Comparison of Spirometric Reference Values for Caucasian and African American Blue-Collar Workers

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Interpretation of lung-function test results, specifically the forced vital capacity and forced expiratory volume in one second, generally involves the comparison of these parameters with reference values based on an individual's age, height, sex, and race. Such comparisons are often used to make important decisions concerning an individual, such as job placement or disability rating. Several studies[1,2,3] have shown that predicted values for African Americans are approximately 15% less than those for Caucasians, most likely because of the use of standing height to estimate the size of the thorax. When an adjustment for race is applied to reference values based on a Caucasian population, a single value (15%) is usually applied to all individuals.[4,5] When using a group of blue-collar workers (766 Caucasian and 633 African-American subjects) without any race adjustment, 10.2% of the Caucasians and 37.4% of the African-American subjects were below the lower limit of normal. When a single adjustment factor was used, 11.5% of the African-American subjects were below the lower limit of normal. Between-subject variability within an ethnic group was far greater than variability between groups. Our results suggest that although a difference between Caucasian and African-American test results for forced vital capacity and forced expiratory volume in one second exists, an application of a single adjustment factor universally applied to all individuals, regardless of their age, sex, and height, is not optimal, and alternative approaches are needed.

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Interpretation of lung-function test results, specifically the forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1), generally involves the comparison of these parameters to reference values. Such comparisons are often used to make important decisions concerning an individual, such as job placement or disability rating. Because both the FVC and FEV_1 vary with age, the age of the individual must be taken into account when computing an individual's reference value. In addition, a healthy individual with a larger thorax will have correspondingly larger volumes and FVC and FEV_1. Measurement or estimation of thoracic size (volume) is not standardized, and standing height is generally used to calculate an individual's reference values. Because thoracic size may vary by gender or ethnic origin in individuals of equal height, this method of calculating reference values may not be accurate for all ethnic and gender groups. Reference values based on adequate population studies are not available for many ethnic groups. One technique in general use is the multiplication of Caucasian reference values by an adjustment factor (ranging from 0.85 to 0.88) to generate reference values for African Americans.[4,5,6] However, a recent study[7] has questioned the use of an adjustment factor because of the continuum of values found in a review of the literature. We have investigated a group of blue-collar workers to determine whether such a single adjustment factor was necessary and whether a single adjustment factor can be appropriately applied to all African-American individuals, regardless of their age, sex, or height.

Methods

Spirometry data from a group of blue-collar workers with no documented occupational pulmonary exposures were chosen for study. These workers were from three major industries—food products, synthetic textile mills, and electrical equipment and supplies. The 14 plants studied were all located in North Carolina. Each participant completed an administered questionnaire on respiratory symptoms, occupational history, and smoking history. Details of the study, including reference values generated from this population, have been reported previously.[2,8,9]

At least five maximal forced expiratory maneuvers from a dry-rolling sealed spirometer were recorded for each subject, and all values were corrected to body temperature, pressure saturated with water vapor. The largest FVC and FEV_1 were reported and used to calculate the FEV_1/FVC percentage, regardless of the curves on which they occurred. The spirometer and methods met the minimum spirometry requirements recommended by the American Thoracic Society.[10]

Only Caucasian and African-American subjects were included in this analysis. Asymptomatic (no cough, wheeze, breathlessness, or excessive phlegm production) nonsmoking Caucasians (93 men and 136 women) were used for the development of regression equations for FVC and FEV_1, with age and standing height as independent variables, and for the estimation of the lower limits of normal (LLN) (1.64·standard error of the estimate) for FVC and FEV_1. The LLN used in our comparisons are defined as the fifth percentiles of these distributions—the values above which 95% of the normal population would be expected to fall. All regression lines were obtained by simple least-squares fit by using the Statistical Analysis System (SAS; SAS Institute Inc., Cary, NC). The omega-squared statistic was calculated to quantify the amount of variability associated with ethnic origin.[11] All statistical tests utilized the 0.05 level of significance.

TABLE 1
Study Population (n = 1399) by Smoking Status

Subjects	Never	Former	Current	Total
Men				
African Americans	91	38	176	305
	29.8%	12.5%	57.7%	
Caucasians	114	90	206	410
	27.8%	22.0%	50.2%	
Women				
African Americans	167	39	122	328
	50.9%	11.9%	37.2%	
Caucasians	171	38	147	356
	48.0%	10.7%	41.3%	

TABLE 2
Symptoms by Ethnic Origin and Gender

Subjects	Total	Cough	Phlegm	Breathlessness	Wheezing
Men					
African Americans	305	31	36	9	11
		10.2%	11.8%	3.0%	3.6%
Caucasians	410	64	60	27	28
		15.6%	14.7%	6.6%	6.8%
Women					
African Americans	328	46	45	25	25
		14.0%	13.7%	7.6%	7.6%
Caucasians	356	46	42	46	40
		12.9%	11.8%	12.9%	11.2%

Results

Table 1 shows the distribution of smoking status for men and women for both African Americans and Caucasians. There are only slight differences between African-American and Caucasian women in all smoking categories. In men, the percentage of never smokers is similar; however, more African-American men reported current smoking and more Caucasian men reported former smoking. Table 2 contains the prevalence of respiratory symptoms, with Caucasian men consistently reporting more symptoms than African-American men.

For women, the relationship of FEV_1 vs age is shown in Figure 1 and vs height in Figure 2. Similar results (not shown) were obtained for FVC. Both the FVC and FEV_1 decrease with increasing age and increase with increasing height. In addition, as other investigators have shown, the FVC and FEV_1 values for African Americans are lower than those observed for Caucasians of the same age and height. However, these differences were, on average, slightly less (13%) than the generally accepted difference of 15%. A line representing 85% of the observed values for Caucasians is also shown in the figures. The differences between Caucasian and African-American values are constant with increasing age (Figure 1) and height (Figure 2). In contrast, the FEV_1/FVC percentage, a measure of airways obstruction, is approximately the same for African Americans and Caucasians regardless of their age or height

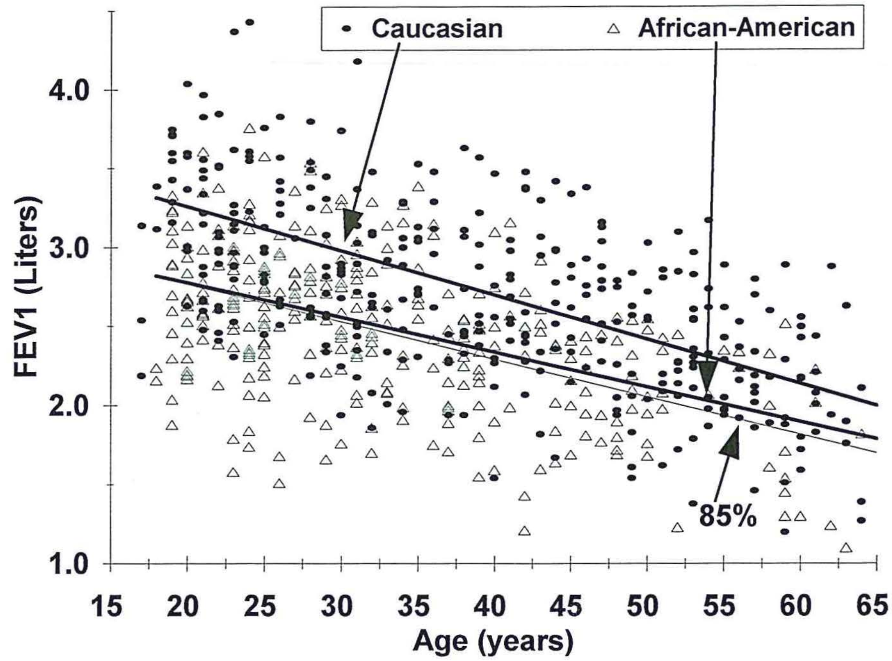

Fig. 1. FEV_1 vs age for women. Thick upper line is least-squares fit to Caucasian values, thick lower line is least-squares fit to African-American values, and thin line represents 85% of Caucasian line. Intercepts of regression lines for African Americans and Caucasians are statistically significantly different, but the slopes are not.

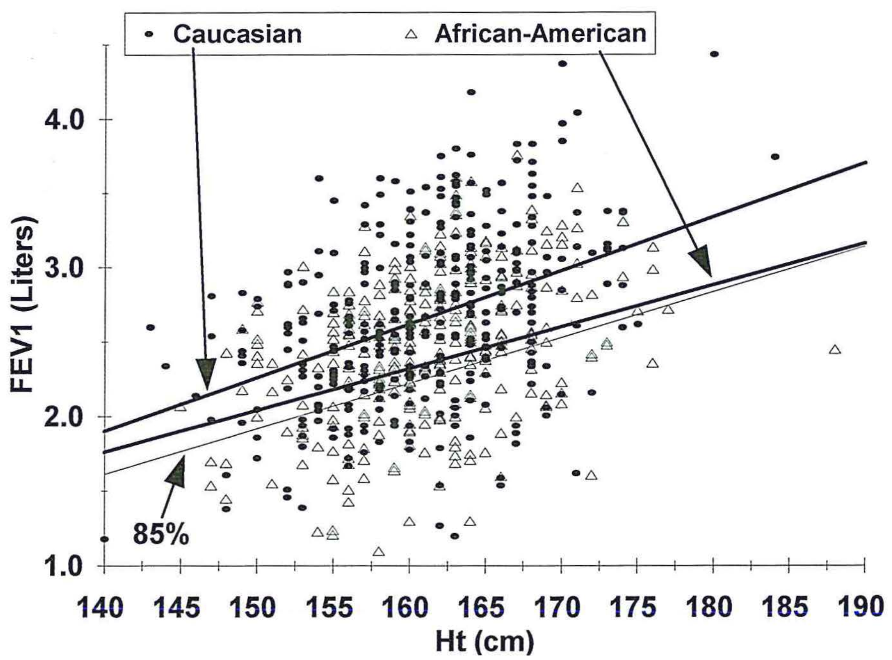

Fig. 2. FEV_1 vs height for women. Thick upper line is least-squares fit to Caucasian values, thick lower line is least-squares fit to African-American values, and thin line represents 85% of Caucasian line. Intercepts of regression lines for African Americans and Caucasians are statistically significantly different, but the slopes are not.

(Figures 3 and 4). This was not surprising because the FEV_1/FVC percentage is known to be somewhat independent of the size of the thorax. Similar results were obtained for male subjects (Figures 5 through 8).

Table 3 contains the number and percentage of Caucasian and African-American subjects falling below the LLN on the basis of reference values derived from the Caucasian asymptomatic nonsmoking group. This analysis was performed to simulate the effect of applying reference values derived from a Caucasian population to an African-American population. As can be seen in Table 3, 10.7% of the male Caucasian subjects, compared with 38% of the male African-American subjects, had values below the LLN. Similarly, 9.5% of the female Caucasian subjects, compared with 36.9% of the African-American subjects, had values below the LLN when no adjustment is used. When a 15% adjustment is applied to the predicted values for FVC and FEV_1, the percentage of African Americans below the LLN is considerably closer to those observed for Caucasian subjects (men, 10.7% vs 12.1%; women, 9.5% vs 11.0%, respectively). Results similar to those shown in Table 3 were obtained when subjects with symptoms were excluded from the analysis.

The calculated values of omega-squared (ω^2) illustrate the small portion of the overall variability that can be attributed to ethnic origin. In men, ethnicity accounts for 8.2% of the variability in FVC, vs 91.8% that is not explained by ethnicity. Of the total variability in FEV_1, only 3.7% can be accounted for by ethnic group in men. Similarly, 8.8% of the total variation in FVC and 4.0% of the total variability in FEV_1 were associated with ethnicity in the blue-collar women.

Discussion

The figures clearly demonstrate the considerable between-subject variability in FEV_1 vs age and height. This between-subject variability is much greater within an ethnic group than between ethnic groups, as shown by the ω^2 statistic. The observation in men that ethnicity accounts for only 3.7% of the total variability in FEV_1, with 96.3% not being explained by ethnicity, illus-

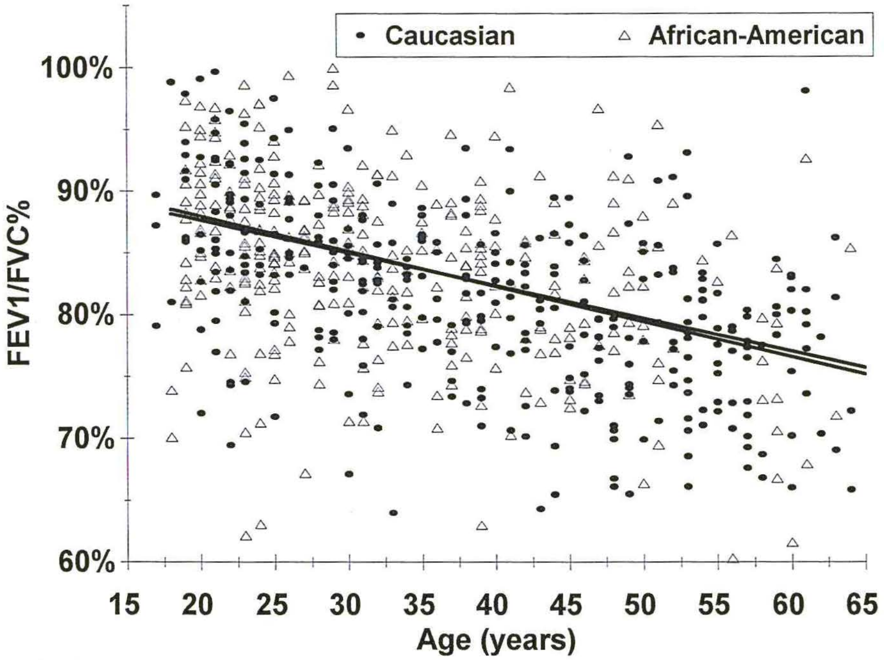

Fig. 3. FEV_1/FVC percentage vs age for women. Two solid lines represent least-squares fit to Caucasian and African-American values. Intercepts and slopes for regression lines for African Americans and Caucasians are not statistically significantly different.

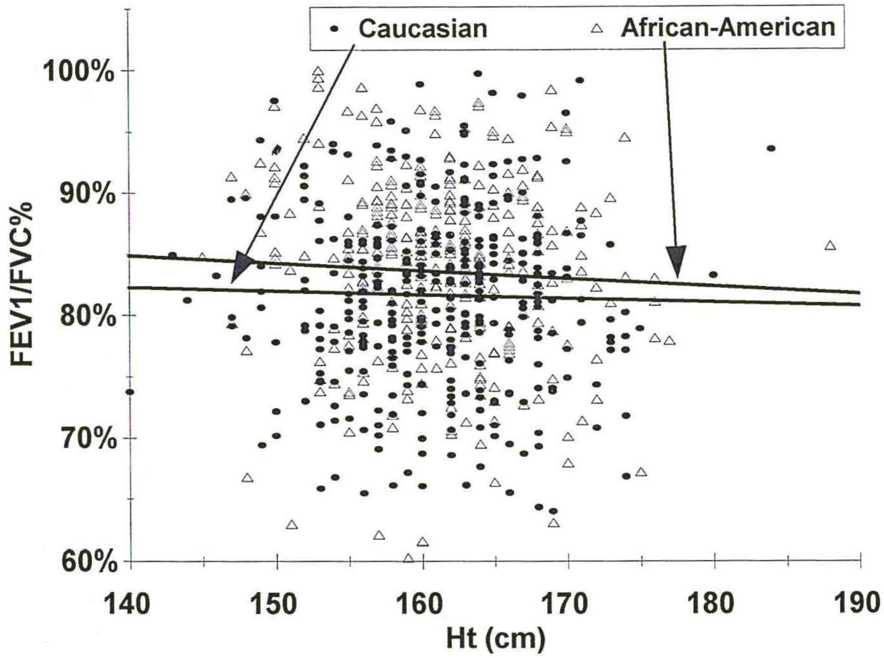

Fig. 4. FEV_1/FVC percentage vs height for women. Thick upper line represents least-squares fit to African-American values and thick lower line represents fit to Caucasian values. Intercepts and slopes for regression lines for African Americans and Caucasians are not statistically significantly different and slopes are not statistically different from zero.

trates the fundamental problem of comparing an individual's values of FVC and FEV_1 with reference values. Therefore, use of a reference population appropriate with respect to ethnicity will reduce the variability only slightly.

However, the results of our study and particularly those shown in Table 3, indicate that use of reference values from a Caucasian population for African-American workers is inappropriate. Use of reference values generated from a Caucasian population causes a higher proportion of African Americans to be misclassified as having an abnormal FVC or FEV_1. Using a single adjustment factor of 0.85 multiplied by a Caucasian reference value, as recommended in the OSHA Cotton Dust Standard,[4] may accurately classify taller African Americans in our study, but may also result in a higher proportion of shorter African Americans in our study being classified as having normal lung function when they may be adversely affected by their work environment. In a review of records from 900 respiratory disability applicants, Harber et al[12] found that use of a 15% reduction in predicted values for FEV_1 and FVC had a major effect upon the relative distribution of impairment assignments between blacks and nonblacks. These results for disability applicants were similar to our findings in blue-collar workers. Harber et al concluded that "employing sex and race corrections represents a complex matter with both scientific and sociopolitical considerations."[12]

The differences in lung function between ethnic groups may not be limited to only Caucasian and African-American populations. Shaffer et al[13] studied 442 patients who had Hispanic surnames, who were between the ages of 25 and 80 years, and who were evaluated at the University of New Mexico Hospital. They found that classification of lung function by using locally derived ethnic-group-specific reference values led to different clinical categorizations for some individuals than when external non-ethnic-group-specific reference values were used. The American Thoracic Society has addressed this problem in their statement on selection of reference values and interpretative strategies by recommending the use of reference values calculated on the basis of the ethnic origins of the subjects being

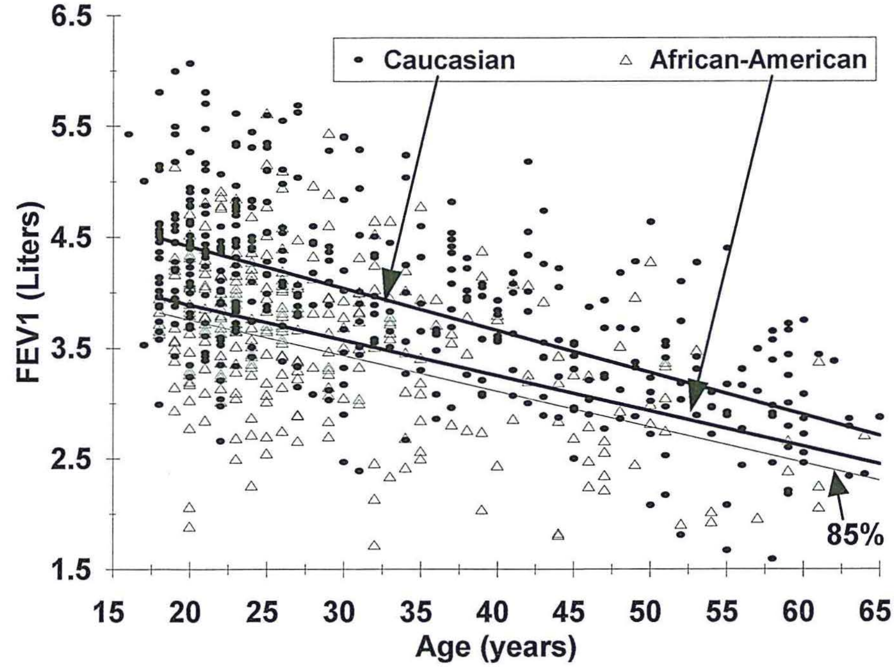

Fig. 5. FEV_1 vs age for men. Thick upper line is least-squares fit to Caucasian values, thick lower line is least-squares fit to African-American values, and thin line represents 85% of Caucasian line. Intercepts for regression lines for African Americans and Caucasians are statistically different, but slopes are not.

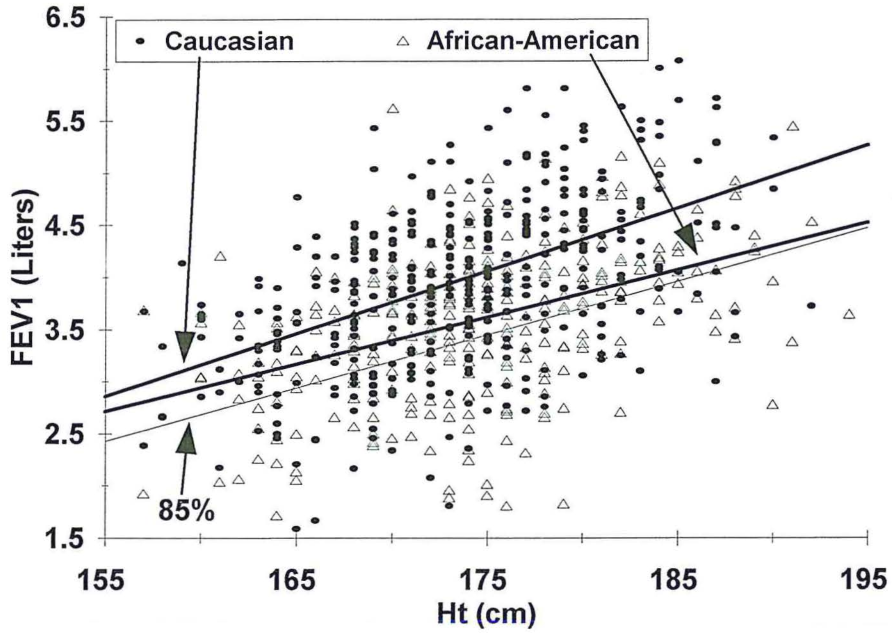

Fig. 6. FEV_1 vs height for men. Thick upper line is least-squares fit to Caucasian values, thick lower line is least-squares fit to African-American values, and thin line represents 85% of Caucasian line. Intercepts and slopes for regression lines for African Americans and Caucasians are not statistically significantly different.

tested.[6] When this is not possible or practical, the Society recommends that Caucasian reference values be adjusted for use with African-American subjects by using a scaling factor of 0.88 for FVC and FEV_1.

The differences between the Caucasian and African-American values of FVC and FEV_1 appear to be the result of differences in lung size (volume). Petersen and Hodous,[9] in a previous study of this population, developed reference values for total lung capacity (TLC) by using a radiographic method. When the total population mean age, height, and weight are used in their reference equations for Caucasians and African Americans, they found 11.8% and 14.8% differences for male and female TLCs, respectively. In addition, Hankinson[14] found that in Caucasian and African-American subjects of the same age and height, all flows, expressed at percentages of FVC, were proportionally reduced for African-American subjects—suggesting differences that occur as a result of smaller TLCs and corresponding FVCs in African-American subjects.

The FEV_1/FVC percentage appears to be relatively independent of lung-size differences between workers, particularly when lung size is estimated by standing height. Therefore, the FEV_1/FVC percentage appears to be a useful parameter in the evaluation of a diverse work force exposed to respiratory hazards. Jacobs et al[15] found that race and sex differences in FVC and FEV_1 exist even after detailed adjustment for frame size based on sitting height, leg height, elbow breadth, and biacromial diameter. However, our results suggest that standardizing FEV_1 by dividing by FVC (FEV_1/FVC percentage) appears to adjust for differences in lung size.

Another approach to circumvent the limitations of comparisons with reference values is to follow workers over time. With this approach, the worker serves as his/her own control[16] and this approach may be better in detecting significant changes in FVC and FEV_1 in a diverse work force. However, because of the relatively small expected decline in FEV_1 over time in comparison with intrasubject variability, only relatively large decrements in FEV_1 can be detected without long periods of observations (5 to 10 years).

Although many studies have investigated the effects of race on lung function, the consequences of failing

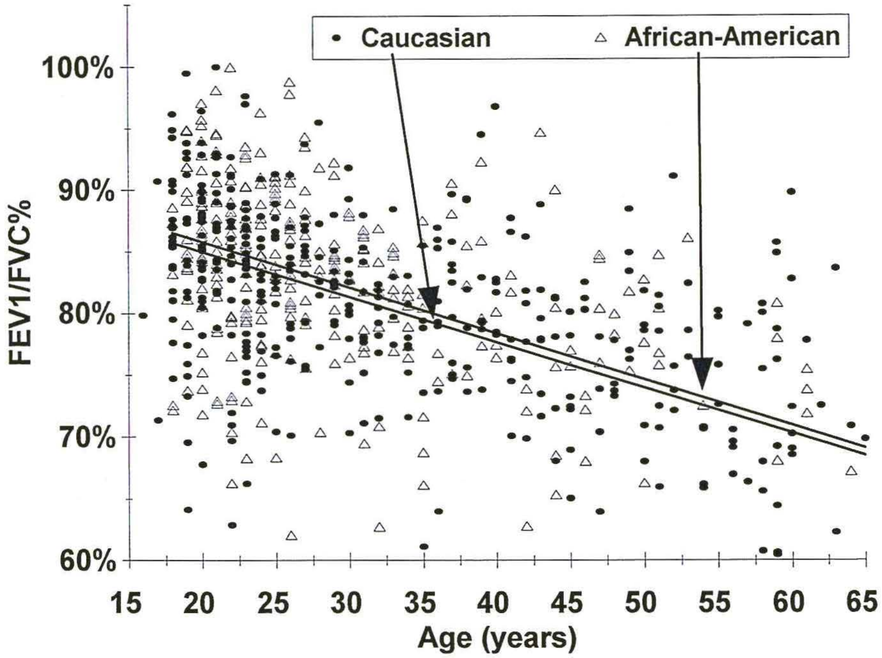

Fig. 7. FEV_1/FVC percentage vs age for men. Upper line is least-squares fit to African-American values and lower line is least-squares fit for Caucasians. Intercepts of regression lines for African Americans and Caucasians are statistically significantly different, but the slopes are not.

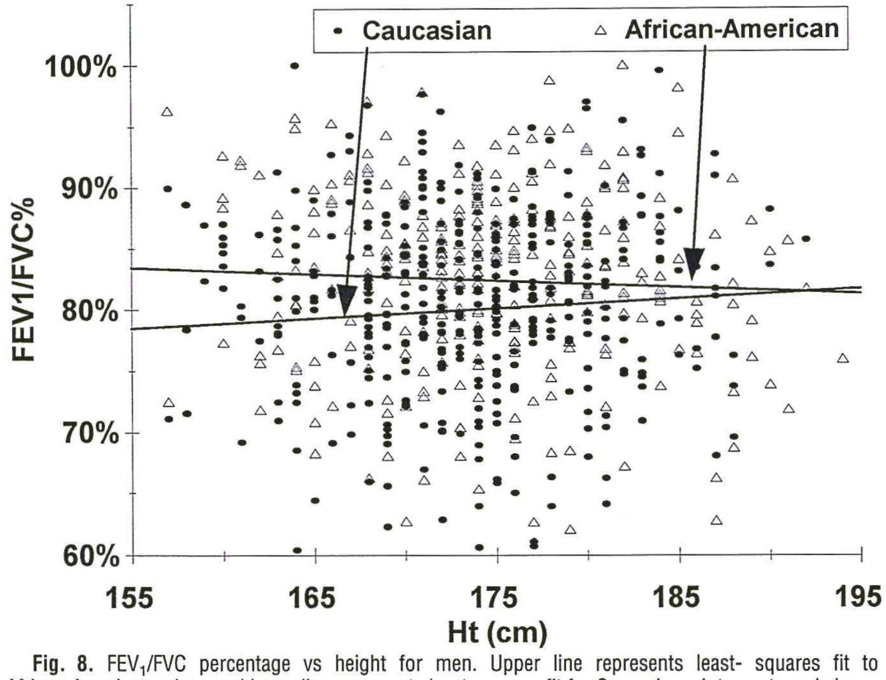

Fig. 8. FEV_1/FVC percentage vs height for men. Upper line represents least- squares fit to African-American values and lower line represents least-squares fit for Caucasians. Intercepts and slopes for regression lines for African Americans and Caucasians are not statistically significantly different, and slopes are not statistically different from zero.

TABLE 3
Number of Subjects by Ethnic Origin, Gender, and Smoking Status Below the LLN of Reference Values for FVC or FEV_1 Based on Asymptomatic Nonsmoking Caucasian Subjects

Subjects	Total	Below LLN
Men		
Caucasians	410	44 (10.7%)
Nonsmokers	114	7 (6.1%)
Exsmokers	90	11 (12.2%)
Current Smokers	206	26 (12.6%)
African Americans	305	116 (38.0%)
Nonsmokers	91	32 (35.2%)
Exsmokers	38	14 (36.8%)
Current Smokers	176	70 (39.8%)
African Americans (15%)	305	37 (12.1%)
Nonsmokers	91	11 (12.1%)
Exsmokers	38	2 (5.3%)
Current Smokers	176	24 (13.6%)
Women		
Caucasians	356	34 (9.5%)
Nonsmokers	171	17 (9.9%)
Exsmokers	38	1 (2.6%)
Current Smokers	147	16 (10.9%)
African Americans	328	121 (36.9%)
Nonsmokers	167	59 (35.3%)
Exsmokers	39	14 (35.9%)
Current Smokers	122	48 (39.3%)
African Americans (15%)	328	36 (11.0%)
Nonsmokers	167	18 (10.8%)
Exsmokers	39	7 (17.9%)
Current Smokers	122	11 (9.0%)

to use either race-specific reference values or an adjustment factor in the medical screening of blue-collar workers has not previously been addressed. The results from the study presented here indicate a need for additional research to develop better estimates of reference values for FVC and FEV_1 for use in evaluating diverse work force populations. To the extent possible, reference values should be selected from a population with comparable age, physical characteristics, socioeconomic background, and ethnic characteristics. In addition, more reliance on the FEV_1/FVC percentage and on following workers over time are possible solutions to the problems of accurately detecting adverse changes in FVC and FEV_1 in a diverse work force.

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