


## Is there a discrepancy between a physical law and the spirometric definition of airflow obstruction?

Masoud Rahimian and  
Mahi HosseiniB

Internal Medicine Department, Division of Pulmonology, Shahid Sadoughi University of Medical Sciences, Yazd, Iran

**Corresponding author:** HosseiniB M

 drsmhb@gmail.com

Division of Pulmonology, Shahid Sadoughi University of Medical Sciences, Ghandi Street, Yazd, Iran.

**Tel:** 00989133533690

**Citation:** Rahimian M, HosseinB M. Is there a discrepancy between a physical law and the spirometric definition of airflow obstruction? *Insights Med Phys.* 2017, 2:1

### Abstract

**Background:** It has long been emphasized that if physicians rely on clinical signs and symptoms only, they may under-diagnose many of the airflow-limited patients. But what if they rely on spirometry alone and overlook physical examinations as the case is now? Interesting studies on physics of sounds show that wheezing is definitely indicative of an airflow limitation, but, according to current guidelines, presence or absence of wheezes has not been taken into consideration for diagnosis. The purpose of present study was to detect the degree of spirometric deterioration in patients who were physically presumed to have definite airflow obstruction, namely diffuse bilateral wheezes.

**Methods:** In a cross-sectional study, adult patients complaining of chronic cough and/or dyspnea were visited by two specialists at a pulmonary clinic. If both pulmonologists' agreement about presence of wheezes, the patients would be sent for spirometry. Spirometry maneuvers were performed according to the American Thoracic Society (ATS) standards. First eighty patients who could perform acceptable spirometry were selected. Prevalence of a forced expiratory volume in first second over forced vital capacity ( $FEV_1/FVC$ ) and/or  $FEV_1$ /slow vital capacity (SVC) below 70% were calculated in these patients with a very high probability of airflow obstruction based on the physical laws.

**Results:** In our patients' setting with diffuse bilateral wheezes, the means of predicted percentages for  $FEV_1$ , FVC and SVC were  $60.3 \pm 7.1\%$ ,  $72.5 \pm 17\%$  and  $69.9 \pm 6.2\%$  respectively. The mean of  $FEV_1/FVC$  and  $FEV_1/SVC$  could be sequenced as  $68.38 \pm 10.6\%$  and  $68.44 \pm 11.6\%$  percent. In 32 (40%) patients, both values were less than 70%, and 31 (38.8%) had both values of more than 70%. On the other hand, in 11 (13.7%) patients, only  $FEV_1/FVC$  and, in 6 (7.5%), only  $FEV_1/SVC$  were less than 70%. As the results show, even in our patients' setting, those who met the gold standards for airflow obstruction from the viewpoint of physical laws, spirometric obstruction was present only in 61.2% ( $40\% + 13.7\% + 7.5\%$ ) of the cases.

**Conclusion:** The results show a discrepancy between wheezing, as a physical symptom of obstruction, and spirometric findings. Spirometry, as a tool for screening asymptomatic persons, has proved to have a good sensitivity, but the results of present study indicate that this may be not the case for wheezy symptomatic patients.

**Keywords:** Obstructive lung diseases; Physical examination; Respiratory function tests; Respiratory sounds; Spirometry

**Abbreviations:** ATS: American Thoracic Society; COPD: Chronic Obstructive Pulmonary Diseases; ERS: European Respiratory Society; GOLD: Global Initiative for Chronic Obstructive Lung Disease; LLN: Lower Limit of Normal; NICE: National Institute for Clinical Excellence

**Received:** February 15, 2017; **Accepted:** April 05, 2017; **Published:** April 05, 2017

## Introduction

Spirometry is a valuable tool in evaluation of patients with airflow obstruction. It is used for diagnosis and staging of chronic obstructive pulmonary disease (COPD), confirmation of asthma and determining the efficacy of asthma treatment [1]. In the medical office setting it is useful for both diagnostic and monitoring purposes [2]. It is also used for screening and surveillance programs in workers with exposures to agents associated with pulmonary diseases [3,4].

Early detection of airflow obstruction is also important for many reasons. Airflow obstruction is a marker of increased risk of death from heart disease, lung cancer, and stroke [5-7]. COPD is a leading cause of both morbidity and mortality [5]. A consensus statement of the European Respiratory Society (ERS) emphasized the importance of spirometry in early diagnosis of COPD in asymptomatic patients [8]. Early detection of airflow obstruction is particularly important for young adults because they are more likely to benefit from intervention [9].

However, the big problem is that the prevalence of airflow obstruction varies widely with the definition used, and there seems to be a need for constant refinement of spirometric standards. In the National Heart, Lung, and Blood Institute (NHLBI) / World Health Organization (WHO), Global Initiative for Chronic Obstructive Lung Disease (GOLD) and National Institute for Clinical Excellence (NICE) guidelines, the  $FEV_1/FVC < 70\%$ , as a fixed value, is used to detect airflow obstruction [10,11]. The ERS defines COPD as  $FEV_1 / (FVC \text{ or } SVC) < 88\%$  of predicted value in men and  $< 89\%$  of predicted value in women (i.e.  $> 1.64$  residual standard deviation below the predicted value) [8]. In November 2005, ATS and ERS developed joint guideline for accurate and reproducible diagnosis of airflow obstruction [12,13].

Up to now there are little emphases on clinical signs and symptoms, like diffuse wheezes, for diagnosis of airflow obstruction. Most guidelines use spirometry only; however, at least in 1995, ATS guideline also used a patient reported symptoms and physician diagnoses taken from patient history, but nothing from physical examination [14].

Importance of wheezing became more relevant when we consider interesting studies on the physics of the sound models proposed by Grotberg and David [15] and Grotberg and Reiss [16,17]. They showed with their models that wheezing will always be accompanied by flow limitation, but that flow limitation will not necessarily be accompanied by wheezing.

The purpose of present study was to detect the degree of spirometric deterioration in patients who were physically presumed to have definite airflow obstruction, which means had diffuse wheezes on auscultation.

## Material and Methods

This cross-sectional study was performed in winter of 2012 at the hospital of Shahid Sadoughi medical university, Yazd, Iran. This study was approved by the Shahid Sadoughi hospital ethics committee (NO. 29352 / Date: June 1st, 2011). The committee waived the need for written consent, and claim it sufficed to inform all the participants that there is no risk in spirometry as a diagnostic test.

Exclusion criteria consist of factors that can make spirometry results inaccurate and unreliable. These are vertebral column, thoracic cage or abdominal abnormalities (e.g. kyphoscoliosis), neuromuscular diseases, cardiovascular diseases (e.g. heart failure), history of chest trauma or anemia, malignancy and thoracic or abdominal surgery in previous three months.

Pulmonary clinic patients who complained of chronic cough and/or dyspnea of more than six weeks' duration, without prior diagnosis, were participated. Two board-certified pulmonary physicians (first author and a colleague) examined participants for the presence of bilateral wheezes. If there was disagreement between two pulmonologists, even for staging of wheezes, the participant was excluded. Those who were included, send for spirometry.

Spirometry was performed by a Fuduka ST-250 spiroanalyzer (Fukuda Sangio Co, Japan) according to ATS criteria [18,19]. Eighty consecutive acceptable tests from patients older than 15 years were included and analyzed (87 patients tested totally).

We consider both  $FEV_1/FVC$  and  $FEV_1/SVC$  percent values below 70% as spirometric equivalent of airflow obstruction (recommended in NICE and GOLD guidelines, respectively).

## Statistical Analysis

Statistical analysis was done using SPSS software for Windows (Release 22.0, SPSS Inc., Chicago, USA). We used Cohen's  $\kappa$  to determine if there was agreement between two pulmonologists' judgement on whether individuals had wheeze or not. We consider standard deviation for participants'  $FEV_1/FVC$  and  $FEV_1/SVC$  percent values equal to 10 based on a pilot study. Desired total width of the confidence interval is 6 (or  $\pm 3$ ) for  $FEV_1/FVC$  and  $FEV_1/SVC$  percent values in COPD, based on spirometry guidelines. Therefore, we need at least 74 participants to achieve 99 percent confidence interval. Two-tailed p-values  $< 0.05$  were considered significant.

## Results

We examined spirometry from 80 patients. There are 68 males (85%) and 12 females (15%), with mean age of  $44.9 \pm 15.7$  and  $34.4 \pm 9.4$  years, respectively. **Table 1** shows the mean values of spirometric parameters. **Table 2** shows spirometric data of all patients. As you see in **Table 2**, using  $FEV_1/FVC$  or  $FEV_1/SVC$  below 70% (as fixed ratios) singly resulted in diagnosis of obstructive pattern only in 53.7% and 47.5% respectively; while, applying both spirometric criteria, could label 61.2% of participants as having an obstructive pattern on spirometry.

The two pulmonologists agreed on 87 patients whom had wheeze and 35 patients whom didn't have wheeze. However, first pulmonologist confirmed seven patients had wheeze when second pulmonologist confirmed they did not. Conversely, first pulmonologist confirmed ten patients did not have wheeze when second pulmonologist confirmed they had wheeze. Cohen's  $\kappa$  test revealed there was a good agreement between the two pulmonologists judgements,  $\kappa = .716$  (95% CI, .591 to .841),  $p < .0005$ .

**Table 1:** Mean values of spirometric parameters.

Spirometric parameters	Mean $\pm$ SD*
FEV <sub>1</sub> predicted %	60.3 $\pm$ 7.1
FVC predicted %	72.5 $\pm$ 17
SVC predicted %	69.9 $\pm$ 6.2
FEV <sub>1</sub> /FVC	68.38 $\pm$ 10.6
FEV <sub>1</sub> /SVC	68.44 $\pm$ 11.6

**Table 2:** Spirometry data in patients.

Number of the patients (percentage)	FEV <sub>1</sub> /FVC < 70%	FEV <sub>1</sub> /FVC > 70%
FEV <sub>1</sub> /SVC < 70 %	32 (40%)	6 (7.5%)
FEV <sub>1</sub> /SVC > 70 %	11 (13.7%)	31 (38.8%)

## Discussion

The present survey may aim to examine the relations between spirometric and physical signs of airflow obstruction. Patients with chronic cough and/or dyspnea plus bilateral diffuse wheezes on auscultation were presumed very suspicion to have airflow obstruction clinically and physically (based on physical law, which consider wheezing as the definite indicator of airflow limitation). However, even in this clinical setting with very high probability for airflow obstruction, applying both spirometric criteria of FEV<sub>1</sub>/FVC and FEV<sub>1</sub>/SVC below 70% (as fixed ratios), could label only 61.2% of patients as having an obstructive pattern on spirometry. These results are indicative of substantial discrepancy, which if correct, means large under-diagnosis by using simple spirometry alone in these situations (even when applying both spirometric criteria to identify more cases (61.2%); rather than using each singly (53.7% and 47.5%).

Our patients had a mean FEV<sub>1</sub> of 60%, which shows a moderate spirometric obstruction. It should be concerned that patients with more severe obstruction will show a better spirometric distinction.

Despite the relevant importance, there is no unique standard reference guideline for accurate distinction of airflow obstruction by spirometry alone. However, use of clinical and spirometric findings concomitantly may help better distinction of airflow limited patients.

The most relevant problem is that the prevalence of airflow obstruction varies widely with the definition used. Anne Lindberg et al. showed the difference in the prevalence of COPD according to spirometric criteria of British Thoracic Society (BTS), ERS, GOLD, and ATS guidelines in a random sample of adults [20]. Although, a majority of patients reported airway symptoms and contact with health care providers due to respiratory complaints, only a minority was diagnosed as COPD patient by spirometry. This can indicate a large under-diagnosis, and show a discrepancy in diagnosis based on patient symptoms and spirometry, same as our results.

Using a fixed FEV<sub>1</sub>/FVC < 0.70 as recommended by GOLD and NICE guidelines, [10,11] will lead to a substantial under-diagnosis of airflow obstruction in younger, and over-diagnosis of COPD in older individuals [21]. Therefore, some researchers suggest the

use of lower limit of normal (LLN) instead of a fixed ratio [22,23]. Cerveri et al. reported that only 45.6% of the subjects with airflow obstruction by the LLN were also identified by a fixed cut-off [9].

In ERS guidelines [8] the predicted value of FEV<sub>1</sub>/FVC or FEV<sub>1</sub>/SVC declines with age and the limit is higher for women (89% of predicted); although, the COPD diagnosis according to the ERS definition will include young females and exclude older men to a greater extent than the NICE and the GOLD definitions [24].

Since the main problem is under-diagnosis of airflow obstruction by spirometry even when the newest guidelines are used, many researchers tried to establish other spirometric criteria for better distinction of airflow obstruction [22,23,25]. Some recommend the use of FEV<sub>6</sub> instead of FVC, but relatively low sensitivity of this criterion may also result in the underestimation of airflow obstruction [26].

Kreider ME and Grippi MA report that uses of the new ATS/ERS interpretation scheme leads to a diagnosis of obstruction in a greater proportion of patients undergoing pulmonary function testing [27].

It seems that no matter what criteria are used; spirometry alone cannot extract a large subgroup of patients with airflow obstruction. Furthermore, there is no place for clinical signs and symptoms alone or in combination with spirometry in most guidelines. In the 1995 ATS guidelines, symptoms and physician diagnosis, both from history are taken into account, but there is no role for physical signs like presence of diffuse wheezes. Results from interesting studies on physics of the sound models by Grotberg and David [15] and Grotberg and Reiss [16,17] showed that wheezing is always an indicative of flow limitation. We suggest that a preclinical air limitation screening symptom, like wheezing, in a patient with difficulty breathing, can prevent the under diagnose of airflow limitation by using spirometry alone.

It is probable that sensitivity of spirometry as an indicator of airflow obstruction in the setting of wheezy patients may be less than for screening of asymptomatic persons.

There are no known prior studies assessing the efficacy of wheezing as a preclinical symptom for clinically diagnosed airflow limitation demonstrated by spirometry. Therefore, the study warrant further study to assess this method of assessment for the diagnosis of the respiratory diseases.

## Conclusion

Our results may show a discrepancy on the presence of airflow obstruction between clinical/physical rules and spirometric definition. It is an idea that adding clinical signs and symptoms to spirometric criteria may lead to better distinction of airflow obstruction.

## Acknowledgements

We wish to thank M. Samet M.D for his very kind cooperation in physical examination of patients even when he wasn't on duty.

## References

- 1 Derom E, Van Weel C, Liistro G (2008) Primary care spirometry. *Eur. Respir. J* 31: 197-203.
- 2 Wanger J, Irvin CG (1997) Office spirometry: Equipment selection and training of staff in the private practice setting. *J. Asthma* 34: 93-104.
- 3 Enright P, Skloot G, Herbert R (2008) Standardization of spirometry in assessment of responders following man-made disasters: World Trade Center worker and volunteer medical screening program Mt Sinai J Med 75: 109-114.
- 4 Townsend MC (2000) ACOEM position statement: Spirometry in the occupational setting. *American College of Occupational and Environmental Medicine. J. Occup. Environ. Med* 42: 228-245.
- 5 Bethesda (2009) Morbidity and mortality chart book on cardiovascular, lung, and blood diseases. National Heart, Lung and Blood Institute.
- 6 Tockman M, Comstock G (1989) Respiratory risk factors and mortality: longitudinal studies in Washington County, Maryland. *Am Rev Respir Dis* 140: S56-S63.
- 7 Kuller LH, Ockene J, Meilahn E (1990) Relation of forced expiratory volume in 1 second (FEV1) to lung cancer mortality in the multiple risk factor intervention trial (MRFIT). *Am. J. Epidemiol* 132: 265-274.
- 8 Siafakes NM, Vermeire P, Pride NB (1995) ERS Consensus Statement. Optimal assessment and management of chronic obstructive pulmonary disease (COPD). *Eur Respir J* 8: 1398-1420.
- 9 Cerveri I, Corsico AG, Accordini S (2008) Underestimation of airflow obstruction among young adults using FEV1/FVC < 70 % as a fixed cut-off: a longitudinal evaluation of clinical and functional outcomes. *Thorax* 63: 1040-1045.
- 10 Pauwels RA, Buist AS, Calverley PM (2001) GOLD Scientific Committee: Global strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease. NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop summary. *Am J Respir Crit Care Med* 163: 1256-1276.
- 11 Chronic Obstructive Pulmonary Disease (2004) National clinical guidelines on management of chronic obstructive pulmonary disease in adults in primary and secondary care. *Thorax* 59: 1-232.
- 12 Miller MR, Crapo R, Hankinson R (2005) General considerations for lung function testing. *Eur Respir J* 26: 153-161.
- 13 Pellegrino R, Viegi G, Brusasco V (2005) Interpretative strategies for lung function tests. *Eur Respir J* 26: 948-968.
- 14 American Thoracic Society: Standards for the diagnosis and care of patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med.* 152: 77S-120S.
- 15 Grotberg JB, Davis SH (1980) Fluid dynamic flapping of a collapsible channel: sound generation and flow limitation. *J Biomech* 13: 219.
- 16 Grotberg JB, Reiss EL (1982) A subsonic flutter anomaly. *J Sound Vibr* 80: 444-446.
- 17 Grotberg JB, Reiss EL (1984) Sub-sonic flapping flutter, Northwestern University Applied Mathematics technical report no. 8200. *J Sound Vibr* 92: 349-361.
- 18 Lung Function Testing (1991) Selection of reference values and interpretative strategies. American Thoracic Society. *Am Rev Respir Dis* 144: 1202-18.
- 19 Standardization of Spirometry (1994) Update on American Thoracic Society. *Am J Respir Crit Care Med* (1995) 152: 1107-1136.
- 20 Lindberg A, Jonsson AC, Rönmark E (2005) Prevalence of chronic obstructive pulmonary disease according to BTS, ERS, GOLD and ATS criteria in relation to doctor's diagnosis, symptoms, age, gender and smoking habits. *Respiration* 72: 471-479
- 21 Hnizdo E, Glindmeyer HW, Petsonk EL (2006) Case definitions for chronic obstructive pulmonary disease. *COPD* 3: 95-100.
- 22 Swanney MP, Ruppel G, Enright PL (2008) Using the lower limit of normal for the FEV1/FVC ratio reduces the misclassification of airway obstruction. *Thorax* 63: 1046-1051.
- 23 Hankinson JL, Odencrantz JR, Fedan KB (1999) Spirometric reference values from a sample of the general U.S. population. *Am J Respir Crit Care Med* 159: 179-187.
- 24 Nathell L, Nathell M, Malmberg P (2007) COPD diagnosis related to different guidelines and spirometry techniques. *Respir Res* 8: 89.
- 25 Akpınar-Elci M, Fedan KB, Enright PL (2006) FEV6 as a surrogate for FVC in detecting airways obstruction and restriction in the Workplace. *Eur Respir J* 27: 374-377
- 26 Demir T, Ikitimur HD, Koc N (2005) The role of FEV6 in the detection of airway obstruction. *Respir Med* 99: 103-106.
- 27 Kreider ME, Grippi MA (2007) Impact of the new ATS/ERS pulmonary function test interpretation guidelines. *Respir Med* 101: 2336-2342.