as mean and standard deviation. Categorical variables were presented in absolute and relative frequency. Comparison between proportions (age group, sex, and presence/absence of respiratory symptoms) in relation to the success rate was performed using Chi-square test. Correlation between the variables of the ventilatory muscle strength test (MIP and MEP) and spirometry test (FEV₁, FVC, FEV₁/FVC, and FEF_{25-75%}) was performed using Pearson correlation test. All data analysis and data processing were carried out using the SPSS program version 18.0 (SPSS Inc., USA). In all cases, differences were considered significant when $p < 0.05$.

RESULTS

A total of 148 children and adolescents were included, with 118 of the school children group and 30 of the preschool children group, with mean age of 8.1 ± 1.7 years. Of these, 51.4% were female and 85.1% were healthy through analysis of the questionnaire of respiratory symptoms (Table 1).

In general, participants of the preschool and school groups presented values of respiratory muscle strength and spirometry within normality. Values (% of the expected) for MIP and MEP in both groups varied between 90.2 ± 21.7 and 100.2 ± 30.5 , while spirometry variables (% of the expected) varied between 77.1 ± 48.8 and 118.4 ± 16.0 (Table 2).

Success rate in manovacuometry test was 91.9%, representing a total of 136 participants who were able to perform the test properly. Similarly, in the spirometry test, a similar success rate (91.2%) was obtained, represented by 135 children and adolescents. In general, success rates in both tests tend to rise in line with the increase in the age of children and adolescents (60-100%). Table 3 shows the success rate in the pulmonary function tests according to the age group evaluated.

Table 1. Characterization of the sample of the study

Variables evaluated	N=148
<i>Demographic characteristics</i>	
Age, years	8.1±1.7
Female, n (%)	76 (51.4)
Caucasian, n (%)	116 (78.4)
Respiratory symptoms, n (%)	22 (14.8)
<i>Anthropometric data</i>	
Weight, kg	32.6±10.0
Height, cm	131.6±12.0
BMI, absolute	18.3±3.0
BMI, percentile	69.5±30.1

N: total number of subjects evaluated; BMI: body mass index

Table 2. Results of ventilatory muscle strength and spirometry test stratified according to the group evaluated

Age group	% of expected	Z-score
<i>Preschool</i>		
MIP	97.6±33.6	-0.10±1.70
MEP	100.2±30.5	0.00±1.22
FEV ₁	116.2±13.3	1.28±1.06
FVC	107.7±12.1	0.59±0.93
FEV ₁ /FVC *	0.94±0.03	0.15±1.0
FEF _{25-75%}	103.7±45.3	0.41±1.31
<i>School</i>		
MIP	97.4±28.1	-0.22±1.69
MEP	90.2±21.7	-0.55±1.18
FEV ₁	118.4±16.0	1.59±1.38
FVC	109.1±17.2	0.76±1.46
FEV ₁ /FVC *	0.88±0.02	0.04±1.24
FEF _{25-75%}	77.1±48.8	0.13±1.15

MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; FEV₁: forced expiratory volume in one second; FVC: forced vital capacity; FEV₁/FVC: tiffeneau index; FEF_{25-75%}: forced expiratory flow between 25 and 75% of forced vital capacity; * Result expressed in liters (absolute value). Data above of 136 participants who succeeded in the ventilatory muscle strength test and of 135 participants in the spirometry test.

Table 3. Success rate of children and adolescents in pulmonary function tests according to the age group evaluated

Age group (years)	Manovacuometry n/N (%)	Spirometry n/N (%)
4	4/5 (80.0)	3/5 (60.0)
5	15/18 (83.3)	14/18 (77.3)
6	6/7 (85.7)	6/7 (85.7)
7	32/36 (88.8)	33/36 (91.6)
8	35/38 (92.1)	35/38 (92.1)
9	16/16 (100.0)	16/16 (100.0)
10	19/19 (100.0)	19/19 (100.0)
11	7/7 (100.0)	7/7 (100.0)
12	2/2 (100.0)	2/2 (100.0)

n/N (%): number of subjects evaluated that were successful in the test performed/total participants evaluated;%: percentage of subjects evaluated successfully.

Success rate in pulmonary function tests behaved differently according to the age group studied, with significantly lower success rate in the group of preschool children compared to the group of school children, both for the manovacuometry test (83.3% versus 94.0%; $p=0.044$) and the spirometry test (76.6% versus 94.9%; $p=0.015$) (Figure 1). There was no significant difference for success rate, when the healthy

group was examined separately in relation to those with respiratory symptoms or even in relation to the sex evaluated.

Finally, in evaluating correlations between variables of the manovacuometry test and spirometry test, positive and moderate correlations were found between the MIP and FVC ($r=0.52$; $p<0.01$) and MEP with FEV₁ ($r=0.46$; $p>0.01$) and with FEF_{25-75%} ($r=0.41$; $p>0.01$).

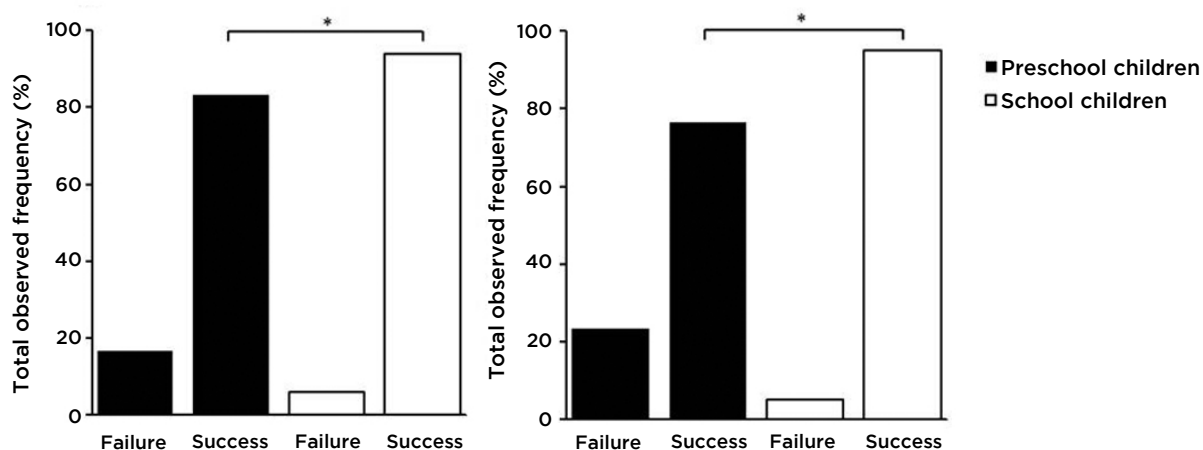


Figure 1. Comparison between the success/failure rate observed in both groups evaluated (preschool and school children) in the manovacuometry test (1A) and spirometry test (1B). * $p < 0.05$

DISCUSSION

The findings of this study have shown that the success rate of pulmonary function test was approximately 91% and success is related to the age of the child and adolescent. In addition, participants in the school children age group showed a significantly higher success rate in manovacuometry and spirometry tests, compared to the preschool children group. Such findings support previous studies showing a greater ease in the performance of pulmonary function tests in school age, since the higher the age of the individual the greater its ability for interpretation, concentration, and motor skills for the performance of the tests^{5,6,9}. Thus, these methods for pulmonary assessment can be characterized as simple tests, of easy understanding and clinical applicability, enabling the measurement of respiratory capacity, volumes, and flows, as well as respiratory muscle strength in young age group^{1,25,26}.

Although, in recent years, several studies have been published with the aim of generating reference values for manovacuometry test in healthy children and adolescents^{9,11,13}, there are still no data on the applicability of this method of according to the age evaluated. This is the first study aimed at assessing success rate according to age group in manovacuometry test in preschool and school children, which complicates the comparison of our results with other studies. However, it is believed that our success rate is considered too high, taking into account the success rate observed in other pulmonary function tests, such as spirometry tests, plethysmography, which showed values between 75-92%²⁷⁻³⁰. Our results can be attributed to a few

factors, such as prior experience of evaluators, detailed explanation of the technique, previous training, long time of measurement, and the patience of the evaluator responsible for measurements.

Although the spirometry test has specific guidelines to facilitate the completion of the test in the preschool age group²³, with more flexible reproducibility and acceptability criteria, the success rate was significantly higher in the school age group, compared to the preschool children. Recently, a literature review² showed that the success rate in the preschool age group varied between 71-92% in various regions of the world, corroborating our results in this age group evaluated, 76%. Similarly, other studies that evaluated the applicability of spirometry test in the school age group showed a success rate of approximately 90%^{4,29,31}, with spirometry measurements performed by a team previously trained and experienced with children. It was reported that the use of trained evaluators and a laboratory adapted to children increases the success of spirometry in this age group²³. The use of incentives of animation and the previous training of the spirometry maneuver by employing a plastic bottle filled with water and a straw with the same diameter of the mouthpiece for simulation of expiration before the test may have contributed to explain our high success rate in the two groups evaluated²⁷⁻²⁹.

In general, pulmonary function tests were not influenced by sex. These findings are in agreement with previous studies, which identified similarities between the success rate of females and males^{27,28}. Although we have not evaluated the level of motor skills and cognition of the subjects included, these results may be justified due to

the fact that both sexes evaluated had a very similar motor and cognitive development in the age groups evaluated. In addition, we found moderate and positive correlations between the variables MIP and FVC and between MEP with FEV₁ and FEF_{25-75%}. These results corroborate previous studies^{9,32}, which showed a positive association between MIP and FVC and MEP with FEV₁, demonstrating that the higher the maximum respiratory pressures the greater the amount of air mobilized out of the lungs, after a maximum inspiration. Such findings are evidence of the fact that although the two pulmonary function tests have different characteristics and objectives, respiratory muscle strength obtained by means of the maximum respiratory pressures is an important determinant to obtain the maximum flows recorded in the spirometry test³.

The fact of using two evaluators and of having an analog equipment for measurement of maximum respiratory pressures may be the main limitations of this study. However, the evaluators had previous experience of one year with the evaluations proposed and were overseen by the researcher responsible for the measurements. In addition, it is believed that the fact of using an analog equipment did not interfere with the results for success rate obtained in the present study, since the only differences in relation to the digital equipment are the measurements every 4cmH₂O and the record of measures up to a maximum of 120cmH₂O.

It is expected that the findings of this study encourage rehabilitation centers and health professionals to further adopt the use of objective methods to quantify pulmonary findings in younger age groups, since these tests proved applicable in the sample evaluated.

CONCLUSION

The findings of this study demonstrate a high success rate in manovacuometry and spirometry tests in children and adolescents, with/without respiratory symptoms. These findings apparently increase as the age group evaluated gets older. In addition, there was a significantly higher success rate for the school children age group, compared to that of preschool children. Further knowledge and understanding regarding the matter can help in increasing the use of such resources in clinical practice, clarifying the applicability of these methods according to the age group evaluated and collaborating to an early therapeutic intervention.

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