

Hand-held turbine spirometer: Agreement with the conventional spirometer at baseline and after exercise

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Portable hand-held spirometers are widely used in outpatient clinics and in field surveys when examining children for asthma. However, the validity of the results obtained from the hand-held spirometers has not been assessed in population-based studies. We evaluated the agreement between the forced expiratory volume (FEV₁) values got by the conventional flow volume spirometer (FVS) and the pocket-sized turbine spirometer (TS) at baseline and after exercise, among the 212 children screened for asthma and asthma-like symptoms from a population of 1633 school-aged children. The comparison was made between and within three diagnostic groups: clinical asthma (n = 34), possible asthma (n = 31), and controls (n = 147). In general, the differences in FEV₁ between the FVS and the TS were small. For all children, the mean difference in FEV₁ and the limits of agreement (difference $\pm$ 2 s.d.) was 0.05 l (0.23 to –0.13) at baseline and 0.06 l (0.24 to –0.12) after exercise. No significant differences were observed in the agreement between the diagnostic groups. In conclusion, although FEV₁ results obtained by the hand-held spirometer are not interchangeable with those by the conventional spirometer, they are in reasonable agreement. The agreement is similar both at baseline and after exercise, and is not influenced by the presence of asthma.

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An increasing prevalence of childhood asthma has become a challenge for public health services. In evaluation of children with asthma-like symptoms, there is a need for simple methods for assessing lung functions. The flow volume spirometers (FVSs) are standard devices for clinical setting. In field conditions, however, size, handling and price, in addition to accuracy of the results, are important factors when selecting the device. For these situations, pocket-sized spirometers, which allow rapid and easy measurements of expiratory flows, may be beneficial. However, the results of different spirometers cannot be directly equated. Therefore, the standardization of each spirometer is essential, including the assessment of agreement with the conventional spirometers (1).

Although many different pocket-sized spirometers have now become available, only a few studies have been published in which pocket-sized spirometers were compared with a conventional spirometer (2–6). Moreover, these studies have usually been carried out in hospital settings, where healthy children have not been included (5). In most studies, the comparison has been performed at baseline (2–4); only one study has been published in which the two spirometers were compared in association with bronchial challenge testing (5).

The aim of this study was to assess agreement between conventional FVS and pocket-sized turbine spirometer (TS) values at baseline and after exercise. Forced expiratory volume in 1 s (FEV₁) was used as the parameter of comparison,

as it is in most guidelines recommended to be used in challenge tests (7). FEV₁ is sensitive for changes of large as well as small airways while peak expiratory flow (PEF), also used in challenge tests, reflect mainly changes of large airways (8).

Methods

Study population

A population-based sample of 1633 children aged 6–12 yr were initially screened for respiratory symptoms by a written questionnaire. After the screening, a sample of 247 children, weighted towards symptomatic children (about two-thirds being symptomatic and one-third non-symptomatic), participated in a clinical study in our outpatient clinic (9). Complete lung function data were available for 218 (88%) of these 247 children. Among them, there were 40 children with clinical asthma [a symptom history consistent with asthma, and at least one objective clinical, lung function or challenge test finding: acute symptoms with auscultatory wheezing disappearing after inhaled β_2 -agonist, associated with > 15% increase in peak flow (PEF); in 4 wk home PEF measurements > 20% variability and > 15% increase in PEF on at least three occasions after inhaled β_2 -agonist; baseline obstruction with > 15% improvement in PEF or FEV₁ after inhaled β_2 -agonist; pathological free running test ($\geq 10\%$ fall in FEV₁) or methacholine inhalation challenge (provocative dose causing $\geq 20\%$ fall in FEV₁ of $\leq 400 \mu\text{g}$)], 31 children with possible asthma [a symptom history consistent with asthma but without any objective finding], and 147 children with no asthma-like or other prolonged or repeated lower respiratory symptoms (9). The six asthmatic children on inhaled steroids were further excluded from the study, leaving 34 children with mild to moderate asthma into the clinical asthma group (9). The remaining 212 children form the subjects of the current analysis.

Baseline spirometry

Baseline spirometric measurements were performed according to the ERS criteria (7). FEV₁ was used as the main lung function measure. The measurements were carried out with two different spirometers: the handheld TS (Micro Plus, Micro Medical Ltd, Rochester, UK) and the conventional pneumotachographic FVS (Medikro Oy, Kuopio, Finland), which was used as a 'gold standard' (9). The FEV₁ values were used to

assess agreement between the two spirometers as described below.

Exercise challenge

After baseline spirometric testing, the children took part in the free running test outdoors (9). After the baseline spirometric tests each child ran outdoors for 8 min while the heart rate was monitored. The heart rate had to stay above 170 beats/min for at least 6 min (9). After exercise, FEV₁ was measured at 5, 10, 15, and 20 min by using the TS (9). In addition, FEV₁ was measured with the FVS at 10 and 20 min after exercise. In each occasion, the best FEV₁ value of two valid flows was recorded. The 10 min FEV₁ recordings by the TS and FVS were used for assessing agreement between the methods in exercise testing.

Statistical analyses

The data were analysed using STATA release 7.0 (<http://www.stata.com>). For comparing mean FEV₁ values obtained from the two spirometers, the paired *t*-test was used. For comparing means between the diagnostic groups, the *t*-test, and one-way ANOVA with Bonferroni multiple comparison test, were used.

The agreement between the two methods was analysed using the difference method described by Bland and Altman (10). The difference in FEV₁ between the FVS and the TS was plotted against their mean, together with the 95% limits of agreement (10).

Ethics

The clinical study was approved by the Ethics Committee of Kuopio University Hospital, Kuopio Finland.

Results

Among all the 212 children, the mean (s.d.) FEV₁ at baseline was slightly higher, 2.20 l/s (0.47 l), by the FVS, when compared with the TS value of 2.15 l (0.46 l) ($p < 0.001$). The respective predicted FEV₁ values (% of the means of height-related references) were 92.3% and 90.0%. Comparison between the diagnostic groups revealed similar results: in children with clinical asthma, the mean FEV₁ was 2.07 l in the FVS and 2.00 l in the TS (% of predicted 91.0% and 87.8%, respectively) ($p < 0.001$); in children with possible asthma 2.12 l (FVS) and 2.07 l (TS) (% of predicted 91.7% and 89.6%,

Table 1. The mean differences in FEV₁ (l) and the limits of agreement (difference ± 2 s.d.) between the flow volume spirometer and the hand-held turbine spirometer

	All groups (n = 212)	Clinical asthma (n = 34)	Possible asthma (n = 31)	Controls (n = 147)	p-value*
Mean FEV ₁ difference (limits of agreement) at baseline	0.05 (0.23 to -0.13)	0.07 (0.25 to -0.12)	0.06 (0.24 to -0.13)	0.05 (0.22 to -0.13)	0.45
Mean FEV ₁ difference (limits of agreement) after exercise (at 10 min)	0.06 (0.24 to -0.12)	0.09 (0.33 to -0.15)	0.05 (0.23 to -0.14)	0.06 (0.22 to -0.10)	0.081

*p-Value for the difference in mean FEV₁ between the diagnostic groups.

respectively) ($p = 0.002$); and in control children 2.24 l (FVS) and 2.19 l (TS) (% predicted 92.7% and 90.7%, respectively) ($p < 0.001$).

In the post-exercise measurements, the differences between the two spirometers remained similar. Among all children, the mean (s.d.) FEV₁ after 10 min of exercise was 2.18 l (0.46 l) by the FVS and 2.12 l (0.46 l) by the TS ($p < 0.001$). Likewise, slightly higher mean FEV₁ after 10 min of exercise in the FVS were seen in all diagnostic groups: in children with clinical asthma, the mean FEV₁ was 2.05 l in the FVS and 1.95 l in the TS ($p < 0.001$); in children with possible asthma 2.06 l (FVS) and 2.01 l (TS) ($p = 0.012$), and in control children 2.23 l (FVS) and 2.18 l (TS) ($p < 0.001$).

Mean differences in FEV₁ and the limits of agreement between the groups and the spirometers are presented in Table 1. At baseline, the mean difference for FEV₁ measured by the FVS and TS was 0.05 l (2.3%). In other words, the values by the FVS were on an average 0.05 l (2.3%) higher than the values by the TS. The mean difference in children with asthma was 3.3%, in children with possible asthma 2.7%, and in control children 2.1%.

Ten minutes after exercise, the mean difference for FEV₁ measured by the FVS and TS was 0.06 l (2.1%). In children with asthma, the mean difference was 4.6%, in children with possible asthma 2.2%, and in control children 2.6% (Table 1).

Figs 1 and 2 show the plot of the difference between the FVS and TS, presented separately before and after exercise, in the whole study population. Before exercise, the limits of agreement were -0.13 to 0.23 l (Fig. 1). This means that, before exercise, FEV₁ values by the TS may be 0.13 l higher or 0.23 l lower than those by the FVS. After exercise, the 95% CI was -0.12 to 0.24 l, respectively (Fig. 2).

Discussion

Previous studies suggest that the portable TS may be a suitable method for measuring lung

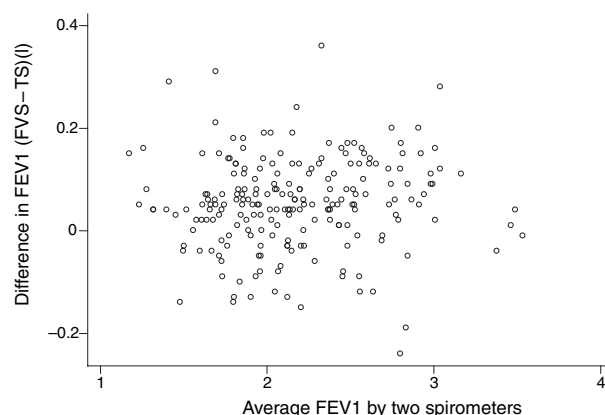


Fig. 1. A plot of the difference between the flow-volume spirometer (FVS) and the hand-held turbine spirometer (TS) against the average FEV₁ (l) by the two spirometers, measured at baseline.

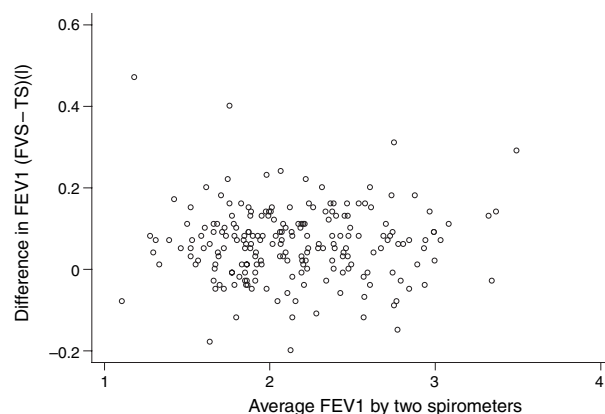


Fig. 2. A plot of the difference between the flow-volume spirometer (FVS) and the hand-held turbine spirometer (TS) against the average FEV₁ (l) by the two spirometers, measured 10 min after exercise.

function during a provocation test, or in the follow-up of children with asthma (2, 3, 5, 6). However, the results obtained from the hand-held TS cannot be considered equivocal with those by the conventional spirometers (3, 5). Paul and Schultz (4) suggested that the hand-held TS should be used with caution in the paediatric age group, as FEV₁ levels may be overestimated by

the hand-held spirometer. Contrary to their results, many authors have reported that the TS give lower values than the conventional spirometric devices (2, 3, 5). However, these differences may also have been caused by those spirometers with which the pocket-sized spirometer has been compared. Our results suggest that the accuracy of the results got by the hand-held TS is sufficient for everyday practice, but the results cannot be used interchangeably with those by the conventional spirometers in a research setting. For measuring changes in FEV₁ within an individual (e.g., in bronchial provocation tests) as well as when measuring day-to-day FEV₁ variation the same type of spirometer (either hand-held or conventional), or even the same individual device, should be used throughout the study.

The best way of estimating the agreement of the results got by different spirometers is to examine the difference of the results against their mean (10). Most previous studies (2–4, 6), however, have used correlation methods in the comparison, an approach that may have been incorrect; for this purpose the comparison of the correlation coefficients probably gives misleading information (10). Our results, based on the agreement method as presented by Bland and Altman (10), showed that the mean difference between the two spirometers was small. In addition, the results between and within the diagnostic groups were very similar. At baseline, the mean difference for FEV₁ varied from 0.05 to 0.07 l between the diagnostic groups, and after exercise from 0.05 to 0.09 l. In the study of Keskinen et al. (6), the accuracy of the pocket-sized Micro Plus TS was compared with the Vitalograph Bellow spirometer. They observed that in patients with occupational asthma, Micro Plus and Vitalograph results had an excellent correlation ($r = 0.99$), and the mean difference was only 0.06 l. However, that study was carried out only at baseline, and a correlation method with its known limitations was used in assessing the agreement of the spirometers.

Previous studies have suggested that the differences between the spirometers increase in association with airway obstruction (3–5). The strength of our study was that we had a population-based sample of children, including both asthmatic and healthy children (9). Therefore, this group of children allowed us to examine the agreement between the two spirometers both within the asthmatic patients and between the

asthmatic and healthy children. During exercise when FEV₁ decrease in asthmatic children, the differences did not significantly increase in our study. After the free running test, in children with clinical asthma, FEV₁ by the TS may be 0.33 l below or 0.15 l (on an average 0.09 l) above that by the FVS, which difference would be acceptable for clinical purposes.

In conclusion, the results of the hand-held TS were in reasonable agreement with the conventional spirometer to be used in a clinical setting. The handheld spirometer seem to be equally reliable in both baseline and post-exercise measurements, and the agreement between the two does not seem to be influenced by the presence of asthma or response to exercise. However, the results of the hand-held spirometer are not interchangeable with those of the conventional spirometer, which needs to be taken into account in a research setting.

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