which obstruction of the main bronchi cannot be distinguished. a fact also reported by Miller and Hyatt.[26]

In some patients, the recordings of the flow-volume curves were extremely noisy, as noted by Miller and Hyatt[26]; noisy records of the relationship of inspiratory flow to alveolar pressure also were observed.

In 6 of the patients, there was a systematic difference between the FRC measured by the helium dilution method and the plethysmographic TGV. This difference did not seem to be due to technical errors, since it was reproducible during a few days. In patients with obstruction of the main bronchi (No. 13 and 14). it was readily explained by air trapping, which was evident in radiographs of the chest. In the patients with upper airway stenosis, in whom disturbance of the distribution of ventilation usually does not occur,[22, 24, 31] the significance of this difference was not clear. Whatever the cause, Raw will be underestimated if SRaw is not considered.

After surgical correction of the stenosis, the difference between FRC and TGV disappeared (Patients No. 4, 8, 9). Also, all parameters studied were dramatically improved, the changes in SRaw being the most important. It is noteworthy that total lung capacity measured by the helium dilation method did not change significantly.

J. C. YERNAULT[32]
M. ENGLERT
R. SERGYSELS
A. DE COSTER
Departments of Respiratory Diseases and Cardiology,
Hôpital Universitaire Saint-Pime,
Brussels, Belgium

Grimaud, C.: C. R. Soc. Biol. (Paris), 1971, 165, 378.

31 Simonsson, B. G., and Malmberg, R.: Thorax, 1964, *19*, 416.

32 We thank Dr. P. Vanderhoeft (Head, Department of Thoracic Surgery) and Dr. Hennebert (Head, Department of Otorhinolaryngology), who referred to us most of the patients studied.

NORMAL VALUES FOR THE RATIO OF ONE-SECOND FORCED EXPIRATORY VOLUME TO FORCED VITAL CAPACITY[1,2]

Summary

Normal standards for the ratio of 1-second forced expiratory volume to forced vital capacity have previously either assumed a value greater than 70 or 75 per cent or else provided prediction formulas based on populations of small size or groups that included cigarette smokers. The ratio was measured in 963 healthy, nonsmoking men and women. Negative correlation was obtained with age, and no significant correlation was found with standing height, Regression equations were derived for men and women. The addition of standing height did not affect the multiple correlation coefficient and standard error of the estimate for women but did have a small influence for men. Normal mean values and standard deviations by age decade were tabulated. With these more precise values, differentiation between restrictive and obstructive abnormalities is improved. The relative contribution of each process to impairment of ventilation is revealed by the relationship of the forced vital capacity and the ratio of 1-second forced expiratory to forced vital capaaty.

(Received in original form June 1, 1973 and in revised form July 13, 1973)

1 Supported by a grant from the Oregon Tuberculosis and Respiratory Disease Association.

2 Requests for reprints should be addressed to Dr. James F. Morris, Veterans Administration Hospital, Portland, Oregon 97207.

The ratio of the forced expiratory volume in 1 second (FEV_1) to the forced vital capacity (FVC) is a commonly computed value. The selection of normal predicted values for the ratio has been even less precise than that of other spirometric measurements, Many investigators recommend either 70 or 75 per cent as the lower limit of normal for the ratio.[3-10] Prediction formulas have been reported by others, using populations varying in number, smoking habits, test position, and health status.[11-15]

The present report provides normal standards for the ratio, FEV_1/FVC, based on a healthy, nonsmoking population. A previously published study described the population and testing procedures.[16] Briefly, the subjects were all healthy nonsmokers, 509 men and 454 women, 20 to 79 years of age. They lived in an area of Oregon relatively free from urban air pollution. A questionnaire eliminated subjects with a history of cigarette smoking, pulmonary disease, or occupational exposure to airborne pollutants. Standing height was measured without shoes. Spirometric tests were performed in the standing position using a calibrated Stead-Wells spirometer and a nose clip. The best effort of at least 2 maximal efforts was selected. The volumes were corrected to body temperature and pressure, saturated with water vapor (BTPS).

The normal values for FEV_1/FVC of the 963 healthy, nonsmoking men and women were calculated for each age decade and are shown in table 1. There was a progressive decline in the values with age, except for the eighth decade in men, but this group had a small sample number. Regression equations were derived using variables of age and sex as shown in table 2. The correlations coefficients for variables of age, sex and standing height are shown in table 3. When height was included in the regression equations, no measurable change occurred in the multiple correlation coefficients and standard deviations for women. There was, however, a 1 per cent increase in the values for men. This agrees with the findings of Anderson and associates.[14] It appears that the correlation is primarily between age and height variables for men rather than between FEV_1/FVC and height.

TABLE 1
NORMAL VALUES FOR THE RATIO OF 1-SECOND FORCED EXPIRATORY VOLUME TO FORCED VITAL CAPACITY BY AGE DECADES

Age Group (years)	Mean Age (years)	Mean Height (inches)	FEV_1/FVC, % (mean)	(SD)	No. of Subjects
Men					
20-29	23.54	70.78	80.21	6.80	166
30-39	34.37	70.22	75.40	9.38	143
40-49	44.15	69.89	75.03	5.68	94
50-59	53.82	69.86	72.13	7.57	67
60-69	64.00	68.29	70.73	11.37	27
70-79	72.75	66.67	73.91	4.82	12
Women					
20-29	24.99	64.71	80.44	6.09	125
30-39	34.37	64.65	77.21	6.38	103
40-49	44.61	64.22	76.01	5.78	88
50-59	53.54	63.59	74.49	7.48	69
60-69	64.17	63.41	73.59	9.06	41
70-79	74.07	62.56	70.10	9.45	28

• • •

The use of the FEV_1/FEV was first advocated by Tiffeneau and associates in 1949[7] and later by Gaensler in 1951.[17] Since then, reports have proposed its use for determining the presence of airway obstruction. Various values for mean normal standards or regression equations for adults tested in sitting or standing position have been reported.[3-15] The lack of precision in normal values may have hampered use of the ratio. The value of the ratio has been in the interpretation of the forced expiratory curve. The relationship between FVC or VC and the FEV_1/FVC is believed to aid in the discrimination between pulmonary impairment due to a restricting process which limits lung inflation and that due to airway obstruction (table 4). If only the 2 measurements are calculated. the relationship does

[3] Gaensler, E. A., and Wright, G. W.: Arch. Environ. Health (Chicago), 1966, *12*, 46.

[4] Snider, G. L.: J. A. M. A., 1966, *197*, 1095.

[5] Leiner, G. C., Abramowitz, S., Small, J. J., Stenby, V. B., and Lewis, W. A.: Amer. Rev. Resp. Dis., 1963, *88*, 644.

[6] Dickman, M. L., Schmidt, C. D., and Gardner, R. M.: Amer. Rev. Resp. Dis., 1971. *104*, 680.

[7] Tiffeneau, R., Bousser, J., and Drutel, P.: Paris Med., 1949, *39*, 543.

[8] Miller, W. F., Johnson, R. L., Jr., and Wu, N.: J. Appl. Physiol., 1959, *14*, 157.

[9] Pemberton, J., and Flanagan, E. G.: J. Appl. Physiol., 1956, *9*, 291.

[10] Kory, R. C. Callahan, R., Boren, H. G., and Syner, J. C.: Amer. J. Med., 1961, *30*, 243.

[11] Berglund, E., Birath, G., Bjure, J., Crimby, G., Kjellmer, I., Sandqvist, L., and Soderholm, B.: Acta Med. Scand., 1963, *173*, 185.

[12] Grimby, G., and Soderholm, B.: Acta Med. Scand., 1965,173,199.

[13] Cotes, J. E., Rossiter, C. E., Higgins, I. T. T., and Gilson, J. C., Brit. Med. J., 1966, *1*, 1016.

[14] Anderson, T. W., Brown, J. R., Hall, J. W.. and Shephard, R. J.: Respiration, 1968, *25*, 140.

[15] Ringqvist, T.: Scand. J. Clin. Lab. Invest., 1966 (Supplement, p. 1).

[16] Morris, J. F., Koski, A., and Johnson, L. C.: Amer. Rev. Resp. Dis., 1971, *103*, 57.

[17] Gaensler, E. A.: Amer. Rev. Tuberc, 1951, *64*, 256.

TABLE 2
PREDICTION FORMULAS FOR THE RATIO OF 1-SECOND FORCED EXPIRATORY VOLUME TO FORCED VITAL CAPACITY WITH MULTIPLE CORRELATION COEFFICIENTS

Prediction Formula	R	SEE*
Men		
$FEV_1/FVC, \% = 84.64 - 0.2253A$†	0.38	7.83
$FEV_1/FVC, \% = 107.12 - 0.3118H$** $- 0.2422A$	0.40	7.79
Women		
$FEV_1/FVC, \% = 84.23 - 0.1789A$	0.39	6.84
$FEV_1/FVC, \% = 88.70 - 0.0679H - 0.1815A$	0.39	6.84

*SEE = standard error of the estimate
†A = age in years
**H = height in inches

provide an approximate method of differentiation. In normal persons, VC and FVC are similar. With increasing airway obstruction, the VC can remain in the normal range while air trapping diminishes the FVC. When this occurs, use of the ratio to differentiate between restrictive and obstructive impairment becomes less useful.

Other elements of the forced expiratory curve are also used to demonstrate the presence of airway obstruction. In particular, the forced midexpiratory flow ($FEF_{25-75\%}$) has been reported to possess more sensitivity for determining airway obstruction than the FEV_1, either as per cent of predicted or per cent of FVC.[18, 19] Kuperman and Riker found the correlation of the maximum midexpiratory flow with FEV_1/VC sufficiently high that they recommended that the FEV_1/VC should suffice for ventilatory function screening of asymptomatic individuals.[20] The $FEF_{25-75\%}$ is believed to reflect frictional resistance of small airways, particularly, the diameter of the small poorly supported airways.[21] After the initial 25 per cent of the forced expiratory curve, there is little or no effort-dependence except for the terminal portion.[22] The effect of a reduced VC or FVC upon the forced midexpiratory flow is difficult to estimate.

Objections have been raised to the use of the FEV_1/FVC.[23, 24] The objections result from observations of respiratory conditions producing parallel effects of impairment of both the FVC and FEV_1. Reference to table 4 would indicate that if the FVC is reduced but the FEV_1/FVC, is maintained in the normal range, this would indicate a restrictive process rather than a combined restrictive and obstructive process even if the FEV_1 was below the predicted normal range.

Certain hazards of interpretation of the FEV_1/FVC should be pointed out to avoid too literal interpretation. If a primary disease such as bronchogenic carcinoma obstructs a larger airway producing atelectasis, this could lead to a reduced FVC or VC. The secondary restriction might mask the basic obstructive process. Similarly, the development of parenchymal emphysema may result in airway obstruction from loss of peribronchiolar radial traction producing functional airway obstruction. Probably the greatest limitation to interpreting the FEV_1/FVC as an indicator of airway obstruction is the relative insensitivity of the FEV_1 to obstruction of terminal bronchioles.

The time of day when the tests are performed probably has no important influence on the ratio either in normal subjects or patients. Lewinsohn and co-workers[25] found large spontaneous variations in both FVC and FEV_1 from 9 a.m. to 5 p.m. in patients with chronic obstructive pulmonary disease. The variation was reported to be similar in magnitude and direction in individual subjects, producing a relatively constant FEV_1/FVC.

Use of the SD is valuable to avoid interpreting a relatively low FEV_1/FVC as abnormal when resulting from an above mean normal FVC or

18 Leuallen, F. C., and Fowler, W. S.: Amer. Rev. Tuberc, 1955, *72*, 783.

19 Lloyd, T. C., Jr., and Wright, G. W.: Amer. Rev. Resp. Dis., 1963, *87*, 529.

20 Kuperman, A. S. and Riker. J. B.: Amer. Rev. Resp. Dis., 1973, *107*, 231.

21 McFadden, E. R. Jr.. and Linden. D. A.: Amer. J. Med., 1972, *52*, 725.

22 Mead, J., Turner, J. M., Macklem, P. T., and Little, J. B.: J. Appl. Physiol., 1967, *22*, 95.

23 Hugh-Jones, P.: Brit. J. Anaesth., 1958, 30, 107.

24 Higgins, I. T. T., and Cochrane, A. L.: Brit. J. Ind. Med., 1961, *18*, 93.

25 Lewinsohn, H. C., Capel, L. H., and Smart, J.: Brit. Med. J., 1960, *1*, 462.

TABLE 3
CORRELATION COEFFICIENTS OF AGE, HEIGHT, AND RATIO OF 1-SECOND FORCED EXPIRATORY VOLUME TO FORCED VITAL CAPACITY BY AGE DECADES

	Age	Height	FEV_1/FVC
Men			
Age	1.00	-0.27	-0.38
Height	-0.27	1.00	0.003
FEV_1/FVC	-0.38	0.003	1.00
Women			
Age	1.00	-0.25	-0.39
Height	-0.25	1.00	0.08
FEV_1/FVC	-0.39	0.08	1.00

VC. Shapiro and co-workers[26] found that athletic men had relatively greater than normal VC and FVC than FEV_1. The resulting FEV_1/FVC tended to be relatively low. This might have resulted from development of accessory muscles of inspiration, enlarging the volume of the thorax.

The relative influence of bronchodilator drugs on the VC and FEV_1 was studied by Thomson and Hugh-Jones.[27] In general, patients with asthma, chronic bronchitis, and emphysema showed no important change in FEV_1/FVC after inhaling 1 per cent isoproterenol aerosol. In further studies, the same workers found that if the originally low ratio remained low after bronchodilator therapy, it could indicate either insufficiently treated asthma or emphysema. With serial readings, the 2 types of patients could be distinguished. Patients with asthma had a constant FEV_1/FVC until the patient's normal VC was attained; then, with continued treatment, the FEV_1/FVC of patients with emphysema remained low.

TABLE 4
RELATIONSHIP OF FORCED VITAL CAPACITY AND FORCED EXPIRATORY VOLUME IN 1 SECOND

FVC	FEV_1/FVC	Interpretation
Normal	Normal	Normal
Normal	Low	Airway obstruction
Low	Normal	Lung restriction
Low	Low	Both obstruction and restriction

Because the FVC and FEV_1 are probably the most commonly used tests of pulmonary function, it would seem desirable to include the measurement of FEV_1/FVC routinely. Despite the limitations inherent in the ratio, it does offer a reasonable estimate of the degree of restrictive and obstructive pulmonary impairment. The use of the values in table 1 will provide maximal accuracy in using the ratio. With the advent of newer techniques of determining airway obstruction such as frequency-dependent compliance and closing lung volume, more sensitive testing can be done. Until such a test can be made simple and inexpensive, spirometry will be commonly used to assess pulmonary functional impairment.

JAMES F. MORRIS
WILLIAM P. TEMPLE
ARTHUR KOSKI
Departments of Medicine
University of Oregon Medical School,
Veterans Administration Hospital
Portland, Oregon and
Department of Health Education
Oregon State University
Corvallis, Oregon

26. Shapiro, W., and Patterson, J. L. Jr.: Amer. Rev. Resp. Dis., 1962, 85, 191.
27. Thomson, W. B., and Hugh-Jones, P.: Brit. Med. J., 1958, 1, 1093.