The American Thoracic Society/European Respiratory Society Acceptability Criteria for Spirometry: Asking Too Much or Not Enough?

To the Editor:

We read with great interest the study by Giner et al,¹ who examined the ability of subjects to satisfy the 2005 American Thoracic Society/European Respiratory Society (ATS/ERS) acceptability standards for spirometry.² The authors' finding that failure to satisfy end-of-test criteria was a common error is consistent with data recently published by Hankinson et al,³ who suggested that strict adherence to end-of-test criteria may result in the unnecessary rejection of valid data. Based on these data, it seems reasonable to expect that future ATS/ERS recommendations may curtail currently used end-of-test criteria.

However, we believe that there is a spirometry error that is understated in the current guideline: failure to achieve maximal inhalation. We submit that an appropriate term for this type of spirometry error is submaximal inhalation error. Submaximal inhalation error occurs when a subject begins forced exhalation before fully inhaling to total lung capacity. Clearly, indices of the FVC maneuver will be underestimated in the presence of a significant submaximal inhalation error. Indeed, a submaximal inhalation error can be expected to have a pseudo-restrictive effect. The current ATS/ERS guideline states that FVC variability is commonly due to incomplete inhalation and that points of maximal inhalation and that points of maximal exhalation before and after forced exhalation should not vary. However, there is no description of how to identify submaximal inhalation, nor is there any definition of how much submaximal inhalation error is tolerable. Moreover, the current guideline permits testing to be performed without measurement of the inspired FVC, with the assumption that tests are performed after full inhalation.

Submaximal inhalation error can most easily be identified by examining a flow-volume loop that includes an inspiratory limb that extends from the end of forced exhalation to total lung capacity. A submaximal inhalation error exists if the end point of the inspiratory loop extends beyond the onset point of forced exhalation on the volume scale (abscissa). This determination must be made from examination of expiratory and inspiratory loops from the same effort. Best-loops graphics in pulmonary function reports may contain expiratory and inspiratory loops

from different efforts. Inspiratory loops reflecting the inhalation preceding forced exhalation cannot detect submaximal inhalation error. Alternatively, a submaximal inhalation error can also be identified if the inspired volume measured after full exhalation extends below the horizontal baseline of a volume-time curve.

As shown in Figure 1A, the inspiratory loop end point extends beyond the onset point of forced exhalation on the volume scale. In this case, the inspired FVC is 260 mL greater than the expired FVC. Figure 1B shows a subsequent effort after the subject was instructed to make sure he inhaled completely before blasting the air out. From this effort, the inspired FVC was 1 mL less than the expired FVC. Table 1 shows the difference in spirometric indices

between the two efforts depicted in Figure 1. Although both efforts indicate severe airflow obstruction, the FVC and FEV₁ are both lower when a submaximal inhalation is present. The difference in FVC is greater than the allowable inter-maneuver variance (ie, 150 mL).² Moreover, the FVC is above the lower limit of normal (Z score of more than -1.64) after the submaximal inhalation error is corrected, indicating that recognition and correction of this type of error may, in fact, result in a change in the interpretation of the results. It is important to recognize that flow-volume loops and volume-time curves do not possess perfect sensitivity for submaximal inhalation error because submaximal inhalations can both precede and follow the same expiratory FVC maneuver. Moreover, inspiratory loops can

Fig. 1. Flow-volume loops from a subject performing spirometry testing. A: The inspiratory loop end point extends beyond the onset point of maximal exhalation on the volume scale. The inspired FVC is 260 mL greater than the expired FVC, indicating a submaximal inhalation error. B: Flow-volume loop after the subject was instructed to make sure he inhaled completely before blasting the air out. On this effort, the inspired FVC was 1 mL less than the expired FVC. Vertical lines indicate the respective FEV₁ and FEV₃ values. Dashed lines show expected/normal.

Table 1. Spirometric Values With and Without Submaximal Inhalation Error

	Value	% Predicted	Z-score
Submaximal inhalation error			
FVC (L)	3.05	74	−1.93
FEV ₁ (L)	1.61	49	−3.86
FEV ₁ /FVC	0.53		−0.04
Corrected submaximal inhalation error			
FVC (L)	3.26	79	−1.54
FEV ₁ (L)	1.76	53	−3.52
FEV ₁ /FVC	0.54		−0.04

be truncated by suboptimal effort, cough, vocal cord adduction, and other errors (eg, mouth leak).

We are unable to report the prevalence of submaximal inhalation error in clinical practice; however, it is likely to depend on the experience and skill of testing personnel. The clinical impact of submaximal inhalation error may be significant in certain settings, such as identifying a low FVC that may suggest restrictive disease, the correct grading of airway obstruction based on percent-of-predicted FEV₁, or the accurate follow-up of FEV₁ or FVC in patients being treated for obstructive or restrictive disease.

We propose that an unacceptable submaximal inhalation error be defined as an inspired FVC that exceeds the expired FVC by ≥ 150 mL in adults. We believe that a ≥ 150 -mL gap is appropriate because this value is the currently recommended maximum inter-maneuver variance for FVC.² Studies are needed to test the ability of patients to satisfy this goal and to determine an appropriate error size for children.

It could be argued that spirometry testing with excessive submaximal inhalation errors may already be identified as low quality by virtue of failure to satisfy repeatability standards; however, it may be possible for this error (like others) to be reproducible, especially if corrective action is not taken by the technologist. In addition, a formal definition of this error is necessary for the training of testing personnel and the development of software to provide computerized technologist feedback regarding submaximal inhalation errors. It is important to realize that a submaximal inhalation error can be the fault of the technologist if a premature command to begin forced exhalation is given (ie, the patient is instructed to exhale before full inhalation is achieved). We therefore encourage manufacturers to include submaximal inhalation error in their quality feedback software with a message such as “the inspired FVC is larger than the expired FVC; ensure that the patient inhales fully before performing forced exhalation.”

The addition of submaximal inhalation error to the existing ATS/ERS spirometry acceptability criteria would require a new recommendation that all spirometry tests record a flow-volume loop, including a full inspiratory maneuver following the forced expiratory maneuver. There are some patients who achieve greater lung inflation when inhalation begins from residual volume compared with functional residual capacity.^{4,5} For these individuals, submaximal inhalation error may be corrected by the following sequence: tidal breathing, exhale to residual volume, full inhalation, forced exhalation, and rapid and full inhalation.^{2,5}

We endorse the comments of Graham⁶ published in an editorial in *RESPIRATORY CARE*: “Pulmonary function standards are not static. They should be questioned. There is always room for improvement in any set of pulmonary function standards.”

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In Reply:

I thank Mr Haynes and Dr Kaminsky for their interest and comments on our study exploring spirometric standards in relation to subject characteristics in routine clinical practice.¹ Regarding the comments about the American Thoracic Society/European Respiratory Society (ATS/ERS) acceptability criteria for spirometry, I share the authors' concerns about the failure to achieve maximal inhalation during the spirometry maneuver; it is also my experience. In addition, I also agree with the proposal to add the term submaximal inhalation error to the ATS/ERS spirometry acceptability criteria.

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