Effects of Body Mass Index on Lung Function Index of Chinese Population

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Abstract. To study the effect of body mass index (BMI) on lung function indexes in Chinese population. A cross-sectional study was performed on 10, 592 participants. The linear relationship between lung function and BMI was evaluated by multivariate linear regression analysis, and the correlation between BMI and lung function was assessed by Pearson correlation analysis. Correlation analysis showed that BMI was positively related with the decreasing of forced vital capacity (FVC), forced expiratory volume in one second (FEV1) and FEV1/FVC (P <0.05), the increasing of FVC% predicted value (FVC%pre) and FEV1% predicted value (FEV1%pre). These suggested that Chinese people can restrain the decline of lung function to prevent the occurrence and development of COPD by the control of BMI.

1. Introduction

Chronic Obstructive Pulmonary Disease (COPD) has been a major public health problem around the world due to the morbidity, mortality and massive economic cost [1]. According to the Ministry of Health, COPD has become the fourth cause of death in urban and third in rural China in 2008 [2]. Approximately 65 million people are expected to die from COPD in next 30 years [3]. Lung function test has been ranked as golden standard for the diagnosis of COPD in Global Initiative for Chronic Obstructive Lung Disease (GOLD) [4]. Lung function indices had a positive relationship with the health condition of lung, low lung function indices were important features of COPD and higher indices means better health condition [5]. Several studies indicated that COPD could be diagnosed in early stage and prevented by early intervention [6]. Therefore we should pay attention to the change of lung function and prevent COPD by improving lung function.

The influence factors of lung function indices including age, sex, height, body mass index (BMI) and cigarette smoking. In which age, sex and height were the factors that cannot be changed, the effect of smoking status on lung function has been well studied. But the influence of BMI on lung function remains unclear. Warren J’s study indicated that there was a positive relationship between BMI and forced vital capacity (FVC) in 2013 [7], which is contrary to the conclusion of Joerg Steier’s study in 2014 [8]. Joyashree Banerjee’s study found a reverse correlation between BMI and forced expiratory volume in one second (FEV1) in obese subjects [9], and this result is in consistent with the study of Joerg Steier [8]. The study of Liu showed that the relationship between lung function and BMI is different in different age groups [10]. Therefore; we performed a cross-sectional study to estimate the
effects of body mass index on lung function indices of Chinese population to provide important reference value for the clinical diagnosis and treatment of COPD.

2. Methods

2.1. Material
The present study enrolled all the physical examination patients in Chinese PLA General Hospital during 2013 to 2015. Out of a total of 13764 patients, 3003 were excluded for the lack of lung function indices, and 169 underweight (BMI<18.5kg/m2) subjects were also excluded. 10592 patients met the criteria (aged 16-74 y, mean age 47.3±7.9 y). All participants were informed before the test.

2.2. Measurement Methods
Demographic characteristics (age and gender), physical activity level and cigarette smoking status were collected using a standardized questionnaire by trained professionals in the examination center. In which physical activity level was valued by International Physical Activity Questionnaire-short form (IPAQ-SF). Anthropometric measurements including height, weight and waist circumference (WC), these indices were measured nearest to 0.1cm, 0.1kg and 0.1cm, respectively. Participants were asked to take off their shoes and wear light clothes during the test. WC was measured at the respiratory minimum point and 1cm above the navel. All the Anthropometric data were measured twice and calculated the mean value for analysis. BMI was calculated from weight in kilograms divided by the square of height in meters. Lung function indices including FVC, FVC % predicted value (FVC%pre), FEV1 and FEV1% predicted value (FEV1%pre) were obtained using the Medikro SpiroStar USB portable spirometry. FEV1/FVC was calculated. The units of FVC and FEV1 are liters. FVC%pre, FEV1%pre and FEV1/FVC were expressed in percentage.

Participants were classified as smoking, quit smoking and non-smoking by inquiry. The following two questions were given to the participants by professional operator: (1) Have you ever smoked hookah, cigarette, cigar or pipe? (2) Do you smoke at present? The answers “yes” and “yes”, “yes” and “no”, “no” and “no” were defined as smoking, quit smoking and non-smoking, respectively. And the participants in smoking group were asked to provide the amount of their daily smoking.

Participants were divided into the normal-weight group (18.5kg/m2 ≤BMI <24.0kg/m2, n = 3449), the overweight group (24.0kg/m2 ≤BMI <28.0kg/m2, n = 5127) and the obese group (BMI ≥28.0kg/m2, n = 2016) [11].

2.3. Statistical Methods
The data were analyzed according to BMI group by SPSS 19.0. Descriptive statistics were used to illustrate physical activity level (low, medium, high), smoking status (smoking, quit smoking, non-smoking) and demographic characteristics (age,sex). Continuous variable such as age, WC, BMI and lung function indices were expressed as mean ± SD. Sex, smoking status, work characteristics, transportation and housework were expressed as categorical variables.

Taking the age, WC and lung function indices as review target, we investigated the factors effecting BMI grouping by one-way analysis of variance. Sex, smoking status, work characteristics, transportation and housework were analyzed by chi-square test. Bivariate correlation analysis was used to evaluate the relationship between BMI and lung function indices. Multivariate stepwise linear regressions were performed to determine the relationship between BMI and lung function indices after divided the data into two groups: (1) the subjects with normal weight or overweight, (2) the subjects with normal weight or obese. Regression analysis was performed in both group with lung function as dependent variable, BMI grouping as independent variable and adjusted age, sex, smoking status and physical activity level as confounding factors.

3. Results
Table 1 showed the basic characteristics of all participants classified by BMI. With the increase of BMI in normal-weight, overweight and obese group, WC (81.9±6.3, 91.3±5.6 and 101.0±7.2, respectively), smoking proportion (34.0%, 39.1% and 43.1%, respectively) and the proportion of participants who
never doing housework (21.0%, 25.0% and 30.2%, respectively) was increased, and reductions were observed in manual labor working (1.7%, 1.5% and 1.2%, respectively), walking or riding to walk (14.5%, 10.5% and 8.5%, respectively) and medium physical activity level (28.2%, 26.7% and 25.0%, respectively). The FVC%pre (87.98±15.60, 83.68±15.34 and 77.46±14.36, respectively) and FEV1%pre (87.04±16.15, 84.32±16.48 and 79.47±15.48, respectively) were reduced with the raise of BMI in normal-weight, overweight, and obese group, meanwhile FEV1/FVC (81.85±9.34, 82.25±8.61 and 82.71±8.42, respectively) was increased. FVC and FEV1 were greater in overweight group (3.58±0.79 and 2.93±0.67) than obese group (3.51±0.76 and 2.90±0.65), and least in normal-weight group (3.44±0.84 and 2.80±0.70). Significant difference in age, sex, WC, smoking status, transportation, housework and lung function indices were seen between different BMI groups (P <0.05). Work characteristics (P = 0.107) and physical activity level (P = 0.084) were not significantly different between BMI groups.

Table 1. Characteristics of the study participants according to BMI

| Characteristics                  | normal weight | BMI overweight | obese | P for trend |
|----------------------------------|---------------|---------------|-------|-------------|
| n                                | 3449          | 5127          | 2016  |             |
| age (yr)                         | 47.4±8.1      | 47.7±7.6      | 46.6±7.7 | <0.001      |
| gender (%)                       |               |               |       | <0.001      |
| male                             | 74.2          | 90.8          | 93.9  |             |
| female                           | 25.8          | 9.2           | 6.1   |             |
| WC (cm)                          | 81.9±6.3      | 91.3±5.6      | 101.0±7.2 | <0.001      |
| BMI (kg/m²)                      | 22.2±1.4      | 25.9±1.1      | 30.2±2.2 | <0.001      |
| smoking status (%)               |               |               |       | <0.001      |
| smoking                          | 34.0          | 39.1          | 43.1  |             |
| quit smoking                     | 9.6           | 14.1          | 14.8  |             |
| nonsmoking                       | 56.5          | 46.8          | 42.1  |             |
| work characteristics (%)         |               |               |       | 0.107       |
| sedentary                        | 58.7          | 56.5          | 56.2  |             |
| light manual                     | 39.7          | 41.9          | 42.7  |             |
| manual labor                     | 1.7           | 1.5           | 1.2   |             |
| transportation (%)               |               |               |       | <0.001      |
| telecommuting                    | 5.7           | 4.5           | 4.4   |             |
| Private transportation           | 51.7          | 52.0          | 55.0  |             |
| public transportation            | 28.1          | 33.0          | 32.1  |             |
| walk or bike                     | 14.5          | 10.5          | 8.5   |             |
| housework (%)                    |               |               |       | <0.001      |
| never                            | 21.0          | 25.0          | 30.2  |             |
| occasionally                     | 49.6          | 57.0          | 55.5  |             |
| frequently                       | 29.3          | 18.0          | 14.4  |             |
| physical activity level (%)      |               |               |       | 0.084       |
| low                              | 65.9          | 67.3          | 69.5  |             |
| medium                           | 28.2          | 26.7          | 25.0  |             |
| high                             | 5.8           | 6.0           | 5.6   |             |
| FVC (L)                          | 3.44±0.84     | 3.58±0.79     | 3.51±0.76 | <0.001      |
| FVC%pre                          | 87.98±15.60   | 83.68±15.34   | 77.46±14.36 | <0.001      |
| FEV1 (L)                         | 2.80±0.70     | 2.93±0.67     | 2.90±0.65 | <0.001      |
| FEV1%pre                         | 87.04±16.15   | 84.32±16.48   | 79.47±15.48 | <0.001      |
| FEV1/FVC                         | 81.85±9.34    | 82.25±8.61    | 82.71±8.42 | 0.002       |

Data are expressed as means ± SD, or percentages

WC, waist circumference; BMI, body mass index; FVC, forced vital capacity; FVC%pre, FVC% predicted value; FEV1, forced expiratory volume in one second; FEV1%pre, FEV1% predicted value
Table 2. Coefficients from multiple linear regression of lung function indices in BMI

| lung function indices | Overweight (normal-weight) | BMI | Obese (normal-weight) |
|-----------------------|-----------------------------|-----|-----------------------|
|                       | β (se)                      | P-value | β (se) | P-value |
| FVC                   | -0.032 (0.015)              | 0.037 | -0.079 (0.010) | <0.001 |
| FVC%pre               | -0.045 (0.003)              | <0.001 | -0.056 (0.002) | <0.001 |
| FEV1                  | -0.005 (0.013)              | 0.687 | -0.047 (0.008) | <0.001 |
| FEV1%pre              | -0.027 (0.004)              | <0.001 | -0.039 (0.002) | <0.001 |
| FEV1/FVC              | 0.005 (0.002)               | 0.006 | 0.004 (0.001) | 0.001 |

FVC, forced vital capacity; FVC%pre, FVC% predicted value; FEV1, forced expiratory volume in one second; FEV1%pre, FEV1% predicted value

The results of multiple linear regression analysis were showed in Table 2. Compared with normal-weight group, overweight and obese were significantly related to the reduction of FVC, FVC%pre and FEV1%pre (P <0.05). In addition, overweight was significantly correlated with the increase of FVC/FEV1 (P = 0.006), but the relationship with FEV1 was not significant (P = 0.687). And the relationship between obese with the decrease of FEV1 (P <0.05) and the increase of FVC/FEV1 (P = 0.001) were also significant.

The results of Pearson correlation analysis indicated that BMI was reversely related to FVC%pre (r = -0.260 P <0.001), FEV1%pre (r = -0.181 P <0.001), and was positively related to FVC (r = 0.044 P <0.001), FEV1 (r = 0.059 P <0.001) and FEV1/FVC (r = 0.049 P <0.005) (Table 3).

Table 3. Lung function index correlation with BMI

| lung function indices | BMI |
|-----------------------|-----|
|                       | P-value | r     |
| FVC                   | <0.001 | 0.044 |
| FVC%pre               | <0.001 | -0.260 |
| FEV1                  | <0.001 | 0.059 |
| FEV1%pre              | <0.001 | -0.181 |
| FEV1/FVC              | 0.003  | 0.029 |

FVC, forced vital capacity; FVC%pre, FVC% predicted value; FEV1, forced expiratory volume in one second; FEV1%pre, FEV1% predicted value

4. Discussion

The present study investigated the relationship between BMI and lung function indices based on Chinese population. Compared with normal-weight group, overweight and obese were significantly related to the reduction of FVC, FVC%pre and FEV1%pre, and overweight was significantly correlated with the increase of FVC/FEV1. These indicated that obesity was related to a decline in lung function indices.

The results of our study showed that with the increase of BMI, WC and FEV1/FVC were increased, FVC%pre and FEV1%pre were reduced, and FVC and FEV1 firstly increased then decreased. Joerg Steier’s study indicated that with the increase of BMI, FVC%pre and FEV1%pre were decreased and the FEV1 and FVC were also decreased in obese subjects [8]. Denis E’s study demonstrated the positive relationship between BMI and FEV1/FVC [12]. These were in consistent with Banerjee’s study that pointed out that overweight and obese were related to lower FVC and obese was related to lower FEV1 [13]. Ji’s study showed that overweight and obese were related to lower FEV1%pre [14], which was also in agreement with our study. The potential physiological mechanism may be the decreased lung function caused by the upper airway soft tissue fat deposition, increased airway resistance, and decreased compliance of the lung and thorax in obese population [15]. The result of Davidson’s study indicated that overweight and obese were related to lower FEV1/FVC [7], which was contrary to our study. This was probably because the target of Davidson’s study was teenager and our study was aimed...
to teenager, middle-aged and elderly population. Zhang’s study found that BMI was positively related to FVC and FEV1 [16], and Gao et al demonstrated that BMI was reversely correlated with FEV1/FVC and FEV1%pre [17]. Both of their conclusions were in consistent with our results. The relationship between BMI and lung function indices was not unified in different studies so far [14]. And this relationship was different in different age stage [10], this may be caused by the difference of the correlation between BMI group and lung function indices and between BMI and lung function indices. BMI can be used as an important index for the evaluation of prognosis of COPD patient [14].

The limitation of this study was similar to the entire cross sectional studies; the data might be biased because the confounding factors that were not considered in the analysis, like education, economic, environment and regional difference. In addition, we only analyzed the relationship between BMI and lung function indices, but previous studies had demonstrated that regional adiposity was related to various health risk factors. Therefore, the association between lung function indices and regional adiposity should be further investigated.

5. Conclusions
In the lung function indices of Chinese population, FVC, FEV1 and FEV1/FVC were positively associated with BMI. FVE% pre and FEV1% pre were negatively associated with BMI. These suggested that Chinese people can restrain the decline of lung function to prevent the occurrence and development of COPD by the control of BMI.

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