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Should forced expiratory volume in six seconds replace forced vital capacity to detect airway obstruction?

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ABSTRACT: **It has been suggested that forced expiratory volume in six seconds (FEV_6) should be substituted for forced vital capacity (FVC) to measure fractions of timed expired volume for airflow obstruction detection. The present authors hypothesised that this recommendation might be questionable because flow after 6 s of forced expiration from more diseased lung units with the longest time constants was most meaningful and should not be ignored. Furthermore, previous studies comparing FEV_6 and FVC included few subjects with mild or no disease.**

The present study used spirometric data from the USA Third National Health and Nutrition Evaluation Survey with prior published ethnicity- and sex-specific equations for FEV_1/FEV_6, FEV_1/FVC and FEV_3/FVC, and new equations for FEV_3/FEV_6, all derived from ~4,000 adult never-smokers aged 20–80 yrs.

At 95% confidence intervals, 21.3% of 3,515 smokers and 41.3% of smokers aged >51 yrs had airway obstruction; when comparing FEV_1/FEV_6 with FEV_1/FVC, 13.5% were concurrently abnormal, 1.5% were false positives and 4.1% were false negatives; and when comparing FEV_3/FEV_6 with FEV_3/FVC, 11.6% were concurrently abnormal, 3.3% were false positives and 5.7% were false negatives.

Substituting forced expiratory volume in six seconds for forced vital capacity to determine the fractional rates of exhaled volumes reduces the sensitivity of spirometry to detect airflow obstruction, especially in older individuals and those with lesser obstruction.

KEYWORDS: **Airway obstruction, cigarette smoking, forced expiratory volume in six seconds, forced expiratory volume in three seconds, forced vital capacity, spirometry**

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In 1999, using the large National Health and Nutrition Examination Survey (NHANES) III database, a number of spirometric reference equations, including those for forced expiratory volume in six seconds (FEV_6) and FEV_1/FEV_6, were published [1]. In 2000, a National Lung Health Education Program consensus statement [2] advocated replacement of forced vital capacity (FVC) and FEV_1/FVC with FEV_6 and FEV_1/FEV_6 to detect airways obstruction. Later, SWANNEY *et al.* [3] reported high sensitivity and specificity for FEV_1/FEV_6 compared to gold standard FEV_1/FVC in 337 out of 502 patients tested in a tertiary hospital-based university laboratory. In a multicentred lung health study, ENRIGHT *et al.* [4] concluded that FEV_1/FEV_6 values could be useful for following the course of obstructive airways disease in smokers and for screening smokers for the presence of airway obstruction. Subsequently, VANDEVOORDE *et al.* [5] concluded from a large patient study that ''the FEV_1/FEV_6 ratio can be used as a valid alternative for FEV_1/FVC in the diagnosis of airway obstruction, especially for screening purposes''. Other investigators recommended using FEV_6 rather than FVC for the mean forced expiratory flow between 25 and 75% of FVC ($FEF_{25–75\%}$) and for measuring lung restriction [3, 6–9].

FEV_1/FVC, FEV_1/FEV_6 and FEV_3/FVC ratios, derived from the large never-smoking NHANES III database, all decrease in a linear fashion as age increases, indicating an increase in long time-constant lung units or 1-FEV_3/FVC [1, 10]. Each of these formulae correctly identifies patients with severe airway obstruction. However, subjects with subtler obstruction also commonly exhale an important portion of their FVC after 6 s, *i.e.* from lung units discharging their gas late in exhalation. Consequently, FEV_1/FEV_6 and FEV_3/FEV_6 measurements, with denominators which exclude the FVC–FEV_6 volumes, may be less discriminating than FEV_1/FVC and FEV_3/FVC in detecting milder airway obstruction. In

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screening for disease, it may be better to focus on detecting lung units with long time constants (after 3 or 6 s) rather than on shaving seconds off expiratory time and centilitres off forced expiratory volumes.

The present authors, therefore, hypothesised that FEV_1/FEV_6 and FEV_3/FEV_6 would be less reliable screening parameters than FEV_1/FVC and FEV_3/FVC in distinguishing changes in lung function due to normal ageing from those due to superimposed airway obstruction from smoking.

METHODS

Data meeting American Thoracic Society (ATS) standards [11] were extracted from the NHANES III database [12] for 13,113 adults, including ex-smokers, 5,943 never-smokers and 3,515 current smokers with no apparent skeletal or neuromuscular disease. Data were obtained nationwide with informed consent. Some data and equations derived from this population were previously published by others [1, 9] and by the present authors [10].

Regression equations [13] for mean and 95% confidence lower limits of normal (95% LLN) for FEV_3/FEV_6 (table 1) were derived for never-smokers identified ethnically as Black, Latin or White [10]. These never-smokers had similar FEV_1/FVC values [8] to those of HANKINSON *et al.* [1], derived from the same database.

The 3,515 current smokers were then divided into four similar-sized groups according to age: 20–29.3 yrs; 29.4–38.1 yrs; 38.2–50.7 yrs; and 50.8–80 yrs. Using sex- and ethnicity-specific equations for FEV_1/FVC and FEV_1/FEV_6 [1], FEV_3/FVC [10] and the newly derived FEV_3/FEV_6, each value of the current smokers was categorised as ''normal'' or ''abnormal'', depending on whether it was above or below 95% LLN values, as all ratios had normal distributions in never-smokers.

Given $x=FEV_1$ or FEV_3, deviations of discordant x/FEV_6 values from x/FVC values, *i.e.* false positive or negative, were calculated as follows:

$$\%\,deviation = \%\,x/FVC\,(actual\text{-}LLN) - \%\,x/FEV_6\,(actual\text{-}LLN) \quad (1)$$

When the paired ratios (x/FVC and x/FEV_6) were both above their LLN, they were concordant normal; when both were below their LLN, they were concordant abnormal. However, when an individual FEV_1/FVC was normal and the FEV_1/FEV_6 was below LLN, for example, the FEV_1/FEV_6 value was considered discordant and false positive. When an FEV_3/FVC was below LLN and FEV_3/FEV_6 was normal, the FEV_3/FEV_6 was considered discordant and false negative.

Deviations of false positive or negative x/FEV_6 values from x/FVC values were calculated as follows:

$$\%\,deviation = \%\,x/FVC\,(actual\text{-}LLN) - \%\,x/FEV_6\,(actual\text{-}LLN) \quad (2)$$

Ratios of false positive and false negative to concordant abnormal values were calculated for groups of differing age and severities of obstruction. In those with abnormal FEV_1/FVC and/or abnormal FEV_3/FVC, severity of obstruction was based on FEV_1 % predicted: severe <50%; moderate 50–65%; mild 65–80%; and minimal >80% and <120%. Two-by-two tables were created for the calculation of sensitivity, specificity, and positive and negative predictive values for each age group. To counter the potential criticism that a 95% LLN (mean-1.645×SE) might be spurious or too strict, all analyses were repeated (but not necessarily reported) using a confidence limit of 99% (99% LLN; mean–2.33×SE).

RESULTS

Figure 1 shows the FVC manoeuvre durations for 13,113 subjects in the NHANES III survey aged ⩾20 yrs who had optimal tests. In individuals with longer forced expirations (late emptying of long time-constant units), the mean and variability of the volume differences from FEV_6 values increased markedly (almost similar in mL to the square of the duration of FVC in s). Table 2 shows that the volume differences between FVC and FEV_6 were higher for smokers and increased with age, especially in current smokers.

Using ethnicity- and sex-specific formulae, percentages of NHANES III current smokers found to have abnormal FEV_1/FVC or FEV_3/FVC are displayed in figure 2 for each age group.

TABLE 1 Forced expiratory volume in three seconds (FEV_3)/forced expiratory volume in six seconds (FEV_6) per cent formula for never-smoking adults

Group	Subjects n	Age factor	Mean constant#	95% LLN constant¶	SE	r^2
Females						
Black	1149	-0.0867	99.94	96.50	2.09	0.305
Latin	1248	-0.0958	100.29	97.31	1.82	0.406
White	1440	-0.1026	100.69	97.30	2.06	0.442
All	3830	-0.0958	100.32	97.03	2.00	0.411
Males						
Black	634	-0.0815	99.31	95.76	2.16	0.239
Latin	699	-0.0942	99.81	97.11	1.64	0.416
White	775	-0.0842	99.38	96.34	1.85	0.396
All	2113	-0.0865	99.50	96.40	1.88	0.367

LLN: confidence lower limits of normal. #: mean FEV_3/FEV_6%=constant+age in yrs×age factor; ¶: LLN at 95% confidence limit=95% LLN constant+age in yrs×age factor.

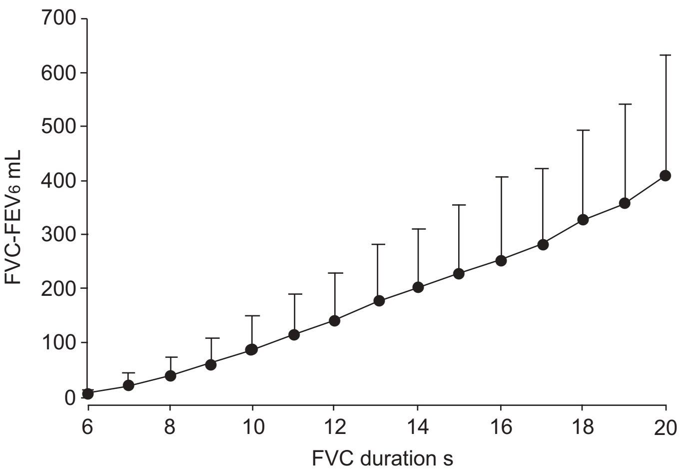

FIGURE 1. Increase in mean±SD of forced vital capacity (FVC)-forced expiratory volume in six seconds (FEV6) volumes in 13,113 adults as durations of FVC increase.

TABLE 2 Changes in forced vital capacity minus forced expiratory volume in six seconds with age and smoking status

Age group yrs	Never-smokers mL	Current smokers mL	p-value
20.0–29.3	28.1±44.5	36.6±51.3	<0.0001
29.4–38.1	57.1±61.5	78.2±89.7	<0.0001
38.2–50.7	92.4±84.8	145.5±124.2	<0.0001
50.8–80.0	144.2±114.6	228.6±171.7	<0.0001

Data are presented as mean±SD, unless otherwise stated.

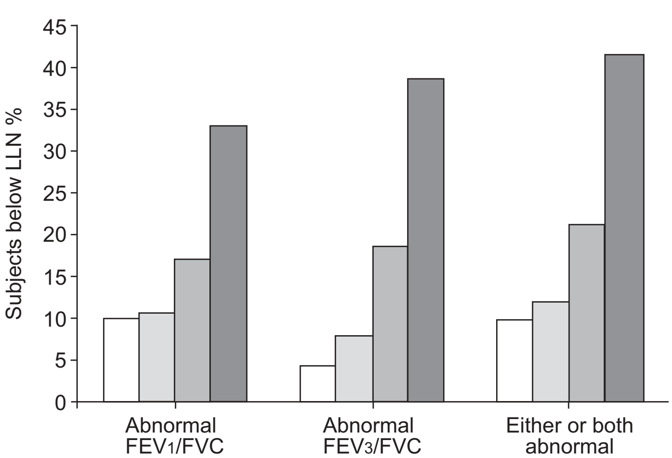

FIGURE 2. Percentage of incidence of airway obstruction using 95% confidence lower limit of normal (LLN) for forced expiratory volume in one second (FEV1)/forced vital capacity (FVC) and FEV3/FVC in 3,515 current smokers divided into equal-sized age groups. □: 20.0–29.3 yrs; ▒: 29.4–38.1 yrs; ▒: 38.2–50.7 yrs; ■: 50.8–80.0 yrs.

TABLE 3 Severity and incidence of airway obstruction in 3,515 current smokers

Severity	Age group yrs				Average
	20.0–29.3	29.4–38.1	38.2–50.7	50.8–80.0	
Severe	0.2	0.1	0.1	2.7	0.8
Moderate	0.5	0.3	1.7	6.1	2.2
Mild	2.2	2.6	5.6	12.9	5.8
Minimal	7.3	8.9	14.4	19.6	12.5
Total	10.1	12.0	21.8	41.3	21.3

Data are presented as per cent incidence. Each subject had forced expiratory volume in one second (FEV1)/forced vital capacity (FVC) and/or FEV3/FVC below their 95% confidence limits. Severity was based on % predicted FEV1: severe <50%; moderate 50–65%; mild 65–80%; minimal >80% and <120%. Some subjects may also have had restriction.

As expected, abnormalities increased in older age groups. Using 95% LLN values, >41% of 50.8–80-yr-old smokers had evidence of airway obstruction. Most commonly, in all age groups, both FEV1/FVC and FEV3/FVC were abnormal. If only one was abnormal, it was more likely to be FEV1/FVC in younger smokers and FEV3/FVC in older smokers. As noted in table 3, using FEV1/FVC and FEV3/FVC as standards, the overall incidence of airway obstruction exceeded 20% in smokers. Severe airway obstruction was rare except in the oldest age group.

Table 4 displays, across age groups, both 95% and 99% LLN values. Using 95% LLN for FEV1/FEV6 and FEV1/FVC, a total of 473 concordant abnormal pairs and 194 discordant pairs (51 false positives and 143 false negatives) were found with a discordant/concordant abnormal ratio of 194/473=41%. For FEV3/FEV6 and FEV3/FVC, 408 concordant abnormal pairs and 315 discordant (115 false positives and 200 false negatives) pairs were found, with a discordant/concordant abnormal ratio of 315/408=77%. The number of false negatives increased strikingly with age. Using 95% LLN for both FEV1 and FEV3 comparisons, total specificities were relatively high, negative and positive predictive values were intermediate, while sensitivities were low.

Using 99% LLN for FEV1/FEV6 and FEV1/FVC pairs and FEV3/FEV6 and FEV3/FVC pairs, (table 4), proportions of discordant to concordant abnormal pairs actually increased while sensitivities declined. The high incidence of discordant values, false-negative values, low sensitivity and even FEV3/FEV6 false positives confirm the low reliability of the FEV1/FEV6 and FEV3/FEV6 to detect airway obstruction in this population.

Figure 3 shows that at 95% LLN, discord increased markedly as the severity of airway obstruction decreased. Table 5 shows that such false-negative discords also tended to be larger than false-positive discords; mean absolute mismatch of these ratios was 2.64%.

DISCUSSION

The present study found low sensitivities, and a high incidence of false negative FEV1/FEV6 and FEV3/FEV6 and a moderate

TABLE 4 Concordant/discordant spirometric measurements in 3,515 current smokers at 95% and 99% confidence limits

	Age groups yrs				Total
	20.0–29.3	29.4–38.1	38.2–50.7	50.8–80.0	
FEV_1/FEV_6 compared with FEV_1/FVC					
Concordant normal tests n	781, 842	773, 850	715, 809	579, 695	2848, 3181
Concordant abnormal tests n	84, 32	77, 19	105, 42	207, 105	473, 208
Discordant false positive n	15, 9	12, 3	12, 1	12, 7	51, 20
Discordant false negative n	3, 5	16, 6	43, 23	81, 72	143, 106
Ratio of discordant to concordant abnormal %	21.4, 43.8	36.4, 47.4	52.4, 57.1	44.9, 75.2	41.0, 60.6
Sensitivity %	96.6, 86.5	82.8, 76.0	70.9, 64.6	71.9, 59.3	76.8, 66.2
Specificity %	98.1, 98.9	98.5, 99.6	98.3, 99.9	98.0, 99.0	98.2, 99.4
Positive predictive value %	84.8, 78.0	86.5, 86.4	89.7, 97.7	94.5, 93.8	90.3, 91.2
Negative predictive value %	99.6, 99.4	98.0, 99.3	94.3, 97.2	87.7, 90.6	95.2, 96.8
FEV_3/FEV_6 compared with FEV_3/FVC					
Concordant normal tests n	827, 862	783, 838	687, 770	495, 618	2792, 3078
Concordant abnormal tests n	34, 11	50, 17	95, 42	229, 135	408, 205
Discordant false positive n	18, 8	26, 9	26, 11	45, 33	115, 61
Discordant false negative n	5, 2	19, 14	67, 52	109, 103	200, 171
Ratio of discordant to concordant abnormal %	67.6, 90.9	90, 135.3	97.9, 150.0	67.2, 100.7	77.2, 118.0
Sensitivity %	87.2, 84.6	72.5, 54.8	58.6, 44.7	67.6, 56.7	67.1, 54.5
Specificity %	97.9, 99.1	96.8, 98.9	96.4, 98.6	91.7, 94.9	96.0, 98.1
Positive predictive value %	65.4, 57.9	65.8, 65.4	78.5, 79.2	83.6, 80.4	78.0, 77.1
Negative predictive value %	99.4, 99.8	97.6, 98.4	91.1, 93.7	82.0, 85.7	93.3, 94.7

All columns show measurements at 95% confidence limits, followed by 99% confidence limits. All comparisons of number of total false negatives to false positives are significant at the $p<0.001$ level.

incidence of false positive FEV_3/FEV_6 in this NHANES III population, supporting the present authors' hypothesis that the use of FEV_6 in place of FVC reduces the sensitivity of spirometry in detecting airway disease. Prior findings [3–7] that promote FEV_6 as an acceptable surrogate for FVC are therefore further detailed in table 6. The study from a university hospital-based laboratory [3], which used spirometry from 310 patients, found high sensitivities and specificities when comparing FEV_1/FEV_6 to FEV_1/FVC. However, 53% of their patients had severe (35%) or moderate (18%) obstruction. Their conclusion, stated in table 6, might not be valid in populations with a lower severity of airway obstruction. ENRIGHT *et al.* [4] followed over 2,800 smokers and concluded that the FEV_1/FEV_6 was nearly as strong a predictor of decline in function in smokers as FEV_1/FVC. Without giving statistical evidence, they stated that ''use of the FEV_1/FEV_6 is a good substitute for the FEV_1/FVC when screening smokers for the presence of airways obstruction'' [4]. A large study from another academic hospital laboratory [5] used patients with an overall incidence of 12.9% for severe obstruction, 12.1% for moderate obstruction and 13.3% for mild obstruction, and 95% confidence limits to define abnormality. They concluded that ''the FEV_1/FEV_6 ratio can be used a valid alternative for FEV_1/FVC in the diagnosis of airway obstruction, especially for screening purposes in high-risk populations for COPD [chronic obstructive pulmonary disease] in primary care''. Their re-analysis of the same data [6], using a fixed ratio of FEV_1/FVC <70% *versus* a selected FEV_1/FEV_6 of <73%, was remarkably similar. The last study [7], which used excellent equipment and technicians in industrial settings, presented similar findings. However, the higher incidence of false positives than false negatives is surprising, since eliminating flow after 6 s would favour a finding of false-negative FEV_1/FEV_6 ratios, as in the present study.

First, the differences in the populations studied will be considered. In the NHANES III database, adult never-smokers outnumbered current smokers. Furthermore, <20% of current smokers had an FEV_1/FVC below 95% LLN and only 3% had obstruction considered moderate or severe. This incidence is much lower than that of 53% and 25% of moderate-to-severe obstruction found in the two university hospital patient studies (table 6). The present authors believe that NHANES III smokers and nonsmokers in their study better represent the USA (or other) general populations likely to request or receive spirometric screening by primary care physicians or other providers. The NHANES III analyses disclose that discord increases as severity of obstructive airways declines (fig. 3) and average sensitivities (table 4) fall to 77 and 67% at 95% LLN and to 66 and 54% at 99% LLN for FEV_1/FEV_6 and FEV_3/FEV_6, respectively, for all NHANES III smokers, with even lower sensitivities for older smokers.

Secondly, as late flow occurs when longer time-constant lung units play a more prominent role in expiratory airflow, it is not surprising that exclusion of late flow by terminating flow, volume and ratio measurements at 6 s, causes low sensitivities and false negatives. As has long been recognised and recently re-emphasised [14], patients with airway obstruction

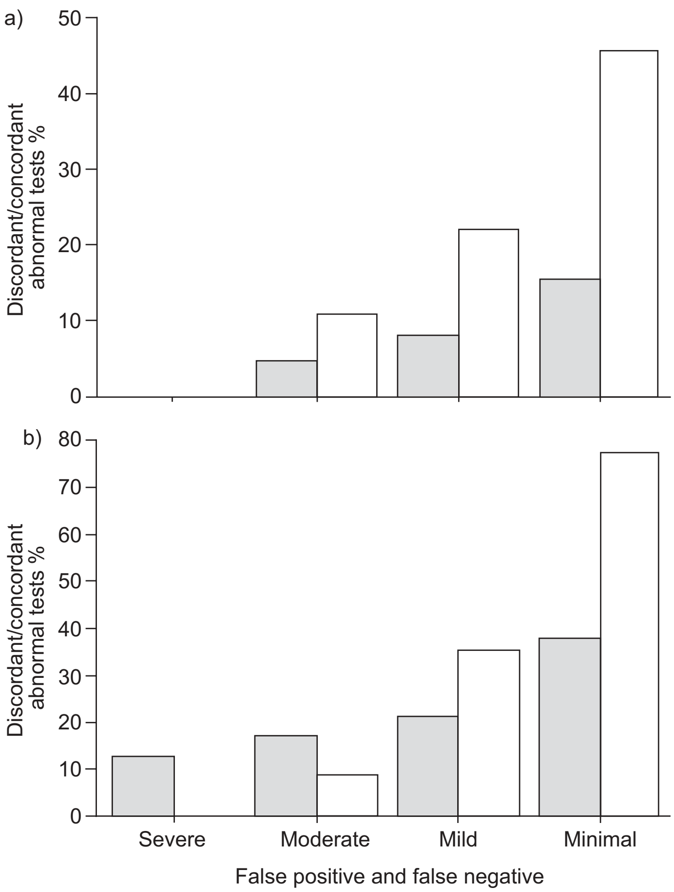

FIGURE 3. Ratios of a) discordant forced expiratory volume in one second (FEV_1/FEV_6) (false positive or false negative) to concordant abnormal FEV_1/forced vital capacity (FVC) and b) discordant FEV_3/FEV_6 (false positive or false negative) to concordant abnormal FEV_3/FVC in current smokers with severe, moderate, mild and minimal obstruction, using 95% confidence limits. FEV_1/FEV_6 and FEV_3/FEV_6 usually correctly identify severe obstruction but are progressively more unreliable in identifying lesser degrees of airway obstruction. ■: false positive; □: false negative.

TABLE 5 Differences of discordant ratios at 95% confidence limits

Comparisons	False positives	False negatives
FEV_1/ FEV_6 *versus* FEV_1/FVC	1.71	-3.47
FEV_3/FEV_6 *versus* FEV_3/FVC	2.56	-3.03

Data are presented as %. FEV_1: forced expiratory volume in one second; FVC: forced vital capacity.

frequently have slow or unforced vital capacity volumes exceeding those of forced manoeuvres. The fact that nearly one-quarter to one-third of smokers with airway obstruction as discerned using FEV_1/FVC and FEV_3/FVC at 95% LLN and one-third to one-half at 99% LLN are excluded by substituting FEV_1/FEV_6 and FEV_3/FEV_6 should curb enthusiasm for use of the latter measures to detect obstructive disease in a general population, including smokers.

Reasons for false positives in the present study using FEV_1/ FEV_6 and FEV_3/FEV_6 are less obvious. On review of the present data, the correlations with age are inferior to those for FEV_1/FVC and FEV_3/FVC ratios for each ethnic and sex group. Perhaps more importantly, SE values for FEV_6 ratios are invariably, but minimally, lower than SE values for FVC ratios for every ethnic and sex group. This results in defining narrower ''windows'' of abnormality, so that ratios using FEV_6 may ''find'' airway obstruction outside those windows when it is not present.

It also appears (fig. 2) that FEV_1/FVC identifies airway obstruction slightly less often than FEV_3/FVC, especially in older smokers. Confirming that both ratios detect deterioration with smoking, the present authors previously found that, by middle age, both FEV_1/FVC and FEV_3/FVC values of current smokers are similar to those of never-smokers who are 20 yrs older [10]. Excluding FEV_3/FVC from spirometric analyses misses some airway obstruction.

Possible limitations

As in all prior studies comparing values and ratios of FEV_6 to FVC, sharp cut-off lines were used in order to distinguish the actual differences between the equations. Although it could be argued that sharp cut-off lines are inappropriate, differences between equations cannot be detected and statistically analysed without using such limits. As populations have a greater variability of FVC or FEV_1 than their ratios, subjects with abnormal ratios and FEV_1 within normal limits (*i.e.* 80–120% pred) could be normal or be minimally obstructed, but have a higher morbidity [14].

Perspective

A recent publication [15] reviewed, discarded, selected and analysed a large number of past studies based on clinical evaluation, spirometry and questionnaires to evaluate the effect of multiple therapies on patients with or suspected of having obstructive lung disease. It concluded that: ''80 percent of adults reporting a clinical diagnosis of chronic bronchitis or emphysema did not have current airflow obstruction'', spirometry increased 1-yr smoking cessation quit rates by only 1% and ''COPD treatment trials including inhaled medications, pulmonary rehabilitation, disease management, or surgery, improved […] functional status […] less than considered clinically significant''. After stating that spirometry was a useful diagnostic tool in evaluating individuals with symptoms suggestive of COPD, WILT *et al.* [15] concluded that: ''spirometric testing is likely to label a large number of individuals (many who do not report respiratory symptoms) with disease and result in considerable testing and treatment costs and healthcare resource utilization''. In reaching their conclusions, which might not find agreement from other pulmonologists, it must be noted that many of their referenced studies inappropriately used fixed ratios of FEV_1/FVC as criteria for obstruction, rather than ratios dependent on age.

EATON *et al.* [16] placed quality spirometers in 30 primary care practices and assessed the results. They found: 1) 2 h of physician and nurse training, and further experience were important in improving quality of tracings; 2) spirometric manoeuvres were commonly terminated prematurely; 3) even with training it was rare to get two (33%) or three (19%) blows

TABLE 6 Studies comparing forced expiratory volume in six seconds (FEV_6) to forced vital capacity (FVC)

First author [ref.]	Sites	Subjects n	Subject characteristics	Severity of obstruction	Sensitivity	Specificity	PPV	NPV	Study observations
SWANNEY [3]	Hospital laboratory, New Zealand	337 out of 502	Aged 20–89 yrs	35% severe, 18% moderate, 12% mild	95.0	97.4	98.6	91.1	"FEV_6 is an acceptable surrogate for FVC…"
ENRIGHT [4]	Clinical centres (10 sites) in USA and Canada	5887	From Lung Health Study; smokers aged >35 yrs	Mean FEV_1/FVC 63%					"…The study demonstrates that the use of the FEV_1/FEV_6 is a good substitute for the FEV_1/FVC when screening smokers for the presence of airways obstruction…"
VANDEVOORDE [5, 6]	University Hospital, Brussels	40% of 11676 with obstruction	Aged 20–82 yrs	13% of total tested and 32% of obstruction severe	94.0	93.1	89.8	96.0	"FEV_1/FEV_6 ratio can be used as a valid alternative to FEV_1/FVC in the diagnosis of airway obstruction, especially for screening purposes…" Using FEV_1/FVC of <70% *versus* FEV_6/FVC <73% found PPV of 92.2 and NPV of 95.2.
AKPINAR-ELCI [7]	In the workplace, West Virginia (USA)	1139	Workers; 43% never-smokers	15% obstructed	92	98	92	98	Used excellent equipment technicians; recommended more studies of flow-sensing spirometers in occupational sites
The present study	Multiple NHANES III sites	3515 current smokers	Ambulatory non-patients aged 20–80 yrs	0.8% of total smokers and 4% of obstruction severe	76.7*	98.2*	90.3*	95.2*	
					66.2**	99.4**	91.2**	96.5**	
The present study#	Multiple NHANES III sites	3515 current smokers	Ambulatory non-patients aged 20–80 yrs	0.8% of total smokers and 4% of obstruction severe	67.1*	96.0*	78.0*	93.3*	
					54.5**	98.1**	77.1**	94.7**	

PPV: positive predictive value; NPV: negative predictive value; NHANES: National Health and Nutrition Examination Survey. #: compared FEV_3/FEV_6 with FEV_3/FVC; all the rest compared FEV_1/FEV_6 with FEV_1/FVC. *: values at $p<0.05$; **: values at $p<0.01$.

meeting ATS criteria; 4) primary care physician interpretations were deemed to be correct only 53% of the time; and 5) only an average of 2.3 tests were performed weekly at each site. Nevertheless, the practitioners believed that 13% of the tests helped in counselling smokers. To place these findings in perspective, one might ask if 13% of radiographs, electrocardiograms, or mammograms performed and interpreted in a primary care practice are helpful in counselling patients. The present authors wonder whether physicians should rely on tests from equipment and personnel used so infrequently.

Despite the recommendation of the Global Initiative for Chronic Obstructive Lung Disease Committee [17], the present authors believe that it is unwise to ignore age and use fixed ratios of FEV_1/FVC such as 70% to identify airway obstruction. Rather than identifying 5% of normal individuals at the 95% confidence limits as abnormal, such fixed limits are certain to underdiagnose airway obstruction in younger individuals and overdiagnose airway obstruction in older individuals.

Therefore, there are diverse approaches and recommendations regarding spirometry. On the one hand, there is the desire to reduce costs by having minimally trained personnel use simpler and cheaper equipment, with emphasis on measurement of FEV_1, FEV_6 and $FEF_{25-75\%}$ and subsequent interpretation at the primary care level. On the other hand, there are concerns that spirometry is costly and of limited value in detecting early lung disease, reducing the incidence of smoking, or following the effect of therapy in those with known lung disease. The present authors favour a third approach: referral of patients with pulmonary symptoms or a significant smoking history to sites where well-trained personnel with excellent equipment test a large number of patients per day, measuring FEV_1, FEV_3, FVC, and their ratios, adding, when indicated, measurements of the slow vital capacity, inspiratory capacity, expiratory reserve volume, inspiratory flow and total lung capacity, with interpretation of the values and tracings by experienced pulmonologists or other similarly well-trained physicians. In the present authors' opinion, this latter approach would be cost-effective, result in more accurate diagnoses and be in everyone's best interests.

It is concluded that quality spirograph measures, with proper reference standards, must be used to accurately identify airway obstruction. The perceived benefit of terminating forced expiratory manoeuvres at 6 s discards data from the most obstructed lung units and reduces the sensitivity of detection of obstructive lung disease.

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