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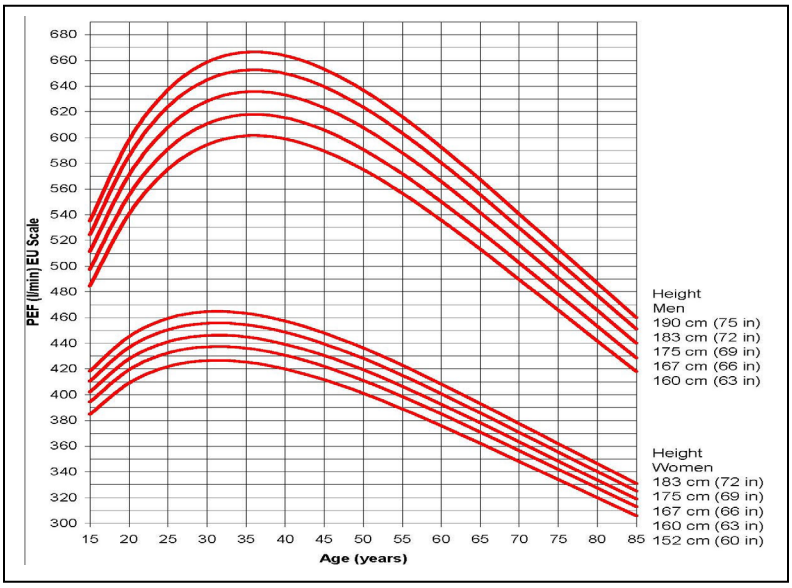
Determining When a Pulmonary Function Test is Normal

Pulmonary function tests (spirometry, plethysmography, and diffusing capacity) measure the maximum capacity of the lung. Results of testing among a reference population of healthy non-smoking volunteers are used to determine what is normal. Statistical analysis of the results among the reference population show that pulmonary function test results vary by sex, age, and height. As an example, Figure 1 shows that the variation of the reference values of "normal" peak flow is greatest between men and women and by age, and less by height.

Figure 1. Peak Expiratory Flow Rate - Normal Values



The largest reference population and the one that previously was most widely used in pulmonary function equipment in the United States was based on a sample of the general US population (National Health and Nutrition Examination Survey (NHANES))[1]. The results published in 1999 showed that Black populations in the United States had on the average 10% lower "normal" values and so race was also included in the computer algorithm programed in pulmonary function equipment. Height is a proxy for lung size and differences between lower limb length and chest length by race may reflect multiple factors in individuals of the same height, including ambient temperature of residence and access to nutrients[2]. Recognition of differences in "normal" in different racial populations and the limitation of the NHANES data to White Non-Hispanic and Black populations led to testing of additional reference populations around the world and the replacement of the NHANES reference equations with the Global Lung Function Initiative equations (GLI)[3]. Ongoing concern on the self-identification by patients and that reasons for differences in "normal" between populations may not represent genetic differences but rather health equity issues of environmental exposures, nutrition, and access to health care has led to the development of race and ethnic neutral equations (GLI -Global equations)[4]. The official recommendation from the European Respiratory Society/American Thoracic Society is that: "As there are observed population differences in body proportions and lung function, in some contexts it may be relevant to interpret results for an individual relative to that of a similar ancestral grouping, whereas in others it may be more appropriate to compare to the whole population. What is of particular importance when a patient has serial pulmonary function tests is that the same reference equation is used for all the testing[5]." Serial pulmonary function testing commonly occurs with workplace screening.

The American College of Occupational and Environmental Medicine (ACOEM) recommends "that the interpretation of pulmonary function change over time start with an evaluation of the technical quality of the tests and an adequate length of follow-up. When high quality spirometry testing is in place, ACOEM recommends further medical evaluation for workers whose forced expiratory volume in 1 second (FEV1) falls ≥15% below that which is expected due to aging (one subtracts the current FEV1 percent of predicted from the baseline (initial) FEV1 percent of predicted)[6]. This Percent Predicted method is the easiest way to assess FEV1 longitudinally for usual occupational health clinic measurements and can be used for all lengths of follow-up. This approach is valid and race and ethnicity neutral as long as one uses the same reference range for both the baseline and current testing.

A more recent suggestion for looking at change over time that is also race and ethnicity neutral is the FEV1Q[7]. FEV1Q is the FEV1 in liters divided by the sex-specific 1st percentile of the FEV1 distribution found in adults with lung disease (the survivable FEV1); the survivable percentile is 0.4 L for females, and 0.5 L for males. The closer the FEV1Q is to one, the greater the risk of death. The normal decrease of FEV1Q is one unit every 18 years, and every 10 years in smokers and the elderly. Over shorter time periods the FEV1Q should be unchanged.

The Table in **Box 1** shows the spirometry results of a worker who died at work from work-related asthma.

BOX 1. A worker was exposed to isocyanate at work. The company did spirometry at the time of hire and annually after that. He developed new onset asthma nine months after beginning work and over the next four years had 18 medical visits for his asthma. He had an acute asthma attack at work four years after he was hired and died. Both race-neutral methods for evaluating changes in pulmonary function results over time indicate spirometry results that are of concern. The percent predicted method shows a 22% decrease in the FEV1 predicted from Test #2 to Test #4, and the FEV1Q method shows a 1.0 unit decrease from Test #2 to Test #3 and 2.34 unit decrease from Test #2 to Test #4. Despite this change in FEV1 no evaluation or work restrictions were implemented by the doctor contracted by the company to review the breathing test results.

Date	FEV1	% Predicted
Test #1 – At time of hire	**3.75 L**	**95**
Test #2 – Nine months later	**3.60 L**	**96**
Test #3 – One year later	**3.27 L**	**87**
Test #4 – One year later	**2.58 L**	**73**

What are the Consequences of Using Race Neutral Reference Equations

An article in the New England Journal of Medicine (NEJM) in 2024 looked at the implications of using race neutral reference equations for determining disability and eligibility to work[8]. When disability or degree of impairment is based on the percent predicted of FEV1, using a race neutral reference equation will increase the number of Black workers and decrease the number of White workers who either meet the criteria for compensation or increase the severity rating among Black workers and decrease the severity rating among White workers.

Whether someone is qualified to work is also affected by using a race neutral reference equation. For example, the National Fire Protection Association (NFPA) guidelines on Occupational Medical Evaluations use an absolute FEV_1/FVC ratio less than 0.70 and an FEV_1 less than 70% predicted measured while off all bronchodilators on the day of testing. The NEJM article estimated the percent of Black adults who would be disqualified to be a firefighter would increase 86% and the number of white adults disqualified would decrease 28%. Although there are no requirements to do spirometry in determining whether a person is medically certified to wear a respirator, many practitioners routinely do spirometry and the use of a race neutral reference equation as part of medical certification for a respirator will increase the number of Black workers who would not be certified.

The implications of the reference equation used in pulmonary function equipment can have a marked effect on clinical care, disability, and qualifications to work. All practitioners ordering pulmonary function tests need to know what reference equation is being used in the equipment to determine “normal.” The results of spirometry need to be one part of an individual’s evaluation and pulmonary function results should not be the sole factor relied on to make clinical decisions or decisions about ability to work. Using longitudinal data with the Percent Predicted method or the FEV1Q are race neutral values that can be useful in work-related assessments as they allow the individual to be their own reference value rather than a population reference.

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*PS Remember to report all cases of occupational disease!

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