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# Reference values for lung function screening in 10- to 81-year-old, healthy, never-smoking residents of Southeast China

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**Abstract**

No official spirometry reference values for Chinese are available.

To establish new Chinese reference values and prediction equations for lung parameters in Chinese individuals of 10 to 81 years of age.

Pulmonary functions were measured according to the American Thoracic Society criteria in 1457 subjects from the Zhejiang coastal province (China). The subjects were 10 to 81 years of age, nonsmokers, and without chronic or acute diseases. Multiple stepwise linear regression analysis was performed for each parameter against age, height, weight, and body mass index (BMI; $kg/m^2$) for males and females separately.

Most lung function variables were nonlinear with age and showed a plateau in younger adults, with a decline after 31 to 35 years. All spirometric data of men were higher than those of women except breathing frequency and forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC). All measured lung function parameters were strongly correlated to age, height, weight, and BMI. The highest correlation being to height in both men and women except for tidal volume and expiratory reserve volume among women. Based on previous studies, Caucasians men from the USA and Switzerland had higher FVC and FEV1 than in the present study, but only slightly higher than American blacks, British, Pakistani, and Singapore; an inverse trend was observed for Malay and Indians. Similar relationships were observed for women. The relationship between height and lung function parameters was nonlinear, with the variance of lung function parameters increasing with increasing height. For each sex, the *z* scores differed significantly by BMI ($P < .001$).

This study provides spirometry equations that can be used for Chinese individuals.

**Abbreviations:** BF = breathing frequency, BMI = body mass index, ERV = expiratory reserve volume, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, IC = inspiratory capacity, MV = minute ventilation volume, MVV = maximal voluntary ventilation, PEF = peak expiratory flow, VC = vital capacity, VT = tidal volume.

**Keywords:** healthy, lung function, never-smoking, reference values, Southeast China

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## 1. Introduction

Normal lung function values are influenced by many factors, including age, height, body mass index (BMI, $kg/m^2$), sex, ethnic origin, physical activity, environmental conditions, altitude, tobacco smoking, and socioeconomic status.[1–4] Recent studies presented equations for many populations in the world, but the Asian populations were only represented by Japanese, Indian, and Caucasian Australasian individuals.[5–7] Caucasian references may be inappropriate for Chinese.[8]

The results of pulmonary function tests in an individual are compared with those of healthy individuals. Therefore, the reference values will influence the treatment decisions, which will have important implications for the patients and the healthcare system. Several sets of normal values had been published over the last decades with considerably variable subject characteristics.[9–17] As a result, healthcare has been forced to adopt reference values derived from several different lung function studies. In Europe and America, the lung functions values and prediction equations are mostly derived from white and black individuals,[18–21] and these values cannot be used for the evaluation of Asian people, especially Chinese residing abroad and/of expatriates of Chinese origin. Since international guidelines discourage the use of spirometry reference equations excluding age, height, and race, there is a need to collect lung function data from Chinese individuals.[22]

The wide range of geographical and climatic conditions in a large country such as China may be associated with regional differences in lung function in healthy people. Failure to consider these ethnic and geographic differences in lung function could lead to errors in diagnosis and disease classification. Several reference values for Chinese populations have been published in the English literature,[8,13,14,23–27] but the available data did not include the influence of sex and age, except 1 study.[26] In addition, embarrassingly, no official reference values for Chinese are available.[8]

Therefore, the aim of this study was to establish new Chinese reference values and prediction equations for lung parameters such as forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), and peak expiratory flow in individuals of 10 to 81 years of age. In addition, this study assessed the differences in lung function parameters using the new values and those from Caucasians from different parts of the world. It is critical to have appropriate standard values for lung function parameters. This would help diagnose various ailments, sometimes in early stage. Such values depend on many factors, and it is of great importance to acquire those specific to the Chinese population.

## 2. Methods

### 2.1. Reference population

Using the stratified-multi-steps-cluster sampling method, 101,182 males and females aged ≥10 yrs from urban and suburban areas (2 cities and 2 counties) of Zhejiang Province were invited to participate in the Chinese Body Physiological Constants Study between September 2016 and July 2017. From these subjects, individuals with any chronic disease were excluded, leaving 38,449 individuals. Among them, never-smokers were selected, leaving 12,142 individuals. Then, the exclusion criteria were applied: history of bronchodilators or antibiotics; common cold or acute bronchitis at spirometry measurement; cough, wheezing, or phlegm at spirometry measurement; history of asthma; history of chronic obstructive pulmonary disease of chronic bronchitis; or history of any lung disease, lung surgery, or pulmonary embolism.[21] After applying these criteria, 1457 individuals (749 males and 708 females) were available for analysis. Never-smokers were defined as subjects with a cumulative smoking history of <1 pack/yr (a pack/yr is defined as years of smoking × the number of cigarettes smoked per day divided by 20). Because of the very small proportion of non-Chinese people in Zhejiang Province, no exclusion was made based on race or nationality. The study was approved by the Ethics Committee of Kunming Medical College of Yunnan province of China.[11,23] Written informed consent was obtained from all subjects before examination.

### 2.2. Stratification

The 1457 subjects were divided into 17 age categories: 10 to 11, 12 to 13, 14 to 15, 16 to 17, 18 to 19, 20 to 22, 23 to 25, 26 to 30, 31 to 35, 36 to 40, 41 to 45, 46 to 50, 51 to 55, 56 to 60, 61 to 65, 66 to 70, ≥71 years.[21,28]

### 2.3. Evaluation of spirometric parameters

The pulmonary capacity tests included tidal volume (VT), breathing frequency (BF), expiratory reserve volume (ERV), inspiratory capacity, and vital capacity. The indices for pulmonary ventilatory tests consisted of FEV1, minute ventilation volume, FVC, FEV1%, and maximal voluntary ventilation. The indices for small airway function tests included peak expiratory flow rate (PEF); expiratory flow rates at 25%, 50%, and 75% (FEF25%, FEF50%, and FEF75%, respectively); and mid expiratory flow (MMEF75/25).[29]

During the time of data collection, "the Chinese Body Physiological Constants" team was equipped with Portable Pulmonary Function Equipment (Master Screen Rotary, Lab4.52, Jaeger, Germany). The equipment was calibrated at least once daily using a 3-L cylinder. The manipulator also performed a daily biological control by assessing the manipulator's own lung function. The manipulator initially went through formal training and was then continuously monitored during the entire study by the head of the project.

The participants were seated and wore a nose clip. Extension or flexion of the neck was avoided. Height and weight were measured bare foot, without clothes, and with standardized equipment. Barometer pressure, temperature, and relative humidity were registered every morning. Tests were performed in the sitting position according to American Thoracic Society guidelines without nose clips after an oral instruction by the technician. The participants were assisted by a specially trained pulmonary function technician during the course of start, duration, and end.[11,21,22,29]

### 2.4. Statistical analysis

All data were analyzed using SPSS 17.0 for Windows (IBM, Armonk, NY). Continuous data were expressed as mean ± standard deviation. Sex-specific regression equations for predicted reference values of pulmonary function in various powers and interactions were formulated based on age, height, weight, and BMI. Two-sided $P$ values <0.05 were considered statistically significant.

## 3. Results

### 3.1. Characteristics of the study population

The characteristics of the study population are shown in Table 1. Of the 1457 subjects, there were 749 males and 708 females. There were few elderly people >71 years. In general, males were taller and heavier than their female counterparts for the same age groups, but the BMI has no difference.

### 3.2. Spirometry data

Spirometry data are presented in Tables 2 to 4 (males) and Tables 5 to 7 (females). When scrutinizing the plots, most lung function variables were nonlinear with age and showed a plateau in younger adults, with a decline after 31 to 35 years. The linearity of decline of spirometric values varied with age. All spirometric data of men were higher than those of women except BF and FEV1/FVC (Fig. 1).

### 3.3. Prediction equations

All measured lung function parameters were strongly correlated to age, height, weight, and BMI. The highest correlation being to height in both men and women except for VT and ERV among females (Tables 8 and 9).

**Table 1**

**Demographic data of the subjects of 10 to 80 years.**

| | Height, cm | | | Weight, kg | | | BMI, kg/m$^2$ | | |
|---|---|---|---|---|---|---|---|---|---|
| Ages | Males (N) | females (N) | *P* | Males (N) | females (N) | *P* | Males (N) | females (N) | *P* |
| 10–11 | 144.1±6.1 (53) | 145.9±6.1 (59) | >.05 | 37.2±7.6 (53) | 36.3±5.8 (59) | >.05 | 17.7±2.4 (53) | 16.9±2.1 (59) | >.05 |
| 12–13 | 157.4±8.8 (85) | 157.1±5.5 (83) | >.05 | 44.9±8.6 (85) | 44.5±6.9 (83) | >.05 | 17.9±1.8 (85) | 17.9±2.2 (83) | >.05 |
| 14–15 | 167.9±6.8 (84) | 158.1±5.0 (85) | <.05 | 55.1±10.4 (84) | 48.2±6.1 (85) | <.05 | 19.4±2.9 (84) | 19.3±2.5 (85) | <.05 |
| 16–17 | 170.5±5.3 (100) | 159.5±4.6 (54) | <.05 | 57.9±8.6 (100) | 51.6±4.8 (54) | <.05 | 19.8±2.7 (100) | 20.2±1.7 (54) | <.05 |
| 18–19 | 171.1±7.4 (26) | 159.1±4.8 (42) | <.05 | 59.5±8.6 (26) | 48.9±4.2 (42) | <.05 | 20.2±2.0 (26) | 19.3±1.7 (42) | >.05 |
| 20–22 | 169.5±5.3 (48) | 161.1±5.4 (35) | <.05 | 59.1±7.2 (48) | 49.9±4.9 (35) | <.05 | 20.5±2.2 (48) | 19.2±1.5 (35) | >.05 |
| 23–25 | 172.4±5.4 (17) | 160.5±4.4 (30) | <.05 | 60.2±6.5 (17) | 51.1±5.6 (30) | <.05 | 20.3±2.2 (17) | 19.8±2.1 (30) | >.05 |
| 26–30 | 172.5±5.5 (17) | 159.1±3.8 (30) | <.05 | 64.6±9.4 (17) | 51.7±5.9 (30) | <.05 | 21.7±2.7 (17) | 20.4±2.1 (30) | >.05 |
| 31–36 | 170.4±6.7 (36) | 160.1±4.4 (50) | <.05 | 66.1±8.8 (36) | 55.1±5.2 (50) | <.05 | 22.7±2.8 (36) | 21.5±1.9 (50) | >.05 |
| 36–40 | 170.6±5.3 (39) | 160.7±4.4 (63) | <.05 | 68.9±8.8 (39) | 56.2±7.7 (63) | <.05 | 23.6±2.1 (39) | 21.7±2.7 (63) | >.05 |
| 41–45 | 170.6±5.8 (40) | 160.9±5.1 (58) | <.05 | 66.6±8.7 (40) | 56.8±7.0 (58) | <.05 | 22.9±2.7 (40) | 21.9±2.5 (58) | >.05 |
| 46–50 | 169.2±5.3 (40) | 160.3±5.5 (32) | <.05 | 67.3±9.7 (40) | 58.2±6.8 (32) | <.05 | 23.4±2.6 (40) | 22.6±2.2 (32) | >.05 |
| 51–55 | 169.1±5.0 (55) | 157.5±4.9 (43) | <.05 | 67.9±9.5 (55) | 58.2±9.4 (43) | <.05 | 23.7±2.9 (55) | 23.4±3.2 (43) | >.05 |
| 56–60 | 168.0±5.1 (39) | 155.7±5.7 (23) | <.05 | 65.0±6.7 (39) | 58.1±8.9 (23) | <.05 | 23.0±2.3 (39) | 23.9±3.2 (23) | >.05 |
| 61–65 | 167.0±5.1 (24) | 153.2±4.8 (16) | <.05 | 61.4±8.1 (24) | 56.51±6.9 (16) | <.05 | 22.0±2.6 (24) | 24.0±2.2 (16) | >.05 |
| 66–70 | 163.0±7.6 (14) | 153.6±5.3 (15) | <.05 | 56.8±7.1 (14) | 52.2±6.5 (15) | <.05 | 21.3±1.7 (14) | 22.1±2.4 (15) | >.05 |
| 71–80 | 164.3±6.4 (16) | 155.06±4.3 (18) | <.05 | 57.7±6.7 (16) | 55.0±5.5 (18) | <.05 | 21.3±1.4 (16) | 22.9±2.0 (18) | >.05 |

BMI = body mass index.

**Table 2**

**Pulmonary capacity data of males among different age groups.**

| Age, yr | VT, L | BF, N/m | ERV, L | IC, L | VC, L |
|---|---|---|---|---|---|
| 10–11 | 0.5±0.2 | 21.6±5.3 | 0.9±0.6 | 1.4±0.3 | 2.2±0.3 |
| 12–13 | 0.6±0.3 | 20.3±4.9 | 1.1±0.5 | 1.7±0.4 | 2.8±0.5 |
| 14–15 | 0.7±0.2 | 17.7±4.4 | 1.3±0.5 | 2.1±0.5 | 3.4±0.6 |
| 16–17 | 0.6±0.2 | 17.0±4.0 | 1.4±0.6 | 2.3±0.7 | 3.8±0.7 |
| 18–19 | 0.5±0.3 | 19.1±4.1 | 1.8±0.6 | 2.3±0.5 | 4.0±0.5 |
| 20–22 | 0.7±0.3 | 16.5±4.1 | 1.8±0.5 | 2.2±0.6 | 3.9±0.5 |
| 23–25 | 0.6±0.3 | 17.4±4.5 | 1.9±0.6 | 2.2±0.5 | 4.1±0.5 |
| 26–30 | 0.6±0.2 | 16.2±3.5 | 1.7±0.6 | 2.4±0.6 | 4.1±0.4 |
| 31–35 | 0.6±0.3 | 17.9±5.5 | 1.3±0.7 | 2.4±0.7 | 3.8±0.6 |
| 36–40 | 0.7±0.4 | 17.0±3.6 | 1.3±0.6 | 2.6±0.7 | 3.8±0.5 |
| 41–45 | 0.6±0.3 | 15.3±3.7 | 1.3±0.6 | 2.4±0.7 | 3.8±0.6 |
| 46–50 | 0.6±0.3 | 17.7±3.8 | 1.3±0.6 | 2.2±0.5 | 3.5±0.5 |
| 51–55 | 0.7±0.2 | 17.1±3.7 | 1.1±0.6 | 2.4±0.6 | 3.4±0.6 |
| 56–60 | 0.7±0.4 | 18.5±4.6 | 1.1±0.4 | 2.2±0.5 | 3.3±0.4 |
| 61–65 | 0.6±0.2 | 18.0±3.3 | 1.0±0.6 | 2.4±0.9 | 3.3±0.5 |
| 66–70 | 0.7±0.4 | 20.1±5.5 | 0.8±0.4 | 2.1±0.6 | 2.7±0.6 |
| ≥71 | 0.6±0.5 | 18.7±5.9 | 0.6±0.3 | 2.1±0.6 | 2.7±0.4 |

BF = breathing frequency, ERV = expiratory reserve volume, IC = inspiratory capacity, VC = vital capacity, VT = tidal volume.

**Table 3**

**Pulmonary ventilation data of males among different age groups.**

| Age, yr | MV, L | FVC, L | FEV1, L | MVV, L | FEV1/FVC, % |
|---|---|---|---|---|---|
| 10–11 | 10.0±3.2 | 2.0±0.3 | 2.0±0.3 | 60.4±14.8 | 96.7±4.4 |
| 12–13 | 12.1±4.4 | 2.6±0.5 | 2.5±0.5 | 82.7±2.5 | 96.9±3.7 |
| 14–15 | 11.1±3.4 | 3.3±0.6 | 3.1±0.6 | 106.7±26.7 | 95.5±11.1 |
| 16–17 | 9.9±4.2 | 3.5±0.6 | 3.4±0.7 | 117.4±25.6 | 96.2±10.5 |
| 18–19 | 10.0±5.8 | 3.8±0.6 | 3.7±0.5 | 103.8±23.7 | 96.9±5.1 |
| 20–22 | 11.2±4.5 | 3.7±0.5 | 3.6±0.4 | 142.1±25.7 | 97.6±3.5 |
| 23–25 | 10.5±5.3 | 3.9±0.6 | 3.7±0.5 | 132.0±20.4 | 96.4±3.7 |
| 36–30 | 9.1±2.5 | 3.8±0.5 | 3.6±0.4 | 132.0±27.0 | 94.0±5.5 |
| 31–35 | 10.0±4.1 | 3.6±0.7 | 3.4±0.6 | 120.2±20.7 | 93.5±4.9 |
| 36–40 | 11.3±5.4 | 3.6±0.5 | 3.3±0.4 | 120.3±24.7 | 92.9±5.5 |
| 41–45 | 9.1±4.2 | 3.5±0.5 | 3.3±0.5 | 106.9±33.4 | 92.6±6.6 |
| 46–50 | 10.2±4.8 | 3.3±0.6 | 3.0±0.4 | 99.1±29.6 | 92.8±6.3 |
| 51–55 | 11.0±3.6 | 3.2±0.6 | 2.8±0.5 | 98.0±28.6 | 89.8±7.1 |
| 56–60 | 12.1±6.6 | 3.2±0.5 | 2.8±0.4 | 95.0±19.1 | 87.5±7.3 |
| 61–65 | 9.8±4.3 | 3.1±0.5 | 2.7±0.4 | 93.7±25.5 | 88.0±9.0 |
| 66–70 | 13.8±7.3 | 2.5±0.6 | 2.2±0.5 | 65.0±25.4 | 89.0±11.4 |
| ≥71 | 13.2±13.0 | 2.4±0.2 | 2.1±0.2 | 63.2±39.6 | 87.2±4.1 |

FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, MV = minute ventilation volume, MVV = maximal voluntary ventilation.

**Table 4**

**Small airway function data of males among different age groups.**

| Age, yr | PEF, L/s | FEF25%, L/s | FEF50%, L/s | FEF75%, L/s | MMEF75/25, L/s |
|---|---|---|---|---|---|
| 10–11 | 4.1±0.7 | 3.7±0.6 | 2.6±0.5 | 1.2±0.4 | 2.3±0.5 |
| 12–13 | 5.1±1.1 | 4.7±1.0 | 3.5±0.9 | 1.8±0.7 | 3.2±1.0 |
| 14–15 | 6.0±1.3 | 5.5±1.1 | 4.2±1.0 | 2.5±0.8 | 4.1±1.0 |
| 16–17 | 7.0±1.6 | 6.3±1.3 | 4.7±1.1 | 2.9±0.8 | 4.7±1.0 |
| 18–19 | 7.3±1.6 | 6.8±1.3 | 5.1±1.0 | 2.9±0.9 | 4.9±1.1 |
| 20–22 | 7.7±1.5 | 7.1±1.2 | 5.1±1.0 | 2.7±0.7 | 4.8±1.0 |
| 23–25 | 7.8±1.4 | 7.0±1.1 | 5.1±1.2 | 2.8±0.8 | 4.5±1.2 |
| 26–30 | 7.8±1.6 | 6.8±1.2 | 4.5±1.0 | 2.3±0.6 | 4.2±0.9 |
| 31–35 | 7.1±1.7 | 6.5±1.3 | 4.6±1.1 | 2.1±1.0 | 4.1±1.3 |
| 36–40 | 7.0±1.5 | 6.4±1.4 | 4.2±1.0 | 1.9±0.5 | 3.8±0.8 |
| 41–45 | 7.1±1.9 | 6.4±1.8 | 4.4±1.5 | 1.8±0.7 | 3.9±1.3 |
| 46–50 | 6.9±1.6 | 6.2±1.4 | 4.1±1.1 | 1.6±0.5 | 3.5±0.9 |
| 51–55 | 6.4±1.7 | 5.7±1.5 | 3.6±1.1 | 1.3±0.6 | 3.0±1.0 |
| 56–60 | 5.6±1.6 | 5.2±1.5 | 3.4±1.0 | 1.2±0.7 | 2.8±1.0 |
| 61–65 | 5.6±2.1 | 5.0±1.9 | 3.3±1.2 | 1.2±0.6 | 2.8±1.1 |
| 66–70 | 4.8±1.7 | 4.2±1.5 | 2.6±1.0 | 1.0±0.5 | 2.2±0.9 |
| ≥71 | 4.3±2.4 | 4.0±1.7 | 2.3±0.7 | 0.9±0.5 | 2.1±0.7 |

FEF25%/FEF50%/FEF75% = expiratory flow rates at 25%/ 50%/75%(respectively), MMEF75/25 = mid expiratory flow, PEF = peak expiratory flow.

**Table 5**

**Pulmonary capacity data of females among different age groups.**

| Age, yr | VT, L | BF, N/m | ERV, L | IC, L | VC, L |
|---|---|---|---|---|---|
| 10–11 | 0.5±0.2 | 20.6±5.8 | 0.7±0.3 | 1.3±0.3 | 2.0±0.3 |
| 12–13 | 0.6±0.2 | 20.3±4.7 | 1.0±0.4 | 1.5±0.4 | 2.5±0.3 |
| 14–15 | 0.5±0.2 | 20.0±5.0 | 1.0±0.4 | 1.6±0.4 | 2.6±0.3 |
| 16–17 | 0.5±0.2 | 18.1±3.7 | 0.8±0.3 | 2.0±0.5 | 2.9±0.4 |
| 18–19 | 0.5±0.2 | 18.8±4.4 | 1.2±0.5 | 1.8±0.5 | 2.8±0.4 |
| 20–22 | 0.5±0.5 | 17.7±4.3 | 1.2±0.5 | 1.6±0.5 | 2.8±0.4 |
| 23–25 | 0.7±0.6 | 18.5±3.2 | 1.2±0.4 | 1.7±0.4 | 2.9±0.3 |
| 26–30 | 0.5±0.2 | 17.4±3.7 | 1.1±0.4 | 1.8±0.4 | 2.9±0.4 |
| 31–35 | 0.6±0.3 | 18.7±5.6 | 1.2±0.5 | 1.8±0.5 | 2.9±0.3 |
| 36–40 | 0.5±0.2 | 19.0±4.0 | 0.8±0.4 | 2.0±0.6 | 2.8±0.3 |
| 41–45 | 0.5±0.1 | 19.2±3.8 | 1.0±0.6 | 1.8±0.5 | 2.7±0.4 |
| 46–50 | 0.6±0.2 | 18.6±5.0 | 1.0±0.3 | 2.0±0.4 | 2.9±0.5 |
| 51–55 | 0.5±0.1 | 19.6±4.2 | 0.8±0.4 | 1.8±0.5 | 2.5±0.4 |
| 56–60 | 0.5±0.1 | 19.8±4.1 | 0.7±0.3 | 1.8±0.4 | 2.5±0.3 |
| 61–65 | 0.5±0.1 | 22.0±7.4 | 0.8±0.4 | 1.6±0.5 | 2.2±0.5 |
| 66–70 | 0.5±0.2 | 20.2±4.2 | 0.7±0.3 | 1.4±0.4 | 2.0±0.4 |
| ≥71 | 1.3±0.2 | 20.1±6.0 | 0.6±0.2 | 1.2±0.1 | 1.8±0.4 |

BF = breathing frequency, ERV = expiratory reserve volume, IC = inspiratory capacity, VC = vital capacity, VT = tidal volume.

**Table 6**

**Pulmonary ventilation data of females among different age groups.**

| Age, yr | MV, L | FVC, L | FEV1, L | MVV, L | FEV1/FVC, % |
|---|---|---|---|---|---|
| 10–11 | 10.5±4.6 | 1.8±0.2 | 1.8±0.2 | 56.1±15.2 | 97.8±3.3 |
| 12–13 | 10.7±4.0 | 2.4±0.4 | 2.3±0.3 | 72.2±16.9 | 97.6±3.4 |
| 14–15 | 9.6±3.4 | 2.5±0.3 | 2.4±0.3 | 77.3±18.2 | 96.9±5.7 |
| 16–17 | 8.7±3.6 | 2.7±0.5 | 2.7±0.4 | 85.7±17.6 | 97.8±4.0 |
| 18–19 | 8.6±2.9 | 2.6±0.4 | 2.5±0.4 | 81.6±18.0 | 98.3±3.0 |
| 20–22 | 8.9±3.3 | 2.7±0.4 | 2.6±0.4 | 90.5±21.3 | 96.8±4.1 |
| 23–25 | 10.2±4.9 | 2.8±0.3 | 2.7±0.3 | 88.1±23.3 | 97.0±4.9 |
| 26–30 | 8.4±3.4 | 2.8±0.4 | 2.6±0.4 | 90.8±20.0 | 95.9±4.8 |
| 31–35 | 10.7±4.6 | 2.8±0.4 | 2.6±0.3 | 91.3±17.6 | 95.0±5.0 |
| 36–40 | 9.5±4.1 | 2.6±0.3 | 2.5±0.3 | 8.0±16.3 | 94.1±5.4 |
| 41–45 | 8.7±2.7 | 2.6±0.4 | 2.4±0.4 | 79.9±19.9 | 92.1±6.0 |
| 46–50 | 10.1±3.3 | 2.6±0.4 | 2.4±0.4 | 77.5±21.2 | 89.5±7.5 |
| 51–55 | 8.4±1.7 | 2.4±0.4 | 2.2±0.3 | 72.8±18.6 | 92.4±6.1 |
| 56–60 | 10.0±3.6 | 2.3±0.3 | 2.0±0.3 | 64.2±12.8 | 88.6±8.1 |
| 61–65 | 9.7±2.9 | 2.1±0.5 | 1.9±0.4 | 60.6±18.4 | 90.1±8.1 |
| 66–70 | 10.3±4.9 | 1.9±0.4 | 1.8±0.4 | 50.6±14.2 | 92.5±6.7 |
| ≥71 | 9.6±0.1 | 1.7±0.1 | 1.7±0.2 | 40.3±0.7 | 90.1±10.1 |

FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, MV = minute ventilation volume, MVV = maximal voluntary ventilation.

**Table 7**

**Small airway function data of females among different age groups.**

| Age, yr | PEF, L/s | FEF25%, L/s | FEE50%, L/s | FEF75%, L/s | MMEF75/25, L/s |
|---|---|---|---|---|---|
| 10–11 | 3.8±0.8 | 3.6±0.7 | 2.6±0.7 | 1.3±0.5 | 2.4±0.7 |
| 12–13 | 4.5±1.0 | 4.3±0.9 | 3.2±0.7 | 1.7±0.6 | 3.0±0.7 |
| 14–15 | 4.6±1.0 | 4.5±1.2 | 3.5±0.8 | 2.1±0.7 | 3.3±0.9 |
| 16–17 | 5.2±1.2 | 4.9±0.9 | 3.7±0.8 | 2.3±0.5 | 3.6±0.7 |
| 18–19 | 5.0±0.9 | 4.8±0.8 | 3.7±0.7 | 2.0±0.6 | 3.5±0.7 |
| 20–22 | 5.2±0.9 | 4.9±0.8 | 3.8±0.7 | 2.0±0.6 | 3.5±0.7 |
| 23–25 | 5.6±1.0 | 5.3±0.9 | 3.9±0.9 | 2.2±0.8 | 3.7±0.9 |
| 26–30 | 5.5±1.2 | 5.2±1.1 | 3.9±0.8 | 2.0±0.6 | 3.5±0.8 |
| 31–35 | 5.3±1.4 | 5.0±1.0 | 3.6±0.9 | 1.7±0.5 | 3.3±0.8 |
| 36–40 | 5.0±1.0 | 4.8±1.2 | 3.4±0.7 | 1.6±0.4 | 3.0±0.6 |
| 41–45 | 5.0±1.0 | 4.8±0.9 | 3.4±0.8 | 1.4±0.5 | 2.9±0.7 |
| 46–50 | 4.5±1.3 | 4.2±1.2 | 2.9±0.8 | 1.1±0.5 | 2.4±0.7 |
| 51–55 | 4.7±1.2 | 4.3±0.9 | 3.0±0.6 | 1.1±0.5 | 2.4±0.6 |
| 56–60 | 4.2±1.2 | 3.9±1.1 | 2.6±0.7 | 1.2±0.8 | 2.2±0.9 |
| 61–65 | 3.9±1.1 | 3.7±1.0 | 2.7±0.8 | 1.1±0.5 | 2.2±0.8 |
| 66–70 | 3.8±0.9 | 3.7±1.0 | 2.4±0.9 | 0.9±0.5 | 1.9±0.7 |
| ≥71 | 3.1±0.5 | 3.5±0.2 | 2.3±0.3 | 0.7±0.1 | 1.5±0.3 |

FEF25%/FEF50%/FEF75% = expiratory flow rates at 25%/ 50%/75%(respectively), MMEF75/25 = mid expiratory flow, PEF = peak expiratory flow.

### *3.4. Comparisons with other populations*

The predicted values of various pulmonary function measurements obtained from these regression equations for subjects of 30 years and height of 1.65 m for men and 1.55 m for women were compared with those from other studies.[3,14,21,30–34] Caucasians males from the USA and Switzerland had higher FVC and FEV1 than in the present study, but only slightly higher than American blacks, British, Pakistani, and Singapore; an inverse trend was observed for Malay and Indians (Fig. 2). Similar relationships were observed for women.

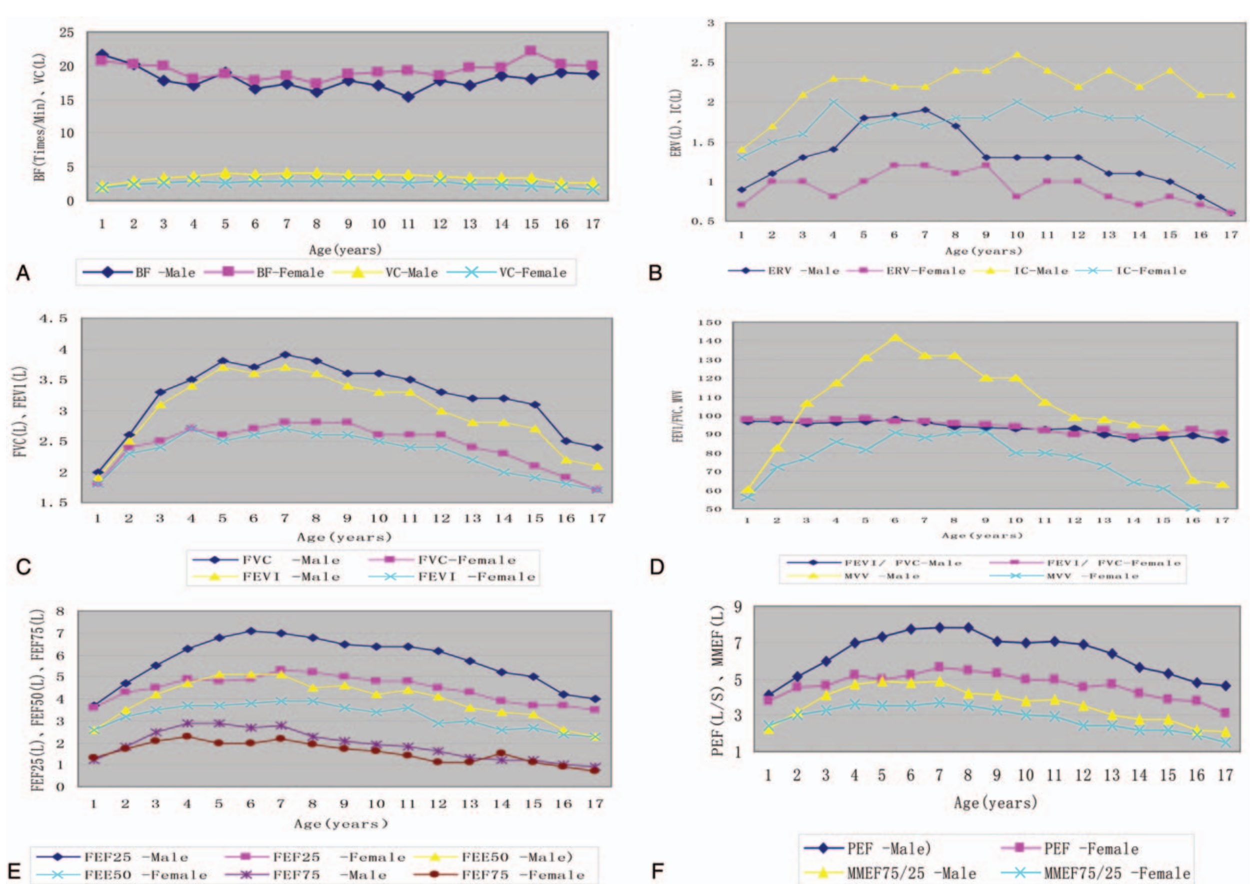


**Figure 1.** Spirometry data of all subjects across the 17 age categories, with 95% confidence. ERV = expiratory reserve volume, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, IC = inspiratory capacity, MVV = maximal voluntary ventilation, PEF = peak expiratory flow, VT = tidal volume.

**Table 8**

**Prediction equations for the lung function variables of females.**

| | Equation | $R^2$ |
|---|---|---|
| VT, L | Yx02C6; = 0.434 + 0.000H − 0.001A + 0.002W − 0.002B | 0.001 |
| ERV, L | Yx02C6; = −2.622 + 0.026H − 0.010W | 0.096 |
| IC, L | Yx02C6; = 0.523 + 0.047W − 0.053B-0.005A | 0.282 |
| VC, L | Yx02C6; = −3.802 + 0.037H + 0.014W − 0.006A | 0.469 |
| FVC, L | Yx02C6; = −3.863 + 0.037H + 0.014W − 0.006A | 0.435 |
| FEV1, L | Yx02C6; = −4.645 + 0.042H − 0.009A + 0.029B | 0.456 |
| FEV1/FVC, % | Yx02C6; = 102.904–0.136A − 0.072W | 0.207 |
| PEF, L | Yx02C6; = −5.042 + 0.057H − 0.013A + 0.025W | 0.183 |
| FEF25, L | Yx02C6; = −3.663 + 0.045H − 0.015A + 0.029W | 0.183 |
| FEF50, L | Yx02C6; = −4.388 + 0.047H − 0.016A + 0.039B | 0.173 |
| FEF75, L | Yx02C6; = −15.609 − 0.021A + 0.111H + 0.355B − 0.136W | 0.262 |
| MMEF75/25, L | Yx02C6; = −15.780 + 0.119H − 0.024A + 0.33B − 0.118W | 0.241 |
| MVV, L | Yx02C6; = −141.456 + 1.294H − 0.284A + 1.135B | 0.187 |

ERV = expiratory reserve volume, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, IC = inspiratory capacity, MVV = maximal voluntary ventilation, PEF = peak expiratory flow, VC = vital capacity, VT = tidal volume.

**Table 9**

**Prediction equations for the lung function variables of males.**

| | Equation | $R^2$ |
|---|---|---|
| VT, L | Yx02C6; = −0.209 + 0.005H | 0.033 |
| ERV, L | Yx02C6; = −3.031 + 0.031H − 0.037BMI − 0.005A | 0.223 |
| IC, L | Yx02C6; = −1.291 + 0.023W + 0.013H | 0.352 |
| VC, L | Yx02C6; = −1.291 + 0.023W + 0.013H | 0.625 |
| FVC, L | Yx02C6; = −5.458 + 0.049H − 0.008A + 0.012W | 0.591 |
| FEV1, L | Yx02C6; = −6.205 + 0.054H − 0.012A + 0.027B | 0.578 |
| FEV1/FVC, % | Yx02C6; = 98.875 − 0.159A | 0.123 |
| PEF, L | Yx02C6; = −11.012 + 0.096H + 0.087B − 0.015A | 0.304 |
| FEF25, L | Yx02C6; = −9.672 + 0.086H − 0.015A + 0.079B | 0.317 |
| FEF50, L | Yx02C6; = −7.057 + 0.07H − 0.02A | 0.297 |
| FEF75, L | Yx02C6; = −15.740–0.026A + 0.115H − 0.108W + 0.274B | 0.395 |
| MMEF75/25, L | Yx02C6; = −7.880 + 0.075H − 0.029A | 0.367 |
| MVV, L | Yx02C6; = −251.175 + 2.12H − 0.504A + 0.888B | 0.383 |

BMI = body mass index, ERV = expiratory reserve volume, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, IC = inspiratory capacity, MVV = maximal voluntary ventilation, PEF = peak expiratory flow, VC = vital capacity, VT = tidal volume.

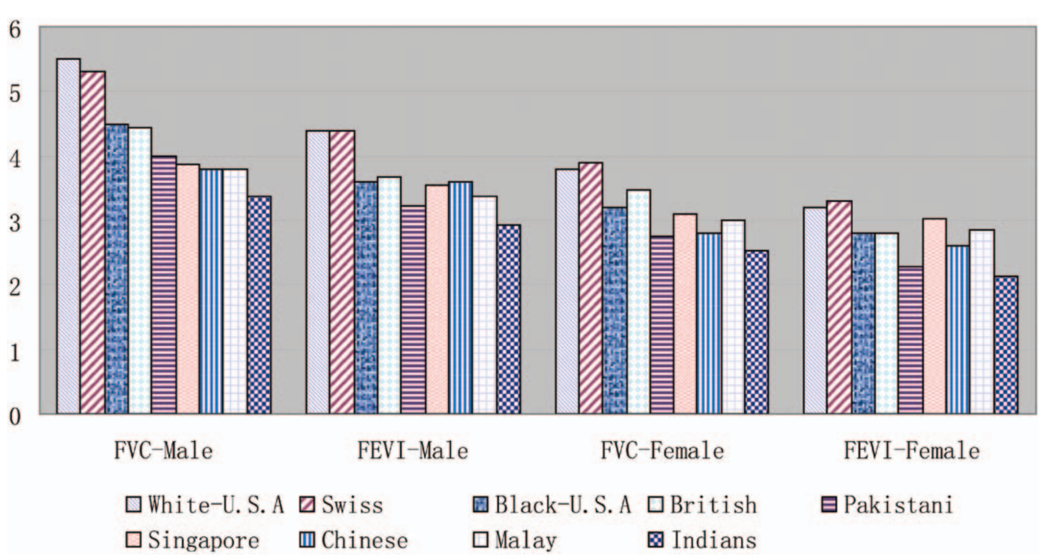


**Figure 2.** Comparison of mean FVC and FEV1 in males and females using values from different populations. FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity.

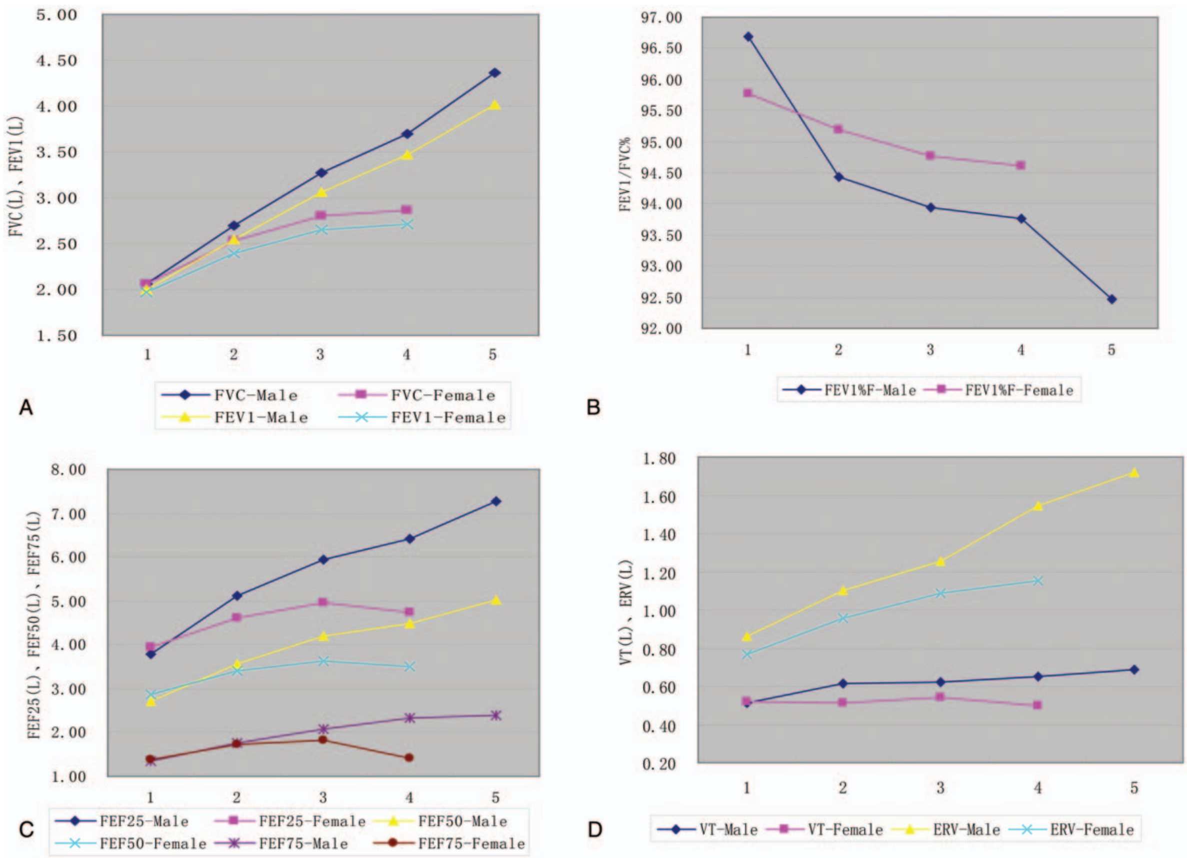


**Figure 3.** Height dependency of mean values of lung function variables, Q1: ≤150 cm; Q2: 151–160 cm; Q3: 161–170 cm; Q4: 171–180 cm; Q5: >180 cm. ERV = expiratory reserve volume, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity, IC = inspiratory capacity, MVV = maximal voluntary ventilation, PEF = peak expiratory flow, VT = tidal volume.

### 3.5. Association between height and lung function

Graphic analysis of raw data revealed that the relationship between height and lung function parameters was nonlinear, with the variance of lung function parameters increasing with increasing height (Fig. 3).

### 3.6. Association between BMI and lung function

The relationships between BMI and FEV1 and FVC were observed by plotting the $z$ scores for each of the 5 quintiles of BMI (Fig. 4). For each sex, the $z$ scores differed significantly by BMI ($P < .001$), being the greatest in the middle quintile ranges and lowest at the extremes. A different pattern was observed for FEV1% ($P < .001$).

## 4. Discussion

Embarrassingly, no official spirometry reference values for Chinese are available. Several reference values for Chinese populations have been published in the English literature,[8,13,14,23–27] but the available data did not include the influence of sex and age, except 1 study.[26] Therefore, the aim of the present study was to establish new Chinese reference values and prediction equations for lung parameters in Chinese individuals of 10 to 81 years of age. The results provide spirometry equations that can be used for Chinese individuals. The results also show that these equations are different from those derived from various populations around the globe.[3,14,21,30–34]

Lung function depends on a variety of individual, behavioral, and environmental factors.[1–4] It is obvious that these characteristics changed with the 1978 Chinese economic reform. Therefore, it is natural that the lung function values changed in the last 2 decades, making older references values obsolete.[35] Indeed, the values of FVC and FEV1 were different from those from earlier studies.[14–17] Although differences in equipment or methodology may explain some of these variations, much of it appears to be real and must therefore be due to other causes such as socioeconomic changes. Therefore, new data are necessary. The present study represents one of the largest evaluations to date of lung function among Chinese living in mainland China.[8,13,14,23–27] In addition to the large sample, strengths of the study include the use of a common manual of operations in all sites that incorporated well-recognized, standardized procedures and strict attention to quality control. These quality controls, based on repetitive measurements, showed no systematic differences among populations.[36]

In spite of the limitations of the sampling design, this large, well-characterized cohort provides useful insights into patterns of lung function among rural workers, industrial workers, teachers, students, and civil servant in the Zhejiang province of China. At the time this study was designed, it was impractical to attempt a true random sampling of local residents. Therefore, our choice of sampling frames within each geographic area was ultimately

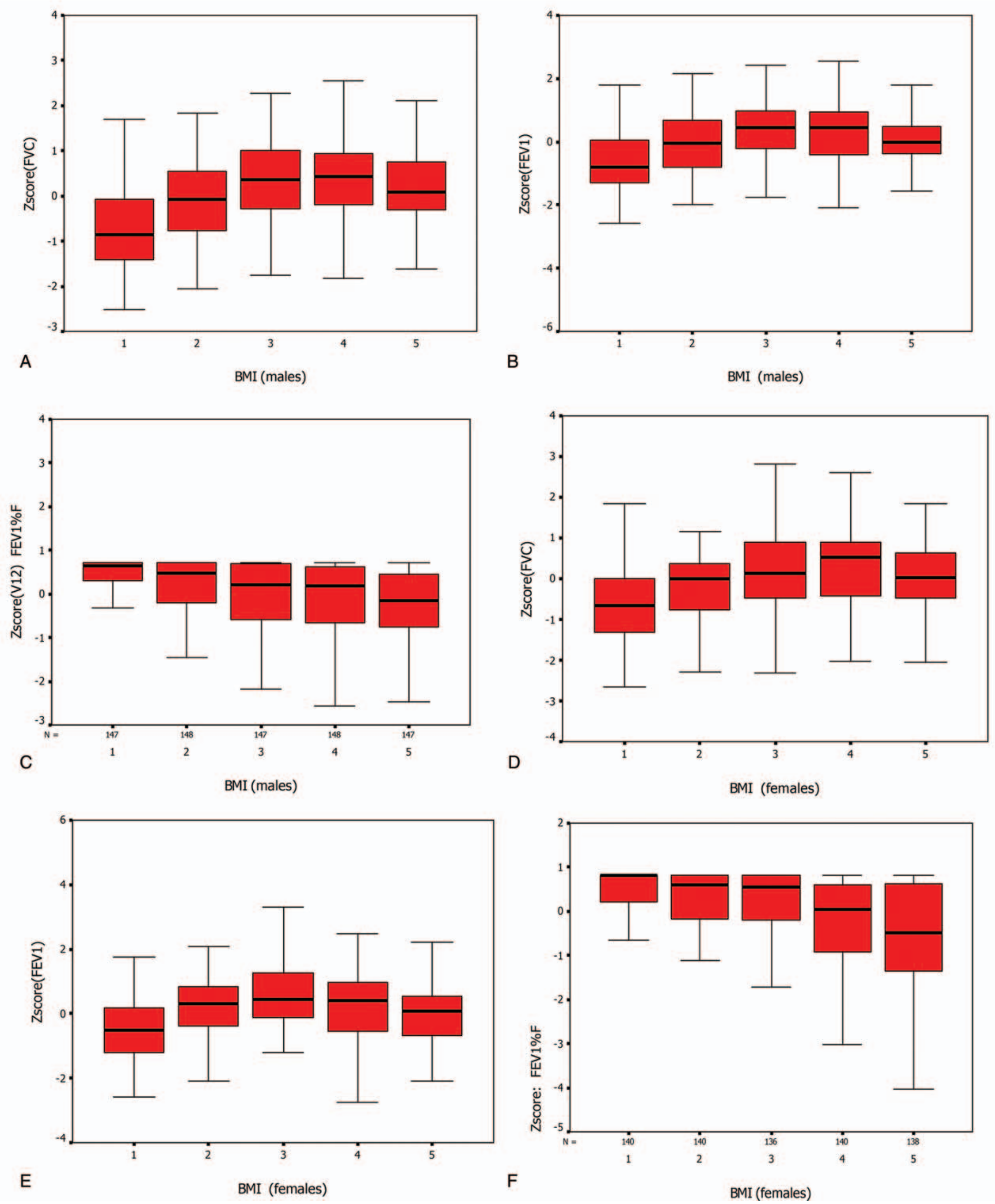


**Figure 4.** *Z* score (observed—predicted/SD about regression line) means and 95% confidence intervals for FEV1, FVC, and FEV1% for Chinese men and women by BMI quintile. In males: Q1: ≤17.94; Q2: 17.95–19.66; Q3: 19.67–21.59; Q4: 21.6–23.64; Q5: 23.65–30.78; in females: Q1: ≤17.94; Q2: 17.95–19.53; Q3: 19.54–20.89; Q4: 20.9–22.94; Q5: 22.94–31.4. BMI = body mass index, FEV1 = forced expiratory volume in 1 second, FVC = forced vital capacity.

dictated by the practical realities of being able to carry out this large field trial with the lowest costs possible. Therefore, we consider that the population used for this study is likely to be no more or less representative of the general population of southeast China mainland.[12,37,38]

The lung function data and prediction equations were derived from 1457 healthy, nonsmoking, Chinese males and females who were living in Zhejiang Province. Establishing regression equations to predict various measurements of normal lung function on a regional basis in a country like China is pertinent because of the wide variations in geography, climate, food habits, and ethnic groups among different regions. Defining should variations is important for the treatment of patients with various illness.[39] Within a given age and height for both sexes, the average age-height adjusted values were consistently higher in males than in females, as supported by previous studies.[8,14,15,26,27] The prediction equations from the European Community for Coal and Steel, which were confirmed by the European Community Respiratory Health Survey, are commonly used in many of countries.[40,41] Approximately 97% of the residents of these countries are Caucasian. With globalization, many Chinese are emigrating to other countries, and lung function equations for Chinese individuals are needed. For these reasons, reference equations should be formulated for Chinese.[42,43]

Finally, the observed differences in lung function may in part reflect differences in BMI. The relationship between FVC, FEV1, and BMI was curvilinear. Lung function appears to increase with BMI at least through the first 60 percentiles of the population. This could be due, at least in part, to the abdominal distribution of body fat, which impedes the maximal expansion of the lungs.[44]

The present study is not without limitations. No infants ($<$10 years of age) were included. In addition, there were few elderly people $\geq$71 years. Therefore the applications of reference equations to this age group should be made with caution. No chest radiographic examinations were performed, which might have resulted in the inclusion of some patients with asymptomatic lung diseases of the restrictive type. The potential effect of altitude (8–43.2 m above sea level) was not tested simply because the Zhejiang province is a coastal region without mountains. Therefore, altitude should not be a confounding variable in the present study, as opposed to studies that included individuals living at high altitude.[45–47] Additional study is necessary to address these issues.

In conclusion, the present study provides spirometry reference values and equations that can be used for Chinese individuals.

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