Value of spirometry in diagnosis and staging of airflow limitation

Sarah H. Tawfik, Ahmed H. Othman, Khaled H. Ahmed, Randa E. El-Din Abdel Kader

Department of Chest Diseases, Faculty of Medicine, Assiut University, Assiut, Egypt

Correspondence to Sarah H. Tawfik, MBBS, Department of Chest Diseases, Assiut Police Hospital, Assiut 71621, Egypt
Fax: 01008152360;
Tel: +20100 815 2360;
e-mail: sarahdous2@gmail.com

Received 13 October 2018
Accepted 01 January 2019
Published 07 September 2023

Journal of Current Medical Research and Practice
2023, 8:117–122

Rationale

Using ventilatory flow limitation (VFL) as a new and simple way to grade chronic obstructive pulmonary disease (COPD) severity accurately.

Aim of the work

Accurate measurement of airflow limitation in COPD patients and correlation between standard forced expiratory volume in 1 s (FEV_1) and VFL as an accurate measurement of airflow limitation.

Patients and methods

This study included 50 patients, 40 patients with COPD from outpatient clinic of Chest Department of Asyut University Hospital and 10 control persons were enrolled into our study. Measurement of spirometric data was taken (FEV_1, forced vital capacity, FEV_1/forced vital capacity) and patients were classified according to GOLD 2017 into mild, moderate, severe, and very severe COPD. Patients in our study were classified into two groups: group I: mild and moderate, group II: severe and very severe COPD. Tidal flow-volume loop was drawn by plotting exercise tidal flow-volume loop inside maximal flow-volume loop. Assessment of airflow limitation was done by measuring VFL: percent from tidal volume (Vt) that expiratory airflows meet or exceed the maximal expiratory flow. End expiratory lung volume (EELV) was measured from exercise tidal flow-volume loop.

Results

All very severe COPD patients had severe VFL. While severe COPD patients who had severe VFL were only 27.3%. The remaining 72.27% of severe COPD patients had moderate VFL. All mild and moderate COPD patients had mild VFL. Patients were classified into three categories: (a) with mild VFL for mild and moderate COPD grades, (b) with moderate VFL for severe COPD grade, (c) with severe VFL for very severe COPD grade. The increase in EELV during exercise is linked to the occurrence of VFL. EELV is increased to mean value of 618 ml in group II and just 240 ml in group I. Group II had significantly higher ($P < 0.0001$) VFL and EELV.

Conclusion

VFL and EELV are specific indices for airway obstruction in COPD patients and are correlated to the degree of severity.

Keywords:
airflow limitation, chronic obstructive pulmonary disease, spirometry

J Curr Med Res Pract 8:117–122

2357-0121

Introduction

Chronic obstructive pulmonary disease (COPD) has become a major epidemic with an increasing incidence worldwide, particularly in developing countries [1] and is now one of the leading causes of death and disability, with a prevalence of more than 10% in individuals above 40 years of age in most countries [2]. Airflow limitation is the hallmark of COPD [3]. Airflow limitation is a mechanical pathophysiological condition occurring, either during physical exercise or at rest, when expiratory flow cannot be further increased by increasing expiratory muscles effort because it is maximum at that tidal volume [4]. Airflow limitation predisposes to pulmonary dynamic hyperinflation and its unfavorable effects such as increased elastic work of breathing, inspiratory muscles dysfunction, and progressive neuroventilatory dissociation, leading to reduced exercise tolerance, marked breathlessness during effort, and severe chronic dyspnea [5].

The diagnosis of COPD needs to be confirmed by the presence of airflow limitation as measured by spirometry. The results of spirometry can be displaced as volume-time tracings, or displayed as flow-volume loop [3].

Flow-volume loop is produced when a patient performs a maximal inspiratory manoeuver which is then followed by a maximal expiratory effort. A graph is produced with a positive expiratory limb and a negative inspiratory limb [6]. Patients with obstructive lung diseases with reduced expiratory flow in the peripheral airways typically have a concave appearance to the descending portion of the expiratory limb rather than a straight line [7].

The results of spirometry testing can be useful in characterizing the presence and severity of the airflow limitation [3]. The advantage of spirometry over other tests of lung function is simplicity. It is also noninvasive and if performed and interpreted correctly spirometry has the potential to be a very effective screening tool for general lung health and in particular airflow limitation.

However, COPD remains substantially under diagnosed and a major reason for this is underuse of spirometry. The diagnosis is often delayed until more severe airflow obstruction is present [8].

The aim of the work was to accurate measure airflow limitation in COPD patients and correlate between standard forced expiratory volume in 1 s (FEV_1) and ventilatory flow limitation (VFL) as an accurate measurement of airflow limitation.

Patients and methods

This study included 50 patients, 40 patients with COPD from outpatient clinic of Chest Department of Asyut University Hospital and 10 healthy control persons enrolled during the period from March 2016 to June 2017. The study had approved from the ethical committe at faculty of medicine Assiut University and a written concent was taken from participants.

Inclusion criteria

Stable COPD patients with a postbronchodilator FEV_1/forced vital capacity (FVC) less than 70%.

Exclusion criteria

Acute exacerbation of COPD, patients with overlap syndromes, interstitial lung diseases, chronic cardiac, renal and hepatic diseases.

Outcome measures

(1) Spirometric measurements: data were taken as the best from at least three satisfactory spirometric tracings using D 97723 (Zan 300 Spirometer, Oberthulba, Germany)
   - (a) Results were derived from volume-time curve and flow-volume loop, and expressed as percentage of normal value for sex, age, and height (% predicted)
   - (b) Predicted, actual, and %FEV_1, FVC, FEV_1/FVC values were obtained and patients were classified according to GOLD 2017 into mild, moderate, severe, and very severe COPD patients
   - (c) GOLD 1 – mild: FEV_1/FVC less than 70% and FEV_1 more than or equal to 80% of predicted value
   - (d) GOLD 2 – moderate: FEV_1/FVC less than 70% and FEV_1 50–80% of predicted value
   - (e) GOLD 3 – severe: FEV_1/FVC less than 70% and FEV_1 30–50% of predicted value
   - (f) GOLD 4 – very severe: FEV_1/FVC less than 70% and FEV_1 less than 30% of predicted value
   - (g) Patients were classified into two groups
   - (h) Group I: mild and moderate COPD
   - (i) Group II: severe and very severe COPD.

(2) Exercise flow-volume loop:

   Patients were asked to begin with multiple exhaled tidal volume maneuver to record multiple exhaled tidal volume loops then do a slow relaxed respiration three times to generate a slow vital capacity then to do a forceful manner to generate a FVC by inhaling maximally from tidal respiration to total lung capacity and then rapidly exhales to the fullest extent until no further volume is exhaled at residual volume.

Analysis of exercise flow-volume loop

Tidal flow-volume loop was drawn by plotting exercise tidal flow-volume loop inside maximal flow-volume loop and assessing degree of airflow limitation by measuring the percent from tidal volume (Vt) that expiratory airflows meet or exceed the maximal expiratory flow and is called: VFL. End expiratory lung volume (EELV) was measured from exercise tidal flow-volume loop (Fig. 1).

Patients were classified according to airflow limitation into [9]:

(1) No constraint: 0
(2) Mild: less than 30%
(3) Moderate: 30–50%
(4) Severe: more than 50%.

Statistical analysis

Data was collected and analyzed those using SPSS (Statistical Package for the Social Science, version 20, IBM, and Armonk, New York), version 24 and statistical analysis carried out with suitable statistical tests. Using χ^2 test, independent *t* test to determine significance between variables in groups and Pearson's correlation to determine significance between variables in the same groups.

P value more than 0.05, nonsignificant.
P value less than 0.05, significant.
P value less than 0.001, moderate significance.
P value less than 0.0001, highly significant.

Results

Mean age of the studied patients was 53.5 years with male predominance. Patients had a smoking index 58.7 pack/year which was significantly higher ($P < 0.0001$) than control. The relation between COPD severity and demographic data were demonstrated in Table 1. The mean age and smoking index were significantly higher ($P < 0.0001$) in group II (59.8 years, 75.07 pack/year, respectively).

Fig. 2 showed that in the current study, 40% were very severe COPD and mild COPD were the least recorded diagnosis (12.5%) according to GOLD 2017. Table 2 showed the mean values of FEV_1 and FEV_1/FVC in groups I and II.

The VFL severity of the studied patients was demonstrated in Fig. 3. VFL measured as a percentage of tidal volume revealed that the highest percentage of COPD patients had severe airflow limitation.

Table 3 showed the relation between COPD severity and degree of VFL. All very severe COPD patients exhibited severe VFL. While severe COPD patients who had severe VFL were only 27.3%. The remaining 72.27% of severe COPD had moderate VFL. All mild and moderate COPD patients had mild VFL.

Table 1 Relation between chronic obstructive pulmonary disease severity and demographic data

Items	Group I (13 patients)	Group II (27 patients)	*P*
Age	47.6±14.2	59.8±5.5	*P*<0.000***
Sex [*n* (%)]			
Male	7 (53.8)	26 (96.3)	*P*<0.001**
Female	6 (46.2)	1 (3.7)	
Smoking index	24.8±14.1	75.07±15.2	*P*<0.0001***

**Means Moderately significant (*P*<0.005), ***Means HS: Highly significant (*P*<0.001)

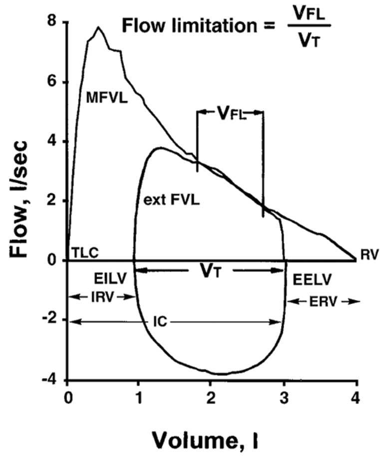
Table 2 Relation between chronic obstructive pulmonary disease Severity and spirometric data

Items	Group I (13 patients) (mean±SD)	Group II (27 patients) (mean±SD)
FEV_1/FVC	62.3±13.8	46.4±8.6
FEV_1% predicted	69.2±13.6	32.4±10.7
FVC% predicted	62.4±5.1	53.2±10.7

FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

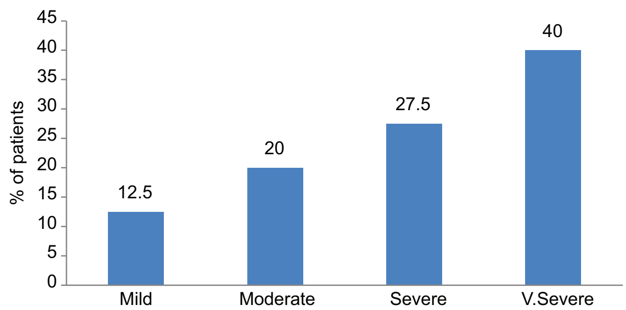
Degree of VFL and EELV were demonstrated among different groups. Normal persons did not present any VFL. Group II had significantly higher ($P < 0.0001$) VFL than group I with a value near 70%. Group I which included mild and moderate COPD patients, had

Figure 1



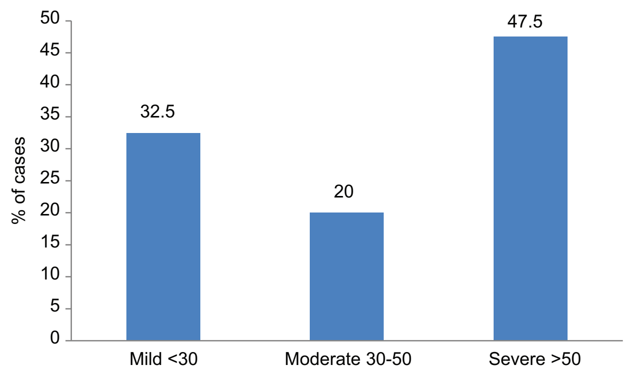
Tidal flow-volume loop. EELV, end expiratory lung volume; EILV, end inspiratory lung volume; ERV, expiratory reserve volume; ext FVL, exercise tidal flow-volume loop; IC, inspiratory capacity; IRV, inspiratory reserve volume; MFVL, maximal flow-volume loop; RV, residual volume; TLC, total lung capacity; VFL, ventilatory flow limitation; VT, tidal volume [9].

Figure 2



Severity of COPD in the studied patients. COPD, chronic obstructive pulmonary disease.

Figure 3



VFL severity of the studied patients. VFL, ventilatory flow limitation.

Table 3 Relation between chronic obstructive pulmonary disease severity and degree of ventilatory flow limitation

Items	Mild COPD (5 patients) [*n* (%)]	Moderate COPD (8 patients) [*n* (%)]	Severe COPD (11 patients) [*n* (%)]	Very severe COPD (16 patients) [*n* (%)]	*P*
VFL					
Mild	5 (100)	8 (100)	–	–	P<0.001***
Moderate	–	–	8 (72.7)	–	
Severe	–	–	3 (27.3)	16 (100)	

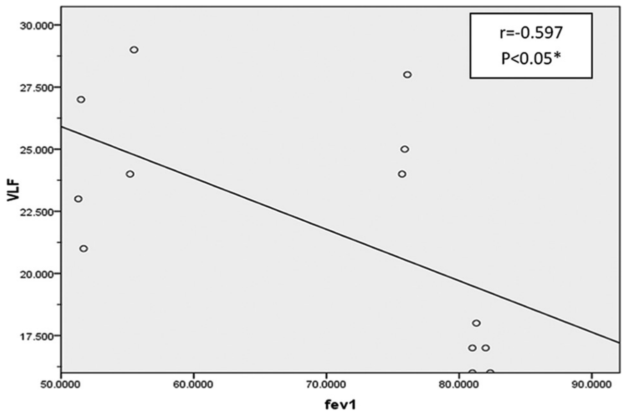
COPD, chronic obstructive pulmonary disease; VFL, ventilatory flow limitation. ***Means HS: Highly significant (P<0..001)

significantly higher ($P < 0.0001$) EELV than normal. On the other hand EELV in group I was significantly lower than group II ($P < 0.0001$). EELV is increased to mean value of 618 ml in severe and very severe COPD group and just 240 ml in mild-to-moderate COPD group.

There was a significant negative correlation between FEV_1 and EELV in group I (r=−0.614 and $P < 0.05$). Also a significant negative correlation was between FEV_1 and VFL in group I (r=−0.597 and $P < 0.05$) as shown in Fig. 4. Fig. 5 showed that there was a significant positive correlation between EELV and VFL in group I (r = 0.991 and $P < 0.0001$).

There was a significant negative correlation between FEV_1 and EELV in group II (r=−909 and $P < 0.0001$). Also a significant negative correlation was between FEV_1 and VFL in group II (r=−0.874 and $P < 0.0001$) as shown in Fig. 6. There was a significant positive correlation between EELV and VFL in group II (r = 0.991 and $P < 0.0001$) as shown in Fig. 7.

Figure 4



Correlation between FEV_1 and VFL in group I. FEV_1, forced expiratory volume in 1 s; VFL, ventilatory flow limitation.

Discussion

COPD is a major cause of chronic morbidity and mortality and represents a substantial economic and social burden throughout the world. It is the fifth leading cause of death worldwide [10].

Airflow limitation is a very important mechanical constraint that frequently occurs in COPD patients, even with mild-to-moderate airflow obstruction, during exercise, fatally inducing the onset of dynamic hyperinflation and its progressive worsening, with the well-known negative mechanical, muscular, cardiovascular, and symptomatic consequences.

Physicians should be aware of this severe functional condition that, once established, rarely can be reversed with the present educational, pharmacological, and rehabilitative therapy and try to avoid it by treating much earlier and more aggressively airflow obstruction and its determinants [5].

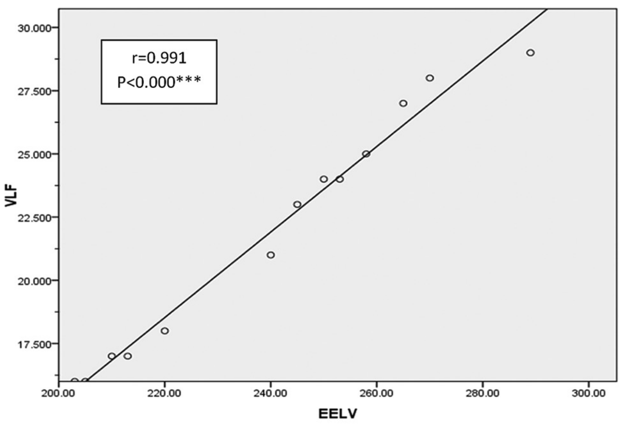
Early diagnosis is worthwhile, as it allows risk factors for COPD such as smoking to be addressed promptly and treatment optimized [8].

Current ATS/ERS guidelines recommend using the FEV_1% predicted to grade the severity of lung disease in the presence of obstruction, restriction, or mixed disorders. Because FEV_1 is such a strong, independent predictor of health status, this recommendation is sensible. However, in the presence of mixed disorders, the severity of the obstructive component alone also might be assessed on the basis of FEV_1, an approach that would be expected to overestimate the degree of obstruction because the reduction in FEV_1 would reflect the combined effects of both the obstructive and the restrictive components [11].

The degree of expiratory flow limitation during exercise has been expressed as the percent from tidal volume (Vt) that expiratory airflows meet or exceed the maximal expiratory flow.

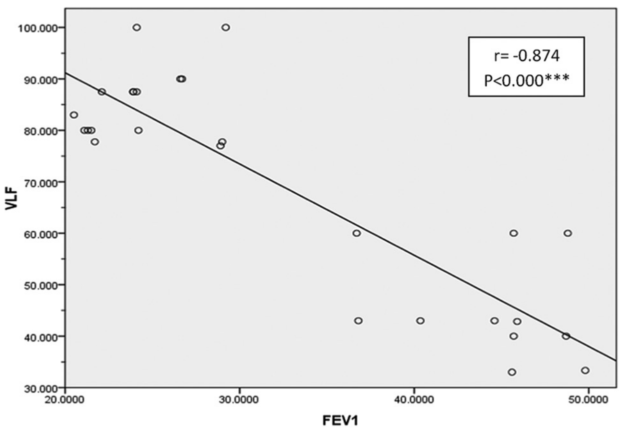
During exercise, in the absence of expiratory flow limitation, EELV typically falls; however, when the degree of expiratory airflow limitation becomes significant (40–50% of the tidal breath), such as may occur with heavier exercise, EELV typically increases sometimes back to resting values or higher (dynamic hyperinflation). This is not typically observed in healthy individuals of average fitness and thus represents a change in the normal breathing strategy during exercise. An acute increase in EELV decreases inspiratory muscle length, increases the work and oxygen cost of breathing, and decreases inspiratory muscle endurance time. Thus the change in EELV likely is another index of ventilatory constraint.

Figure 5



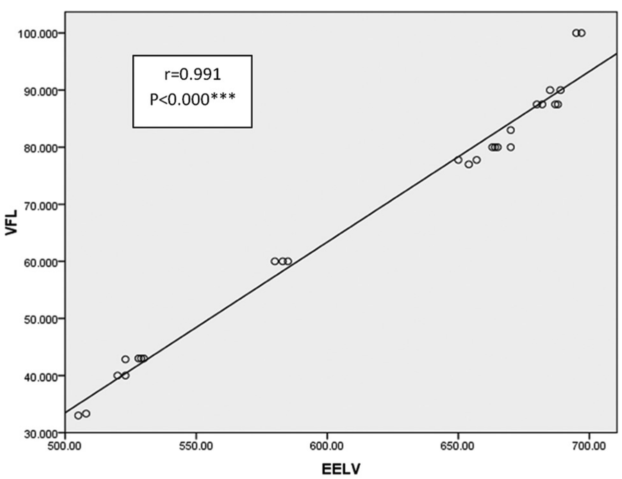
Correlation between EELV and VFL in group I. EELV, end expiratory lung volume; VFL, ventilatory flow limitation.

Figure 6



Correlation between FEV_1 and VFL in group II. FEV_1, forced expiratory volume in 1 s; VFL, ventilatory flow limitation.

Figure 7



Correlation between EELV and VFL in group II. EELV, end expiratory lung volume; VFL, ventilatory flow limitation.

By defining and quantifying the suggested indexes of constraint, a more precise assessment of the degree of mechanical limitation to breathing can be applied. Using these indexes, the degree of constraint can be defined as no or minimal constraint, mild, moderate, or severe [9].

In our study, the mean age of COPD patients was 53.5 ± 12.9 years, which is nearly consistent with a recent study with mean age of 105 patients with stable COPD was 59.6 ± 11.9 years [12].

Male predominance (82.5%) was noticed in our study which is similar to Roberts *et al.* [13] study in which significantly more men (87.5%) had their diagnosis of definite COPD.

The smoking index in our study was significantly higher in patient group than control and also significantly higher ($P < 0.000$) in severe and very severe COPD patients than mild and moderate COPD patients.

Bano *et al.* [14] conducted a study which examined the PFT findings among smoking and nonsmoking adults. Spirometry screening test were performed on 100 male patients that comprised of 50 smoking and 50 nonsmoking adults. There was significant reduction in almost all the pulmonary function parameters in smokers, most common of which was obstructive pulmonary impairment. It was also observed that pulmonary function was 17.3 times more impaired in smokers as compared with that of nonsmokers. Majority of the people who subsequently developed COPD were found to be light smoker in the age group of 41–50 years, who continued to smoke.

Regarding the classification of the severity of COPD by GOLD 2017 using postbronchodilator values of FEV_1, the highest frequency in our study was among very severe stage. But Said *et al.* [15] found that GOLD 2 (moderate) and GOLD 3 (severe) were higher than the other grades of COPD (68.6 and 17.1%, respectively).

All very severe COPD patients had severe VFL. While severe COPD patients who had severe VFL were only 27.3%. The remaining 72.27% of severe COPD had moderate VFL. All mild and moderate COPD patients had mild VFL. We can categorize our patients into three categories:

(1) Category 1: with mild VFL for mild and moderate COPD grades
(2) Category 2: with moderate VFL for severe COPD grade
(3) Category 3: with severe VFL for very severe COPD grade.

This was consistent with a recent study by Nickolaos *et al.* [16], in which VFL occurred mainly in GOLD 3 and 4 COPD patients.

EELV in our study was more increased in severe and very severe COPD patients than mild and moderate COPD patients. These data were comparable with a previous study, among nine persons, six were healthy and three had mild-to-moderate airflow obstruction. Six patients showed evidence of FL. The increase in EELV during exercise is linked to the occurrence of FL. Compression of airways downstream from the flow-limiting segment may elicit a reflex mechanism that influences breathing pattern by terminating expiration prematurely, thus increasing EELV [17].

Changes in EELV have been well studied in a number of population during exercise. Most studies have demonstrated an intensity related fall in EELV in normal participants of 0.5–1.0 l. However, with expiratory flow limitation, EELV often rises, sometimes to levels above the resting functional residual capacity (FRC) [9].

O'Donnell *et al.* [18] demonstrated that EELV is increased above resting values by 300–600 ml in as many as 85% of patients with moderate to severe COPD during exercise. This is concordant with the results of our study where EELV is increased to mean value of 618 ml in severe and very severe group and just 240 ml in mild-to-moderate group.

Conclusion

Expiratory flow limitation and EELV are specific indices for airway obstruction in COPD patients and are correlated to the degree of severity.

Recommendations

(1) Repeated pulmonary function tests to smokers to assess severity of obstruction and airflow imitation.
(2) Using VFL as anew, practical, and simple way to accurately grade COPD severity according to airflow limitation.
(3) EELV measurement is useful in estimating increase in airflow limitation during exercise.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1 Barnes PJ. Chronic obstructive pulmonary disease: a growing but neglected epidemic. PLoS Med 2007; 4:e112.
2 Mannino DM, Buist AS. Global burden of COPD: risk factors, prevalence, and future trends. Lancet 2007; 370:765–773.
3 William L. Eschenbacher: airflow limitation and spirometry, COPD clinical perspectives', Prof. Ralph Panos (Ed.), ISBN: (2014); 978-953-51-1624-0. DOI: 10.5772/57549.
4 Pride NB, Milic-Emili J. Lung mechanics. In: P Calverley, NB Pride, eds. *Chronic obstructive lung disease*. London, UK: Chapman Hall; 1995. 135–160.
5 Tantucci C. Expiratory flow limitation definition, mechanisms, methods, and significance. Pulmon Med 2013; 2013:749860.
6 Janine K. The clinical utility of forced vital capacity measured at six seconds in the spirometric detection of airways obstruction [Masters dissertation]. Dublin: Dublin Institute of Technology; 2007.
7 Harpreet R, Maichel W, *et al.* Pulmonary function tests. Ulster Med J 2011; 80:84.
8 David PJ, Julia AE, *et al.* Diagnosis and early detection of COPD using spirometry. J Thorac Dis 2014; 6:1557–1569.
9 Johnson BD, Weisman IM, *et al.* Emerging concepts in the evaluation of ventilatory limitation during exercise, the exercise tidal flow-volume loop. Chest 1999; 116:488–503.
10 Romain L, Ghezzo H, *et al.* Orthopnea and tidal expiratory flow limitation in patients with stable COPD. Chest 2004; 119:99–104.
11 Gardner ZS, Ruppel GL, *et al.* Grading the severity of obstruction in mixed obstructive-restrictive lung disease. Chest 2011; 140:598–603.
12 Hassan G, Saeid SA, *et al.* The relationship between COPD assessment test (CAT) scores and severity of airflow obstruction in stable COPD patients. Tanaffos 2012; 11:22–26.
13 Roberts NJ, Patel IS, *et al.* The diagnosis of COPD in primary care; gender differences and the role of spirometry. Respir Med 2016; 111:60–63.
14 Bano R, Mahagaonkar AM, *et al.* Study of pulmonary function tests among smokers and non-smokers in a rural area. Pravara Med Rev 2009; 4:11–15.
15 Said AF, Ewis AA, *et al.* Prevalence and predictors of chronic obstructive pulmonary disease among high-risk Egyptians. Egypt J Bronchol 2014; 9:27–33.
16 Nickolaos PT, Holdsworth SR, *et al.* Lung diffusing capacity in adult bronchiectasis: a longitudinal study. Respir Care 2012; 55:1686–1692.
17 Pellegrino R, Brusasco V, *et al.* Expiratory flow limitation and regulation of end-expiratory lung volume during exercise. J Appl Physiol 1993; 74:2552–2558.
18 O'Donnell DE, Katherine KA *et al.* Lung hyperinflation in COPD: applying physiology to clinical practice. COPD Res Pract 2015; 1:4.