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

Abstract


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. FEV1 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

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 years 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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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.
(r value for the correlation between tPEF and age \( r = 0.057; \text{NS} \)). 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 (\( r = -0.14, \text{NS} \)). 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.
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.

References


