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ORIGINAL RESEARCH

Forced expiratory volumes in 3 s is a sensitive clinical measure for assessment of bronchodilator reversibility in elderly Chinese with severe lung function impairment

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Purpose: Sensitively assessing bronchial reversibility by spirometry is difficult in patients with serious airflow limitation and the elderly. Some patients cannot exhale for ≥6 s to achieve FVC testing criteria. The aim of this study was to assess if FEV_3 could be a more sensitive and an acceptable surrogate for evaluating bronchial reversibility in such patients.

Patients and methods: Subjects who had undergone pulmonary function examination in Beijing hospital from July 2003 to April 2015 were included in the study. Patients with FEV_1<50% of the predicted value were classified as the severely lung function–impaired group. Correlation between the severity of lung function impairment and changes in FEV_1, FEV_3 and FVC in response to a bronchodilator was estimated.

Results: A total of 7745 tests on elderly subjects with a median age of 71 years were reviewed. The severely lung function–impaired group of 1728 accounted for 22.3% of the total number of subjects. There were significantly more patients in the severely lung function–impaired group who exhibited positive response in FEV_3 or FVC and negative response in FEV_1 after bronchodilator test (FEV_1 negative response but FVC positive response, $\chi2$=626.97, P<0.001; FEV_1 negative response but FEV_3 positive response, $\chi2$=372.83, P<0.001). With the progressive increase in lung function impairment, ΔFEV_1 increased and then declined, while ΔFVC and ΔFEV_3 increased progressively. Changes in FEV_3 or FVC significantly exceeded the change in FEV_1 in the severely lung function–impaired groups (P<0.001).

Conclusion: In elderly subjects, especially those with severe lung function impairment, FEV_3 combined with FVC is a more effective and sensitive primary clinical outcome measure to detect bronchial reversibility. In subjects who cannot complete ≥6 s forced expiration and whose FVC is unreliable, FEV_3 combined with FEV_1 might be clinically more valuable in detecting bronchial reversibility.

Keywords: airway obstruction, FEV_3, forced expiratory volume in 3 second, bronchodilator responsiveness, lung function tests, elderly patients

Introduction

Therapeutic effectiveness of inhaled drugs in patients with chronic airway inflammatory diseases such as COPD and asthma is usually assessed by the changes in pulmonary function. FEV_1 is the most commonly used indicator of pulmonary function. Clinical trials have revealed that changes in FEV_1 before and after treatment are not sensitive enough to reflect the effect of bronchodilators in patients

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with serious airflow limitation, especially the elderly.[1] FVC was reported to be more sensitive than FEV_1 in detecting bronchial reversibility in COPD patients.[2] Patients who did not show bronchial responsiveness in FEV_1 might show changes in lung volume measurements called "volume response".[3]

According to the American Thoracic Society/European Respiratory Society (ATS/ERS) criteria, FVC testing requires a forced expiratory time of 6 s or a plateau in the volume–time curve.[4] This is often a relatively long time to exhale, especially for patients with severe airway limitation, aged people and patients with diseases such as severe cough and heart failure.[5,6] In a study on elderly population, 25% of the subjects could complete FEV_3 but not FVC.[7] Another study demonstrated that among 2,928 lung function tests only 47% could exhale for <4 s.[6]

The FEV_3 is the rapidly exhaled volume during the first 3 s of a forced expiratory maneuver, which starts at the level of total lung capacity. It is reproducible, needs shorter expiratory effort and provides an exact outcome.[8] Studies have reported that FEV_3 could be considered as a possible surrogate for FVC[9] as well as an alternative to FEV_1.[10] However, whether FEV_3 can detect bronchodilator responsiveness as sensitively as FVC in the elderly population remains controversial.

In the present study, we studied a large unselected Chinese elderly population presenting to our hospital defined by lung function characteristics in relation to bronchodilator response. We attempted to evaluate the changes in FEV_1, FVC and FEV_3 in response to a bronchodilator and reveal if changes in FEV_3 post-bronchodilator test could be an acceptable and sensitive indicator to evaluate bronchodilator response in the elderly patients with severe airflow limitation. In addition, we attempted to find some sensitive indicators that would reflect the improvement in lung function accurately in patients who in spite of their best ability could not breathe continuously for 6 s – a problem that needs clinical resolution.

Materials and methods

Elderly subjects who had undergone pulmonary function examinations in Beijing hospital from July 2003 to April 2015 were analyzed with the following characteristics: age 60 years or older, completion of post-bronchodilator spirometry that included FEV_3 in lung function test.

Measurement of pulmonary function: All subjects underwent pulmonary function tests in Beijing Hospital on a Vmax 622 pulmonary function instrument (Sensormedics, USA) and plethysmograph (Sensormedics, USA) according to pulmonary function test guidelines.[5] Each lung function test was repeated 3 times and the best value was considered for analysis. All subjects underwent a bronchodilator test which required the administration of 400 μg of salbutamol via metered dose inhaler. Spirometry was repeated 15 mins after short-acting β_2-agonist administration. Data from patients were collected anonymously. The enrollees were divided into 6 groups according to ERS criteria for categorizing the severity of lung function impairment based on FEV_1% predicted value:[4] Group A, $FEV_1 \geq 80\%$ predicted value; Group B, 70% predicted value $\leq FEV_1 < 80\%$ predicted value; Group C, 60% predicted value $\leq FEV_1 < 70\%$ predicted value; Group D, 50% predicted value $\leq FEV_1 < 60\%$ predicted value; Group E, 35% predicted value $\leq FEV_1 < 50\%$ predicted value and Group F, $FEV_1 < 35\%$ predicted value.[4] Changes (Δ) in FEV_1, FEV_3 and FVC after the bronchodilator test were expressed in milliliters, percentage of predicted value or percentage of baseline. To minimize any bias due to age, height and weight, ΔFEV_1, ΔFEV_3 and ΔFVC were also z score normalized. Correlation between lung function impairment and changes in FEV_1, FEV_3 and FVC after bronchodilator responsiveness test was estimated. The study protocol was approved by the Beijing Hospital ethics committee.

Data was analyzed using the SPSS 17.0 software. Normally distributed data was expressed as $\bar{x} \pm s$, and non-normally distributed data was expressed as M (Q1, Q3). Chi-square test was used to compare the relative frequencies of patients among the groups. Mann–Whitney U test was used for comparing data that was not normally distributed. $P<0.05$ was regarded as statistically significant.

Ethics approval and informed consent

The study was conducted in accordance to the Declaration of Helsinki and approved by the ethics committee of Beijing hospital. Informed consents were waived due to the retrospective nature of the study, and all patient data was anonymized.

Results

In the present study, a total of 7745 tests in subjects aged 60 years or older with a median age of 71 years were reviewed. Out of the total, 61.7% were males (4781) and 38.3% were females (2964). Out of the 7745 patients, 2985 (38.5%) were in Group A, 1129 (14.6%) were in Group B, 1066 (13.8%) were in Group C, 837 (10.8%) were in Group D, 1183 (15.3%) were in Group E and 545 were in Group F (7%). There was no significant difference in age and gender distribution between the groups ($P>0.05$) (Table 1). In order to facilitate statistical analysis, Groups E and F were classified as severely lung

Table 1 Baseline characteristics of the study population in subgroups stratified by severity of lung function impairment

Group	No.	Age (years, *M* [Q_1, Q_3])	Male (no.)	Female (no.)
A	2985	68 (63, 73)	1725	1260
B	1129	70 (65, 74)	674	455
C	1066	71 (66, 75)	654	412
D	837	71 (66, 76)	544	293
E	1183	72 (68, 76)	775	408
F	545	71 (67, 74.8)	409	136

Notes: Δ = change; % pred, percentage of the predicted value; Group A: $FEV_1 \geq 80\%$ pred; Group B: $70\% \text{ pred} \leq FEV_1 < 80\%$ pred; Group C: $60\% \text{ pred} \leq FEV_1 < 70\%$ pred; Group D: $50\% \text{ pred} \leq FEV_1 < 60\%$ pred; Group E: $35\% \text{ pred} \leq FEV_1 < 50\%$ pred; Group F: $FEV_1 < 35\%$ pred.

function–impaired groups and Groups A–D were classified as not severely lung function–impaired groups.

According to FVC criteria in evaluating positive bronchodilator response (a change post-bronchodilator test in FVC ≥12% of baseline and ≥200 mL), the cutoff value of FEV_3 in evaluating positive bronchodilator test has been counted. A ROC curve was used to determine the best corresponding cutoff for FEV_3 (Figure 1). The area under the ROC curve was 0.969 (95% CI: 0.965–0.973, $P<0.001$). Post-bronchodilator test a change in $FEV_3 \geq 10\%$ of baseline and ≥165 mL had the best sensitivity (92.5%) and specificity (90.4%), and there

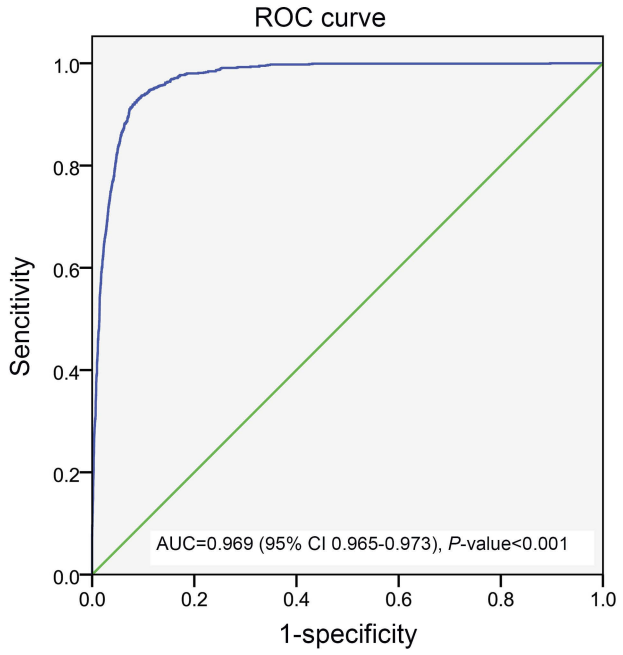

Figure 1 Receiver operating characteristic (ROC) curve showing the performance of FEV_3 in evaluating bronchodilator test based on FVC evaluation criteria.
Abbreviation: AUC, area under the curve.

was an excellent agreement between the two diagnostic cutoffs (κ=0.737; $P<0.001$).

Post-bronchodilator FEV_1 increased by ≥12% of baseline in 21% (1627) of subjects, but the percentage was reduced to 14.6% (1131) according to the criteria that both FEV_1 changed ≥12% of baseline and ≥200 mL. Similar results were observed with FEV_3 and FVC (Table 2). Out of the 496 subjects with post-bronchodilator increase in FEV_1 by ≥12% of baseline but <200 mL, 389 were in the severely lung function–impaired group (213 cases, 18% in Group E; 176 cases, 32.3% in Group F). There was a significant difference in the frequency of patients between the severely lung function–impaired group and the not severely lung function–impaired group ($\chi2$=962.77, $P<0.001$) (Table 3, Figure 2).

Significant bronchodilation is regarded as a change in post-bronchodilator FEV_1 or FVC ≥12% of baseline and ≥200 mL according to the ATS/ERS guidelines.[4] There were 314 subjects – mainly in the severely lung function–impaired groups (129 cases, 10.9% in Group E; 122 cases, 22.4% in Group F) – whose bronchodilator test was negative when evaluated with FEV_1, but became positive with FVC. There was a significant difference in the frequency of patients between the severely lung function–impaired group and not-severely lung function–impaired group ($\chi2$=626.97, $P<0.001$) (Table 3, Figure 3). There were 593 subjects, mainly in the severely lung function–impaired groups, whose bronchodilator test was negative when evaluated with FEV_1 but was positive when evaluated with FEV_3 (196 cases, 16.6% in Group E; 136 cases, 25% in Group F). There was a significant difference in the frequency of patients between severely lung function–impaired group and not severely lung function impaired ($\chi2$=420.14, $P<0.001$). (Table 3, Figure 4).

The post-bronchodilator changes in the z score of FEV_1, FVC and FEV_3 were related to the severity of lung function impairment (Table 4, Figure 5). As the severity increased, $\Delta zFEV_1$ after the bronchodilator test increased gradually and peaked in Groups D and E, but decreased in Group F. In contrast, ΔzFVC continued to increase with the increase in the severity of ventilatory impairment, which peaked in Group F. Post-bronchodilator changes in zFVC were less than $zFEV_1$ in Groups A, B and C (Group A z= –3.16, Group B z= –2.86, Group C z= –2.86, all $P<0.05$) and similar to $\Delta zFEV_1$ in Group D (z= –0.27, $P>0.05$). But in Groups E and F, ΔzFVC significantly exceeded $\Delta zFEV_1$ (Group E z= – 4.15, Group F z= –6.96, all $P<0.001$). Changes in $zFEV_3$ exhibited similar trends. Post-bronchodilator $\Delta zFEV_3$ was less than or equal to the change in $zFEV_1$ for subjects in Groups A to D (Group A z= –2.03, $P<0.05$, Group B z= –1.51, Group C z= –0.98, Group

Table 2 Characteristics of bronchodilator response in the study population

Group	No. (%)	Age (years, *M* [Q_1, Q_3])	ΔFEV_1% init≥12% (%)	ΔFEV_1% init≥12% & ΔFEV_1≥200 mL (%)	ΔFEV_3% init≥10% (%)	ΔFEV_3 % init≥10% & ΔFEV_3≥165 mL (%)	ΔFVC % init≥12% (%)	ΔFVC % init≥12% & ΔFVC≥200 mL (%)
Male	4781 (61.7%)	72 (67–77)	22.2	16.6	24.1	22.8	21.4	17.4
Female	2964 (38.3%)	70 (65–74)	19.1	11.4	20.5	16.8	18.3	12.9
Total	7745 (100%)	71 (66–76)	21	14.6	22.7	20.5	20.2	15.6

Notes: Δ= change; % init = percentage of the initial value.

Table 3 Characteristics of post-bronchodilator response in subgroups stratified by level of lung function impairment

Group	No.	Age (years, *M* [Q_1, Q_3])	ΔFEV_1% init≥12% & ΔFEV_1<200 mL (n)	Become positive with ΔFVC response (n)	Become positive with ΔFEV_3 response (n)
A	2985	70 (65, 75)	2	2	69
B	1129	71 (66, 77)	14	9	50
C	1066	72 (67, 76)	28	18	63
D	837	73 (66, 77)	63	34	79
E	1183	73 (68, 77)	213	129	196
F	545	71 (66, 76)	176	122	136

Notes: Δ= change; % init, percentage of the initial value; % pred, percentage of the predicted value; Group A: FEV_1≥80% pred; Group B: 70% pred≤FEV_1<80% pred; Group C: 60% pred≤FEV_1<70% pred; Group D: 50% pred≤FEV_1<60% pred; Group E: 35% pred≤FEV_1<50% pred; Group F: FEV_1<35% pred.

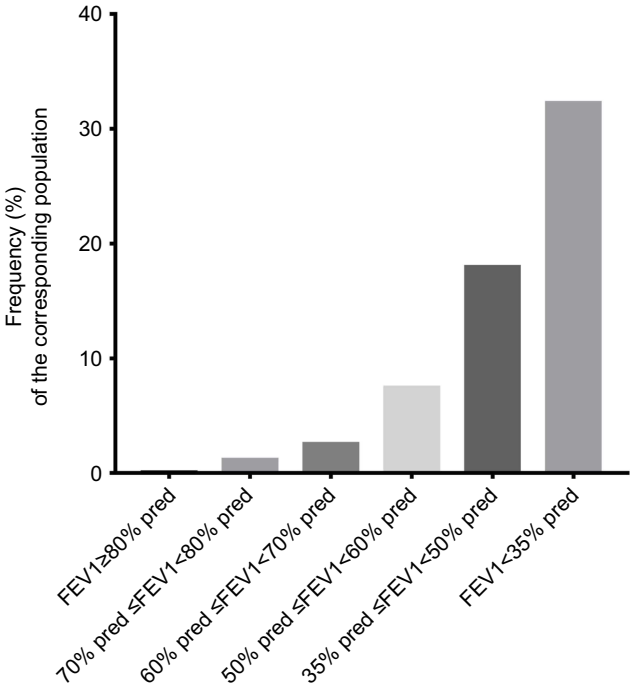

Figure 2 Frequency distribution of subjects in each group showing post-bronchodilator change in FEV_1 of more than 12% of baseline but ≤200 mL in various subgroups stratified by level of lung function impairment.
Note: Δ= change.

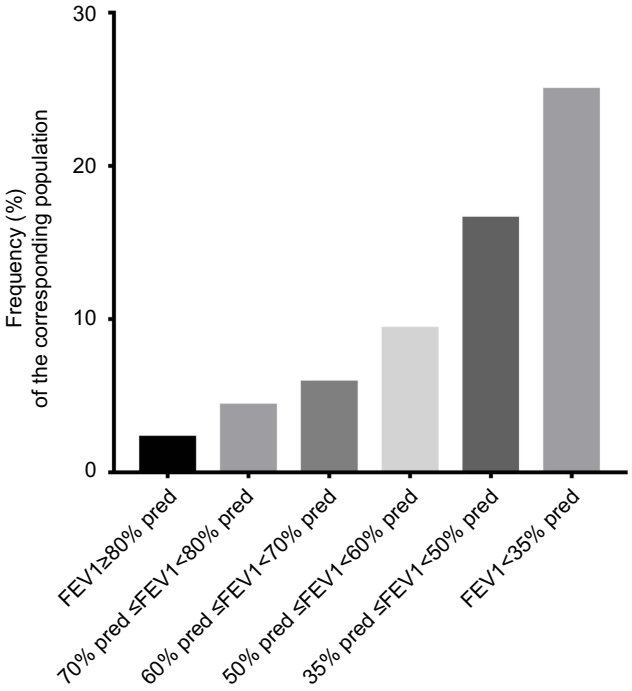

Figure 4 Frequency distribution of subjects in each group whose post-bronchodilator responses become positive with ΔFEV_3 response in various subgroups stratified by level of lung function impairment.
Note: Δ= change.

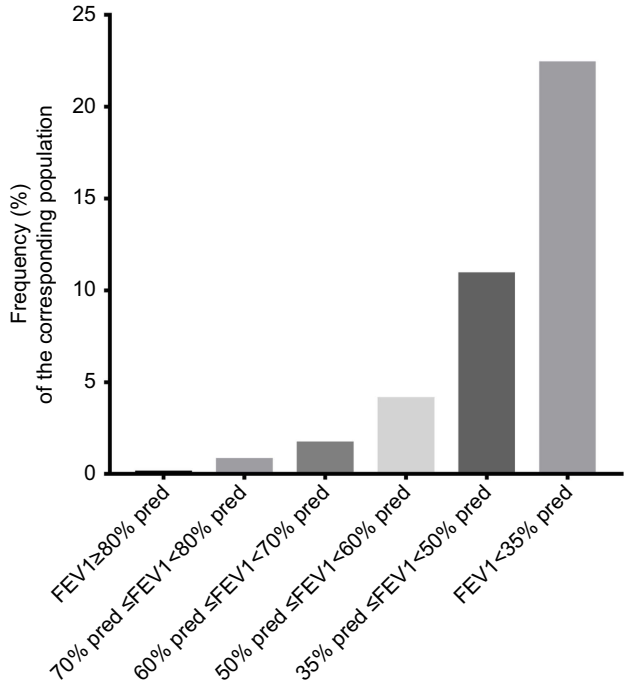

Figure 3 Frequency distribution of subjects in each group whose post-bronchodilator responses become positive with ΔFVC response in various subgroups stratified by level of lung function impairment.
Note: Δ= change.

D z= –0.68, $P>0.05$), but in Groups E and F, $\Delta zFEV_3$ significantly exceeded ΔzFEV1 (Group E z= –3.16, $P<0.05$, Group F z= –4.41, $P<0.001$). Similar results were obtained after subgroup analysis of male and female subjects (Tables 4–6).

Discussion

Elderly subjects – who are also the main population of COPD – are more prone to severe and fixed airways resistance. Increased airway resistance increases intrathoracic gas volume and results in diminished lung elastic recoil pressure.[11] After treatment with a bronchodilator, elderly patients – especially those with serious airflow limitation – report improvement in symptoms and exercise tolerance with little change in FEV_1.[12] Although FEV_1 is a widely used efficacy end point, it cannot sensitively reflect the real change in lung function due to the improvement in airway obstruction.[13]

The bronchodilator test is a better guide to disease progression and can identify patients who might benefit from treatment with a bronchodilator.[14] In this study, we evaluated changes in lung function parameters before and after bronchodilator treatment to find appropriate indicators for evaluating lung funtion improvement in the elderly. The findings showed

Table 4 Spirometric Indexes expressed as change post-bronchodilator and z scores in subgroups stratified by level of lung function impairment

Group	No.	Age (years, *M* [Q_1, Q_3])	ΔFEV_1 (mL, *M* [Q_1, Q_3])	ΔFVC (mL, *M* [Q_1, Q_3])	ΔFEV_3 (mL, *M* [Q_1, Q_3])	$\Delta zFEV_1$(*M* [Q_1, Q_3])	$\Delta zFVC$(*M*[Q_1, Q_3])	$\Delta zFEV_3$(*M* [Q_1, Q_3])
A	2985	70 (65, 75)	40 (−30, 40)	30 (−75, 150)	30 (−50, 120)	−0.28 (−0.74, 0.26)	−0.33 (−0.76, 0.16)	−0.32 (−0.76, 0.17)
B	1129	71 (66, 77)	70 (0, 150)	70 (−50, 190)	60 (−20, 160)	−0.07 (−0.54, 0.46)	−0.17 (−0.66, 0.32)	−0.16 (−0.59, 0.39)
C	1066	72 (67, 76)	70 (0, 170)	80 (−30, 220)	80 (−10, 190)	−0.07 (−0.54, 0.60)	−0.13 (−0.58, 0.45)	−0.05 (−0.54, 0.55)
D	837	73 (66, 77)	90 (10, 190)	140 (0, 295)	110 (10, 220)	0.06 (−0.48, 0.73)	0.12 (−0.46, 0.76)	−0.11 (−0.43, 0.71)
E	1183	73 (68, 77)	90 (20, 170)	160 (20, 330)	110 (20, 240)	0.06 (−0.41, 0.60)	0.20 (−0.37, 0.90)	0.11 (−0.37, 0.82)
F	545	71 (66, 76)	80 (30, 160)	230 (60, 405)	130 (40, 250)	0 (−0.34, 0.52)	0.49 (−0.21, 1.21)	0.22 (−0.27, 0.88)

Notes: Δ= change; % pred, percentage of the predicted value; Group A: $FEV_1 \geq 80\%$ pred; Group B: 70% pred$\leq FEV_1 <80\%$ pred; Group C: 60% pred$\leq FEV_1 <70\%$ pred; Group D: 50% pred$\leq FEV_1 <60\%$ pred; Group E: 35% pred$\leq FEV_1 <50\%$ pred; Group F: $FEV_1 <35\%$ pred.

that there were notably more subjects in the severely lung function–impaired group exhibiting significant improvement in FEV_3 or FVC with less change in FEV_1 in response to the bronchodilator test (FEV_1 less than 50% predicted value). To minimize any bias due to age, height and weight, we also expressed values or changes as z scores. The z scores indicate the standard deviation of a measurement that differed from, the average predicted value, which was free of any bias. Hence, this result showed that an increase in airflow obstruction increased ΔFEV_1 followed by a decline, while ΔFVC and ΔFEV_3 increased progressively. In subjects with mild respiratory defect, ΔFEV_3 or ΔFVC was less than or equal to ΔFEV_1, but ΔFEV_3 or ΔFVC exceeded the relative change in FEV_1 in severely lung function–impaired group. Results also indicated that FEV_3 and FVC are sensitive indicators of bronchodilation in severe airway obstruction, whereas FEV_1 is more sensitive in assessing bronchodilation in mild ventilatory dysfunction.

It has been reported that acute FVC response to bronchodilators was significantly more correlated with health-related quality of life than FEV_1 response.[15] Using the criterion of "clinically significant" to describe an increase in FVC, FEV_1 (≥12% of pre-bronchodilator and ≥0.2 L) or FEV_3 (≥10% of pre-bronchodilator and ≥0.165 L), we observed that FVC and FEV_3 were better measurements for assessing reversibility than FEV_1, especially in patients with severely impaired lung function. Also, there was a strong correlation between FEV_3 and FVC in assessing the responsiveness to bronchodilator. Repeated FVC can be stressful in aged patients with severe obstruction.[5] Thus, it seems that when FVC is not reliable, FEV_3 might have special clinical application value in detecting bronchial reversibility.

Our study presents new data on FEV_3 implying its clinical applicability for better interpretation of reversibility monitoring, particularly in severely impaired patients who cannot blow for ≥6 s even after their best attempts. Larger FEV_3 and FVC responses can provide useful information regarding reduction of hyperinflation with beneficial effects on dyspnea, exercise tolerance and function of small airways,[16] which has important clinical application value.

FEV_6 has been proposed as an alternative to FVC. Our previous research[17] found that FEV_6 strongly correlated with FVC which did not vary with the forced expiratory time and it could be used as a valid alternative to FVC in diagnosing airflow obstruction in elderly males. FEV_6 is closer to FVC in terms of expiratory time, whereas FEV_3 is between FEV_1 and FEV_6 in expiratory time. FEV_3 also makes spirometry easier, faster and safer than FVC measurement and does not correlate with forced expiratory time.

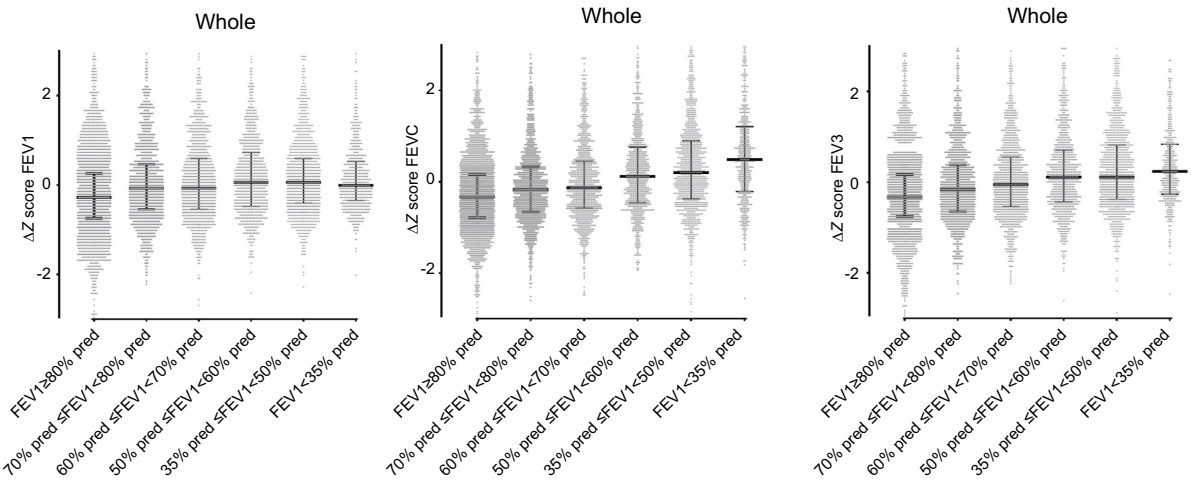

Figure 5 Post-bronchodilator change in z score of FEV_1 (left) is larger in 70% pred≤FEV_1<80% pred group, 60% pred≤FEV_1<70% pred group and 50% pred≤FEV_1<60% pred group compared with FEV_1≥80% pred group and declines as obstruction becomes most severe. Conversely, the post-bronchodilator effect on FVC (middle) increased with the severity of lung function impairment. The patterns for FEV_3 and FVC are similar. Thin lines, 5th and 95th percentiles; central thick line, median.
Note: Δ= change; % pred, percentage of the predicted value.

Table 5 Spirometric Indexes in male subjects expressed as change in post-bronchodilator and z scores in subgroups stratified by level of lung function impairment

Group	No.	Age (years, *M* [Q_1, Q_3])	ΔFEV_1 (mL, *M* [Q_1, Q_3])	ΔFVC (mL, *M* [Q_1, Q_3])	ΔFEV_3(mL, *M* [Q_1, Q_3])	ΔzFEV_1(*M* [Q_1, Q_3])	ΔFVC (*M* [Q_1, Q_3])	ΔzFEV_3 (*M* [Q_1, Q_3])
A	1725	71 (66, 77)	40 (–30, 130)	30 (–80, 160)	30 (–60, 130)	–0.31 (–0.81, 0.25)	–0.38 (–0.79, 0.11)	–0.36 (–0.81, 0.14)
B	674	72 (66, 77)	70 (0, 160)	70 (–50, 220)	70 (–22.5, 190)	–0.12 (–0.56, 0.44)	–0.23 (–0.68, 0.33)	–0.16 (–0.62, 0.44)
C	654	73 (67, 78)	90 (0, 200)	90 (–30, 260)	90 (–10, 220)	0 (–0.56, 0.69)	–0.16 (–0.61, 0.48)	–0.62 (–0.56, 0.59)
D	544	73 (68, 78)	100 (20, 220)	170 (10, 330)	130 (12.5, 250)	0.06 (–0.44, 0.81)	0.14 (–0.46, 0.74)	0.14 (–0.45, 0.74)
E	775	73 (67, 78)	100 (20, 200)	190 (30, 380)	130 (30, 280)	0.06 (–0.44, 0.81)	0.21 (–0.38, 0.93)	0.14 (–0.36, 0.89)
F	409	72 (66, 76)	90 (30, 180)	250 (60, 430)	150 (50, 270)	0 (–0.37, 0.56)	0.44 (–0.27, 1.12)	0.24 (–0.26, 0.84)

Notes: Δ= change; % pred, percentage of the predicted value; Group A: FEV_1≥80% pred; Group B: 70% pred≤FEV_1<80% pred; Group C: 60% pred≤FEV_1<70% pred; Group D: 50% pred≤FEV_1<60% pred; Group E: 35% pred≤FEV_1<50% pred; Group F: FEV_1<35% pred.

In addition, FEV_3 has unique application advantages in patients who cannot exhale for 6 s. In such subjects, addition of FEV_3 in the daily practice of pulmonary medicine will help physicians to find clinically important relief for hyperinflation.

One of the strengths of our study is that we discussed unselected data on bronchodilator response across various lung function impairment in an aging population. Also, the subjects involved in this study were not limited to any disease or a diagnosis of airflow obstruction. The result reflected the characteristics of common clinical practices in the real world, thus highlighting their clinical usefulness. However, the present study also has some limitations. Being a retrospective study, it failed to provide information about clinical symptoms and disease severity of the subjects. It also lacked information about the use of medication before spirometry. The lung function tests were part of the routine clinical maneuvers, and some subjects might not have withheld medications before testing which may have led to an underestimation of bronchodilator responsiveness. Another significant caveat is the lack of specific diagnosis-related subgroup analyses, which requires further study in the future.

Currently, FEV_3 can be recorded with many spirometers. Thus, according to the result of our study, we encourage to report and analyze FEV_3 for better assessment of spirometry. Compared with the score of the clinical symptom and life quality, parameters of spirometry such as FEV_3 are more objective. Sensitive assessment of improvement in pulmonary function is helpful for disease evaluation and treatment options. However, correlations between the characteristic changes in FEV_3 and subsequent clinical manifestations remains to be further studied.

Table 6 Spirometric Indexes in female subjects expressed as change in post-bronchodilator and z-scores in subgroups stratified by level of lung function impairment

Group	No.	Age (years, *M* [Q_1, Q_3])	ΔFEV_1 (mL, *M*[Q_1, Q_3])	ΔFVC (mL, *M* [Q_1, Q_3])	ΔFEV_3 (mL, *M* [Q_1, Q_3])	$\Delta zFEV_1$ [*M* (Q_1, Q_3)]	$\Delta zFVC$ (*M* [Q_1, Q_3])	$\Delta zFEV_3$(*M* [Q_1, Q_3])
A	1260	68 (63, 73)	40 (–30, 100)	20 (–70, 120)	30 (–40, 110)	–0.21 (–0.75, 0.26)	–0.29 (–0.76, 0.22)	–0.25 (–0.71, 0.28)
B	455	70 (65, 74)	60 (0, 130)	60 (–40, 170)	30 (–40, 110)	–0.05 (–0.52, 0.49)	–0.09 (–0.60, 0.48)	–0.12 (–0.58, 0.41)
C	412	71 (66, 75)	70 (0, 140)	60 (–40, 170)	50 (–20, 130)	0.02 (–0.52, 0.57)	–0.09 (–0.60, 0.48)	–0.08 (–0.58, 0.61)
D	293	71 (66, 76)	70 (10, 155)	100 (–10, 215)	55 (–20, 160)	0.02 (–0.44, 0.69)	0.12 (–0.45, 0.71)	–0.15 (–0.42, 0.75)
E	408	72 (68, 76)	60 (10, 130)	110 (10, 240)	90 (5, 180)	–0.05 (–0.44, 0.49)	0.17 (–0.35, 0.84)	0.12 (–0.38, 0.75)
F	136	71 (67, 74.8)	70 (20, 130)	190 (50, 310)	85 (10, 180)	0.02 (–0.36, 0.49)	0.58 (–0.35, 0.84)	0.18 (–0.32, 0.95)

Notes: Δ= change; % pred, percentage of the predicted value; Group A: FEV_1≥80% pred; Group B: 70% pred≤FEV_1<80% pred; Group C: 60% pred≤FEV_1<70% pred; Group D: 50% pred≤FEV_1<60% pred; Group E: 35% pred≤FEV_1<50% pred; Group F: FEV_1<35% pred.

In summary, this population-based retrospective study showed that in elderly subjects, especially those with severe lung function impairment, FEV_3 combined with FVC can be a clinically effective and sensitive outcome measure to detect bronchial reversibility. In those elderly subjects who cannot complete ≥6 s of forced expiration and whose FVC is not reliable, FEV_3 combined with FEV_1 can be clinically valuable in detecting bronchial reversibility.

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Disclosure

The authors report no conflict of interest in this work.

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