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The quality of spirometric measurements in children younger than 10 years of age in the light of recommendations

Abstract

Introduction: In 2005 the *European Respiratory Society/American Thoracic Society* (ERS/ATS) published an updated document on the standardization of spirometry (*European Respiratory Journal 2005; 26: 319–338*). It defines criteria for the acceptability of spirometric measurements. The aim of this retrospective study was to assess the adherence to those standards of flow-volume measurements in children younger than 10 years of age.

Material and methods: The analysis was carried out on the results obtained from 233 children aged 4.2–10 years, referred to a spirometric lab during a period of three months.

Results: 116 children (all but one preschool) did not cooperate; the results of the 117 who completed the procedure of flow-volume measurement were analysed using ERS/ATS criteria. 80.3% of the children had back extrapolated volume (Vbe) within the defined limit, but only 23.9% had forced expiratory time > 3 s. FEV_1 and FVC were repeatable in 78.6% of the children. When these three criteria were used together, the measurements were acceptable according to ATS/ERS recommendations in 17.1% of the children. Elimination of the forced expiratory time criterion has further increased their number to 63.2%.

Conclusions: Specific recommendations for children should be developed, as the current requirements appear too restrictive, especially regarding the time of forced expiration.

Key words: spirometry, flow-volume, children, quality, recommendations

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Introduction

The measurement of flow-volume loop has been used for 50 years in lung function laboratories [1], and has become one of the most popular tests in the diagnosis and monitoring of pulmonary diseases in adults and children. The test procedure is standardized, and standardization statements have been published several times as national standards or global international organizations statements [2–4]. In 2005 the newest standardization papers were published, presenting the joint ERS/ATS view and formulating unique requirements for the measurement of flow-volume loop [6–7]. In 2006 the Polish Respiratory Society also published its own document on the standardization of spirometry [5].

In comparison to previous versions of standards, the current recommendations are similar for Europe and the USA, although the required forced expiratory time is different: for children up to 10 yeas of age, the required value is 3 seconds. Table 1 summarizes the acceptability and repeatability criteria for FV measurements.

The accessibility of spirometric examinations in Poland has enormously increased during the last twenty years, causing increased interest in examining very young children. It is stated in the above-mentioned publications [6, 7] that 'with appropriate coaching it is possible to perform spirometry in children starting at the age of 5' — but it is a difficult task. Some works show that the degree of cooperation in preschool children may reach 90% or more. Kanegiser and Dozor [8] reported 90% cooperation in 3- to 5-year-old chil-

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Table 1. Acceptability and repeatability criteria for flow-volume loop

Acceptability criteria	1. Short time to PEF
	2. Back-extrapolated volume < 5% FVC or 150 ml
	3. Forced expiratory time > 3 s and plateau on volume-time curve or the subject cannot or should not continue forced exhalation
Repeatability	The difference between the best and the second best value of FVC and FEV_1 < 150 ml (100 ml if FVC or FEV_1 < 1000 ml)

Explanations of abbreviations in the text

dren, but initially they selected, for spirometry, children that were regarded as cooperating. In a publication of Piccioni [9], the reported cooperation rate was 95.3%. On the other hand, in 2001 Arets et al. [10] evaluated the performance of spirometry in children aged 5–18 and postulated the revision of quality assessment criteria in a time when there was no distinction between younger and older children according to the value of FET. The aim of our study was to evaluate the performance of the flow volume measurements in children younger than 10 years of age, according to current standards.

Material and methods

This is a retrospective study. The analysis was carried out on the results of recorded flow-volume curves in children younger than 10 years of age during a 3 month period in the Department of Respiratory System Physiopathology at the Institute for Tuberculosis and Lung Diseases, Rabka Branch, in 2007. The children were subjected to tests from the clinics of the Institute as well as from the Outpatient Department. The main reasons for the spirometry were respiratory system symptoms and suspected asthma. During the mentioned 3-month period there were 233 children tested aged 4.2–10 years. Figure 1 presents the distribution of the children's ages.

The measurement of the flow-volume loop was preceded by careful instruction and a demonstration of the forced manoeuvre. During the tests no incentives were used. The children were tested in the morning hours, in a sitting position with a nose clip attached. Special attention was paid to the position of the head and the placement of the mouthpiece, to avoid any leaks. All the measurements were made using MasterLab (Jaeger, Germany) equipped with a Lilly type pneumotachograph. Prior to the measurements the spirometer was calibrated with a 3-litre calibration syringe, and additional assessments of linearity of the flow measurements were made on a weekly basis according to the standard [5, 7].

The procedure itself was controlled by technicians and performed according to the cited standards.

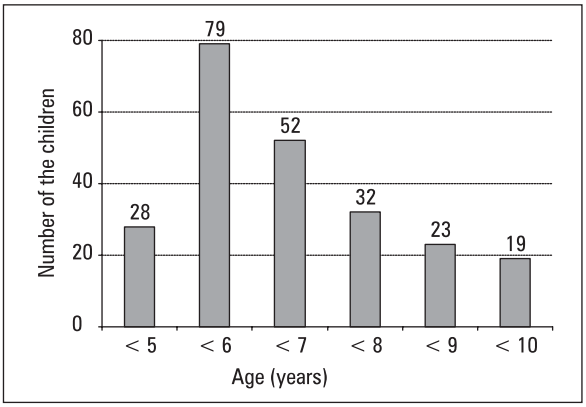

Figure 1. Age distribution in analysed group

The time tracings and flow-volume curie were on-line displayed on screen and then analyzed off-line. Statistical analyses were made using MS Excel™.

Results

Of the total number of 233 children, 116 did not finish the examination (all but one were < 7 years old). The reasons were: a lack of understanding of the procedure leading to improper respiratory effort, lack of peak expiratory flow in the early part of expiration, variable (submaximal) respiratory efforts, or lack of interest (refusal). In 10 children only one trial was recorded, after that they refused to continue.

The tests were successfully finished by 117 children (39 girls and 78 boys) aged 4.8–10 years; between 3 and 6 manoeuvres were recorded. The manoeuvre was considered well done if there was transient, maximal respiratory effort with no artefacts during the first second of the forced expiration, and if there was no premature termination (sharp decrease of expiratory flow). A histogram showing the percentage of successful tests against age is presented in figure 2.

Assessment of acceptability

Time to PEF (tPEF)

Mean tPEF was 99 ± 37 ms (range 30–210 ms). tPEF did not correlate with the ages of the children

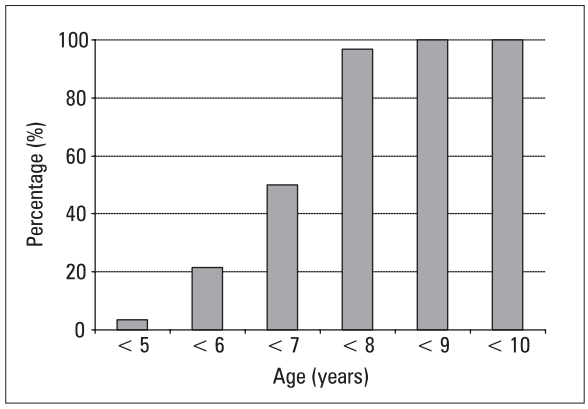

Figure 2. Percentage of cooperating children in relation to their age

(r value for the correlation between tPEF and age r = 0.057; NS). A value of less than 100 ms was achieved by 72 children (61.5%).

Back-extrapolated volume (Vbe)

This is the criterion which describes the proper start of the manoeuvre: if the manoeuvre is submaximal, the value of Vbe is increasing. In the tested group, Vbe was on average: 65 ± 25 ml (mean ± SD), range 40 to 156 ml. There was weak, but significant correlation between Vbe and age (r = 0.27, p = 0.002). According to the recommendations, Vbe should be less than 150 ml and 5% of FVC. This condition was met by 94 out of 117 children (80.4%).

Forced expiratory time (FET)

The FET values were between 0.71 and 6.9 s, with a mean value of 2.2 ± 1.2 s. Only 28 children had FET > 3 s (23.9%). In 12 children (aged 5.3––8.5 years) FET was shorter than 1 s. Forced expiratory time significantly correlated with the age of the children (r = 0.35; p < 0.001) — see figure 3.

Repeatability

The difference between the best and the second best values of FVC was on average greater than that of FEV_1: the differences were 48.0 ± 43.2 ml and 70.3 ± 62.8 ml, respectively. The reproducibility of FEV_1 correlated negatively with age (r = –0.22; p < 0.05), while that of FVC did not (r = –0.14, NS). In total, 105 children fulfilled the condition for FVC, and 101 for FEV_1. Regarding both, the criteria were met in 92 children (78.6%).

Overall evaluation of quality

In all the children time to peak expiratory flow was short. 80.3% of the children had a low value of Vbe, but only 23.9% were able to expire forcefully for 3 seconds or more. The results were reproducible in 80.6% of children. When all the four criteria are taken together, the spirometry was made according to the criteria in 17.1% of the children. However, if the FET criterion is discarded, the percentage rises to 63.2%.

Discussion

This work addresses the quality of performing spirometric examinations by experienced personnel who have worked with children for many years in the Department of Physiopathology of Respiratory System, having the appropriate equipment. Nevertheless, the department itself is not especially oriented to work with the youngest children; the age of the examined children varied from 4 to 18 years.

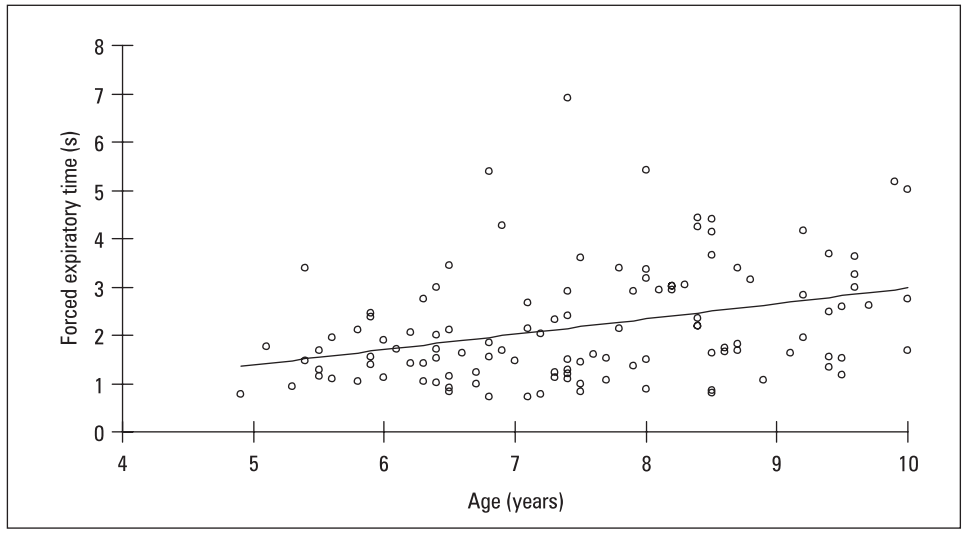

Figure 3. Scatterplot of forced expiratory time *vs.* age

The newest ERS/ATS recommendations concerning spirometry stress the possibility of examining small children and introduce the distinction of children younger than 10 years of age (for whom FET > 3 s) and older, for whom FET should be, as in the case of adults, at least 6 seconds.

This paper deals with acceptability and reproducibility criteria for flow volume curves. Out of 2 criteria of a good start, time to PEF criterion is descriptive, while back-extrapolated volume has defined limits. In our material the mean time to PEF was 0.099 ± 0.037 s (maximal value — 0.21 s) and 61.5% of the children were able to reach PEF below 100 ms. In the work of Arets et al. [10], 75.3% of children younger than 8 years and 77.8% of children aged 8–11 years had tPEF less than 100 ms. Concerning Vbe, 80.3% of the children in our study fulfilled the criterion, while Arets reported that 77.2% of the younger children and 80.6% of the children aged 8–11 fulfilled the condition, which is a very similar result.

A forced expiratory time greater than 3 seconds was achieved by only 23.9% of the children; however, FET significantly correlated with age, which may explain such a low percentage. Similar observations were made by Arets et al. [10] and Enright in children aged 9–18 years [13].

Generally, performing spirometry in children is a much more difficult task than in adults. Despite some obvious, specific requirements regarding a friendly atmosphere, or specially trained personnel prepared to work with paediatric subjects, the procedure of testing is the same as in adults. Thus, especially in the group of younger children (< 10 years), there are many difficulties. In that group, the percentage of cooperating children increases with age, reaching 50% for 6-year-old children and almost 100% in older ones. In a subgroup of children aged 4–7 the mean percentage of cooperation was 23.3%. In the literature one can find much higher numbers. Kanegiser and Dozor [8] reported a 90% cooperation rate, but their children were initially assessed by a paediatrician as 'cooperative'. Vilozni [11, 12] also published a high percentage of cooperation, but preschool children were prepared for the examination with the use of specially designed computer programs, games, and tools. Such time-consuming actions in the lab, examining all children, are simply impossible.

Figure 2 also shows that above 7 years of age the degree of cooperation does not matter because all the children can understand the examination procedure. This is why recommendations addressed to adults and schoolchildren are not appropriate for preschool children. In July 2007 in the *American Journal of Respiratory and Critical Care Medicine* [14] a statement concerning lung function testing in preschool children was published. The approach presented therein is different from the recommendations of ERS/ATS from 2005, and a big chapter is devoted to spirometry. There are 14 steps in analyzing the performance of the flow-volume loop registration in preschool children. Recommended actions differ significantly: there are specific criteria for back-extrapolated volume, end of forced expiration, and reproducibility. The most important, however, is that FVC and timed flows may be assessed from different curves.

Conclusions

The results presented in this work, and current recommendations, suggest the necessity of separation of spirometric measurements made in preschool children (aged 7 or less) from those made in schoolchildren. There are other conditions and criteria defined for both groups, and it is likely that it will be necessary to modify spirometer software to control the registration of flow-volume curves in preschool children, according to the 2007 statement [14]. For the older group, 2005 ERS/ATS [7] recommendations are obligatory, and the only problem (despite the will to participate) is long enough forced expiratory time. It seems that the actual standards are too restrictive for children (especially when considering FET) and should be revised.

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