Peak Expiratory Flow Is Not a Quality Indicator for Spirometry*

Peak Expiratory Flow Variability and FEV_1 Are Poorly Correlated in an Elderly Population

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Background: **Peak forced expiratory flow (PEF) and FEV_1 are spirometry measures used in diagnosing and monitoring lung diseases. We tested the premise that within-test variability in PEF is associated with corresponding variability in FEV_1 during a single test session.**

Methods: **A total of 2,464 healthy adults from the Health, Aging, and Body Composition Study whose spirometry results met American Thoracic Society acceptability criteria were screened and analyzed. The three "best" test results (highest sum of FVC and FEV_1) were selected for each subject. For those with acceptable spirometry results, two groups were created: group 1, normal FEV_1/FVC ratio; group 2, reduced FEV_1/FVC ratio. For each subject, the difference between the highest and lowest PEF (ΔPEF) and the associated difference between the highest and lowest FEV_1 (ΔFEV_1) were calculated. Regression analysis was performed using the largest PEF and best FEV_1, and the percentage of ΔPEF (%ΔPEF) and percentage of ΔFEV_1 (%ΔFEV_1) were calculated in both groups.**

Results: **Regression analysis for group 1 and group 2 showed an insignificant association between %ΔPEF and %ΔFEV_1 ($r^2 = 0.0001$, p = 0.59, and $r^2 = 0.040$, p = 0.15, respectively). For both groups, a 29% ΔPEF was associated with a 1% ΔFEV_1.**

Conclusion: **Within a single spirometry test session, %ΔPEF and %ΔFEV_1 contain independent information. PEF has a higher degree of intrinsic variability than FEV_1. Changes in PEF do not have a significant effect on FEV_1. Spirometry maneuvers should not be excluded based on peak flow variability.**

(CHEST 2007; 131:1494–1499)

Key words: forced expiratory flow rate; forced expiratory volume; peak expiratory flow; respiratory function tests; spirometry

Abbreviations: ATS = American Thoracic Society; ERS = European Respiratory Society; ΔFEV_1 = difference between the highest and lowest FEV_1; %ΔFEV_1 = percentage of ΔFEV_1; FEV_1-A = FEV_1 associated with the largest peak expiratory flow; FEV_1-B = FEV_1 associated with the smallest peak expiratory flow; PEF = peak expiratory flow; ΔPEF = difference between the highest and lowest peak expiratory flow; %ΔPEF = percentage of difference in peak expiratory flow; PEF-A = largest peak expiratory flow

Peak expiratory flow (PEF) is a measure of maximal expiratory flow that is used to assess qualitative and quantitative effort in spirometry maneuvers and is clinically utilized independently for asthma monitoring via handheld devices.[1–5] FEV_1 is a measurement of volume in the first second of a spirometry maneuver that is used for the diagnosis and monitoring of lung disease.[1,6] Both of these measurements have played an important role in the identification and management of lung disease, particularly asthma.

Physiologically, flow characteristics influence measurements of both PEF and FEV_1. Although the viscosity and density of the gas measured, and the length and caliber of the airways impact change in PEF and FEV_1 measurements,[7–9] PEF and FEV_1 measure different aspects of flow. PEF is thought to be a measurement of large-caliber airway function (> 2 mm diameter) and is very effort dependent. FEV_1, however, is thought to be a reflection of intermediate and smaller airways. This measurement has both effort-dependent and effort-independent components.

Effort during spirometry is, in part, judged by the individual's PEF. It directly correlates to maximal work and the initial effort during a spirometry maneuver.[10] It is also easily quantifiable and can be incorporated in automatic defaults on spirometers that use computer-assisted markers for spirometry acceptability standards. Prior guidelines[11] state that individual PEF measurements should be within 10% of the maximal value. Some popular spirometers provide an error code if there are no trials within 10% of the "best" (largest) trial for PEF. As a result, PEF reproducibility has been used as a measure of quality assurance for spirometry. Despite this, the most recent American Thoracic Society (ATS)/European Respiratory Society (ERS) criteria for standardization of spirometry do not use differences in PEF between maneuvers to assess quality within a single session.[12]

PEF and FEV_1 are used to objectively monitor obstructive lung disease and to evaluate occupational asthma, and are often used as primary outcomes in drug studies.[1,13–16] FEV_1 is commonly assumed to be partly dependent on PEF, based on a high correlation between PEF and FEV_1.[17] Hence, PEF has been used as a surrogate for FEV_1, particularly within an individual over time (*ie*, change in PEF reflects a similar degree of change in FEV_1). There is debate about whether or not changes in PEF truly reflect changes in FEV_1 and subsequently correspond to the degree of obstructive disease in an individual.[18,19] It has also been suggested that there is a *negative effort dependence*, also referred to as *inverse effort dependence*, of the FEV_1.[10,20] This states that maximal effort corresponding to the highest PEF will result in a reduced FEV_1 due to thoracic gas compression. In an attempt to clarify these issues, we tested the premise that difference between the highest and lowest PEF (ΔPEF) within an individual during a single session is associated with a parallel difference between the highest and lowest FEV_1 (ΔFEV_1).

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This study was supported by contracts N01-AG-6–2101, N01-AG-6–2103, and N01-AG-6–2106, and was also supported in part by the Intramural Research program of the National Institutes of Health, National Institute on Aging.
The authors have no conflicts of interest to disclose.
Manuscript received November 15, 2006; revision accepted January 21, 2007.

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DOI: 10.1378/chest.06-2707

Materials and Methods

Participants from the Health, Aging, and Body Composition Study were analyzed. All participants were 70 to 79 years old during recruitment, free of disability in activities of daily living, and free of functional limitations. The institutional review boards at both field centers approved the study, and informed consent was obtained. Subjects performed spirometry and were coached to perform maximal efforts. A National Institute for Occupational Safety and Health volume-based spirometer using a digital shaft encoder to measure volume displacement was used. Three-liter syringe calibrations were done daily. Two of the authors (R.L.J. and R.O.C.) from LDS Hospital in Salt Lake City, UT, scored the quality of the spirograms as "A" (best) through "F" (worst) for FEV_1 and FVC based on ATS acceptability and reproducibility standards. Spirograms with FEV_1 and FVC quality scores of "C" or better were then analyzed. All of these met ATS criteria published in 1995 for reproducibility, with 200 mL between the highest and the next highest FEV_1.[21] Of those that were acceptable, two groups were formed: group 1, normal FEV_1/FVC ratio; group 2, reduced FEV_1/FVC ratio, based on the lower limits of normal using prediction equations of Crapo et al.[22]

For each group, the three best tests (based on the highest sum of FVC and FEV_1) were selected for each subject as recommended by ATS spirometry guidelines.[21] The largest PEF (PEF-A) and the smallest PEF in a single session were chosen from those three best tests. FEV_1 values associated with each PEF were labeled as FEV_1-A and FEV_1-B, respectively. Equations associated with these values are as follows:

Equation 1: $\Delta PEF = PEF\text{-}A - PEF\text{-}B$;

all ΔPEF values were positive.

Equation 2: $\Delta FEV_1 = FEV_1\text{-}A - FEV_1\text{-}B; \Delta FEV_1$;

values could be either positive or negative.

Equation 3: $\%\Delta PEF = (\Delta PEF/PEF\text{-}A) \times 100$.

Equation 4: $\%\Delta FEV_1 = (\Delta FEV_1/\text{largest } FEV_1) \times 100$,

where PEF-B is the smallest PEF in a single session. Regression analysis was performed on PEF-A and the largest FEV_1, and %ΔPEF and %ΔFEV_1 to look for significant relationships between these variables in both normal and obstructed individuals.

The frequency of negative effort dependency was determined by calculating the percentage of subjects in which the largest FEV_1 was associated with a submaximal PEF. Those subjects with acceptable spirometry results based on ATS acceptability and reproducibility criteria, and a > 50% ΔPEF were excluded from analysis to reduce the effect of outliers. This resulted in exclusion of 1.9% of subjects.