Sex Differences in the Effects of Obesity on Lung Volume

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ABSTRACT

Background: Obesity is linked to variation of lung volume; however, it is still unclear whether a sex difference exists. The study aimed to find out the effect of obesity on lung volume and sex difference among the Chinese population.

Method: Pulmonary function test results were collected from 300 patients (aged 18 to ~80 years) with normal airway function and a wide range of body mass indexes (BMI). Measures of total lung capacity, vital capacity (VC), inspiratory capacity (IC), reserve volume, expiratory reserve volume (ERV) and functional reserve capacity (FRC) were analyzed by sex and different BMI groups.

Results: BMI was correlated with VC inversely and IC positively in liner relationships (VC: $r = -0.115$, $P < 0.05$; IC: $r = 0.168$, $P < 0.05$, respectively), whereas ERV and FRC decreased exponentially with increasing BMI (FRC: $r = -0.298$, $P < 0.01$; ERV: $r=-0.348$, $P < 0.01$, respectively). Significant correlations were identified for the effect of BMI on ERV and IC and FRC in females ($r = -0.354$, $P < 0.01$; $r = 0.206$, $P < 0.05$; $r = -0.335$, $P < 0.01$), whereas only on ERV in males ($r = -0.230$, $P < 0.05$).

Conclusions: BMI affected the lung volume, and females were more susceptible to the effects than males.

Key Indexing Terms: Lung volume; Body mass index; Sex difference; Obesity. **[Am J Med Sci 2017;353(3):224–229.]**

INTRODUCTION

There has been a greatly increased burden of obesity worldwide during the past 2 decades. Obesity has been identified as a risk factor for impairment of pulmonary function. Obesity not only contributes to chronic respiratory diseases such as sleep apnea and asthma[1,2] but also increases the risk of anesthesia failure.[3] Even without specific respiratory disease, people with obesity could exhibit respiratory symptoms such as breathlessness during light exercise[4] and wheezing without asthma.[5] Several studies had investigated the relationship between body mass index (BMI) and lung volume, but the findings were equivocal. Jones and Nzekwu[6] reported that lung volumes such as total lung capacity (TLC), vital capacity (VC), reserve volume (RV), expiratory reserve volume (ERV) and functional reserve capacity (FRC) decreased as BMI increased, whereas some studies found that TLC and RV were well preserved in people with obesity.[7,8] The recommended BMI criteria for the Asian population by the World Health Organization differs from the western population; for the Asian population,—normal weight: 18-24.9 kg/m^2, overweight: 25-27.5 kg/m^2 and obese: >27.5 kg/m^2. With specific definition and phenotype of obesity, the effect of obesity on lung volume in Chinese population is not well known.

It has been confirmed that sex difference exists in pulmonary mechanics and development of some respiratory diseases. Healthy female non-smokers had better lung function and exhibited smaller airway lumens with thicker airway walls.[9,10] Furthermore, elastic recoil decreased with age faster in males than in females.[11] The response to lung damage and airway hyperresponsiveness are different between sexes, which result in different presentation and phenotypes of some respiratory diseases.[12-14] It is also indicated that sex differences exist on the interaction between obesity and respiratory diseases, and it is related to decreased lung volumes. A specific BMI-dependent predisposition for obstructive sleep apnea was showed in men but not in women until menopause.[15] Females present stronger association between obesity and asthma.[16] Even in children, obesity affects lung function such as forced vital capacity rate of 1 second (FEV_1), forced VC (FVC) in a sex-dependent manner.[17]

In view of the effect of obesity on lung volume and sex difference in the development of respiratory disease among populations with obesity, the study aimed to explore the effect of obesity on lung volume and the possible sex difference.

MATERIALS AND METHODS

Study Subjects

A total of 300 eligible patients were retrospectively recruited from May 2015 to December 2015 from Ruijin Hospital, Shanghai, China and their pulmonary function test (PFT) results were reviewed. The most common indication for PFT was dyspnea. Inclusion criteria for eligible PFT results were described as follows: (1) aged

18 to <80 years (both male and female patients), (2) BMI ≥ 18.5 kg/m^2, (3) a smoking history <10 pack-years or smoked less than 100 cigarettes in their lives, (4) no diagnosis of cardiopulmonary disease or musculoskeletal abnormalities, (5) normal FEV_1 to FVC ratio (92% of predicted), (6) normal forced expired flow at 75% of the FVC (FEF75), (7) RV below the upper limit of normal and (8) single-breath diffusing capacity of the lung for carbon monoxide (DL_{co}) above the lower limit of normal after adjusting for the patient's alveolar volume. The upper limit of normal and lower limit of normal of lung volume above were derived from prediction equations for normal lung function in China.[18] A total of 300 eligible patients were divided into 3 BMI groups according to World Health Organization recommendations for Asian population: normal weight group (NW, 18-24.9 kg/m^2, $n = 142$), overweight group (OW, 25-27.5 kg/m^2, $n = 76$) and obese group (OB, >27.5 kg/m^2, $n = 82$). The study has been approved by the ethics committee of Ruijin Hospital. Informed consent was obtained from all patients.

Pulmonary Function Test

PFTs were performed according to the 2005 American Thoracic Society and European Respiratory Society standards.[19-23] By using Masterscreen JLAB 5.3 systems (Jaeger, German), FVC, FEV_1, FEF75, inspiratory capacity (IC), VC, RV, ERV and FRC were measured in the seated position using the helium dilution technique. DL_{CO} was measured via the single-breath determination of carbon monoxide uptake. Values are expressed as percentage of predicted on FEV_1/FVC, TLC, VC, ERV, IC, RV, FRC and DL_{CO} or as absolute ratios on RV/TLC and FRC/TLC.

Statistical Analysis

Data were analyzed using IBM SPSS v22.0 (IBM Corp., Armonk, NY). The Student's *t* test was used to compare the pulmonary function results between females and males. Difference in variables which were not normally distributed was analyzed by the Kruskal-Wallis test. Differences of pulmonary function results among BMI groups were analyzed using analysis of variance with a Tukey *post hoc* analysis. Pearson or Spearman correlations were used to access the effects of BMI on lung volumes. Linear or nonlinear exponential regression was further investigated. Significance was taken as $P < 0.05$.

RESULTS

Demographic Characteristics

A total of 300 eligible patients were divided into 3 groups (NW, 21.9 ± 1.6 kg/m^2, $n = 142$; OW, 26.0 ± 0.7 kg/m^2, $n = 76$; OB, 30.1 ± 3.9 kg/m^2, $n = 82$). There were no significant differences in age and the number of female and male patients in each group (age: 53.9 ± 14.6 versus 57.7 ± 11.5 versus 54.5 ± 13.8, $P > 0.05$; female, male number: 70, 72 versus 37, 39 versus 41, 41, respectively, $P > 0.05$) (Table 1).

Effect of BMI on Lung Volumes

Significant differences of VC, FRC and ERV were found among BMI groups (Table 1, Figure 1). VC was lower in OB group than in NW group significantly (88.3 ± 8.9 versus 93.0 ± 11.8% of predicted, $P < 0.01$). FRC and ERV were higher in NW group than in OW group or in OB group (FRC: 87.9 ± 19.4 versus 80.0 ± 18.5 %

TABLE 1. Pulmonary function results in various BMI groups.

Variables	BMI group			*P* Value
	NW ($n = 142$)	OW ($n = 76$)	OB ($n = 82$)	
Age (y)	53.9 ± 14.6	57.7 ± 11.5	54.5 ± 13.8	0.241
Female (*n*)	70	37	41	
BMI (kg/m^2)	21.9 ± 1.6	26.0 ± 0.7	30.1 ± 3.9	0.000
FEV_1/FVC (%)	108.6 ± 7.6	109.4 ± 7.4	107.6 ± 7.5	0.320
VC (%Pred)	93.0 ± 11.8	91.5 ± 11.0	88.3 ± 8.9*	0.024
TLC (%Pred)	83.4 ± 9.9	83.4 ± 10.8	83.4 ± 10.1	0.998
ERV (%Pred)	80.9 ± 42.0	58.2 ± 40.9**	56.2 ± 35.4*	0.000
IC (%Pred)	97.7 ± 22.7	104.5 ± 20.0	101.3 ± 19.3	0.074
RV (%Pred)	92.7 ± 19.7	90.7 ± 18.3	93.8 ± 18.8	0.573
FRC (%Pred)	87.9 ± 19.4	81.0 ± 18.5**	80.5 ± 18.1*	0.004
RV/TLC (%)	38.7 ± 6.2	39.0 ± 7.4	39.1 ± 8.4	0.856
FRC/TLC (%)	56.3 ± 9.4	51.1 ± 10.5*	51.6 ± 10.1*	0.000
DL_{co} (%Pred)	99.4 ± 14.0	101.4 ± 14.6	100.5 ± 16.8	0.616

Note: %Pred: percentage of predicted.
BMI, body mass index; normal weight group (NW): BMI 18.5-24.9 kg/m^2; overweight group (OW): BMI = 25-27.5 kg/m^2; obese group (OB): BMI >27.5 kg/m^2; ERV, expiratory reserve volume; DL_{co}, diffusing capacity of the lung for carbon monoxide; FEV_1/FVC, forced vital capacity rate of 1 second/forced vital capacity; FRC, functional reserve capacity; IC, inspiratory capacity; RV, reserve volume; TLC, total lung capacity; VC, vital capacity.
* $P < 0.05$, OB vs. NW.
** $P < 0.05$, OW vs. NW.