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SHORT REPORT

Spirometric "Lung Age" Estimation for Motivating Smoking Cessation

JAMES F. MORRIS, M.D.,[1] AND WILLIAM TEMPLE

Pulmonary Disease Section, Veterans Administration Medical Center, P.O. Box 1034, Portland, Oregon 97207

Motivation for smoking cessation benefits from physician counseling. To further improve this educational process, spirometry can demonstrate ventilatory impairment to the smoker. In addition to comparing a person's spirometric results with predicted reference values for normal subjects, estimation of "lung age" can be used to demonstrate the effects of cigarette smoking. Equations were developed from reference linear regression equations permitting lung age estimation in terms of ventilatory function. This age can then be compared with the individual's chronological lung age. Normal and abnormal groups determined by a respiratory health questionnaire and pulmonary function testing were used to compare the value of single and combination spirometric tests. The forced expiratory volume at 1 sec proved superior to any other single test or combination for best separation of the two groups and had the lowest standard error for estimated lung age. Both spirometry and estimated lung age calculation may be useful for motivating cessation of cigarette smoking.

INTRODUCTION

Many physicians consider that their patients are refractory to admonishments about self-destruction by smoking. Various techniques have been used to induce cigarette smokers to abstain, usually with minimal success (although there have been notable exceptions) (12). The role of spirometric testing probably has not been fully exploited. One approach has been to assess initially the individual's pulmonary function. If the test results are within a predicted normal range, the smoker can be counseled that lung damage can be prevented by smoking cessation (5). Two studies have reported that approximately 11% of individuals having normal spirometry stopped cigarette smoking for follow-up periods of between 2 and 7 years (6, 14). If spirometric test values are abnormal, their relation to smoking can be pointed out and abstention urged to prevent further lung damage (7). Another approach is to use spirometry to follow serially the subject's pulmonary function after smoking cessation. Improvement in pulmonary function has been correlated with successful smoking cessation and has provided reinforcement for not smoking (13).

In a prior study from this laboratory, a health questionnaire and routine pulmonary function testing were used in an urban emphysema screening center to motivate smoking cessation (9). The individuals were informed of the clinical

[1] To whom reprint requests should be addressed.

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significance of their respiratory symptoms listed in the questionnaire and the degree of functional impairment from spirometric results. An estimate of "lung age" was included in the test results. Despite the brief encounter and the absence of physician or nurse participation, a smoking cessation rate of 20% resulted after an interval of 18 to 36 months.

This experience suggested the value of using an estimated lung age based on ventilatory function as a psychological tool to confront the smokers with the apparent premature aging of their lungs. Comparison can be made between the expected effects of aging on the pulmonary system and the presumed additional damage from tobacco smoke inhalation. The purposes of the present article are to present a method for calculating lung age and to determine which pulmonary function test or combinations of tests best reflect lung damage expressed as the discrepancy between chronological age and estimated lung age.

METHODS AND RESULTS

The proposed calculations are based on previously reported normal values for components of the forced expiratory vital capacity (FVC) (7) in 988 healthy nonsmoking adults, ages 20 to 84 years. From these values, linear regression equations and nomograms for predicting normal pulmonary function values from the sex, age, and height of an individual were derived. Two methods of obtaining an individual's estimated lung age were employed. First, the prediction equations were rearranged to solve for lung age. The resulting equations are shown in Table 1 applicable to the four components of the FVC maneuver. The values for height and the observed test result are substituted in the appropriate test equations and solved for age. The result is the estimated lung age; the method can be easily done on a calculator. Alternatively, a nomogram as shown in Figs. 1 and 2 (10, 11) can be used by placing a straight edge connecting the individual's height and test value and then reading the intersecting value for age. Spirograms of two subjects tested in the Portland Veterans Administration Medical Center Pulmonary Function Laboratory are shown in Figs. 3 and 4. Figure 3 shows a normal

TABLE 1
EQUATIONS FOR ESTIMATION OF "LUNG AGE"

Men	
FVC (liters)	Lung age = $5.920H - 40.000$(Obs. FVC) $- 169.640$
FEV_1 (liters)	Lung age = $2.870H - 31.250$(Obs. FEV_1) $- 39.375$
$FEF_{200-1,200}$ (liters/sec)	Lung age = $2.319H - 21.277$(Qbs. $FEF_{200-1,200}$) $+ 42.766$
$FEF_{25-75\%}$ (liters/sec)	Lung age = $1.044H - 22.222$(Obs. $FEF_{25-75\%}$) $+ 55.844$
Women	
FVC (liters)	Lung age = $4.792H - 41.667$(Obs. FVC) $- 118.833$
FEV_1 (liters)	Lung age = $3.560H - 40.000$(Obs. FEV_1) $- 77.280$
$FEF_{200-1,200}$ (liters/sec)	Lung age = $4.028H - 27.778$(Obs. $FEF_{200-12,000}$) $- 70.333$
$FEF_{25-75\%}$ (liters/sec)	Lung age = $2.000H - 33.333$(Obs. $FEF_{25-75\%}$) $+ 18.367$

Note. H = height (in in.); lung age = years; FVC = forced expiratory vital capacity; FEV_1 = forced expiratory volume at 1 sec; $FEF_{25-75\%}$ = mean forced expiratory flow during the middle half of the vital capacity; $FEF_{200-1,200}$ = mean forced expiratory flow between 200 and 1,200 ml of the FVC.

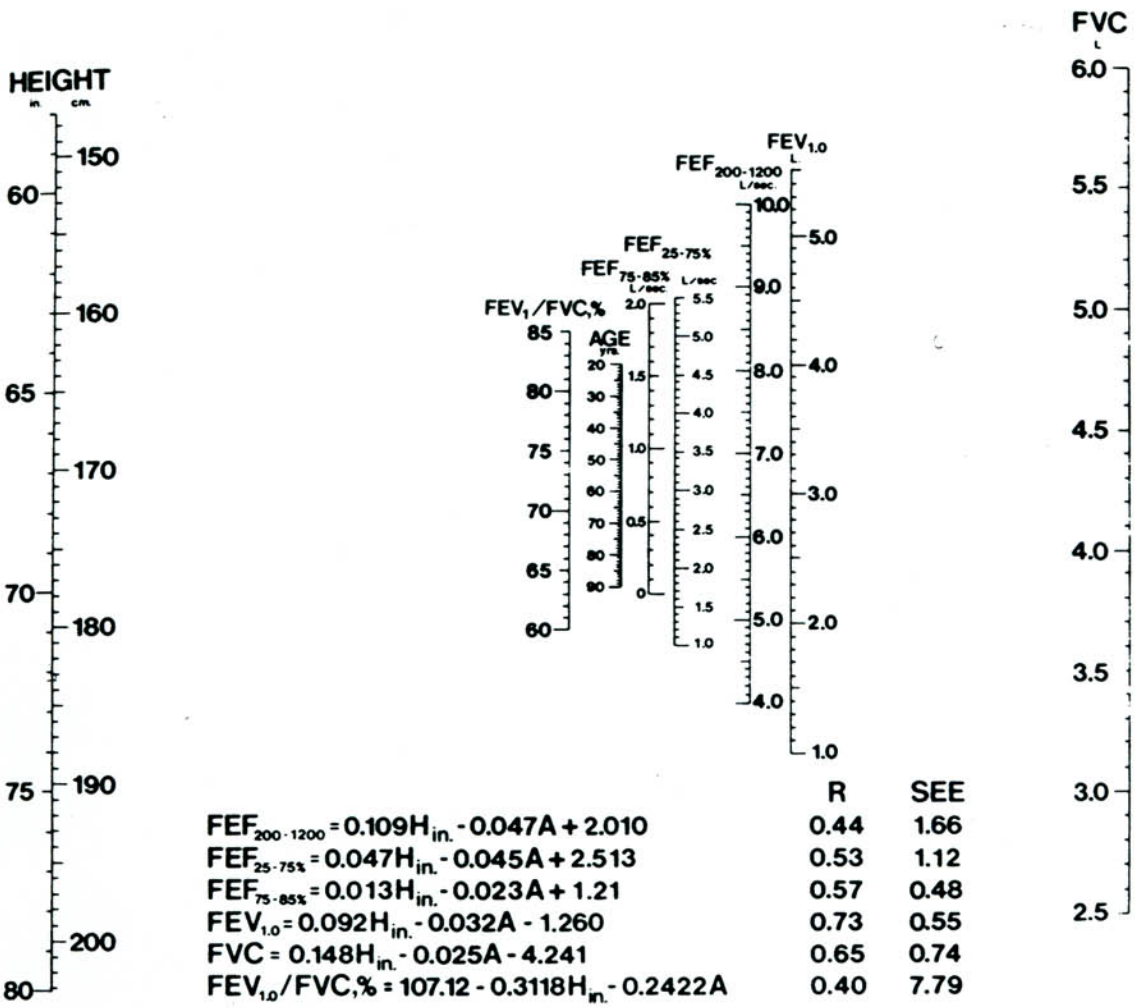

FIG. 1. Prediction nomogram for normal men (BTPS). A straight edge connecting the individual's height and test result (FEV_1) intersects the age column at the "lung age." Reprinted by permission of the *Western Journal of Medicine* (11).

test in which the measured forced expiratory volume at 1 sec (FEV_1) value is similar to the normal predicted value obtained from either Table 1 or Fig. 1, and therefore chronological age and lung age are similar. Figure 4 shows a measured value that is abnormally low compared with the normal predicted value. This leads to an estimated lung age 20 years older than chronological age. It may be desirable to combine tests to avoid reliance upon a single test. The estimated lung age for any combination of the components of the FVC is the mean value of the individual lung ages for all the selected tests in the combination.

To determine the relative validity of each spirometric test or combination of tests for estimating lung age, the standard error (SE) for each test or combination was determined. The estimated lung age for any test combination was the mean value of the individual lung ages for all the selected tests used in the combination. The SE was obtained by comparing the estimated lung age for each spirometric test and combination of tests with the chronological age for all of the 988 originally tested normal subjects (10). Table 2 lists the SE for each test and combination for

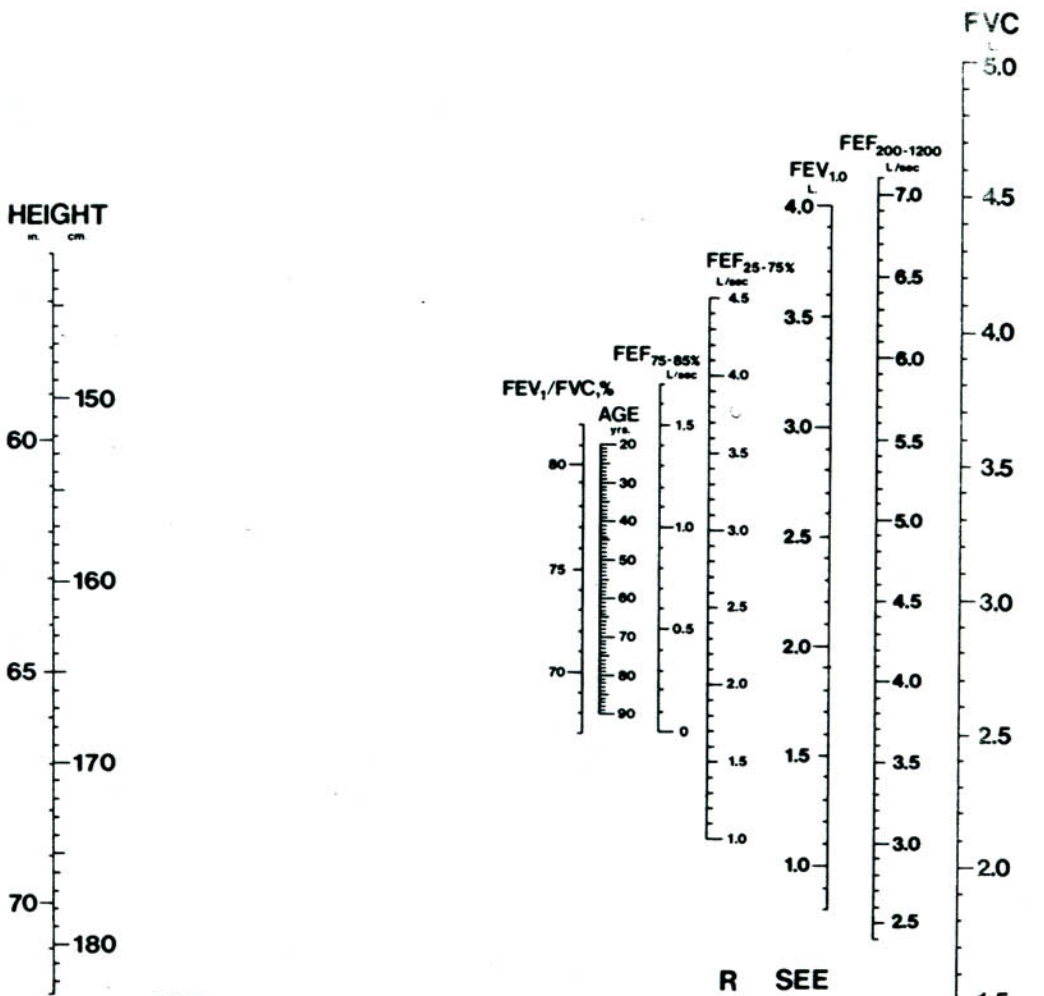

FIG. 2. Prediction nomograms for normal women (BTPS). See Fig. 1 for instructions. Reprinted by permission of the *Western Journal of Medicine* (11).

both sexes. The discrepancy between the SE for each test or combination by sex appears to be minimal. The smallest SE, representing the best value, proved to be for the FEV_1. An alternative is the combination of the forced expiratory vital capacity (FVC), the FEV_1, and the forced expiratory flow between 25 and 75% of vital capacity ($FEF_{25-75\%}$), which had the second lowest SE. [See Ref. (8) for 95% confidence limits of normal values for spirometric tests.]

The relative merits of the single tests or combinations for estimating lung age were investigated next. For this purpose, a different population was examined, consisting of hospital employees and patients with a diversity of pulmonary function, as previously reported in a separate study (1). They were classified into a normal and abnormal group based on answers to a respiratory health question-

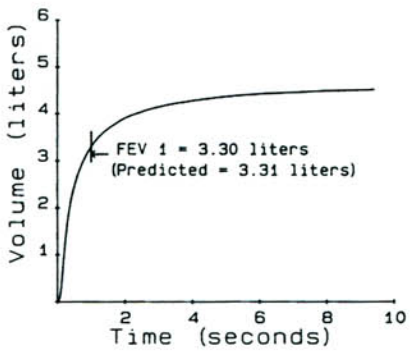

FIG. 3. Spirogram of a 54-year-old, 69 in. nonsmoker with an identical "lung age."

naire and pulmonary function test results. In the normal group, lung age is the same as chronological age. The purpose of using these retrospective data is only to compare the lung age equations for their ability to achieve best separation of the two test groups and to show the fewest outliers. This is graphically displayed in Figs. 5 and 6, which plot the comparisons between the actual and estimated lung ages for the FEV_1 and three-test combination. The figures illustrate the range of lung ages and the degrees of separation of previously determined normal and abnormal groups.

DISCUSSION

The physician can play a crucial role in motivating a patient to cease cigarette smoking (3, 15, 17). Smoking cessation programs vary in content but frequently include an educational session; expression of optimism as to the chances of individual success; a self-administered kit such as that provided by the American Lung Association, American Cancer Society, or others; and reinforcement by follow-up contact (4, 18). An additional dimension can be added by performing spirometric measurement of expiratory air flow. Once the physician identifies a person with diminished pulmonary function, there is an imperative need to impress upon the individual the necessity of smoking cessation. Spirometry deserves wider use by physicians to quantitate the degree of obstructive ventilatory impairment. Reduction of the FEV_1 is generally accepted as both a sensitive and a specific measurement for clinically significant obstructive pulmonary disease. In addition to informing patients of their percentage of predicted normal values, the

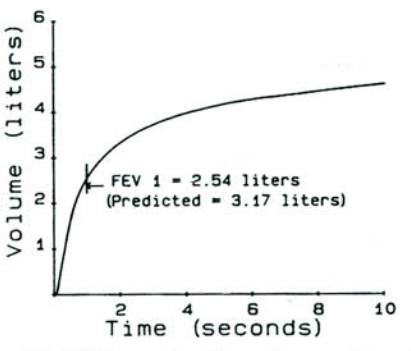

FIG. 4. Spirogram of a 57-year-old, 68 in. male cigarette smoker with a "lung age" 20 years older than chronological age.

TABLE 2
STANDARD ERROR OF ESTIMATED "LUNG AGE" VALUES USING SINGLE SPIROMETRIC TESTS AND COMBINATIONS

	Men	Women	Both
FVC	26.1915	22.4704	24.4879
FEV_1	16.2527	15.3657	15.8449
$FEF_{25-75\%}$	24.0471	26.1986	25.0870
FVC + FEV_1	19.8944	17.9626	19.0038
FVC + $FEF_{25-75\%}$	19.0222	18.7703	18.8943
FEV_1 + $FEF_{25-75\%}$	18.4157	18.6365	18.5129
FVC + FEV_1 + $FEF_{25-75\%}$:	17.8222	17.1975	17.5227

Note. See Table 1 for definitions.

estimation of lung age based on the FEV_1 may provide additional incentive to abstain from cigarette smoking and avoid further damage. Caution should be exercised not to translate lung age into life expectancy. The functional age or rate of aging of one organ such as the lung cannot be used to predict that of another organ system or the individual (2). The estimation of spirometric lung age as described is offered as a tool to impress upon the cigarette smoker the degree of ventilatory impairment caused by tobacco smoke inhalation. As part of an educational program used by a physician or health professional, it can provide additional incentive to prevent further loss of pulmonary function and the potential for improved function and lung age reduction. The recommended sequence is to identify a cigarette smoker, perform spirometry, and, if the FEV_1 is less than the lower limit of predicted normal value (8), estimate the lung age. Further studies are necessary to validate the lung age estimate as a motivating factor in smoking cessation.

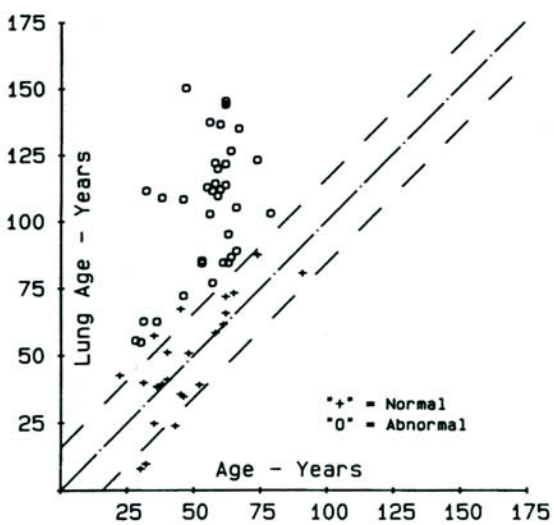

FIG. 5. Comparison of chronological with estimated "lung age" using FEV_1 in previously determined normal and abnormal groups. Abscissa represents chronological age and ordinate, the estimated lung age. Line of identity is shown with dashed lines as one SE.

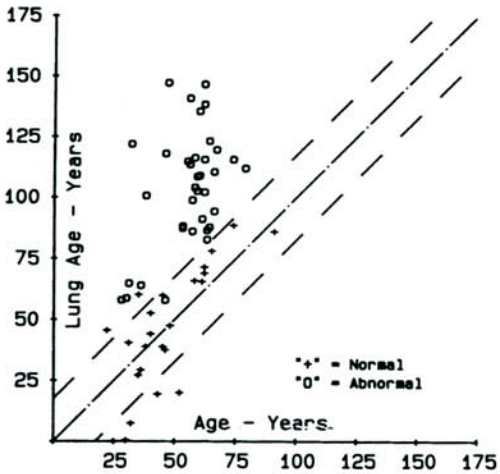

FIG. 6. Comparison of chronological with estimated "lung age" using FVC, FEV_1, and $FEF_{25-75\%}$ in previously determined normal and abnormal groups. Line of identity is shown with dashed lines as one SE. Abscissa represents chronological age and the ordinate, the estimated lung age.

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