The effects of body mass index on spirometry tests among adults in Xi’an, China

Shengyu Wang, MDa,b, Xiuzhen Sun, MDc, Te-Chun Hsia, MD, PhDd, Xiaobo Lin, MDb, Manxiang Li, MD, PhD.a

1. Introduction

Obesity is one of the most important issues in the area of public health worldwide[1] because it has been associated with many common diseases (such as hypertension, diabetes, and hyperlipidemia[2]). It is usually measured by using body mass index (BMI) which is a reflection of weight and height. However, it is an ignored fact that obese people have higher risk of respiratory symptoms. They often feel short breath, particularly during exercise, even if they have no pulmonary diseases. To investigate the effect of obesity on the respiratory system, many researchers use the values of pulmonary function tests (PFTs), and also analyzed the data from 373 patients in North American and found BMI had the significant negative effects on all of the lung volumes, especially on functional residual capacity (FRC) and expiratory reserve volume (ERV). Pelosi et al[16] also investigated the effect of BMI on FRC, respiratory mechanics and gas exchange during general anesthesia in Italy. They concluded that FRC and compliance of the total respiratory system decreased exponentially with increasing BMI. Watson and Pride[7] also drew the similar results that total lung capacity (TLC) decreased in obese subjects from United Kingdom. Nevertheless, Fung et al[8] found BMI had a positive effect on lung function in girls from 1586 healthy children in Singapore.

In fact, the values of PFTs are usually determined by many factors, such as age, height, gender, weight, race, or ethnic origin. The total lung volumes and capacities decline when people get older, and the total lung capacities and force expiratory volume are larger in males than females.[9] Additionally, lung function is different among Blacks, Hispanics, Native Americans, and Caucasians. Ethnic differences in lung function have been proved, especially for Asians,[10] Latin Americans,[11] Indians,[12] and South Africans.[13] Thus, the relationship between BMI and PFTs varies with age, race, geographical region and the different obesity standards that are used.

To date, few studies have examined the relationship between obesity and lung function among adults in the northern Chinese urban communities according to the Chinese criteria for obesity.

Abstract

Obese people have higher risk of respiratory symptoms. The relationship between obesity and lung function varies with age, race, and geographical region. The objective of this study is to examine the effects of body mass index on spirometric tests among adults in Xi’an city.

This is a cross-sectional study. Pulmonary function testing was conducted on participants recruited from Xi’an, China between July and August 2012. Force expiratory volume in first second (FEV1), force vital capacity (FVC), FEV1/FVC, peak expiratory flow (PEF), and forced expiratory flow at 25–75% (FEF25–75) were measured by portable Spirometer. Lung function was analyzed according to Chinese standard of general obesity.

A total of 770 subjects were analyzed in this study, of whom 299 were males and 471 were females. FVC% (P<.037) decreased significantly in obese subjects than in nonobese subjects. FVC% (P<.02) declined significantly in overweight subjects than in normal subjects. For smoker, FEV1% (P<.03) and FVC% (P<.02) were lower notably in overweight subjects than in normal subjects. FEV1% (P=.0008), FVC% (P=.0004), and PEF% (P<.0001) were higher significantly in normal subjects than in underweight subjects. FVC notably decreased in obese people, not FEV1, FEV1/FVC, PEF, and FEF25–75, FEV1, FVC, and PEF were higher significantly in normal subjects than in underweight subjects. FVC is affected by BMI in diphasic change.

Abbreviations: BMI = body mass index, ERV = expiratory reserve volume, FEF25–75 = forced expiratory flow at 25–75%, FEV1 = forced expiratory volume in first second, FRC = functional residual capacity, FVC = force vital capacity, PEF = peak expiratory flow, PFTs = pulmonary function tests, TLC = total lung capacity.

Keywords: body mass index, obesity, pulmonary function tests, spirometry.
Thus, the aim of our study is to investigate the effect of BMI on spirometric tests in a community of Xi’an city.

2. Methods

2.1. Subjects

This is a cross-sectional study, which was conducted between July and August 2012. Subjects (aged 18–80 years) who had lived in Xi’an, China for more than 2 years were recruited. Participants provided informed consent and completed a healthy questionnaire about height, weight, smoking status, and medical history. Patients that self-reported chronic lung disease on the health survey were excluded from the analysis. This study was approved by the ethic committee from the First Affiliated Hospital of Xi’an Medical University.

2.2. Pulmonary function tests

Force expiratory volume in first second (FEV1), forced vital capacity (FVC), FEV1/FVC, peak expiratory flow (PEF), and forced expiratory volume at 25–75% (FEF25–75) were measured by portable Spirometer (Spirobank, GTM, Medical International Research, Rome, Italy). Three FVC maneuvers should be performed to meet acceptability for 1 subject. Repeatability should be checked once 3 acceptable FVC maneuvers obtained and if not met, more FVC maneuvers should be performed (not usually more than 8). The exclusion criteria were incomplete efforts or subjects coughed. PFTs were performed by certified respiratory therapists, according to American Thoracic Society/European Respiratory Society.114 All predicted values were based off the Knutson prediction model.

2.3. Definition of obesity

BMI is calculated according to the formula of weight (kg)/height² (m²) for all subjects. Subjects were classified according to the criteria set forth by the Chinese Obesity Working Group: underweight (BMI < 18.5); normal (18.5 ≤ BMI < 24); overweight (24 ≤ BMI < 28); and general obesity (BMI ≥ 28).115

2.4. Statistic method

The data were analyzed by using JMP® version 10 (SAS, Inc., Cary, NC) and GraphPad Prism Version 5.0 (GraphPad Software, Inc., San Diego, CA). The categorical variables were analyzed by Chi-square test or Fisher exact test. The measurement variables were analyzed by Student t test or Mann–Whitney U test. Results are reported as mean ± standard error of the mean (SEM), P-value (2-tailed) < .05 was considered statistically significant.

3. Results

Figure 1 shows a total of 803 volunteers participated in this study and 33 subjects were excluded because PFTs did not meet the requirements. Summary characteristics and spirometric variables of 770 subjects are shown in Table 1. The total population was with a mean age of 58.15 ± 0.56 years. There were 299 males and 471 females. No significant differences in age or BMI were found between the males and females. As for spirometric tests, FEV1 (P < 0.0001), FVC (P < 0.0001), PEF (P < 0.0001), and FEF25–75 (P < 0.0001) were higher significantly in males than in females (Table 1). However, FEV1/FVC (P < 0.0001) was lower significantly in males than in females. Male smokers were more significantly than female smokers (P < 0.0001).

To analyze the effect of BMI on spirometric values, the subjects firstly were divided into 2 groups: nonobesity (BMI < 24 kg/m²) and obesity (BMI ≥ 24 kg/m²). Only FVC% (P = 0.037) decreased significantly in obesity than in nonobesity. No differences in other

| Table 1 | Summary characteristics and spirometry tests variables between genders. |
|---------|-------------------------------------------------------------------|
|         | Male (n = 299)          | Female (n = 471)          | Total (n = 770)          |
|         | Mean (SEM or percent)   | Mean (SEM or percent)     | Mean (SEM or percent)    |
| Age, y  | 57.97 (0.95)            | 58.76 (0.70)              | 58.15 (0.56)             |
| Height, cm | 170.1 (0.35)           | 158.6 (0.24)              | 163.1 (0.28)             |
| Weight, kg | 67.35 (0.60)          | 58.61 (0.43)              | 62.01 (0.38)             |
| BMI, kg/m² | 23.24 (0.18)          | 23.28 (0.16)              | 23.27 (0.12)             |
| Smoker | 207 (69.23%)           | 17 (3.6%)                 | 224 (29.09%)             |
| FEV1, L | 2.72 (0.04)            | 1.94 (0.03)               | 2.24 (0.03)              |
| FEV1 predict | 0.68 (0.01)           | 0.62 (0.01)               | 0.64 (0.01)              |
| FVC, L | 3.69 (0.05)            | 2.52 (0.03)               | 2.98 (0.03)              |
| FVC predict | 0.97 (0.01)           | 0.87 (0.01)               | 0.91 (0.01)              |
| PEF, L/S | 5.13 (0.11)            | 3.54 (0.06)               | 4.16 (0.06)              |
| FEF25–75, L | 2.43 (0.06)          | 1.95 (0.04)               | 2.14 (0.03)              |
| FEF25–75 predict | 0.75 (0.02)         | 0.78 (0.01)               | 0.77 (0.01)              |

BMI = body mass index, FEF25–75 = forced expiratory flow at 25–75%, FEV1 = force expiratory volume in first second, FVC = force vital capacity, PEF = peak expiratory flow, PEF = standard error of the mean.

| Table 2 | Summary characteristics and spirometry tests variables between nonobesity and obesity. |
|---------|-------------------------------------------------------------------|
|         | Nonobesity (BMI < 24), N = 457         | Obesity (BMI ≥ 24), N = 313          | P       |
|         | Mean (SEM or percent)   | Mean (SEM or percent)     |         |
| FEV1 predict | 0.85 (0.01)          | 0.83 (0.01)               | .201     |
| PEF predict | 0.64 (0.01)           | 0.63 (0.01)               | .564     |
| FEF25–75 predict | 0.76 (0.01)       | 0.77 (0.01)               | .37      |

BMI = body mass index, FEF25–75 = forced expiratory flow at 25–75%, FEV1 = force expiratory volume in first second, FVC = force vital capacity, PEF = peak expiratory flow, PEF = standard error of the mean.

The bold values indicate FVC% decreased significantly in obesity than non-obesity.
spirometric variables were found (Table 2). Secondly, the subjects were divided into 4 groups: underweight, normal, overweight, general obesity. FVC% (P = 0.02) was lower significantly in overweight subjects than in normal subjects. FEV1% (P = 0.0008), FVC% (P = 0.0004), and PEF% (P < 0.0001) were higher significantly in normal subjects than in underweight subjects (Fig. 2). No differences in FEV1%, FVC%, and PEF% were found between overweight and general obesity subjects. As for FEV1/FVC and FEF25–75%, no difference was found among 4 groups. To exclude the effect of smoke on lung function, the subjects were divided into smoker and nonsmoker subgroups. As shown for 2 subgroups (Table 3), FVC% was lower significantly in overweight subjects than in normal subjects (smoker subgroup: P = 0.02; nonsmoker subgroup: P = 0.04). However, FEV1%, FVC%, and PEF% were higher significantly in normal subjects than in underweight subjects for 2 subgroups. For smoker subgroup, FEV1% (P = 0.03) and FVC% (P = 0.02) subjects were lower significantly in overweight than in normal subjects.

4. Discussion

Lung function is affected by many factors, such as age, gender, obesity, smoking status, and so on. The effect of age, gender, and smoking status on lung function has been confirmed.[16,17] As for obesity, no unique conclusion is drawn yet because different obese standard is adopted and race is diverse. Our results showed that for Xi’an subjects, FVC notably decreased in obese people, not FEV1, FEV1/FVC, PEF, and FEF25-75. Especially for smoker, FVC and FEV1 declined in overweight subjects significantly. FEV1, FVC, and PEF were higher in normal subjects than in underweight subjects. There are some reasons why obesity decreases the lung compliance. Firstly, the position of diaphragm in the thoracic cavity is elevated obviously when individual gains weight. The change will result in the decline of pulmonary function and the extra work of breathing.[5] Secondly, fat accumulation on the chest wall will impede the movement of thoracic cage by a direct resistance or the abnormal function of intercostal muscle.[18] Thirdly, obesity increases the release of inflammatory markers in the lung, for example hormone leptin.[19] The major effect of these inflammatory markers is on the lung tissue, with slight effect on airway diameter. Thus, obesity is related with the lung volumes, not airway obstruction. In pulmonary function test, FVC reflects lung volumes and other variables are related with airway obstruction.

Our study concludes that FVC notably decreased in obese people, not FEV1, FEV1/FVC, PEF, and FEF25-75. Besides, we have another interesting result that FEV1, FVC, and PEF were
higher in normal subjects than in underweight subjects. The lung volumes and capacities become larger with increasing BMI when BMI below 24 kg/m², otherwise the lung volumes and capacities get smaller with increasing BMI when BMI above 24 kg/m². The major spirometric parts of lung function (FEV₁, FVC, FEV₁/FVC, FEF₂₅₋₇₅, and PEF) are adopted by us because the early screen of pulmonary diseases is related with these values, and they are easy and reliable to be conducted in primary care.

Smoking is the main problem to affect respiratory system status. Smoking would harm the airways with less than 2 mm internal diameter, so it results in airway obstruction. Our study showed for smoker, FEV₁ declined significantly in overweight subjects than in normal subjects. But nonsmoker has no such trend. These results indicate that smoke harms the lung function, especially FEV₁.

However, there are 2 limitations in our study. Firstly, BMI takes no account of fat distribution in body as an indicator of obesity. For example, fat is usually accumulated in the hip for American, but fat is usually accumulated in the abdomen for Chinese. The difference in fat distribution may cause the change of lung function. In future, it is suggested that chest circumference, abdomen circumference and hip circumference or the ratio between them is used instead of BMI. Another limitation of the study is that subjects recruited are smaller. A study with a larger sample size would provide more data and enhance the generalizability of the findings. In summary, FVC is affected by BMI in diphasic change in Xi’an city.

5. Conclusion
FVC notably decreased in obese people, not FEV₁, FEV₁/FVC, PEF, and FEF₂₅₋₇₅. FEV₁, FVC, and PEF in normal subjects were better than in underweight subjects. FVC is affected by BMI in diphasic change.

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Table 3
Summary characteristics and spirometry tests variables between smoker and nonsmoker.

|                  | Smoker |          |          |          |                  |          |          |          |          |
|------------------|--------|----------|----------|----------|------------------|----------|----------|----------|----------|
|                  | Mean (SEM) | Mean (SEM) | Mean (SEM) | Mean (SEM) | Mean (SEM) | Mean (SEM) | Mean (SEM) | Mean (SEM) | Mean (SEM) |
| Number           | 17     | 112      | 80       | 15       | 37               | 291      | 180      | 38       |          |
| FEV₁ predict     | 0.80 (0.04) | 0.91 (0.02) | 0.04     | 0.84 (0.02) | 0.88 (0.04) | 0.46     | 0.78 (0.02) | 0.84 (0.01) | 0.007     |
| FVC predict      | 0.80 (0.03) | 1.01 (0.02) | 0.006    | 0.93 (0.02) | 0.91 (0.04) | 0.53     | 0.84 (0.02) | 0.90 (0.01) | 0.01      |
| PEF predict      | 0.48 (0.04) | 0.67 (0.02) | 0.003    | 0.62 (0.02) | 0.60 (0.07) | 0.46     | 0.54 (0.03) | 0.64 (0.01) | 0.005     |
| FEV₁/FVC         | 0.73 (0.04) | 0.72 (0.01) | 0.95     | 0.73 (0.01) | 0.77 (0.02) | 0.08     | 0.75 (0.02) | 0.76 (0.01) | 0.40      |
| FEF₂₅₋₇₅ predict | 0.73 (0.07) | 0.75 (0.03) | 0.99     | 0.69 (0.03) | 0.86 (0.08) | 0.03     | 0.72 (0.03) | 0.78 (0.02) | 0.29      |

Symbols (*, #) indicate significance between over- and underweight groups (* = 0.03, # = 0.02, $ = 0.04).
BMI = body mass index, FEF₂₅₋₇₅ = forced expiratory flow at 25–75%, FEV₁ = forced expiratory volume in first second, FVC = forced vital capacity, PEF = peak expiratory flow, SEM = standard error of the mean.