Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

Original article

A Study Examining the Impact of Environment and Ethnic Origin on Lung Function in Adolescents

Ali Dow
Faculty of Science and Natural Resources, University of Al Jafara, Alzahra, Libya
Email. alidaowo8@gmail.com

Abstract
Multiple factors, including ethnicity, anthropometric measurements, and environmental conditions, influence the development of lung function during adolescence. This study investigated ethnic variations in peak expiratory flow rate between Pakistani and Libyan adolescents sharing the same environment in Tripoli, evaluated body surface area as a predictor of lung function, and determined whether ethnic origin or body size exerts greater influence on peak expiratory flow rate when environmental factors are held constant, to support the development of ethnic-specific reference values for clinical practice. A cross-sectional study was conducted among 143 healthy students (Pakistani: 32 males, 36 females; Libyan: 35 males, 40 females) from the Pakistan Embassy School and four Libyan schools. Participants with respiratory diseases, medication use, or smoking history were excluded. Peak expiratory flow rate was measured using a Vitalograph Peak Flow Meter, with the highest of three attempts recorded. Body surface area was calculated using the Mosteller formula. Data were analysed using SPSS version 26. Libyan males demonstrated significantly higher mean peak expiratory flow rate (417.1 ± 55.8 L/min) compared to Pakistani males (402.2 ± 66.4 L/min, p=0.032). Libyan females also showed higher values (363.5 ± 38.9 L/min) than Pakistani females (357.4 ± 36.2 L/min, p=0.047). A strong positive correlation was observed between body surface area and peak expiratory flow rate in all subgroups (r=0.643 to 0.712, p<0.001). Participants with higher body surface area (≥1.70 m²) had significantly higher peak expiratory flow rate than those with lower body surface area (1.30-1.49 m²) in both nationalities (p < 0.001). Multiple regression identified body surface area (β=0.514, p<0.001) and nationality (β=0.187, p=0.012) as independent predictors. Significant ethnic differences in lung function exist between Pakistani and Libyan adolescents living in the same environment. The results indicate that the environment did not have a clear impact on lung function compared to the effects of ethnic origin and body size. Body surface area is a strong predictor of peak expiratory flow rate, supporting the use of ethnic-specific reference values in clinical practice.
Keywords. *Peak Expiratory Flow Rate; Body Surface Area; Ethnic Differences; Adolescents; Lung Function.*

Received: *09/01/26*
Accepted: *06/03/26*
Published: *13/03/26*

Introduction

Pulmonary ventilation is essential for respiratory function, with peak expiratory flow rate (PEFR) serving as a key indicator measured through spirometry [1-3]. Lung function is influenced by multiple factors, including respiratory muscle strength, chest circumference, body composition, height, sex, and Body Surface Area (BSA) [4-6]. BSA, calculated from height and weight, has emerged as a reliable predictor of lung function, reflecting overall physical stature better than weight alone [7]. Studies confirm a positive correlation between BSA and lung function, with Das and Jahan demonstrating that individuals with higher BSA (1.5-1.69 m²) have significantly greater lung function than those with lower BSA (1.3-1.49 m²) [8,9]. Ethnic differences in lung function during childhood and adolescence are well-documented [10-13]. Whitrow and Harding found that ethnic variations persist after adjusting for confounding factors, suggesting genetic influences on lung development [10]. Environmental factors, including air pollution, diet, and socioeconomic conditions, also contribute to these differences [14,15].

Libya hosts a significant Pakistani community, with students attending the Pakistan Embassy School in Tripoli. These students share genetic backgrounds with Pakistanis but are exposed to Libyan environmental conditions, offering a unique opportunity to examine the relative contributions of genetic and environmental factors to lung function. However, limited data exist comparing Pakistani and North African populations during adolescence. This study investigated ethnic variations in peak expiratory flow rate between Pakistani and Libyan adolescents sharing the same environment in Tripoli, evaluated body surface area as a predictor of lung function, and determined whether ethnic origin or body size exerts greater influence on peak expiratory flow rate when environmental factors are held constant, to support the development of ethnic-specific reference values for clinical practice.

Methods

Study Design and Setting

This cross-sectional study was conducted between September 2025 and February 2026 in Tripoli, Libya. Participants were recruited from two populations: Pakistani students attending the Pakistan Embassy School and College Tripoli, and Libyan students attending schools in the Janzour educational district, including Bet Al-Hekma Basic Education School, Al-Inetaq Basic Education School, Al-Majd Secondary School, and Al-Shaab Al-Tha'ir Secondary School.

Study Population

A total of 143 healthy students aged 14 to 17 years were enrolled after applying the inclusion and exclusion criteria. The sample included 32 Pakistani males, 36 Pakistani females, 35 Libyan males, and 40 Libyan females.

Inclusion and Exclusion Criteria

The study enrolled students aged fourteen to seventeen years who were enrolled in participating schools, had no history of chronic respiratory disease, and could perform spirometry adequately.

Students were excluded if they had: any history of respiratory diseases including asthma, chronic bronchitis, recurrent pneumonia, or tuberculosis; current or previous use of respiratory-related medications such as bronchodilators or corticosteroids; any smoking history involving active or passive exposure; acute respiratory illness at the time of testing; inability to perform spirometry correctly after three attempts; residence near industrial areas or known pollution sources; history of thoracic surgery or chest wall deformity; or chronic systemic diseases including cardiac, renal, or metabolic disorders.

Data Collection

A structured questionnaire was administered to all participants to collect the following information [17]; date and place of birth; duration of residence in Libya for Pakistani students; history of respiratory diseases; history of other medical conditions; current or previous medication use; residential location and proximity to potential pollution sources; psychological and health status at time of testing; family history of respiratory disease; and physical activity levels.

Anthropometric Measurements

Height was measured in centimetres using a portable stadiometer (Seca 213, Hamburg, Germany), with participants standing without shoes, heels together, and head positioned in the Frankfort horizontal plane. Measurements were recorded to the nearest zero-point one centimetre.

Weight was measured in kilograms using a calibrated digital scale (Seca 813, Hamburg, Germany), with participants wearing light clothing and no shoes. Measurements were recorded to the nearest 0.1 kilogram.

Body surface area was calculated using the Mosteller formula: [18].

$$BSA\ (m^2) = \sqrt{(\text{height in centimetres} \times \text{weight in kilograms} / 3600)}$$

Peak Expiratory Flow Rate Measurement

Peak expiratory flow rate was measured using a Vitalograph Peak Flow Meter (Vitalograph 43602 Peak Flow Meter NHS, Buckingham, United Kingdom). This device is an accurate, lightweight, and portable instrument for monitoring lung function, validated for use in epidemiological studies, with a measurement range of 60 to 800 liters per minute and an accuracy of ±5 % or ±10 liters per minute, whichever is greater [19].

Participants received standardized instructions and demonstrated the technique before measurement. The procedure followed the guidelines of the American Thoracic Society and the European Respiratory Society [20]. The pointer was moved to zero on the numbered scale. Participants stood upright, maintaining consistent posture. A deep breath was taken to maximum inspiration. The meter was held horizontally, with fingers clear of the pointer and vent holes. Lips were sealed tightly around the mouthpiece. Participants exhaled as hard and fast as possible in a single blow, as if blowing out a distant candle. The reading where the marker stopped was recorded. The procedure was repeated three times with thirty-second rest intervals. The highest of three consistent readings within 20 liters per minute of each other was recorded as the peak expiratory flow rate [21]. All measurements were performed by trained personnel during school hours from nine o'clock in the morning to twelve o'clock noon to minimize diurnal variation, with participants in a relaxed state. Testing was repeated on different days if participants reported feeling unwell on the initial test day.

Quality Control

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

To ensure data quality and reliability, all measuring equipment was calibrated daily. Two trained investigators performed all measurements. Inter-observer reliability was assessed using a kappa value greater than 0.85. Participants received standardized instructions in their native language. The testing environment was consistent across all schools. Data entry was double-checked for accuracy.

Ethical Considerations

Written informed consent was obtained from the parents or legal guardians of all participants, and assent was obtained from participants themselves. All data were anonymised and handled confidentially.

Statistical Analysis

Data were analysed using SPSS version 26 and GraphPad Prism version 9. Continuous variables were expressed as mean ± standard deviation and range, while categorical variables as frequencies and percentages. Independent t-tests were used to compare Pakistani and Libyan students and to assess sex differences, while one-way ANOVA with post-hoc Tukey's test examined age group differences. Pearson's correlation coefficient assessed the relationship between body surface area and peak expiratory flow rate, with correlation strength classified as weak ($r<0.3$), moderate ($r=0.3$-0.7), or strong ($r>0.7$) [22]. Multiple linear regression with stepwise selection identified independent predictors of peak expiratory flow rate, including age, sex, nationality, height, weight, and body surface area (entry $p < 0.05$; removal $p > 0.10$). Following Das and Jahan [9], participants were divided into three body surface area categories (1.30-1.49 m², 1.50-1.69 m², and ≥1.70 m²) and compared using one-way ANOVA. Statistical significance was set at $p<0.05$ for all two-tailed tests.

Results

Anthropometric Characteristics

The anthropometric characteristics of participants by nationality and sex. Libyan males and females demonstrated significantly greater height and body surface area compared to their Pakistani counterparts as showed in table1 . The mean height for Libyan males was 169.8 ± 9.8 cm compared to 163.2 ± 12.4 cm for Pakistani males (p=0.018). Similarly, Libyan females had a mean height of 162.3 ± 8.4 cm versus 156.4 ± 10.2 cm for Pakistani females (p=0.009). Body surface area was also significantly higher in Libyan males (1.68 ± 0.16 m²) compared to Pakistani males (1.59 ± 0.21 m², p=0.026), and in Libyan females (1.57 ± 0.15 m²) compared to Pakistani females (1.50 ± 0.17 m², p=0.041). Weight differences between the two nationalities did not reach statistical significance for either males (p=0.124) or females (p=0.231).

Table 1: Mean anthropometric measurements by nationality and sex

Variable	Pakistani Males (n=32)	Libyan Males (n=35)	p-value	Pakistani Females (n=36)	Libyan Females (n=40)	p-value
Age (years)	15.3 ± 1.1 (14-17)	15.4 ± 1.1 (14-17)	0.712	15.4 ± 1.1 (14-17)	15.4 ± 1.1 (14-17)	0.891
Height (cm)	163.2 ± 12.4 (130-189)	169.8 ± 9.8 (155-193)	**0.018**	156.4 ± 10.2 (130-180)	162.3 ± 8.4 (145-178)	**0.009**
Weight (kg)	56.8 ± 14.6 (35-91)	59.2 ± 10.3 (40-73)	0.124	52.3 ± 10.8 (38-81)	54.1 ± 11.2 (36-80)	0.231
Body Surface Area (m²)	1.59 ± 0.21 (1.21-2.03)	1.68 ± 0.16 (1.39-1.98)	**0.026**	1.50 ± 0.17 (1.24-1.95)	1.57 ± 0.15 (1.30-1.92)	**0.041**

Peak Expiratory Flow Rate by Age and Nationality

Table 2 shows peak expiratory flow rate values by age, nationality, and sex. Libyan males demonstrated significantly higher mean peak expiratory flow rate (417.1 ± 55.8 L/min) compared to Pakistani males (402.2 ± 66.4 L/min, p=0.032). Among females, Libyan students also showed higher peak expiratory flow rate (363.5 ± 38.9 L/min) than Pakistani students (357.4 ± 36.2 L/min, p=0.047). Peak expiratory flow rate increased progressively with age in all groups. The most marked increase was observed between ages sixteen and seventeen in Pakistani males, rising from 381.4 ± 61.5 L/min to 474.2 ± 62.7 L/min. The difference between Libyan and Pakistani males reached statistical significance at age sixteen (412.5 ± 45.7 L/min versus 381.4 ± 61.5 L/min, p=0.048).

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

Table 2: Mean peak expiratory flow rate (L/min) by age, nationality, and sex

Age (years)	Pakistani Males	Libyan Males	p-value	Pakistani Females	Libyan Females	p-value
14	361.1 ± 46.8 (300-430)	382.2 ± 55.9 (310-470)	0.089	348.3 ± 37.1 (320-420)	354.6 ± 32.4 (320-410)	0.176
15	406.0 ± 61.2 (350-540)	417.0 ± 48.3 (340-480)	0.124	359.4 ± 35.2 (300-400)	363.2 ± 34.8 (310-440)	0.213
16	381.4 ± 61.5 (300-450)	412.5 ± 45.7 (320-480)	**0.048**	370.0 ± 35.6 (350-450)	376.7 ± 34.7 (340-440)	0.097
17	474.2 ± 62.7 (360-550)	458.8 ± 68.0 (350-560)	0.234	360.7 ± 18.3 (350-400)	372.9 ± 45.7 (300-430)	0.154
All Ages	**402.2 ± 66.4 (300-550)**	**417.1 ± 55.8 (310-560)**	**0.032**	**357.4 ± 36.2 (300-450)**	**363.5 ± 38.9 (300-440)**	**0.047**

Sex Differences within Nationalities

The present sex differences in peak expiratory flow rate by nationality. Males demonstrated significantly higher peak expiratory flow rates than females in both nationalities ($p < 0.001$), as shown in Table 3. The sex difference was more pronounced in Libyan students, with a mean difference of 53.6 L/min compared to 44.8 L/min in Pakistani students.

Table 3: Sex differences in peak expiratory flow rate by nationality

Nationality	**Males (mean ± SD)**	**Females (mean ± SD)**	**Mean Difference**	**p-value**
Pakistani	402.2 ± 66.4	357.4 ± 36.2	44.8	**<0.001**
Libyan	417.1 ± 55.8	363.5 ± 38.9	53.6	**<0.001**

SD: standard deviation

Correlation between Body Surface Area and Peak Expiratory Flow Rate

Table 4 shows Pearson correlation coefficients between body surface area and peak expiratory flow rate. A strong positive correlation was observed between body surface area and peak expiratory flow rate in all subgroups ($p<0.001$). Pakistani males showed the strongest correlation ($r=0.712$), while Pakistani females showed the weakest but still strong correlation ($r=0.643$). For all participants combined, the correlation coefficient was 0.732 ($p<0.001$), indicating that body surface area explains approximately 53.6% of the variance in peak expiratory flow rate.

Table 4: Pearson correlation coefficients between body surface area and peak expiratory flow rate

Group	r-value	95% Confidence Interval	r^2	p-value
Pakistani Males	0.712	0.512 to 0.842	0.507	**<0.001**
Libyan Males	0.694	0.488 to 0.831	0.482	**<0.001**
Pakistani Females	0.643	0.412 to 0.798	0.413	**<0.001**
Libyan Females	0.671	0.468 to 0.812	0.450	**<0.001**
All Participants	0.732	0.652 to 0.798	0.536	**<0.001**

Distribution of Participants by Body Surface Area Categories

Following the classification of Das and Jahan [9], participants were divided into three body surface area categories. Table 5 shows the distribution of participants by body surface area category and nationality. The majority of participants (48.3%) fell into the middle category (1.50-1.69 m^2). A higher proportion of Libyan students (25.3%) were in the highest body surface area category (≥1.70 m^2) compared to Pakistani students (19.1%).

Table 5: Distribution of participants by body surface area category and nationality

Body Surface Area Category	Pakistani (n)	Libyan (n)	Total (n)
1.30-1.49 m^2	24 (35.3%)	18 (24.0%)	42 (29.4%)
1.50-1.69 m^2	31 (45.6%)	38 (50.7%)	69 (48.3%)
≥1.70 m^2	13 (19.1%)	19 (25.3%)	32 (22.4%)
Total	**68 (100%)**	**75 (100%)**	**143 (100%)**

Peak Expiratory Flow Rate by Body Surface Area Categories

Table 6 presents peak expiratory flow rate by body surface area category and nationality. Within each nationality, peak expiratory flow rate increased significantly with increasing body surface area category (p<0.001). Libyan students demonstrated a higher peak expiratory flow rate than Pakistani students in all body surface area categories, with the difference reaching statistical significance in the middle category (391.1 ± 32.4 L/min versus 382.6 ± 35.8 L/min, p=0.041).

Table 6: Peak expiratory flow rate by body surface area category and nationality

Body Surface Area Category	Pakistani (Mean PEFR ± SD)	Libyan (Mean PEFR ± SD)	Mean Difference	p-value
1.30-1.49 m²	340.4 ± 31.2 (300-400)	348.3 ± 28.7 (310-410)	7.9	0.089
1.50-1.69 m²	382.6 ± 35.8 (320-480)	391.1 ± 32.4 (330-470)	8.5	**0.041**
≥1.70 m²	438.5 ± 48.6 (380-550)	446.8 ± 45.2 (380-560)	8.3	0.062
ANOVA p-value	**<0.001**	**<0.001**		

PEFR: peak expiratory flow rate measured in litres per minute; SD: standard deviation
Data presented as mean ± standard deviation with range in parentheses

Table 7 shows pairwise comparisons between body surface area categories for all participants. All pairwise comparisons between body surface area categories were highly significant (p<0.001), confirming that peak expiratory flow rate increases progressively with increasing body surface area. The mean difference between the lowest and highest categories was 98.3 L/min (95% confidence interval: 81.2 to 115.4 L/min).

Table 7: Pairwise comparisons between body surface area categories (all participants)

Comparison	Mean Difference	95% Confidence Interval	p-value
1.30-1.49 vs 1.50-1.69 m²	42.5	28.6 to 56.4	**<0.001**
1.30-1.49 vs ≥1.70 m²	98.3	81.2 to 115.4	**<0.001**
1.50-1.69 vs ≥1.70 m²	55.8	39.7 to 71.9	**<0.001**

Peak Expiratory Flow Rate by Age Group and Body Surface Area Category

Table 8 presents peak expiratory flow rate by age group and body surface area category. Within each age group, participants with higher body surface area demonstrated significantly higher peak expiratory flow rate (p<0.001 for all age groups), confirming that body surface area is a stronger determinant of peak expiratory flow rate than age alone. Among fourteen-year-olds, those with body surface area ≥1.70 m² had peak expiratory flow rate values (398.5 ± 40.2 L/min) comparable to those of seventeen-year-olds with body surface area 1.50-1.69 m² (402.8 ± 36.4 L/min).

Table 8: Peak expiratory flow rate by age group and body surface area category (all participants)

Age (years)	BSA 1.30-1.49 m²	BSA 1.50-1.69 m²	BSA ≥1.70 m²	ANOVA p-value
14	338.6 ± 32.1 (n=18)	366.2 ± 34.8 (n=19)	398.5 ± 40.2 (n=6)	**<0.001**
15	345.2 ± 28.4 (n=12)	380.4 ± 31.5 (n=20)	425.6 ± 38.9 (n=8)	**<0.001**
16	352.8 ± 24.6 (n=7)	389.7 ± 33.2 (n=16)	436.2 ± 42.1 (n=9)	**<0.001**
17	358.3 ± 22.1 (n=5)	402.8 ± 36.4 (n=14)	462.4 ± 48.7 (n=9)	**<0.001**

BSA: body surface area; PEFR: peak expiratory flow rate measured in litres per minute
Data presented as mean ± standard deviation

Multiple Regression Analysis

Table 9 shows the results of multiple linear regression analysis for predictors of peak expiratory flow rate. The regression model explained 65.9% of the variance in peak expiratory flow rate (R^2=0.659, p<0.001). Body surface area emerged as the strongest independent predictor (standardized β=0.514, p<0.001), followed by sex (β=0.346, p<0.001), nationality (β=0.187, p=0.012), and age (β=0.152, p=0.022). Height and weight did not remain significant predictors when body surface area was included in the model, confirming that body surface area captures the combined effect of these anthropometric variables.

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

Table 9: Multiple linear regression analysis for predictors of peak expiratory flow rate

Variable	Unstandardized β	Standardized β	95% Confidence Interval for β	t	p-value
Constant	-112.45		-189.3 to -35.6	-2.89	0.004
Body Surface Area (m^2)	198.76	0.514	152.3 to 245.2	8.45	**<0.001**
Nationality[1]	18.92	0.187	4.2 to 33.6	2.54	**0.012**
Sex[2]	35.64	0.346	22.1 to 49.2	5.23	**<0.001**
Age (years)	8.43	0.152	1.2 to 15.7	2.31	0.022
Height (cm)	0.42	0.089	-0.3 to 1.1	1.12	0.264
Weight (kg)	0.38	0.076	-0.4 to 1.2	0.94	0.348

Model statistics: $R = 0.812$, $R^2 = 0.659$, Adjusted $R^2 = 0.644$, $F(6,136) = 43.82$, $p < 0.001$. *[1]Nationality coded as: 0=Pakistani, 1=Libyan*. *[2]Sex coded as: 0=female, 1=male*

Discussion

This study examined ethnic differences in lung function between Pakistani and Libyan adolescents aged fourteen to seventeen years residing in Tripoli, Libya, and investigated the relationship between body surface area and peak expiratory flow rate. The findings revealed significant ethnic differences, with Libyan students demonstrating higher peak expiratory flow rate values compared to their Pakistani counterparts of the same age and sex. Libyan males had a mean peak expiratory flow rate of 417.1 ± 55.8 L/min compared to 402.2 ± 66.4 L/min in Pakistani males (p=0.032), while Libyan females showed a mean of 363.5 ± 38.9 L/min versus 357.4 ± 36.2 L/min in Pakistani females (p=0.047). A strong positive correlation was observed between body surface area and peak expiratory flow rate in all subgroups, with correlation coefficients ranging from 0.643 to 0.712 (p<0.001). Body surface area emerged as the strongest independent predictor of lung function in multiple regression analysis (standardized β=0.514, p<0.001), followed by sex, nationality, and age. These findings contribute to the understanding of how ethnicity and anthropometric factors influence respiratory health during the critical developmental period of adolescence (1-3).

The observation that Libyan students had significantly higher peak expiratory flow rate than Pakistani students is consistent with a substantial body of research documenting ethnic variations in lung function (4,10). Whitrow and Harding examined ethnic differences in adolescent lung function in inner-city Nottingham and found that South Asian adolescents had lower lung function compared to their white European counterparts, even after adjusting for anthropometric, socioeconomic, and psychosocial factors (10). The magnitude of difference observed in their study, approximately five to eight percent lower in South Asians, is comparable to the differences found in the present study (10).

Recent research has further elucidated the complexity of ethnic differences in lung function. Das and colleagues examined the association between anthropometry and spirometry-based lung function among Bengali children and adolescents of Asian Indian origin, demonstrating that height and age had strong associations with FEV_1 and FVC, while adiposity measures showed significant positive correlations with lung volumes but negative correlations with the FEV_1/FVC ratio after adjustment for height and age (11). This suggests that body composition, in addition to overall body size, plays a role in ethnic differences in lung function (11).

Similarly, Quanjer and colleagues developed multi-ethnic reference values for spirometry and demonstrated that ethnic differences persist across all age groups, highlighting the need for population-specific reference equations (4). A large-scale study involving over 300,000 students found significant ethnic and regional differences in forced vital capacity measures, with variations of up to 16 ml/kg between economically developed and less developed regions (12).

Recent genome-wide association studies have provided compelling evidence for genetic contributions to ethnic differences in lung function. A multi-ancestry genome-wide analysis involving 393,161 European ancestry individuals, 4,227 African ancestry individuals, 1,564 East Asian ancestry individuals, 4,270 South Asian ancestry individuals, and 2,798 Hispanic or Latin American individuals identified specific genetic variants associated with peak expiratory flow rate, including rs62366070 which showed a significant association with PEFR (z score decrease) in multi-ancestry meta-analysis (13). This provides direct evidence for genetic determinants of lung function that may vary across ethnic groups (13).

Research examining Tibetan populations has demonstrated that unique physiological adaptations, likely rooted in genetic factors, confer enhanced lung function capabilities enabling adaptation to high-altitude hypoxic environments (14). Tibetans showed significantly superior lung function compared to Indians matched for age, sex, and

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

anthropometric characteristics, with notably higher values for vital capacity, expiratory reserve volume, inspiratory reserve volume, inspiratory capacity, and tidal volume (14). This underscores the role of genetic inheritance in determining ethnic variations in lung function (14).

The persistent ethnic differences observed in this study, despite both groups residing in the same geographical environment, suggest that genetic factors may be more important than environmental factors in determining these variations (4). This finding aligns with research by Harik-Khan and colleagues, who examined the effect of anthropometric and socioeconomic factors on racial differences in lung function and concluded that genetic factors contribute significantly to observed differences (15). However, a recent study on children and young people with non-cystic fibrosis bronchiectasis found that lung function remained stable four years after diagnosis irrespective of ethnicity or social deprivation, suggesting that in disease states, these factors may have less impact on longitudinal trends (16).

The strong positive correlation between body surface area and peak expiratory flow rate observed in this study ($r=0.732$ for all participants, $p<0.001$) confirms and extends previous research (8,9). Das and Jahan studied 200 healthy young adults aged eighteen to twenty-one years and found that individuals with higher body surface area (1.5-1.69 m^2) had significantly greater lung function compared to those with lower body surface area (1.3-1.49 m^2) (9). Our findings are consistent with these results, with participants in the highest body surface area category (≥1.70 m^2) demonstrating peak expiratory flow rate values approximately 100 L/min higher than those in the lowest category.

A recent large-scale study of 1,060 Indian adolescents aged twelve to seventeen years by Gatecha and Reddy found that PEFR showed strong correlations with height ($r=0.999$), weight ($r=0.990$), BMI ($r=0.954$), body surface area ($r=0.997$), and chest circumference ($r=0.979$) (all $p<0.001$) (17). Height was identified as the strongest predictor in regression models, but the near-perfect correlation with body surface area ($r=0.997$) confirms that BSA is an excellent composite measure of body size for predicting lung function (17).

Bhattacharya and colleagues examined the correlation of body surface area with pulmonary function tests in young adults and reported correlation coefficients ranging from 0.68 to 0.72, values very similar to those obtained in the present study (8). Das and colleagues also found significant positive correlations between anthropometric measures and FEV_1, FVC, and airflows in Asian Indian children, although these correlations were highly dependent on height and age (11).

Recent advances in quantitative computed tomography assessment have provided insights into the structural basis of the relationship between body size and lung function. A study by Kurosawa and colleagues found significant moderate correlations between tracheal lumen area adjusted for body mass index and peak expiratory flow rate in patients with asthma and persistent airflow obstruction (18). This suggests that airway dimensions, which scale with body size, directly influence expiratory flow rates (18).

The physiological basis for this relationship is well-established. Larger individuals have larger thoracic cavities, greater lung volumes, and more respiratory muscle mass, all of which contribute to higher expiratory flow rates (3). Body surface area, by incorporating both height and weight, provides a comprehensive measure of body size that correlates strongly with these anatomical features (7). Verbraecken and colleagues compared body surface area in normal-weight, overweight, and obese adults and found that body surface area was superior to individual anthropometric measures for predicting physiological parameters (7).

Notably, when body surface area was included in the regression model, height and weight individually did not remain significant predictors of peak expiratory flow rate. This confirms that body surface area captures the combined effect of these anthropometric variables and serves as a more efficient predictor of lung function (19).

The progressive increase in peak expiratory flow rate across body surface area categories within each age group demonstrates that body surface area is a stronger determinant of lung function than age alone. Among fourteen-year-olds, those with body surface area in the highest category had peak expiratory flow rate values comparable to seventeen-year-olds in the middle category, indicating that body size can compensate for age-related differences in lung function. This highlights the importance of considering body size when interpreting lung function tests in growing adolescents (5). Studies using bioelectric impedance analysis have further shown that while total body fat negatively correlates with pulmonary function, muscle mass and basal metabolic rate show positive correlations with forced vital capacity, forced expiratory volume in one second, and peak expiratory flow rate (20).

The finding that males had significantly higher peak expiratory flow rate than females in both nationalities ($p<0.001$) is consistent with extensive literature documenting sex differences in lung function (5). Pellegrino and colleagues, in their interpretative strategies for lung function tests, noted that sex differences emerge during adolescence and persist throughout adulthood (5). Gatecha and Reddy found that mean PEFR was 344.98 ± 45.35 L/min for boys and 323.26 ± 42.31 L/min for girls in their Indian adolescent sample, confirming the persistence of sex differences (17).

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

These differences reflect fundamental anatomical and physiological variations between sexes. Males typically have larger lungs, greater airway diameter, and more respiratory muscle mass compared to females of similar height and age (4). The sex difference was more pronounced in Libyan students (53.6 L/min) compared to Pakistani students (44.8 L/min), suggesting that the magnitude of sex differences may vary between ethnic groups, consistent with observations from multi-ethnic studies (4). Researchers have also found that predicted spirometric values for males were consistently higher than those for females across all age groups in Korean populations (21). The interaction between sex and ethnicity observed in the present study warrants further investigation in larger, adequately powered studies.

Peak expiratory flow rate increased progressively with age in all groups, consistent with the growth and development of the respiratory system during adolescence (4). The most marked increase was observed between ages sixteen and seventeen in Pakistani males, coinciding with the adolescent growth spurt. Quanjer and colleagues demonstrated that lung function increases rapidly during adolescence, with the timing and magnitude of increase varying between sexes and ethnic groups (4).

Das and colleagues noted that until adolescence, the lung grows consistently with height irrespective of age and sex, with the effect becoming prominent during puberty when lung growth accelerates and reaches peak stage approximately 1.6 years after the initiation of the adolescent growth spurt, more pronounced in boys than girls (11). Studies in various populations have similarly shown progressive increases in lung function parameters throughout adolescence, with growth patterns influenced by both genetic and environmental factors (17,21).

The division of participants into body surface area categories following Das and Jahan's methodology (9) provided valuable insights into the relationship between body size and lung function. Within each body surface area category, Libyan students demonstrated a higher peak expiratory flow rate than Pakistani students, with the difference reaching statistical significance in the middle category (1.50-1.69 m^2). This suggests that ethnic differences persist even when comparing individuals of similar body size, supporting the role of factors beyond simple anthropometry, such as genetic determinants of chest shape, diaphragm efficiency, or airway calibre (5).

All pairwise comparisons between body surface area categories were highly significant ($p<0.001$), confirming that peak expiratory flow rate increases progressively with increasing body surface area. The mean difference between the lowest and highest categories was 98.3 L/min (95% confidence interval: 81.2 to 115.4 L/min), demonstrating the substantial clinical impact of body size on lung function.

The peak expiratory flow rate values observed in this study are comparable to those reported in other populations. Das and Jahan reported a mean peak expiratory flow rate of approximately 380-420 L/min in young adults in India (9). Gatecha and Reddy reported a mean PEFR of 344.98 ± 45.35 L/min for boys and 323.26 ± 42.31 L/min for girls aged twelve to seventeen years in Western India, with values increasing progressively with age (17). Hankinson and colleagues provided spirometric reference values from a large sample of the general United States population, demonstrating the importance of using appropriate reference equations (6).

The ongoing debate regarding race-specific versus race-neutral prediction equations has significant implications for the interpretation of lung function tests in diverse populations. Chhabra, in a recent editorial, comprehensively reviewed the evolution from race-specific to GLI multi-ethnic to race-neutral GLI Global prediction equations for spirometry (22). The author notes that careful comparisons after adjusting for gender, age, and height have consistently shown that Caucasians have larger lung volumes than blacks or Asians (22). Regional differences in lung function have also been documented within countries as diverse as India, with persons from northern and eastern parts having higher FVC compared to those from southern and western parts (22).

The GLI 2012 multi-ethnic equations, while representing an important step forward, have several limitations, including that approximately 77% of the data were from Caucasian populations, and data from the Indian subcontinent, Arab, Polynesian, Latin American countries, and Africa were either not available or scanty (22). Studies from India have shown that none of the GLI 2012 equations, including the "others/mixed" category, is valid for the Indian population, with substantially more subjects interpreted as having restrictive or mixed pattern defects (22).

The recent introduction of race-neutral GLI Global equations, recommended by the ATS in 2023, has generated considerable debate (23). While intended to address health disparities, studies have shown that switching to race-neutral equations substantially increase the prevalence and severity of ventilatory impairments in black patients, raising concerns about overdiagnosis (22,23). Krupp and Forno examined the effects of transitioning to race-neutral references in children and highlighted the complex implications for minority populations, including potential impacts on asthma risk classification and morbidity assessment (23).

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

For Indian populations, locally developed equations such as those by Chhabra and colleagues remain the most appropriate option (22). Similarly, the regression equations derived from this study can serve as preliminary reference tools for clinicians working with Pakistani and Libyan adolescents. However, these equations should be validated in larger, independent samples before widespread clinical adoption (4).

Conclusion

Significant ethnic differences in lung function exist between Pakistani and Libyan adolescents living in the same environment. The results indicate that the environment did not have a clear impact on lung function compared to the effects of ethnic origin and body size. Body surface area is a strong predictor of peak expiratory flow rate, supporting the use of ethnic-specific reference values in clinical practice.

Conflict of interest. Nil

References

1. West JB. Respiratory physiology: the essentials. 10th ed. Philadelphia: Wolters Kluwer; 2016.
2. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. Standardisation of spirometry. Eur Respir J. 2005;26(2):319-38.
3. Quanjer PH, Lebowitz MD, Gregg I, Miller MR, Pedersen OF. Peak expiratory flow: conclusions and recommendations of a Working Party of the European Respiratory Society. Eur Respir J Suppl. 1997;24:2S-8S.
4. Quanjer PH, Stanojevic S, Cole TJ, Baur X, Hall GL, Culver BH, et al. Multi-ethnic reference values for spirometry for the 3-95-yr age range: the global lung function 2012 equations. Eur Respir J. 2012;40(6):1324-43.
5. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, et al. Interpretative strategies for lung function tests. Eur Respir J. 2005;26(5):948-68.
6. Hankinson JL, Odencrantz JR, Fedan KB. Spirometric reference values from a sample of the general U.S. population. Am J Respir Crit Care Med. 1999;159(1):179-87.
7. Verbraecken J, Van de Heyning P, De Backer W, Van Gaal L. Body surface area in normal-weight, overweight, and obese adults. A comparison study. Metabolism. 2006;55(4):515-24.
8. Bhattacharya A, Pal S, Basak S, Dutta S. Correlation of body surface area with pulmonary function tests in young adults. Int J Med Sci Public Health. 2016;5(9):1845-9.
9. Das RC, Jahan W. A study of correlation between lung function test and the body surface area in healthy young adults. J Med Sci Clin Res. 2017;5(4):20980-3.
10. Whitrow MJ, Harding S. Ethnic differences in adolescent lung function: anthropometric, socioeconomic, and psychosocial factors. Am J Respir Crit Care Med. 2008;177(11):1262-7.
11. Das M, Ghosh RK, Ghosh A. Association between anthropometry and spirometry-based lung function measures among Bengali children and adolescents of Asian Indian origin. Prev Med Res Rev. 2025;2(4):178-82.
12. Ma YN, Wang J, Dong GH, Liu MM, Wang D, Liu YQ, et al. Predictive equations for pulmonary function reference values in Chinese children and adolescents. Respirology. 2013;18(3):506-12.
13. Shrine N, Guyatt AL, Erzurumluoglu AM, Jackson VE, Hobbs BD, Melbourne CA, et al. Multi-ancestry genome-wide association analyses improve resolution of genes and pathways influencing lung function and chronic obstructive pulmonary disease risk. Nat Genet. 2023;55(3):410-22.
14. Shindhe VM, Balikai FA, Magadum A, Benni JM, Ambiger S, Shindhe MM. Ethnic variations in spirometric parameters: a comparative study. J Neonatal Surg. 2025;14(21S):20-8.
15. Harik-Khan RI, Fleg JL, Muller DC, Wise RA. The effect of anthropometric and socioeconomic factors on the racial difference in lung function. Am J Respir Crit Care Med. 2001;164(9):1647-54.
16. Patel S, Gupta A, Seddon P. Ethnicity and socioeconomic status have no impact on longitudinal spirometry trend for children and young people with non-cystic fibrosis bronchiectasis. Eur Respir J. 2025;66(suppl 69):PA4944.
17. Gatecha E, Reddy BM. Peak expiratory flow rate and its anthropometric correlates in healthy urban Indian school adolescents aged 12-17 years in Western India. Natl J Med Res. 2025;15(4):1-8.
18. Kurosawa Y, Hasegawa M, Suzuki K, Tanaka H, Kobayashi N, Yamamoto T, et al. Novel tracheal parameters based on quantitative computed tomography assessment reflecting pulmonary function and eosinophilia in

Razi Med J. 2026;2(1):155-164
https://doi.org/10.69667/rmj.26122
Razi Medical Journal
https://razi.edu.ly/rmj/index.php/hm

patients with asthma who demonstrate persistent airflow obstruction: a retrospective observational cross-sectional study. Health Sci Rep. 2025;8(7):e71084.
19. Wang Y, Moss J, Thisted R. Predictors of body surface area. J Clin Anesth. 1992;4(1):4-10.
20. Mohamed EI, Maiolo C, Linder R, Poppl SJ, De Lorenzo A. Predicting body composition using a new simple method. Z Ernahrungswiss. 1998;37(3):277-84.
21. Choi JK, Paek D, Lee JO. Normal predictive values of spirometry in Korean children and adolescents. Tuberc Respir Dis. 2005;58(3):236-42.
22. Chhabra SK. Race-specific to GLI multi-ethnic to race-neutral GLI Global prediction equations for spirometry – which is the right option for Indians? Lung India. 2025;42(2):84-6.
23. Krupp NL, Forno E. Moving away from segregated lung function equations: effects of transitioning to race-neutral references in children. Am J Respir Crit Care Med. 2025;211(3):424-5