Original Article

Body plethysmography in chronic obstructive pulmonary disease patients: A cross-sectional study

Yogesh Satyendra Gupta, Swati S Shah[1], Chaya K Ahire[1], Prathamesh Kamble[2], Anupam S Khare[1], SS More[3]

Departments of Physiology and [3]Pediatrics, Government Medical College, Chandrapur, [1]Department of Physiology, BJGMC and SGH, Pune, Maharashtra, [2]Department of Physiology, AIIMS, Jodhpur, Rajasthan, India

ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is the fourth most common cause of death in the world, for which smoking is a common cause. It is preferable to diagnose COPD at an earlier stage and to assess its progression so that mortality and morbidity of the disease could be reduced. Hence, we conducted this study to assess parameters of body plethysmography in Indian population where the data are lacking and to assess whether the use of body plethysmography can detect COPD earlier. **Subjects and Methods:** The study was approved by the Ethics Committee at B. J Government Medical College, Pune. In this comparative randomized cross-sectional study, healthy control subjects (CN), smokers without COPD diagnosis (SM) who were smoking for more than 5 pack-years and smokers with COPD who were further classified depending upon GOLD criteria as mild COPD (C1), moderate COPD (C2), and severe COPD (C3) ($n = 30$ each group) were considered. All the participants were males who gave written informed consent. Subject underwent routine spirometry (FEV_1, FVC, FEV_1/FVC, PEFR, and $FEF_{25-75\%}$) along with body plethysmography where sGaweff, sGawtot, residual volume (RV), total lung capacity (TLC), and inspiratory capacity (IC) were recorded. **Statistical Analysis:** The differences in lung function were compared between healthy controls and smokers and also between the three groups of COPD severity (GOLD guidelines) employing univariate analysis of variance and Bonferroni's *post hoc* test. **Results:** Spirometry could not differentiate between smokers without COPD and healthy controls. However, three parameters on body plethysmography (IC, sGawtot, and sGaweff) were sensitive enough to detect differences between smokers without COPD and healthy controls. **Conclusion:** Using body plethysmography, the vexed question troubling the clinician, which of the smokers progress to COPD and who do not before they develop irreversible changes can perhaps be answered if further large-scale multicenter studies and long-term follow-up studies confirm the findings in this study.

KEY WORDS: Body plethysmography, early chronic obstructive pulmonary disease, lung conductance, smoking, spirometry

Address for correspondence: Dr. Yogesh Satyendra Gupta, Quarter No. 3, Type III Quarter, Government Medical College, Chandrapur Campus, Ramnagar, Chandrapur - 442 401, Maharashtra, India. E-mail: dryogi.gupta@gmail.com

INTRODUCTION

Smoking is a big ongoing hazard for humanity and regarded as an important risk factor for chronic obstructive pulmonary disease (COPD) and other systemic dysfunctions.[1,2] Nearly 33%–35% people die in India because of smoking for 15 years continuously.[3]

COPD is the fourth most conjoint reason of death in the world, and its liability has increased, due to unceasing risk of respiratory diseases and modifications in lifestyle.[4,5] In this era of modern technology, it is preferable to diagnose COPD at an earlier stage and to observe its progression so that mortality and morbidity of the disease could be

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reduced. For diagnosing COPD, spirometry is the gold standard but early detection of minute changes in airway conduction is not possible. This drawback can be overcome with body plethysmography, especially in smokers.[6,7]

Hence, we led this study to evaluate parameters of body plethysmography in Indian population where the data are lacking. We also would like to assess the use of body plethysmography for early detection of COPD and changes in its values in mild, moderate, and severe COPD (C1, C2, and C3, respectively).

SUBJECTS AND METHODS

The study was accepted by the Ethical Committee at B. J Government Medical College, Pune, (Maharashtra) India. In this comparative randomized cross-sectional study, healthy control subjects (CN), smokers without COPD diagnosis (SM) who had smoked at least 5 pack-years, and smokers with COPD categorized as mild COPD (C1), moderate COPD (C2), and severe COPD (C3) depending on GOLD criteria[8] (n = 30 each group) were considered. Participants were selected by simple randomization to avoid selection bias. All the participants were in the age group of 35–60 years were males, and those who provided written informed consent for performing spirometry and body plethysmography were considered for the study. Screening test was performed for willing participants to categorize them under CN, SM, and COPD patients, for which the following criteria were considered for inclusion and exclusion of participants.

For inclusion of controls

1. No past or present history of COPD or any other respiratory disease
2. Participants with no present or past history of smoking
3. Normal spirometry.

For inclusion of smokers without chronic obstructive pulmonary disease

1. A smoker without any symptoms of respiratory diseases or diagnosed COPD
2. Participants smoking at least 5 pack-years.

For inclusion of chronic obstructive pulmonary disease patients

1. Smoking >5 pack-years
2. Diagnosed cases of COPD with FEV_1 <70% as per GOLD guidelines for COPD[8]
3. No exacerbation of COPD in past 1 month or history of hospitalization for COPD within past 3 months
4. Able to cooperate and perform spirometry and body plethysmography.

Exclusion criteria

1. FEV_1/FVC <30% On spirometry or COPD requiring hospitalization
2. Unstable or high-risk patients unable to perform spirometry or body plethysmography
3. Known cases of ischemic heart disease, heart failure, atrial fibrillation, hypertension, or any electrocardiographic abnormality
4. Patients in need of long-term oxygen therapy.

Flow chart for selection of participants

Three hundred and fifty participants selected for study, of which 200 selected by simple randomization of odd and even number technique and 50 were excluded as per the exclusion criteria.

Spirometry and body plethysmography were performed according to established protocol at the time of visit after a week of screening avoiding their morning medications.[9,10]

Body plethysmography is used for the purpose of computing total lung capacity (TLC) and airway conductance (Gaw). During body plethysmography, the participant was asked to sit in a chamber prepared to measure pressure and flow or volume changes [Figure 1]. Airways resistance (Raw) could also be calculated as the inverse of Gaw. Specific airway conductance (sGaw) (that is conductance/unit of lung volume) was reported as sGaw in L/s/cmH_2O (Liter per second per centimeter of water). For measuring sGaw dynamic pressure, flow volume type plethysmograph; CRF Master Screen Body Diff., JAEGER Hochberg, Germany was used.

With spirometry FEV_1, FVC in liters (L) FEV_1/FVC in percentage and $FEF_{25-75\%,}$ and PEFR in liters/second (L/s) parameters were recorded by the following ATS/ERS guidelines.[10] With body plethysmography, sGaweff, sGawtot in L/s/cm H_2O, and inspiratory capacity (IC), residual volume (RV), and TLC in liters (L) were recorded. The differences in lung function were compared among these groups using analysis of variance and Bonferroni's *post hoc* test.

RESULTS

In present study, males of similar age group with no demographical differences were discovered; hence, all the groups are comparable, details are as given in Table 1.

Results of spirometry and body plethysmography are depicted in Tables 2 and 3, respectively.

Table 4 summarizes that results of differences in lung function were compared among the three groups using univariate ANOVA and Bonferroni's *post hoc* test.

The difference in mean values of FEV_1, FVC, FEV_1/FVC%, $FEF_{25-75\%}$, and PEFR by spirometry were not significant in smokers without COPD and normal healthy controls. Intergroup changes were not significantly different in spirometry parameters.

Figure 1: Participant performing body plethysmography

Table 1: Demographic values of subjects (mean±standard deviation)

	CN	SM	C1	C2	C3
n (number of subjects)	30	30	30	30	30
Age (years)[#]	44.9±3.67	45.66±4.56	46.36±4.49	47.63±6.73	47.87±4.88[#]
Height (cm)[#]	165.65±6.87	163.48±8.04	164.8±5.85	161.85±8.03	161.54±2.97[#]
Weight (kg)[#]	68.03±8.75	70.19±6.72	67.43±7.58	66.8±10.4	66.1±9.22[#]

[#] $P>0.05$ statistically insignificant (ANOVA). ANOVA: Analysis of variance, CN: Control subjects, SM: Smokers without COPD, COPD: Chronic obstructive pulmonary disease

Table 2: Spirometry parameter values (mean±standard deviation)

	CN	SM	C1	C2	C3
FEV_1	2.48±0.67	2.3±0.39	2.43±0.69	1.01±0.37	0.81±0.28
FVC	3.09±0.7	2.93±0.35	2.48±0.64	2.1±0.5	2.26±0.54
FEV_1/FVC (%)	81.8±5.04	78.89±9.1	56.09±8.07	54.14±8.45	37.33±9.56
$FEF_{25\%-75\%}$	2.59±1.33	2.16±0.39	0.99±0.67	0.81±0.54	0.5±0.72
PEFR	7.38±1.73	6.8±0.77	3.81±1.08	3.79±1.19	2.96±1.41

PEFR: Peak expiratory flow rate, FEV_1: Forced expiratory volume in 1 s, FVC: Forced vital capacity, $FEF_{25\%-75\%}$: Forced expiratory flow 25%-75% of FVC, CN: Control subjects, SM: Smokers without COPD, COPD: Chronic obstructive pulmonary disease

Table 3: Body plethysmography parameters values (mean±standard deviation)

	CN	SM	C1	C2	C3
RV	1.3±0.52	1.78±0.71	2.39±0.67	3.37±1.35	4.41±1.65
IC	2.41±0.69	2.07±0.53	1.72±0.43	1.66±0.73	1.05±0.5
TLC	4.15±1.07	4.22±0.55	5.11±0.48	5.64±1.82	7.02±1.58
sGtot	1.27±0.41	0.84±0.44	0.83±0.49	0.4±0.14	0.21±0.11
sGeff	1.5±0.45	0.87±0.45	0.84±0.43	0.44±0.15	0.34±0.18

CN: Control subjects, SM: Smokers without COPD, COPD: Chronic obstructive pulmonary disease, TLC: Total lung capacity, IC: Inspiratory capacity, RV: Residual volume, sGawatot: Total specific airway conductace, sGaweff: Effective specific airway conductance

Mean values of IC, sGawtot, and sGaweff values were assessed by body plethysmography, which showed significant differences among smokers without COPD and normal healthy controls. TLC, RV, IC, sGawtot, and sGaweff showed significant changes in intergroup analysis.

DISCUSSION

For uncovering changes in pulmonary function test, spirometry is generally used. However, spirometry has its own limitations for the early detection of COPD. Hence, more advanced techniques such as body plethysmography can be used. Body plethysmography gives us idea about Gaw and TLC which are supposed to be more sensitive and specific for revealing the changing form in airways causing diseases.[11]

In the present study, we observe that FEV_1, FEV_1/FVC, and $FEF_{25-75\%}$ values were not significantly different between healthy controls (CN) and smokers without COPD (SM). We observed three parameters in body plethysmography (IC, sGawtot, and sGaweff) were sensitive enough to detect early lung injury that spirometry was unable to detect [Table 4].

As in the present study, age-matched males are taken in consideration fall in FEV_1 is attributed to smoking causing increased mucus secretion but to diagnose early COPD more advanced techniques should also be considered.[12-14]

de Mir Messa *et al*. had shown that sensitivity of lung conductance parameters (sGawtot and sGaweff) is more for knowing the changes in airway caliber causing obstructive lung diseases when compared with spirometry parameters. Similar results were observed in the present study when healthy control (CN) compared with smokers without COPD (SM).[15]

As far as IC values were concerned, similar results were observed by Houghton *et al*., they established that IC goes on decreasing due to increased resistance offered by airway passage with the advancement of disease. Moreover, similar changes can also be observed in other parameters of body plethysmography specifically related to conductance.[16]

According to Reilly in COPD patients, there is increased residual air inside lungs, loss of elastic recoil of lung parenchyma, and there is decreased Gaw. All of these contribute in augmented work of breathing. Increased work will give load on active processes of respiration that is inspiration. This may lead to a reduction in volume of air entering lungs clarifying fall in IC. These findings could be attributed to mechanisms mentioned.[17]

Borrill studied effect of bronchodilator drugs in smokers without COPD, severe COPD, and controls by measuring Gaw and concluded that sGaw values can sensitively differentiate between different drug effects as compared to spirometric parameters. At the same time, they also stated that sGaw values were progressively lower in smokers and COPD. This observation goes in line with the present study.[18]

Table 4: Analysis of variance and Bonferroni's *post hoc* results

	Spirometry					Body plethysmography				
	FEV_1	FVC	FEV_1/FVC	$FEF_{25\%-75\%}$	PEFR	RV	TLC	IC	sGtot	sGeff
CN-SM	N	N	N	N	N	N	N	++	++	++
CN-C1	N	++	++	++	++	++	++	++	++	++
CN-C2	++	++	++	++	++	++	++	++	++	++
CN-C3	++	++	++	++	++	++	++	++	++	++
SM-C1	N	+	++	++	++	N	+	N	N	N
SM-C2	++	++	++	++	++	++	++	++	++	++
SM-C3	++	++	++	++	++	++	++	++	++	++
C1-C2	++	N	N	N	N	++	N	N	++	++
C1-C3	++	N	N	N	N	++	++	++	++	++
C2-C3	N	N	++	N	N	++	++	++	N	N

N: $P>0.05$ not significant, +: $P<0.05$ Significant, ++: $P<0.005$ highly significant. CN: Control subjects, COPD: Chronic obstructive pulmonary disease, TLC: Total lung capacity, IC: Inspiratory capacity, RV: Residual volume, PEFR: Peak expiratory flow rate, FEV_1: Forced expiratory volume in 1 s, FVC: Forced vital capacity, $FEF_{25\%-75\%}$: Forced expiratory flow 25%–75% of FVC, sGawatot: Total specific airway conductace, sGaweff: Effective specific airway conductance, SM: Smokers without COPD

Considering spirometry and body plethysmography results, similar results were found by Thomas R Gildea and they stated that with spirometry, there are limitations as it cannot measure RV, FRC, and TLC but with body plethysmography in addition to these parameters other parameters such as sGawtot and sGaweff can also be measured which can give comprehensive evaluation of COPD for early diagnosis, progression, and assessment of severity of disease.[19]

Hence, if these smokers refrained from smoking, then there will be reduction in the rate of damage to the lungs. Hence, the early detection of changes in pulmonary function test is possible which will reduce morbidity and mortality.

CONCLUSION

It can be concluded that body plethysmographic parameters such as IC, sGawtot, and sGaweffare of importance to identify the participants early in the course of their disease at a stage where the present guidelines using spirometry are unable to detect any change and further studies are required in the Indian population to assess whether they are good predictors of progression of disease, prognosis, and disease severity.

If it is possible to detect these participants who smoke early in the course of their disease, smoking cessation may reduce the rate of lung damage. Studies need to confirm whether this has a role in halting further progression into COPD and potentially could have a significant benefit in reducing morbidity and mortality due to COPD.

However, there are very few studies emphasizing the importance of body plethysmography, especially in India. This could be due to lack of awareness or lack of infrastructure. The finding of the present study can be a stepping stone toward more research on the assessment of pulmonary function tests with body plethysmography. It can lay a foundation for early detection of various respiratory disorders.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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