PULMONARY FUNCTION TESTING IN YOUNG SCHOOL-age CHILDREN – CHALLENGES AND POSSIBILITIES

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Abstract

Introduction: Pulmonary function testing is an essential clinical measurement in the assessment of children with respiratory diseases **Purpose:** The aim of this study was to evaluate the main difficulties in the assessment of lung function parameters in young schoolchildren.

Materials and Methods: One hundred and seventy-nine healthy Bulgarian school children (90 males) in the age span 7 – 10 years took part in the study. All participants underwent anthropometric measurements – standing height, weight and body mass index (BMI). Studied group completed comprehensive pulmonary function assessment – slow and forced spirometry (MasterScreen Diffusion, Jaeger, Wuerzburg, Germany) in a certified laboratory applying the ATS and ERS criteria to ensure quality.

Results: Spirometry performance standards and quality control in school-age children are the same as for adults. All participants were divided into age groups and our findings were that youngest children – aged 7 years - needed longer time for training and more efforts to produce technically acceptable spirometry results. Applying the start of test criteria: back-extrapolated volume ≤ 5% and within test criteria – flow-volume loop free from artifacts - were met by all studied children. Applying the end of test criteria - duration of forced expiration ≥ 6 sec. - we found that this criteria was not met by the studied group; 97 % had forced expiratory time (FET) less than 3 sec.

Conclusions: Young schoolage children can perform spirometric measurements to meet currently established criteria after careful preparation and enough efforts. The recommendation for a minimum of 6 sec. FET should be modified especially in youngest children. The success rate of acceptable and repeatable spirometric tests increases with age.

Keywords: *children, young age, pulmonary function testing*

Introduction

Spirometry is an essential part of the comprehensive objective assessment of respiratory diseases in children of all ages. This measurement plays an important role in the diagnosis and management of respiratory illnesses such as asthma and restrictive lung disorders. Pulmonary function testing (PFT) is easy to conduct but healthy controls and patients, especially children, need a specific training period before producing technically acceptable efforts that can be used in the practice. Using appropriate coaching and motivation even children as young as 2.5 years old with normal cognitive and neuromotor function are able to perform acceptable spirometry [1]. The international guidelines [1,2,3] suggest applying acceptability and reproducibility criteria in children same as proposed in adults and this is often combined with challenges and difficulties in the performance of the tests. Our study aimed to reveal the most often seen difficulties in PFT in young children and the possibilities to overcome them and to increase the success rate in spirometry testing.

Materials and Methods

One hundred and seventy-nine healthy Bulgarian school children (90 males and 89 females) in the age span 7 – 10 years took part in the study. Prior to the test procedures written informed consent was obtained from a parent or guardian. All procedures used in this study were approved by the Institutional Ethics Committee at the Medical University – Plovdiv. The participants in the study were subjected to complete anthropometric measurements – standing height, body weight, and body mass index (BMI). Dimensions of the thorax were assessed through measurements of chest circumference at full inspiration (CCI) corresponding to total lung capacity (TLC) as well as the measurements of chest circumference at full expiration (CCE) corresponding to residual volume (RV). Pulmonary function testing was carried out with a diagnostic system Masterscreen Diffusion™ (E. Jaeger, Wuerzburg, Germany) in a seated position with a nose clip in the following order: 1. Slow spirometry; 2. Forced expiration; 3. Maximal inspiratory and expiratory pressures.

The equipment was suited for pediatric measurements e.g. chair, the mouthpiece and the whole setting was accommodated to fit children's proportions. Regular calibration was done with a 3-liter calibration syringe.

Forced expiratory maneuvers complied with the general acceptability criteria suggested in the international guidelines. Individual flow-volume curves were reviewed for technical acceptability. At least three technically acceptable attempts of maximal forced expiratory flow-volume curves were recorded. Reproducibility of FVC and FEV_1 was considered acceptable when the highest FVC and FEV_1 values did not exceed the second-highest value by more than 5%. Because in young children is difficult to obtain both a satisfactory FEV_1 and FVC in one maneuver, the largest FEV_1 and the largest FVC are selected from 3 technically satisfactory maneuvers. International accepted GLI 2012 reference values were used [4].

Results and Discussion

The acceptability and repeatability criteria of flow-volume loops in young school-age children that were applied in the studied group are presented in **Table 1**. All participants met the start-of-test criteria for rapid and fast expiration after the full and complete inspiration and the within test criteria – flow-volume curves free from artifacts and premature glottic closure, that may change the values of important parameters. The end-of-test criteria, even not clearly specified in the guidelines, is accepted to be like in adults at least 6 seconds, and these criteria were not met by most of the children – only 3.4 % from the studied population were able to produce forced expiration for 6 seconds. In 14 % of the young school-age children we found a forced expiratory time (FET) of more than 3 seconds and this was evident mostly in the older children. This correlation between age and FET is presented in **Figure 1.** The age of 10 is already combined with a better understanding of the spirometry measurements and children are able to produce acceptable, reliable, and repeatable tests. The main anthropometric and spirometric parameters in our group are presented in **Table 2.** All measured variables were in the reference ranges.

The importance of the procedures of pulmonary function testing and the correct measurement performance is very high especially in chronic respiratory diseases that need long-term treatment and management of the condition [5]. In the follow-up of these conditions we may find a clinically significant change only if we obtain an acceptable and repeatable test.

The majority of the studied children produced flow-volume loops according the ERS/ATS start-of-test and within test criteria but only few schoolchildren were able to meet the end-of-test criteria. The main challenges in pediatric spirometry testing and the possibilities are listed below:

Start-of-test-criteria

In young school-age children often the initial efforts to produce a fast and rapid expiration need more time. The specific measurement and the hesitation on the onset of the expiration may lead to a decrease in the forced parameters. Apart from the age many other factors may influence the results of the pulmonary function testing – envinronment in the spirometry lab; the time and patience of the PFT technicians; initial expirience of the child and the disease state. This initial step in the measurements need enough time to repeat the maneuvre, quite and friendly athmosphere in the PFT lab, trained PFT technicians that will motivate and encourage the child and also the use of incentives during the test.

Within test criteria

These criteria are also very easy met by the majority of the studied population but one of the pitfalls is the early termination of the expiration and the glottic closure that can affect the values of the studied forced expiration parameters. Due to the early termination often is difficult to record the values of FEV_1 and many authors [5,6,7] suggest the use of FEV_t or $FEV_{0.75}$ and $FEV_{0.5}$ in very young children. Prior the first test performance young children need to be familiarized with the equipment, to be trained with patience and to understand the meaning of words inspiration and expiration. Prolonged and forceful expiration should be demonstrated and the child will be trained to repeat efforts as many as needed to improve the performance. The repeated efforts in children cause the learning effect that increase they ability for better PFT results.

End-of-test-criteria

The limit for minimal expiration time for at least 6 seconds is one of the most difficult to achieve criteria in young children but also in healthy adults [7]. Another criteria is the visual inspection of time-volume curve where a "plateau" is reached with no change in the volume for at least 1 second. Both criteria were established to ensure the accuracy of the FVC that is recorded because this parameter is dependent on the maximal expiratory volume and duration of the maneuver. Young children have lower lung volumes and in the same time higher elastisity of the lung tissue that cause the fast empting of the lungs during the expiration. This lead to rejection of good efforts in children that can not sustain the expiratory effort for 6 seconds. Recently this end-of-test-criteria for children under the age of 10 is suggested to be changed to 3 seconds. As children are able to reach a plateau earlier than 6 seconds the achivement of no flow for at least 1 second will be easy and simple criteria independent of age or health condition.

Conclusions

Young school-age children can perform spirometric measurements to meet currently established criteria after careful preparation and enough efforts. The recommendation for a minimum of 6 sec. FET should be modified especially in youngest children. The success rate of acceptable and repeatable spirometric tests increases with age.

Conflict of Interest: Authors do not declare a conflict of interest.

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Table 1 Criteria for acceptability and repeatability of flow-volume loops in school-age children as stated by the guidelines of ERS/ATS 2005[2]

Acceptability	
Start-of-test criteria: back-extrapolated volume	≤5% or 100 mL FVC, whichever is greater
Within test criteria	The flow-volume loops should be free from artefacts – cough, glottic closure that affects the measurements
End-of-test criteria	Duration of forced expiration; end-expiratory volume plateau
Repeatability: difference between two highest values of FVC and FEV_1	At least three flow-volume curves Within 5% FVC or < 100 mL if FVC < 1000 mL

FVC: forced vital capacity; FEV_1: forced expiratory volume in one second;

Table 2 Main anthropometric and spirometric parameters in the studied age group

Parameter	Units	Mean value	Range
Age	years	8.99±1.2	7-10
Height	cm	138.7±9.6	118-171
Weight	kg	34.9±9.5	20-73
Body mass index	m^2/kg	17.9±3.2	10.7-29.1
FVC	L	2.23±0.47	1.32-4.02
FVC %pred	%	98.8±9.78	80.2-128.9
FEV_1	L	2.04±0.39	1.27-3.37
FEV_1%pred	%	107.3±9.67	83.1-129.4
FEV_1%/FVC	%	88.7±4.86	77.5-98.9

Data are presented as mean±SD and (range); FVC: forced vital capacity; FVC%: FVC % of predicted; FEV_1: forced expiratory volume in one second; FEV_1%: FEV_1% of predicted; $FEV_{1\%}$ /FVC: FEV_1 as a % of FVC

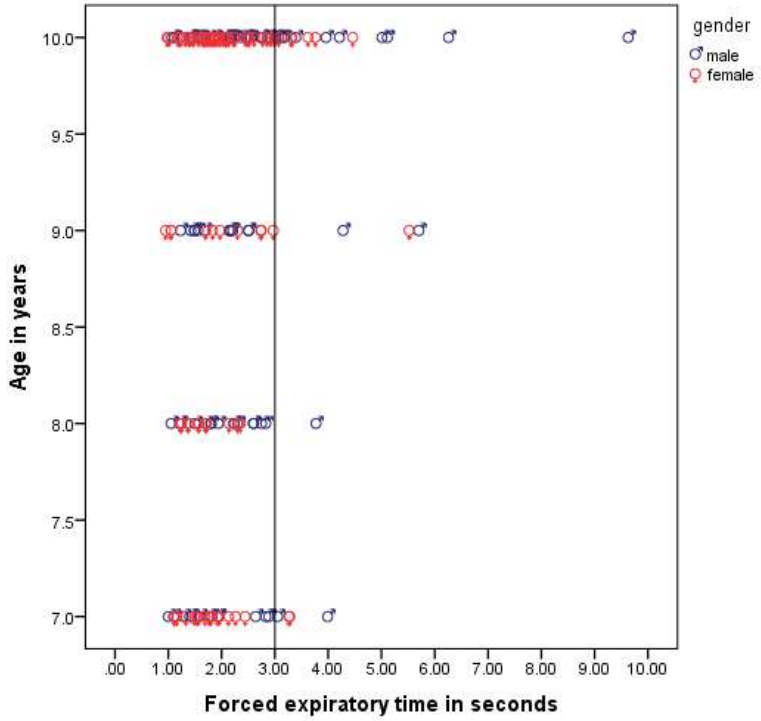

Figure 1. Forced expiratory time (FET) in seconds vs. age in the studied group