Pulmonary Function Test Outcomes in Healthy Navajo Native American Adolescents

SUZANNE M. BERMAN, DAVID A. ARNALL, and MARK W. CORNWALL

Physical Therapy Department, College of Health Professions, Northern Arizona University, Flagstaff, Arizona

Prediction equations for estimating lung volumes have been determined for Caucasians, African-Americans, and Mexican-Americans. These separate equations were determined because of differences in thoracic morphology between people of various racial groups, making it impossible to use one prediction formula to accurately estimate lung volumes for all individuals. One hundred ninety-one adolescent Navajo children (males, n = 110; females, n = 81) between 11 and 18 yr of age volunteered for the study and underwent a series of pulmonary function tests (PFT). New pulmonary function prediction equations for Navajo youth were generated for estimating pulmonary volumes and capacities that more accurately predict expected PFT outcomes than formulas in common use for Caucasian, Mexican-American, or African-American youth. **Berman SM, Arnall DA, Cornwall MW. Pulmonary function test outcomes in healthy Navajo Native American adolescents. Am J Respir Crit Care Med 1994;150:1150–3.**

It is widely accepted that race is one determinant of lung function (1–7). Race-specific pulmonary nomograms are used to more accurately predict normal pulmonary function for those few groups that have been characterized to date, namely Caucasians, African-Americans, and pediatric Mexican-Americans. Pulmonary function in Native American populations has been only minimally characterized (1, 8–10) and only one published paper includes Navajo subjects in the test population (11). In a study by Crapo and colleagues (11), most but not all participants (75% of women and 85% of men) were Navajo. However, it was not clear whether Navajo subjects were residents on the Navajo reservation or living in communities outside the reservation at the time of testing.

To date, pulmonary function in Navajo patients has been compared with predicted volumes/capacities for healthy Caucasians, even though studies involving other ethnic populations have shown that Caucasian pulmonary values are not necessarily valid in assessing non-Caucasian patients. The purpose of this study was to characterize spirometric pulmonary function in a sample of apparently healthy Navajo adolescents between 11 and 18 yr of age and derive by regression analysis, prediction equations for normal values of FVC, FEV_1, FEV_3, $FEF_{25-75\%}$ and PEF.

Subjects were recruited in two ways. Children between 11 and 18 yr of age were asked to participate in the study on reporting to the Public Health Hospital at Chinle, AZ for mandatory physical exams before entering junior high and high school. Also, students attending junior high or high school in Tuba City, AZ were tested during physical and health education classes.

(Received in original form June 1, 1993 and in revised form January 27, 1994)

Correspondence and requests for reprints should be addressed to David Arnall, PhD., P.T., Northern Arizona University, Physical Therapy Program, C.U. Box 15105, Flagstaff, AZ 86011.

Am J Respir Crit Care Med Vol 150. pp 1150–1153, 1994

Subjects volunteered and were selected on the basis of demonstrating (*1*) normal growth and development, (*2*) no congenital thoracic abnormality or history of thoracic surgery, (*3*) no history of chronic pulmonary disease such as tuberculosis, asthma, bronchitis, or emphysema, (*4*) no systemic disease known to affect the respiratory system, (*5*) no more than incidental smoking experience (i.e., isolated incidence but no habitual or regular use), and (*6*) no recent acute respiratory illness (12).

After completion of medical history, tribal lineage for each subject was reviewed. All data used in the final data analysis came from subjects with an entirely Navajo tribal lineage (n = 191). A small number of children reported their familial lineage (n = 24) to include marriage with members of a nearby Pueblo tribe or people of Hispanic descent. Pulmonary function data from these subjects were excluded from statistical analysis.

Information on the study and an informed consent form were sent to each subject's parents or guardian to be signed and returned prior to testing. Approval to begin the study was obtained from Navajo Health Boards from the Navajo Reservation Service Unit Districts in Chinle, and Tuba City, AZ. Also, the Institutional Review Board (IRB) of Northern Arizona University approved the study protocol prior to the beginning of testing.

Testing was performed on a Flowmate Plus Spirometer (Spirometrics, Inc., Auburn, ME) that met or exceeded all American Thoracic Society (ATS) criteria for approved spirometers, defined in the 1987 Standardization of Spirometry (13). FVC, FEV_1, FEV_3, $\%FEV_1$, $FEF_{25-75\%}$ and PEF values were printed out for each subject.

The spirometer was calibrated on-site using a 3-L syringe at beginning of testing and whenever it was moved to a new testing site. When it was at a testing station for > 2.5 h, the spirometer was recalibrated before additional pulmonary function tests were conducted.

Recommendations on procedures for pulmonary function testing, recommended by the 1991 ATS Statement, were followed throughout this study (14).

Spirometric testing procedure was explained to each subject individually, emphasizing the importance of giving the best effort possible. Each subject was tested standing and without nose clips, standard procedure for testing children (15). At least three acceptable PFTs were performed by all subjects. If there was > 5% variation between individual trial results for either FVC or FEV_1, procedure was repeated until all three trials were

within 5% variation. Expirations had to last longer than 4 s to be accepted.

Based on observations of others who studied pulmonary function in children, the only information collected on each child used as independent variables were age (to nearest whole yr), sex, and standing height (2, 3, 6, 8, 15, 16). These authors have demonstrated that other anthropometric values such as gross wt, lean body wt, sitting height and trunk length contribute comparatively little to the resulting prediction formulas, regardless of the race being studied.

The largest FVC, FEV_1, and $\%FEV_1$ for each subject was used for analysis, even if from different trials. Flow rates were taken from the trial with greatest sum of FVC and FEV_1 (5, 8, 11, 16, 17). After data were separated by sex, both linear and nonlinear regression analyses were performed on each spirometric parameter to find best predictive equations. Finally, a series of paired *t* tests were performed for both male and female subjects and each of the dependent variables tested. Data for these analyses consisted of subject's actual pulmonary function values recorded in the present study and their predicted values based upon regression formulas published by Hsu and colleagues (6) and Wall and associates (8). A comparison could thus be made regarding the ability of previously published equations to predict pulmonary function values in our sample of adolescent Native American children. An alpha level of 0.01 was used as the criterion for determining statistical differences. This level was chosen to make a more stringent test of possible differences.

Two hundred seventeen subjects were originally recruited; 26 were not included in the final data set because they either (*1*) had acute pulmonary disease at the time of testing (n = 2 for asthma), or (*2*) reported lineage as not being Navajo (n = 24). Consequently, 191 Navajo adolescents (n = 110 males, 81 females), 11 to 18 yr of age comprised the final data set. No parent or guardian refused permission for children to participate. Number of subjects in the final data set for this study represented a 9% sample of the junior high and high school students in the Tuba City, AZ and Chinle, AZ areas.

Scatter plots of FVC and FEV_1 for girls and $FEF_{25-75\%}$ for boys revealed one to three obvious outlying values, which were brought to the next most extreme value for a child of same sex and height (18). This did not significantly improve correlation coefficients for these equations, but did improve the limits of normal as measured by standard error of estimate (SEE).

Table 1 lists spirometric prediction equations derived in this study and SEE for each. Age did not contribute significantly to any equation, and all equations were thus derived without age as a factor (6, 8). Nonlinear equations were used because they provided greater predictive value compared with linear equations. This agrees with the findings of other investigators (6 ,8, 19). Data obtained from female subjects consistently resulted in equations with lower correlation coefficients. Equations derived for adolescent Navajo FVC and FEV_1 for males and females were graphed and superimposed on equations published for other racial groups and for one other Native American tribe (Figures 1–4) for subjects of similar age. The studies of Hsu and coworkers (6) and Wall and associates (8) were chosen for comparison because these tested children of various racial groups. The equations for Caucasians produced in the study by Hsu and coworkers (6) tend to give predicted values greater than those from other authors whose equations are still in clinical use (20, 21). If the equations by Polgar and colleagues (20) and Dickman and associates (21) are used when clinically testing a young Navajo, the patient's normal pulmonary function may be underpredicted, and clinically significant loss of function may not be realized.

In using prediction equations to determine the limits of normal pulmonary function, several methods have typically been used, leaving the definition of "normal" somewhat arbitrary. Traditionally, minimum limits of normal have been defined as 80% predicted for FVC, FEV_1, and PEF; 65% predicted for $FEF_{25-75\%}$; and a $\%FEV_1$ ratio of 0.75 (22, 23). Sobol and Sobol (24) challenged this approach because the line representing percent predicted deviates increasingly from the regression line the further one moves along the regression line, though the variance in pulmonary function tests is homoscedastic. Another method currently in use for predicting limits of normal is to subtract twice SEE value from predicted value (3, 6, 8, 15), indicating that statistically, only 2.5% of normal population will have values less than that calculated; thus someone with a lower value is very likely abnormal. We have provided SEE values for each prediction equation with this method.

TABLE 1

SPIROMETRIC PREDICTION EQUATIONS FOR ADOLESCENT NAVAJOS 11–18 YR OF AGE

Variable	Sex	Equation	r^2	SEE
FVC	M	$0.006\ (HT^{1.431}) - 4.619$	0.710	0.480
	F	$0.010\ (HT^{1.286}) - 3.141$	0.401	0.385
FEV_1	M	$0.010\ (HT^{1.321}) - 5.089$	0.695	0.444
	F	$0.031\ (HT^{1.080}) - 4.475$	0.367	0.380
FEV_3	M	$0.011\ (HT^{1.328}) - 5.629$	0.730	0.463
	F	$0.192\ (HT^{0.893}) - 4.248$	0.213	0.485
FEF_{25-75}	M	$0.001\ (HT^{1.787}) - 3.208$	0.369	0.931
	F	$136.35\ (HT^{-0.751}) - 9.205$	0.034	0.847
PEF	M	$0.008\ (HT^{1.449}) - 5.975$	0.372	1.379
	F	$0.00009\ (HT^{2.387}) - 3.358$	0.014	1.317
$\%FEV_1$	M	$0.348\ (HT) + 59.537$	0.042	6.399
	F	$0.005\ (HT^{1.878}) + 69.915$	0.009	8.321

Definition of abbreviations: Ht = standing height (inches); SEE = standard error of estimate.

The result of paired *t* tests showed that FEV_1 values derived from prediction equations of Hsu and colleagues (6) for Caucasian females and African-American and Caucasian males were not statistically different ($p > 0.01$) from corresponding FEV_1 values of males and females obtained in the present study. However, FEV_1 values for males and females based on equations for other racial groups were found to be statistically different from values measured in the present study. FVC values measured in this study were also found significantly different ($p < 0.01$) from all prediction equations reported by Hsu and colleagues (6). These results

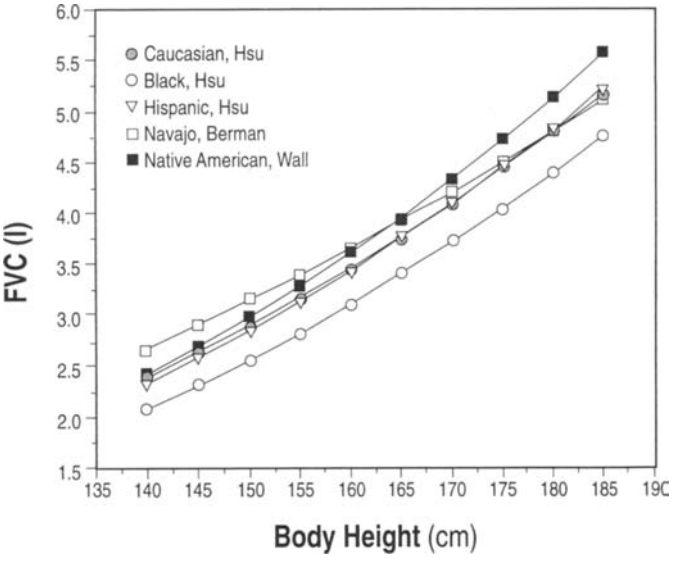

Figure 1. Regression plots of FVC for female Navajo adolescents compared with predicted values based on formulas by Hsu and colleagues (6) and Wall and associates (8).

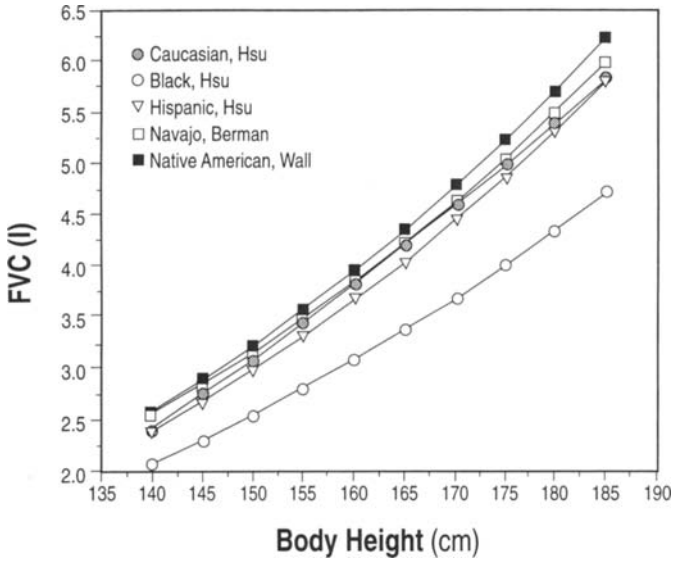

Figure 2. Regression plots of FVC for male Navajo adolescents compared with predicted values based on formulas by Hsu and colleagues (6) and Wall and associates (8).

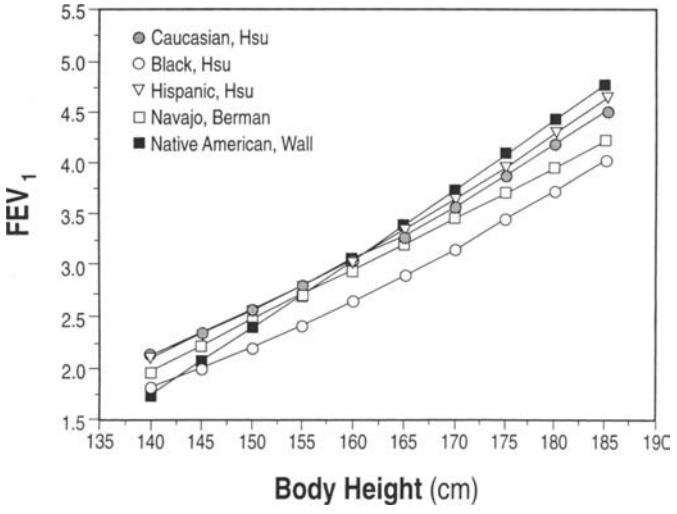

Figure 4. Regression plots of FEV_1 for male Navajo adolescents compared with predicted values based on formulas by Hsu and colleagues (6) and Wall and associates (8).

indicate that equations by Hsu and colleagues (6) for various racial groups do not adequately predict pulmonary function values in Navajo adolescents. This information is important because the use of previously published predictive equations could result in inaccurate estimates of pulmonary function in Navajo adolescents. A similar comparison using equations reported by Wall and coworkers (8) showed no statistical ($p < 0.01$) difference between FVC and FEV_1 using their equations and values measured in the present study. Although there was no statistical difference found, equations of Wall and colleagues (8) gave consistently higher values than that measured in our study (Figures 1 through 4).

* * *

Studies assessing racial differences in pulmonary function have invariably led to conjecture about anthropometric effects on lung volume. A smaller ratio of sitting height to standing height is generally accepted as relating to the relatively smaller lung volumes seen in African-Americans (2, 3, 5). When vital capacity of African-American children is compared with that of Caucasians with the same sitting height, no difference is found (19). Also, though African-Americans have somewhat lower expiratory flow rates than Caucasians of the same age and height, no racial difference is seen when matched by lung volume (5). Because flow rates are an important diagnostic indicator for lung disease, it is thus vital that predictions be accurate across racial groups.

Inuit people, on the other hand, have higher spirometric values than predicted (25). Compared with Caucasians, their shorter stature, and possibly larger trunk-to-standing height ratio, have been proposed as explanations. Inter-tribal differences in spirometric values have been found among North American Indian children (8, 10), leading to the suggestion that lung function may be tribe-specific.

Our results were compared with those of Wall and associates (8) who tested Native American children from the Warm Springs Indian Reservation in Oregon. As can be seen in Figures 1 through 4, no statistical differences were found between the two regression lines, although they are not identical. This is especially true at the greater body heights of the male subjects (Figures 2 and 4). It is thus possible to overestimate an adolescent Navajo male's pulmonary function based upon the regression equations of Wall and colleagues (8). A clinician would therefore be wise to use caution when applying the equations of Wall and colleagues (8) for FVC and FEV_1 values in male Navajo adolescents. Further study is needed in this area to determine if pulmonary function values are indeed tribe-specific or are gender-related.

In conclusion, our results indicate that Navajos enter adulthood with pulmonary volumes and flow rates equivalent to or larger than those of Caucasians. Common formulas (4, 6) do not accurately reflect the full spectrum of predicted values for pulmonary volumes and capacities when testing adolescent Navajo subjects. The formulas by Wall and colleagues (8) do not differ significantly from ours, but further study with large populations of Native Americans is warranted to determine accuracy of prediction equations from both studies. The use of non-Native American prediction equations in the pulmonary screening of Navajo adolescents should be discouraged.

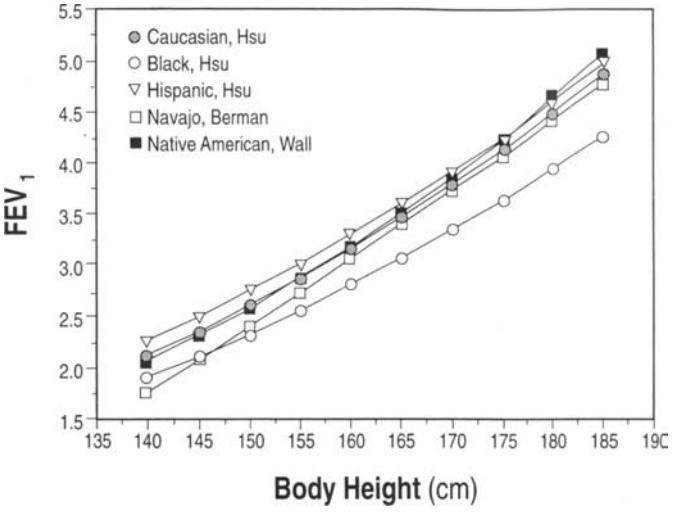

Figure 3. Regression plots of FEV_1 for female Navajo adolescents compared with predicted values based on formulas by Hsu and colleages (6) and Wall and associates (8).

Acknowledgment: The writers wish to thank the Navajo Health Board members from the Chinle and Tuba City, Arizona areas for their support for and approval of this project. They also wish to thank Horacio Alvarez, RRT and Flagstaff Medical Center for providing the researchers with the Flowmate Plus Spirometer. Horacio was the Director of the Respiratory Therapy Department of the Flagstaff Medical Center, Flagstaff, Arizona. Their appreciation is also extended to Dr. Charles Fuenzalida who was the inspiration behind this project and whose encouragement kept them pushing forward when it seemed as though no light existed at the end of the tunnel.

References

1. Gould BA. Investigations in the military and anthropological statistics of American soldiers. New York: Hurd and Houghton, 1869.
2. Schoenberg JB, Beck GJ, Bouhuys A. Growth and decay of pulmonary function in healthy blacks and whites. Respir Physiol 1978;33:367–93.
3. Chehreh MN, Young RC, Viaene H, Ross CW, Scott RB. Spirometric standards for healthy inner-city black children. Am J Dis Child 1973; 126:159–63.
4. Binder RE, Mitchell CA, Schoenberg JB, Bouhuys A. Lung function among black and white children. Am Rev Respir Dis 1976;114:955–9.
5. Lapp NL, Amandus HE, Hall R, Morgan WKC. Lung volumes and flow rates in black and white subjects. Thorax 1974;29:185–8.
6. Hsu KHK, Hsi BP, Thompson V, Hsieh GSJ. Ventilatory functions of normal children and young adults—Mexican-American, white and black. I. Spirometry. J Ped 1979;95:14–23.
7. Miller GJ, Ashcroft MT, Swan AV, Beadnell HM. Ethnic variation in forced expiratory volume and forced vital capacity of African and Indian adults in Guyana. Am Rev Respir Dis 1970;102:979–81.
8. Wall MA, Olson D, Bonn BA, Creelman T, Buist AS. Lung function in North American Indian children: reference standards for spirometry, maximal expiratory flow volume curves, and peak expiratory flow. Am Rev Respir Dis 1982;125:158–62.
9. Lanese RR, Keller MD, Foley MF, Underwood EH. Differences in pulmonary function tests among whites, blacks and American Indians in a textile company. J Occup Med 1978;20:39–44.
10. Ernst P, Thomas D, Becklake MR. Respiratory survey of North America Indian children living in proximity to an aluminum smelter. Am Rev Respir Dis 1966;133:307–12.
11. Crapo RO, Lockey J, Aldrich V, Jensen RL, Elliott CG. Normal spirometric values in healthy American Indians. J Occup Med 1988;30:556–60.
12. Taussig LM, Cherniack V, Wood R, Farrell P, Mellins RB. Standardization of lung function testing in children. J Pediatr 1980;97:668–76.
13. American Thoracic Society Statement: Standardization of Spirometry—1987 update. Am Rev Respir Dis 1987;136:1285–98.
14. American Thoracic Society Statement: Lung Function Testing: selection of reference values and interpretative strategies. Am Rev Respir Dis 1991;144:1202–18.
15. Hibbert ME, Lannigan A, Landau LI, Phelan PD. Lung function values from a longitudinal study of healthy children and adolescents. Pediatr Pulmonol 1989;7:101–9.
16. Sinclair SW, Avery SF, Brady DM, Smith DA, Holst PE, O'Donnell TV. Prediction formulae for normal pulmonary function values in New Zealand European subjects. NZ Med J 1980;91:1–5.
17. Archer VE, Gillam JD, Wagoner JK. Respiratory disease mortality among uranium miners. NY Acad Sci 1976;271:280–93.
18. Tabachnick BG, Fidell LS. Using multivariate statistic. New York: Harper & Row, 1983.
19. Roberts FL, Crabtree JA. The vital capacity of the Negro child. JAMA 1927;88:1950–2.
20. Polgar G, Promadhat V. Pulmonary function testing in children, techniques and standards. Philadelphia: WB Saunders Co., 1971.
21. Dickman ML, Schmidt CD, Gardner RM. Spirometric standards for normal children and adolescents (ages 5 years through 18 years). Am Rev Respir Dis 1971;104:680–7.
22. Wall MA. Office pulmonary function testing. Ped Clinics NA 1984;31: 773–83.
23. McBride JT, Wohl ME. Pulmonary function tests. Ped Clinics NA 1979; 26:537–51.
24. Sobol BJ, Sobol PG. Editorial: percent of predicted as the limit of normal in pulmonary function testing: a statistically valid approach. Thorax 1979;43:1–3.
25. Rode A, Shephard RJ. Pulmonary function of Canadian Eskimos. Scand J Respir Dis 1973;54:191–205.