

Spirometric Reference Values for the 6-s FVC Maneuver*

John L. Hankinson, PhD; Robert O. Crapo, MD, FCCP; and Robert L. Jensen, PhD

Study objectives: The guidelines of the National Lung Health Education Program for COPD screening proposed a shorter FVC maneuver (forced expiratory volume at 6 s of exhalation [FEV₆]). Although reference values for FEV₆ are available from the third National Health and Nutrition Examination Survey, forced expiratory flow between 25% and 75% of FVC (FEF_{25-75%}) reference values for the shorter 6-s maneuver are not available and are needed. In particular, calculation of largest observed volume during the first 6 s of an FVC maneuver (FVC₆), from a shortened FVC maneuver, is necessary because the FEF_{25-75%} measurement is based on a percentage of FVC or, for a shorter maneuver, FVC₆.

Design: We reanalyzed the raw volume-time curves from the third National Health and Nutrition Examination Survey to calculate FVC₆, forced expiratory volume at 0.5 s of exhalation, forced expiratory volume at 3 s of exhalation, ratio of the FEV₁ to largest observed volume during the first 6 s of an FVC maneuver expressed as a percentage (FEV₁/FEV₆%), and forced expiratory flow between 25% and 75% of the largest observed volume during the first 6 s of an FVC maneuver (FEF_{25-75%6}) in addition to the previously reported values for FEV₁, FEV₆, and FEV₁/FEV₆%.

Patients or participants: Using the same normal, asymptomatic, nonsmoking reference population from a previous study, reference values for these parameters were derived from best values.

Results: A total of 2,261 white, 2,564 African-American, and 2,666 Mexican-American subjects aged 8 to 80 years were included in the analysis. Fifty-four subjects from the previous study were not included due to missing raw volume-time curves.

Conclusions: These reference values, utilizing the FVC₆, provide investigators with the means of evaluating the relative merits of using the shorter FVC maneuver as a surrogate for the traditional FVC. They are needed particularly for calculating FEF_{25-75%}, as statistically significant differences were observed between the FEF_{25-75%} and FEF_{25-75%6}. (CHEST 2003; 124:1805-1811)

Key words: FEV₁; forced expiratory volume at 6 s of exhalation; FVC; reference values; spirometry

Abbreviations: FEF_{25-75%} = forced expiratory flow between 25% and 75% of FVC; FEF_{25-75%6} = forced expiratory flow between 25% and 75% of the largest observed volume during the first 6 s of an FVC maneuver; FEV_{0.5} = forced expiratory volume at 0.5 s of exhalation; FEV₁/FEV₆% = ratio of the FEV₁ to forced expiratory volume at 6 s of exhalation expressed as a percentage; FEV₁/FVC₆% = ratio of the FEV₁ to largest observed volume during the first 6 s of an FVC maneuver expressed as a percentage; FEV₃ = forced expiratory volume at 3 s of exhalation; FEV₆ = forced expiratory volume at 6 s of exhalation; FVC₆ = largest observed volume during the first 6 s of an FVC maneuver; Ht²LLN = height-squared coefficient for lower limit of normal; Ht²PRD = height-squared coefficient for predicted value; InterceptPRD = intercept of predicted; InterceptLLN = intercept of lower limit of normal; LLN = lower limit of normal

The National Lung Health Education Program screening guidelines for COPD¹ proposed using a shortened, 6-second FVC maneuver (forced expiratory volume at 6 s of exhalation [FEV₆]) for "office" spirometry. The shorter FVC maneuver may prove to have the same utility, with less subject

effort, in terms of identifying subjects with obstructive or restrictive lung disease patterns. It also provides a more explicit end of test, making it easier for spirometry software to identify end of test. In addition, several less expensive, flow-type spirometers are available that may be able to accurately measure FEV₁ and largest observed volume during the first 6 s of an FVC maneuver (FVC₆), but have difficulties accurately measuring FVC from maneuvers with long exhalation times due to zero flow errors. The 6-s volume can be calculated in two ways: the FVC₆ and the FEV₆. Time zero is calculated using back-extrapolation for both methods. These two methods produce similar results, but sometimes FEV₆ is slightly smaller than FVC₆ because the

*From Hankinson Consulting (Dr. Hankinson), Valdosta, GA; and Pulmonary Divisions (Drs. Crapo and Jensen), University of Utah and LDS Hospital, Salt Lake City, UT.

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Correspondence to: John L. Hankinson, PhD, PO Box 3905, Valdosta, GA 31604-3905; e-mail: hankinson@bellsouth.net

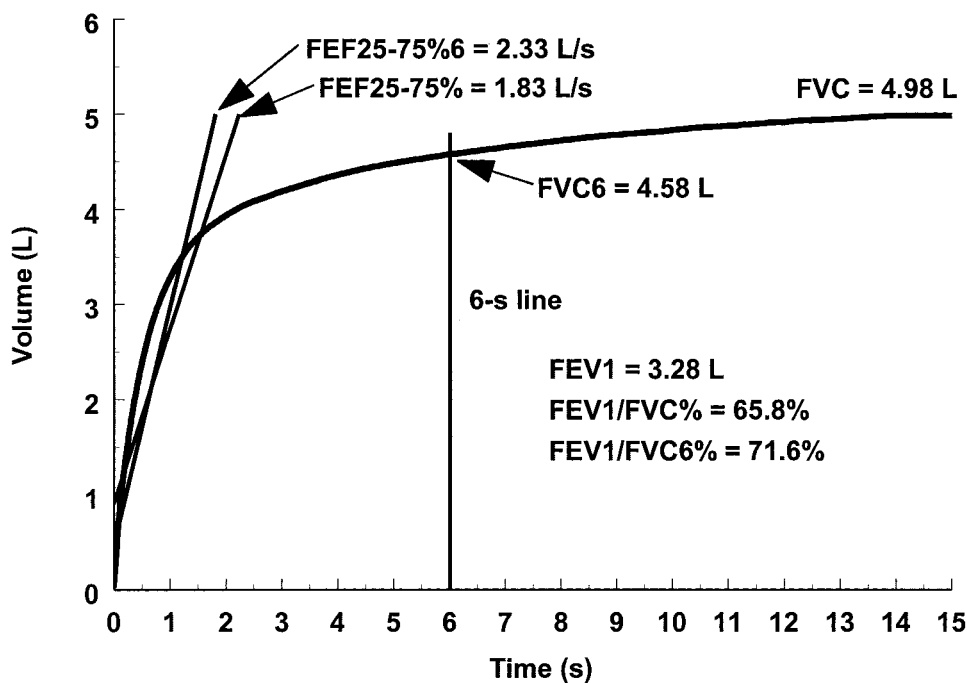


FIGURE 1. Sample volume-time curve illustrating differences between FVC- and FVC₆-derived parameters.

volume-time curve slightly decreases immediately before the 6-s point where the FEV₆ is measured. The differences between FVC and FVC₆ are illustrated in Figure 1.

Although reference values for FEV₆ are available from the third National Health and Nutrition Examination Survey, reference values for forced expiratory flow between 25% and 75% of FVC (FEF_{25-75%}) using the shorter 6-s maneuver, FVC₆, forced expiratory volume at 0.5 s of exhalation (FEV_{0.5}), and ratio of the FEV₁ to largest observed volume during the first 6 s of an FVC maneuver expressed as a percentage (FEV₁/FVC₆%) are not available. It is more appropriate to measure and report FVC₆ than FEV₆ because FEV₆ is sometimes less than FVC₆. For this reason, the FEF_{25-75%} should be based on FVC or FVC₆, and be labeled as FEF_{25-75%} and forced expiratory flow between 25% and 75% of the largest observed volume during the first 6 s of an FVC maneuver (FEF_{25-75%6}), respectively.

At least a portion of the variability in FEF_{25-75%} is associated with FVC measurement, and using a truncated curve may reduce the within and between-subject variability of FEF_{25-75%}. This may be particularly true for older individuals and those with airways obstruction, where expiratory maneuvers typically exceed 6 s and FVC gradually increases with expiratory times up to 20 s.

In Figure 1, a subject with mild airways obstruction exhaled for 15 s. The FVC in this example is 4.98 L, and the FEF_{25-75%} is 1.83 L/s. If the curve is

truncated at 6 s (vertical 6-s line), the resulting FVC₆ would be 4.58 L. When the new FVC₆ is used in the calculation of the FEF_{25-75%}, the new line is steeper because 25% and 75% of the FVC₆ is smaller than 25% and 75% of the FVC. The resulting FEF_{25-75%6} is 2.33 L/s or approximately 500 mL/s higher than the initial FEF_{25-75%}. In addition, the FEV₁/FVC₆% is 71.6% higher than the FEV₁/FVC ratio of 65.8%, a difference of 5.8%.

MATERIALS AND METHODS

Raw spiromgrams from the third National Health and Nutrition Examination Survey used in the derivation of previous reference values^{2,3} were reanalyzed by truncating all maneuvers after 6 s of exhalation. Time zero was calculated using back-extrapolation. FVC₆, FEV_{0.5}, FEV₁, forced expiratory volume at 3 s of

Table 1—Subjects by Age, Gender, and Race*

Variables	Race (n = 7,375)		
	White	African American	Mexican American
Male subjects	896	1,023	1,112
< 20 yr old	414 (46.21)	585 (57.18)	576 (51.80)
≥ 20 yr old	482 (53.79)	438 (42.82)	536 (48.20)
Female subjects	1,365	1,474	1,505
< 18 yr old	400 (29.30)	583 (39.55)	562 (37.34)
≥ 18 yr old	965 (70.70)	891 (60.45)	943 (62.66)

*Data are presented as No. or No. (%).

Table 2—Spirometry Coefficients for Prediction and LLN Equations for Male Subjects*

Parameters	Intercept	Age	Age ²	Ht ² PRD	Ht ² LLN	R ²
White < 20 yr of age						
FEF _{25-75%6}	- 1.174	0.12900		0.0001148	0.00006172	0.549
FEV _{0.5}	- 0.542	0.00294	0.0022700	0.0000962	0.00007519	0.813
FEV ₁	- 0.783	- 0.03800	0.0043350	0.0001420	0.00011714	0.851
FEV ₃	- 0.462	- 0.15200	0.0086100	0.0001758	0.00014784	0.867
FEV ₆	- 0.317	- 0.18500	0.0096410	0.0001819	0.00015310	0.868
FVC ₆	- 0.318	- 0.18400	0.0096150	0.0001817	0.00015289	0.867
White ≥ 20 yr of age						
FEF _{25-75%6}	2.193	- 0.04000		0.0001148	0.00006172	0.549
FEV _{0.5}	0.354	0.00950	- 0.0002997	0.0000962	0.00007517	0.813
FEV ₁	0.513	- 0.01300	- 0.0001740	0.0001420	0.00011714	0.851
FEV ₃	0.403	- 0.02000	- 0.0001365	0.0001758	0.00014784	0.867
FEV ₆	0.077	- 0.00717	- 0.0002353	0.0001819	0.00015310	0.868
FVC ₆	0.089	- 0.00735	- 0.0002339	0.0001817	0.00015289	0.867
Whites all ages						
FEV ₁ /FEV ₆ %	87.36%†	- 0.139			78.30%‡	0.213
FEV ₁ /FVC ₆ %	87.27%†	- 0.137			78.26%‡	0.211
African American < 20 yr of age						
FEF _{25-75%6}	- 1.129	0.1250		0.0001049	0.00004605	0.478
FEV _{0.5}	- 0.457	- 0.0280	0.0030570	0.0000934	0.00007101	0.772
FEV ₁	- 0.613	- 0.0710	0.0048850	0.0001314	0.00010528	0.809
FEV ₃	- 0.575	- 0.1290	0.0069270	0.0001593	0.00013085	0.829
FEV ₆	- 0.463	- 0.1540	0.0077730	0.0001638	0.00013468	0.831
FVC ₆	- 0.455	- 0.1550	0.0077830	0.0001638	0.00013467	0.830
African American ≥ 20 yr of age						
FEF _{25-75%6}	2.099	- 0.0370		0.0001049	0.00004605	0.478
FEV _{0.5}	0.486	- 0.0130	- 0.0000451	0.0000934	0.00007101	0.772
FEV ₁	0.514	- 0.0320	0.0000969	0.0001314	0.00010528	0.809
FEV ₃	0.252	- 0.0350	0.0001177	0.0001593	0.00013085	0.829
FEV ₆	0.086	- 0.0280	0.0000729	0.0001638	0.00013468	0.831
FVC ₆	0.090	- 0.0280	0.0000737	0.0001638	0.00013467	0.830
African American all ages						
FEV ₁ /FEV ₆ %	88.72%†	- 0.128			78.83%‡	0.090
FEV ₁ /FVC ₆ %	88.58%†	- 0.125			78.70%‡	0.086
Mexican American < 20 yr of age						
FEF _{25-75%6}	- 1.340	0.1120		0.0001421	0.00008473	0.549
FEV _{0.5}	- 0.539	- 0.0140	0.0029170	0.0001046	0.00008315	0.819
FEV ₁	- 0.950	- 0.0220	0.0036140	0.0001501	0.00012573	0.856
FEV ₃	- 0.944	- 0.0640	0.0054870	0.0001751	0.00014811	0.868
FEV ₆	- 0.821	- 0.0890	0.0064240	0.0001783	0.00015043	0.869
FVC ₆	- 0.815	- 0.0890	0.0064290	0.0001784	0.00015056	0.869
Mexican American ≥ 20 yr of age						
FEF _{25-75%6}	1.681	- 0.0390		0.0001421	0.00008473	0.549
FEV _{0.5}	0.509	- 0.0046	- 0.0001732	0.0001046	0.00008315	0.819
FEV ₁	0.567	- 0.0250	- 0.0000451	0.0001501	0.00012573	0.856
FEV ₃	0.537	- 0.0280	- 0.0000394	0.0001751	0.00014811	0.868
FEV ₆	0.401	- 0.0190	- 0.0001022	0.0001783	0.00015043	0.869
FVC ₆	0.399	- 0.0190	- 0.0001032	0.0001784	0.00015056	0.869
Mexican American all ages						
FEV ₁ /FEV ₆ %	89.22%†	- 0.150			80.52%‡	0.159
FEV ₁ /FVC ₆ %	89.09%†	- 0.147			80.42%‡	0.156

*If the coefficient is blank, it is not used in the equation.

†InterceptPRD.

‡InterceptLLN.

inhalation (FEV₃), forced expiratory volume at 6 s of exhalation (FEV₆), FEF_{25-75%6}, ratio of the FEV₁ to forced expiratory volume at 6 s of exhalation expressed as a percentage (FEV₁/FEV₆%), and FEV₁/FVC₆% were then calculated from the truncated raw volume-time curves. As in the previous reference value study,^{2,3} only asymptomatic, nonsmoking subjects with at least two acceptable maneuvers based on Amer-

ican Thoracic Society⁴ standards were included in the study. As recommended by the American Thoracic Society,⁴ the largest observed FVC₆, FEV_{0.5}, FEV₁, FEV₃, and FEV₆ from acceptable curves were reported for each subject. The FEF_{25-75%6} was selected from the maneuver with the largest sum of FVC₆ plus FEV₁. The FEV₁/FVC₆% and FEV₁/FEV₆% were obtained using the largest FEV₁, FEV₆, and FVC₆,

Table 3—Spirometry Coefficients for Prediction and LLN Equations for Female Subjects*

Parameters	Intercept	Age	Age ²	Ht ² PRD	Ht ² LLN	R ²
White < 18 yr of age						
FEF _{25-75%6}	- 0.156	0.10200		0.0000874	0.00003916	0.454
FEV _{0.5}	- 0.945	0.14200	- 0.0035070	0.0000763	0.00005856	0.700
FEV ₁	- 1.205	0.12500	- 0.0021930	0.0001131	0.00009185	0.765
FEV ₃	- 0.839	0.01300	0.0020520	0.0001407	0.00011668	0.771
FEV ₆	- 0.751	- 0.01200	0.0027370	0.0001464	0.00012151	0.758
FVC ₆	- 0.745	- 0.01200	0.0027500	0.0001465	0.00012161	0.758
White ≥ 18 yr of age						
FEF _{25-75%6}	2.292	- 0.03400		0.0000874	0.00003916	0.454
FEV _{0.5}	0.366	0.01100	- 0.0002679	0.0000763	0.00005856	0.700
FEV ₁	0.410	- 0.00069	- 0.0002225	0.0001131	0.00009185	0.765
FEV ₃	0.085	0.00340	- 0.0002776	0.0001407	0.00011668	0.771
FEV ₆	- 0.187	0.01200	- 0.0003453	0.0001464	0.00012151	0.758
FVC ₆	- 0.184	0.01200	- 0.0003449	0.0001465	0.00012161	0.758
White all ages						
FEV ₁ /FEV ₆ %	90.19%†	- 0.15900			81.47%‡	0.315
FEV ₁ /FVC ₆ %	90.08%†	- 0.15800			81.39%‡	0.313
African American < 18 yr of age						
FEF _{25-75%6}	- 0.566	0.10300		0.0000944	0.00004068	0.355
FEV _{0.5}	- 0.740	0.07500	- 0.0008657	0.0000763	0.00005657	0.617
FEV ₁	- 0.954	0.05300	0.0001981	0.0001088	0.00008611	0.677
FEV ₃	- 0.751	- 0.01800	0.0027240	0.0001307	0.00010540	0.679
FEV ₆	- 0.684	- 0.03500	0.0032630	0.0001344	0.00010837	0.670
FVC ₆	- 0.691	- 0.03400	0.0032160	0.0001346	0.00010856	0.669
African American ≥ 18 yr of age						
FEF _{25-75%6}	1.907	- 0.03500		0.0000944	0.00004068	0.355
FEV _{0.5}	0.430	- 0.00322	- 0.0001459	0.0000763	0.00005657	0.617
FEV ₁	0.338	- 0.01300	- 0.0000943	0.0001088	0.00008611	0.677
FEV ₃	- 0.011	- 0.00655	- 0.0001726	0.0001307	0.00010540	0.679
FEV ₆	- 0.192	0.00080	- 0.0002330	0.0001344	0.00010837	0.670
FVC ₆	- 0.184	0.00015	- 0.0002237	0.0001346	0.00010851	0.669
African American all ages						
FEV ₁ /FEV ₆ %	91.19%†	- 0.15600			81.17%‡	0.165
FEV ₁ /FVC ₆ %	91.14%†	- 0.15900			81.14%‡	0.169
Mexican American < 18 yr of age						
FEF _{25-75%6}	- 0.284	0.08400		0.0001114	0.00005840	0.374
FEV _{0.5}	- 0.933	0.12500	- 0.0028200	0.0000832	0.00006368	0.650
FEV ₁	- 1.356	0.14000	- 0.0026930	0.0001175	0.00009485	0.723
FEV ₃	- 1.230	0.08400	- 0.0002572	0.0001370	0.00011160	0.728
FEV ₆	- 1.139	0.06100	0.0005522	0.0001407	0.00011451	0.719
FVC ₆	- 1.146	0.06300	0.0004865	0.0001407	0.00011453	0.719
Mexican American ≥ 18 yr of age						
FEF _{25-75%6}	1.802	- 0.03200		0.0001114	0.00005840	0.374
FEV _{0.5}	0.369	0.00560	- 0.0002291	0.0000832	0.00006368	0.650
FEV ₁	0.486	- 0.00864	- 0.0001445	0.0001175	0.00009485	0.723
FEV ₃	0.364	- 0.00611	- 0.0001826	0.0001370	0.00011160	0.728
FEV ₆	0.222	- 0.00018	- 0.0002257	0.0001407	0.00011451	0.719
FVC ₆	0.225	- 0.00035	- 0.0002240	0.0001407	0.00011453	0.719
Mexican American all ages						
FEV ₁ /FEV ₆ %	91.71%†	- 0.17000			83.07%‡	0.248
FEV ₁ /FVC ₆ %	91.57%†	- 0.16800			82.95%‡	0.245

*If the coefficient is blank, it is not used in the equation.

†InterceptPRD.

‡InterceptLLN.

regardless of the acceptable curve on which they occurred. Statistical analyses were performed using Mathcad 2000 (MathSoft; Cambridge, MA). Based on results from the previous reference values study² (same population used in this reanalysis), the general form of the reference equations for FVC₆, FEV_{0.5}, FEV₁, FEV₃, FEV₆, and FEF_{25-75%6} is as follows:

Equation 1, lung function parameter

$$= b_0 + b_1 \times \text{age} + b_2 \times \text{age}^2 + b_3 \times \text{height}^2$$

Separate equations were derived for male subjects < 20 years old and ≥ 20 years old. For women, separate equations were used for subjects < 18 years old and ≥ 18 years old, consistent

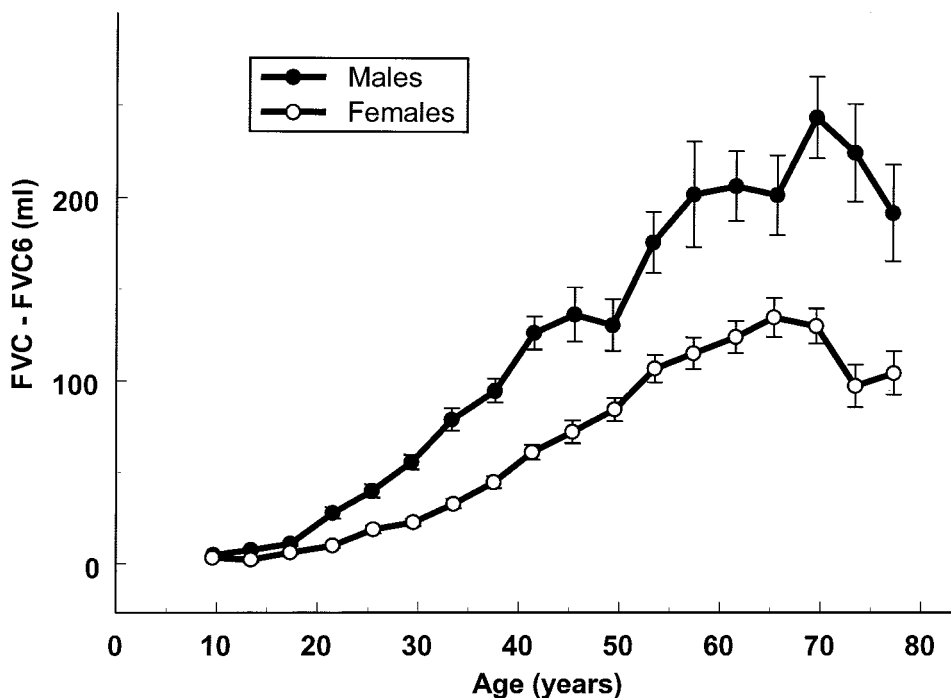


FIGURE 2. Differences between FVC and FVC₆ vs age for male and female subjects.

with the previous study.² The equations on either side of the age break points were constrained to intercept at 18 years and 20 years of age to prevent a discontinuity.

The lower limit of normal (LLN) for the population was computed for lung function parameters as predicted ($1.645 \times$ standard error of the estimate), with an additional adjustment for a slight change in the standard error of the estimate for different heights. For the computation of the LLN, the height-squared coefficient for the predicted value coefficient (Ht^2PRD), used for calculation of predicted values, is replaced by the height-squared coefficient for LLN (Ht^2LLN). Specifically, in equation 1, b_3 is Ht^2PRD for calculating predicted values and Ht^2LLN for calculating the LLN.

The general form for calculating predicted FEV₁/FEV₆% and FEV₁/FVC₆% is as follows:

$$\text{Equation 2, lung function parameter} = b_0 + b_1 \times \text{age}$$

The LLN for FEV₁/FEV₆% and FEV₁/FVC₆% is calculated by

replacing the b_0 or intercept coefficient in equation 2 (intercept of predicted [InterceptPRD] vs intercept of LLN [InterceptLLN]).

RESULTS

Table 1 shows the number of adult and youth subjects by age, gender, and race groups for the selected reference population. This distribution is approximately the same as in the previous reference value study,² as only those subjects without raw volume-time curves were excluded.

Table 2 (male subjects) and Table 3 (female subjects) show the results or the coefficients for the reference equations for FVC₆, FEV_{0.5}, FEV₁, FEV₃, FEV₆, FEV₁/FVC₆%, FEV₁/FEV₆%, and FEF_{25-75%6}. A total of 2,261 white, 2,564 African-

Table 4—Parameters for Male Subjects, Three Age Groups, and All Races Combined*

Parameters	Age, yr		
	< 20 (n = 1,575)	20–40 (n = 928)	> 40 (n = 528)
FVC, L	3.22 (1.28)	4.93 (0.78)	4.34 (0.87)
FVC ₆ , L	3.21 (1.28)†	4.94 (0.77)†	4.17 (0.84)†
FVC – FVC ₆ , mL	7.3 (20.6)	54.8 (64.6)	175.0 (134.6)
FEF _{25-75%} , L/s	3.17 (1.32)	4.39 (1.14)	3.12 (1.23)
FEF _{25-75%6} , L/s	3.22 (1.33)	4.53 (1.13)	3.50 (1.20)
FEF _{25-75%} – FEF _{25-75%6} , mL/s	– 53.1 (62.2)†	– 143.3 (125.4)†	– 280.0 (297.5)†
FEV ₁ /FVC%, %	86.1 (5.92)	83.2 (5.98)	77.6 (7.18)
FEV ₁ /FVC ₆ %, %	86.4 (5.77)	84.1 (5.53)	80.7 (5.88)
FEV ₁ /FVC% – FEV ₁ /FVC ₆ %, %	– 0.18 (0.60)†	– 0.89 (1.03)†	– 3.15 (2.28)†

*Data are presented as mean (SD).

†Statistically significant from zero and other age group means ($p < 0.01$).

Table 5—Parameters for Female Subjects, Three Age Groups, and All Races Combined

Parameters	Age, yr		
	< 20 (n = 1,725)	20–40 (n = 1,389)	> 40 (n = 1,320)
FVC, L	2.82 (0.77)	3.53 (0.56)	2.99 (0.66)
FVC ₆ , L	2.81 (0.77)	3.50 (0.56)	2.99 (0.65)
FVC – FVC ₆ , mL	3.9 (24.1)†	24.9 (38.4)†	99.8 (92.70)†
FEF _{25–75%} , L/s	3.08 (0.69)	3.49 (0.90)	2.33 (0.95)
FEF _{25–75%6} , L/s	3.13 (1.00)	3.58 (0.89)	2.60 (0.92)
FEF _{25–75%} – FEF _{25–75%6} , mL/s	– 48.5 (68.5)†	– 88.6 (89.3)†	– 264.1 (221.5)†
FEV ₁ /FVC%, %	89.1 (5.96)	85.5 (5.92)	78.9 (6.96)
FEV ₁ /FVC ₆ %, %	89.2 (5.76)	86.1 (5.56)	81.5 (5.69)
FEV ₁ /FVC% – FEV ₁ /FVC ₆ %, %	– 0.11% (0.70)†	– 0.60% (0.90)†	– 2.62% (2.43)†

*Data are presented as mean (SD).

†Statistically significant from zero and other age group means ($p < 0.01$).

American, and 2,666 Mexican-American subjects aged 8 to 80 years were included in the analysis. Of the 7,429 subjects included in the previous reference values study,² the raw volume-time curves of 54 subjects were not available due to curve storage problems. Although these few missing subjects resulted in only slightly different results for FEV₁, FEV₆, and FEV₁/FEV₆% than previously reported,² the revised coefficients for these parameters are presented in Tables 2, 3.

Figure 2 shows the differences between FVC and FVC₆ for male and female subjects vs age. The three racial groups were combined because the differences between FVC and FVC₆ between races were not statistically significant ($p > 0.05$); however, there was a small statistically significant difference between male and female subjects (mean, 52 mL and 42 mL, respectively; $p < 0.01$). The differences between FVC and FVC₆ increased with age.

Table 4 (male subjects) and Table 5 (female subjects) show the mean and SD for several parameters for three age groups. Since there were no differences between races, all races were combined for this analysis. Differences between FVC – FVC₆, FEF_{25–75%} – FEF_{25–75%6}, and FEV₁/FVC% – FEV₁/FVC₆% were all statistically different from zero ($p < 0.01$) for all three age groups. There was also a statistically significant increase in the differences between the FVC- vs FVC₆-derived parameters with increased age (< 20 years vs 20 to 40 years, vs > 40 years).

DISCUSSION

These results provide reference values for a shorter or 6-s exhalation for use when a longer, more complete, FVC maneuver may not be warranted (eg, “office spirometry”). Reference values for the FVC₆, FEV_{0.5}, FEV₁, FEV₃, FEV₆, FEF_{25–75%6}, FEV₁/

FEV₆%, and FEV₁/FVC₆% are provided. Although reference values for the FEV₁, FEV₆, and FEV₁/FEV₆% have been previously published,² values for FVC₆, FEV₁/FVC₆%, FEV_{0.5}, FEV₃, and FEF_{25–75%6} were not previously available.

The increasing differences between the FVC- and FVC₆-derived parameters with age (Fig 2; Tables 4, 5) were expected. Older adult subjects require longer expiratory times to reach their FVC, and the impact of a shortened maneuver is greatest in these subjects. The statistically significant difference between FEF_{25–75%} and FEF_{25–75%6} for subjects > 40 years of age (280 mL/s for male and 264 mL/s for female subjects) demonstrates the need for separate reference equations for the shortened FVC₆ maneuver.

Swanney et al⁵ studied the utility of shortened 6-s FVC maneuver in consecutive patients tested in a referral pulmonary laboratory. They found the reproducibility of FEV₆ was superior to that of FVC. In addition, FEV₆ was found to be a reliable alternative to FVC for diagnosing airway obstruction, and was reasonably comparable to FVC for the spirometric diagnosis of restriction. In a longitudinal study of adult smokers, Enright et al⁶ found FEV₁/FEV₆% was nearly as strong an independent predictor of subsequent decline in lung function as FEV₁/FVC%.

The reference values for additional spirometric parameters should allow other investigators to study the utility of the 6-s FVC maneuver. Specifically, classification results using FVC₆, FEV₁/FVC₆%, and FEF_{25–75%6} can now be compared to those using a complete FVC maneuver.

We had hypothesized that reducing the variability in FVC would mean FEF_{25–75%6} would show less population variability than the FEF_{25–75%}; but as can be seen in Tables 4, 5, there is essentially no difference in the SD of these two parameters. Although the LLN was slightly closer to the predicted due to slightly less variation within the population

(eg, for white male subjects, 58.1% vs 56.1% of predicted $FEF_{25-75\%6}$ and $FEF_{25-75\%6}$, respectively), these differences were also small in this healthy population. In populations where long exhalations are required to reach FVC, with a correspondingly greater variability in FVC, this may not be the case. Additional research will be needed to determine if $FEF_{25-75\%6}$ variability is reduced, and its clinical utility improved, in such circumstances.

The youngest people in this study were 8 years old. As with any reference values study, the reference equations are not recommended for use beyond the age range used in deriving the equations. Use outside the test range is particularly problematic with reference equations that contain squared terms, such as those used in our analysis.

APPENDIX

Calculation of FVC_6 and $FEF_{25-75\%6}$ Predicted and LLN for a White Male Subject, 175 cm Tall and 30 Years of Age

From Table 2, the equation for FVC_6 is as follows:

$$\text{predicted } FVC_6 = 0.089 - 0.00735 \times \text{age} - 0.0002339 \times \text{age}^2 + 0.0001817 \times \text{Ht}^2\text{PRD}$$

$$\text{predicted } FVC_6 = 0.089 - (0.00735)(30) - (0.0002339)(30)(30) + (0.0001817)(175)(175) = 5.22 \text{ L}$$

$$\text{LLN } FVC_6 = 0.089 - 0.00735 \times \text{age} - 0.0002339 \times \text{age}^2 + 0.00015289 \times \text{Ht}^2\text{LLN}$$

$$\text{LLN } FVC_6 = 0.089 - (0.00735)(30) - (0.0002339)(30)(30) + (0.00015289)(175)(175) = 4.34 \text{ L}$$

From Table 2, the equation for $FEF_{25-75\%6}$ is as follows:

$$\text{predicted } FEF_{25-75\%6} = 2.139 - 0.04 \times \text{age} + 0.0001148 \times \text{Ht}^2\text{PRD}$$

$$\text{predicted } FEF_{25-75\%6} = 2.139 - (0.04)(30) + (0.0001148)(175)(175) = 4.45 \text{ L/s}$$

$$\text{LLN } FEF_{25-75\%6} = 2.139 - 0.04 \times \text{age} + 0.0001148 \times \text{Ht}^2\text{LLN}$$

$$\text{LLN } FEF_{25-75\%6} = 2.139 - (0.04)(30) + (0.00006172)(175)(175) = 2.83 \text{ L/s}$$

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