Comparable Obesity Parameters with Lung Function in A Chinese Rural Adult Population

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Keywords: Obesity, lung function, rural area, adult population, China

Posted Date: October 30th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-97841/v1

Abstract

Background: To assess association between different obesity parameters and lung function indicators in a Chinese rural adult population.

Methods: A total of 8,284 Chinese adults aged 20 to 80 years old from Xinxiang were recruited in this study. Obesity parameters including BMI, waist circumference (WC), hip circumference (HC), waist hip ratio (WHR), waist height ratio (WHtR), body fat percentage (BFP), basal metabolism (BM), and visceral fat index (VFI) and lung function parameters such as forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV_1) were measured according to previous guidance.

Results: The total prevalence of obesity defined by BMI, WL, WHR, WHtR, and BFP were 23.2%, 58.2%, 66.7%, 69.2%, and 56.5%. In general, the prevalence of obesity in women was higher than that in men. The average levels of FVC and FEV_1 in participants were 3.19 ± 0.72 (L) and 2.68 ± 0.64 (L), respectively. Men have a higher lung function levels than that of women. Lung function levels in obesity group were lower than those in non-obesity group, regardless of gender. Spearman correlation analyses showed that obesity parameters including BMI, WC, HC, WHR, WHtR, BFP, BM, and VFI were significantly correlated with lung function levels such as FVC and FEV_1. After adjustment for the potential confounders in further linear regression analyses, BMI, WHtR, BFP, and obesity defined by BMI, WHtR and BFP were negatively associated with lung function, while WC, WHR, and obesity defined by WC and WHR were positively associated with lung function.

Conclusions: Taken together, obesity status is closely related to lung function in general Chinese adult population. Weight control and lose is an important strategy to improve of lung function and reduce incidence of respiratory diseases.

Background

Obesity is a significant global public health challenge, owing to its growing prevalence, global pandemic, and accompanying enormous morbidity and mortality. It is estimated that more than one-third of adults are overweight or obese around the world [1], and the global prevalence of obesity will to be 1.12 billion in 2030 [2]. Obesity and overweight have caused approximately 3.4 million deaths worldwide in 2010 [3]. The epidemic of overweight and obesity is a major public health problem in China, although is lower than in developed countries [4–6]. As far as different urban regions of China are concerned, the overall prevalence of overweight ranges from 15.7–41.8%, and the prevalence of obesity ranges from 6.3–19.5% in adults [7–9]. Obesity is an important risk factor and modifier for metabolic disorders, cardiovascular disease, dyslipidemia, asthma, as well as cancer [10–12]. Previous studies demonstrated that obesity may cause restrictive ventilation dysfunction by reducing lung and chest wall compliance due to excessive fat deposits in the diaphragm, chest wall and abdominal cavity among obese patients [11–15]. In addition, weight loss and exercise can help patients with obesity-related lung disease reduce the resistance to respiration caused by excess fat [16–18]. However, less is known regarding detrimental influence of obesity on non-asthmatic respiratory consequences, particular for respiratory lung function and damage in general Chinese rural populations.

There are several common indicators that inflect body fat distribution and define obesity, including body mass index (BMI), waist circumference (WC), hip circumference (HC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), body fat percentage (BFP) and visceral fat index (VFI) [19–23]. Among them, BMI has been commonly-used to define general obesity, while WC, WHR, WHtR and BFP have been commonly-used to define abdominal obesity. Briefly, general obesity for is defined as BMI ≥ 25 kg/m^2 according to WHO recommendations for Asians [24]. While abdominal obesity (clinically known as central obesity) is defined as WL ≥ 90 cm for men and WL ≥ 80 cm for women, or WHR ≥ 0.90 for men and WHR ≥ 0.80 for women, or BFP ≥ 25% for men and BFP ≥ 33% [19, 25–27]. General obesity has its strengths in classifying the severity of obesity and weaknesses in the specificity of obesity, which cannot distinguish between fat mass and lean mass, and is not able to point out the pattern of regional fat distribution. While abdominal or central obesity, in particular, is closely related to central fat localization and all-cause mortality, independently of general obesity [28]. The deposition of fat in the thorax, abdomen, visceral organs, and an apple-like body shape are the main characteristics of central obesity. Systemic or peripheral obesity is characterized by deposition of fat in the hips, thighs, limbs, subcutaneous tissue, and a pear-like body shape. The distinction between different types of obesity is important since central obesity tend to have a more direct impact on lung mechanics and metabolic inflammation than peripheral obesity [11]. Several feasible mechanisms have been proposed to explain how does obesity affect respiratory impairment, such as decreased total respiratory system compliance, increased airway resistance, reduced lung volumes, and altered ventilation and gas exchange [4, 11, 13].

Relationship between obesity and lung function was inconsistent in various studies for different conditions and status [29–39]. For instances, there is a higher metabolic risk in Asians than Caucasians at a given BMI level [37]. Up to date, there is still a lack of comparative study on the relationship between different obesity parameters and lung function within the same study. Therefore, we conducted a cross-sectional study on rural residents of China, analyzed the big data, and aimed to further confirm the relationship between several obesity parameters and lung function indicators in adult population in central China. The possible adverse effects of obesity on lung function needs to be on the alert, and weight control and body shape management should be noticed in the prevention and improvement of respiratory disease.

Methods

Study sites and participants

This study was conducted in rural areas in Xinxiang county, Henan Province, China (Fig. 1). The inclusion criteria are that subjects with no acute disease or hospitalization experience within one month and not pregnant for women during the period of investigation. A total of 8,375 subjects aged 20–80 years met the inclusion criteria and subsequently screened from several villages of the two towns (Qiliying and Langgongmiao) in Xinxiang county using cluster sampling method (Fig. 1). Of which 91 subjects were excluded because that they were unable to complete lung function test. There were 8,284 adults finally

included in the analyses of this study. The participants completed a general health questionnaire and underwent routine physical examination. The study protocol was approved by the Human Ethical Committee of Xinxiang Medical University, China. All participants provided their written informed consent before enrollment and data collection.

Questionnaire

Participants were required to complete a questionnaire through face-to-face conversation by trained staff. Physical measurements were conducted using standardized procedures as described below. The questionnaire collected individual basic information including age, gender, marital status, residential address, income, education, and lifestyle characteristics such as smoking habit, and alcohol consumption. The physical examination parameters included body height, weight, WC, HC, BFP and VFI.

Physical measurements

All participants undergo weights, heights, waists, hips, BFP, and VFI measurements according to a standard protocol [19]. Physical examination was measured after participants had taken off shoes and heavy clothes. Weight was measured to the nearest 0.1 kg, height was also measured to one decimal. WC was determined to the nearest 0.5 cm around the abdomen at the level of the umbilicus/belly button, and hip circumference HC was read to the nearest 0.5 cm at the fullest part between abdomen and crotch. Body mass index (BMI) was defined as weight (kg) divided by the height squared (m^2). Waist to hip ratio (WHR) was calculated as WC divided by HC. Waist to height ratio (WHtR) was calculated as WC divided by height. BFP and VFI were measured using Omron HBF-371 body fat and weight measurement scales (Omron, Kyoto, Japan) and bioelectrical impedance analysis (BIA). BFP was defined by body fat weight divided by total weight. All measurements were taken twice and the average of the two values was used in the further analyses.

Definition of obesity

Individuals with BMI ≥ 25 kg/m^2 was defined as general obesity [22, 32]. Central obesity is defined as WC ≥ 90 cm for men and WC ≥ 80 cm for women or WHR ≥ 0.90 for men and WHR ≥ 0.80 for women or WHtR ≥ 0.5 both for men and women [23]. Obesity is defined as BFP ≥ 25 for men and BFP ≥ 33 for women [27]. VFI was divided into four categories (from “thin” to “high”) according to the criteria in the previous study, respectively [40].

Spirometry

The lung function test was conducted with a portable spirometer (Chestgraph HI-801, CHEST M.I., INC., Tokyo, Japan) in a standing position following the standardized procedures of the ATS-criteria, and at least three measurements and the highest value of forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), vital capacity (VC), inspiratory capacity (IC), residual volume (RV), tidal volume (TV), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), total lung capacity (TLC), peak inspiratory flow (PIF), peak expiratory flow (PEF), and peak expiratory flow time (PEFT) were used in the analyses [41]. The spirometer was calibrated prior to each test according to the instruction of the manufacturer. Predicted values for FVC and FEV_1 were derived from the equations for Chinese [42]. The lung function and its predicted values, and restrictive respiratory defect were the main outcome variables [43].

Statistical analysis

All data were inputted and established using EpiData version 3.0 software. A statistical analysis was performed using SPSS version 22.0 (IBM Corporation, NJ, USA). The normally distributed continuous variables were presented as the mean ± standard deviation, and are compared using the t test. The non-normally distributed quantitative data were displayed as median and interquartile range, and compared using the Mann-Whitney U test. Categorical variables were expressed as percentages and were analyzed using the chi-square test or Fisher's exact test as appropriate. Spearman correlation analysis was used to explore the correlation between obesity and lung function parameters. Multivariate linear regression analyses were further carried out to evaluate the association between obesity and lung function. Potential confounders were included in each full model when the p-value of the confounder was lower than 0.05. A value of $p < 0.05$ was considered statistically significant.

Patient and public involvement

No patient involved

Result

General characteristics of the study population

The average age of the men and women participants in Xinxiang county were 52.12 ± 12.42 and 51.23 ± 12.09 years, respectively. The percentage of men and women was 40.2% and 59.8%, respectively. As shown in Table 1, men have a higher current smoking and drinking rate, family income and educational level when compared to women (Table 1). There was no significant difference in BMI between men and women (Fig. 2). In addition, height, weight, WL, HL, WHR, BM, and VFI of men were higher than those of women (Table 2). However, WHtR and BFP of men were lower than those of women (Table 2).

Table 1
Demographic characteristics of the study population.

Characteristics	Men (n = 3,327)	Women (n = 4,957)	Statistics	P-value
Age (years)	52.12 ± 12.42	51.23 ± 12.09	t = 6.847	0.009[a]
Smoking, n (%)			χ^2 = 4345.75	< 0.001[b]
Never smokers	1,095 (32.9)	4,904 (98.9)		
Ex-smokers/Former smokers	586 (17.6)	13 (0.3)		
Current smokers	1,645 (49.5)	39 (0.8)		
Drinking, n (%)			χ^2 = 3497.79	< 0.005[b]
Never drink	1,336 (40.2)	4,848 (97.8)		
Ex-drinkers/Former drinkers	294 (8.8)	11 (0.2)		
Current drinkers	1,696 (51.0)	97 (2.0)		
Family income level per capita by month (CNY), n (%)			χ^2 = 34.32	< 0.001[b]
< 500	971 (29.2)	1569 (31.7)		
500–999	1183 (35.6)	1804 (36.4)		
1000–1999	735 (22.1)	1103 (22.3)		
2000–2999	238 (7.2)	294 (6.0)		
> 3000	197 (5.9)	175 (3.5)		
Education level, n (%)			χ^2 = 253.69	< 0.001[b]
Illiteracy	115 (3.5)	599 (12.1)		
Primary school	577 (17.3)	1073 (21.6)		
Middle school	1,490 (44.8)	1,988 (40.1)		
Secondary school or high school	890 (26.8)	953 (19.2)		
College/university and above	254 (7.6)	341 (6.9)		

[a]Analysis by independent-sample t-test.

[b]Analysis by chi-square test.

Table 2
Levels of obesity and lung function parameters in adult population from Qiliying and Langgongmiao in Xinxiang.

Characteristics	Men (n = 3,327)	Women (n = 4,957)	Statistics	P-value
Lung function parameters				
FVC (L)	3.87 ± 0.50	2.72 ± 0.40	t = 115.74	< 0.001[a]
FVC predicted (L)	3.73 ± 0.49	2.67 ± 0.34	t = 78.93	< 0.001[a]
FEV_1 (L)	3.18 ± 0.54	2.34 ± 0.43	t = 117.88	< 0.001[a]
FEV_1 predicted (L)	2.98 ± 0.47	2.16 ± 0.33	t = 92.73	< 0.001[a]
FEV_1 / FVC	0.81 (0.79–0.84)	0.85 (0.83–0.87)	Z = -33.75	< 0.001[b]
VC (L)	3.68 ± 0.34	2.64 ± 0.27	t = 155.78	< 0.001[a]
IC (L)	2.12 ± 0.73	1.64 ± 0.61	t = 32.21	< 0.001[a]
RV (L)	1.56 ± 0.15	1.59 ± 0.18	t = -7.50	< 0.001[a]
TV (L)	0.56 ± 0.33	0.52 ± 0.29	t = 20.25	< 0.001[a]
ERV (L)	0.97 ± 0.53	0.59 ± 0.37	t = 38.17	< 0.001[a]
IRV (L)	1.47 ± 0.62	1.13 ± 0.53	t = 26.81	< 0.001[a]
TLC (L)	5.57 ± 0.34	4.04 ± 0.28	t = 225.87	< 0.001[a]
RV/TLV (%)	30.4 (26.9–33.7)	28.9 (26.5–31.0)	Z = -16.86	< 0.001[b]
PIF (L/s)	2.24 ± 0.99	1.90 ± 0.75	t = 17.90	< 0.001[a]
PEF (L/s)	8.38 ± 0.71	6.00 ± 0.54	t = 172.34	< 0.001[a]
PEFT (s)	0.36 ± 0.34	0.36 ± 0.30	t = -0.54	0.588[a]
Physical parameters				
Height (cm)	168.66 ± 6.43	157.44 ± 5.88	t = 81.95	< 0.001[a]
Weight (kg)	72.90 ± 11.51	63.29 ± 10.02	t = 40.29	< 0.001[a]
BMI (kg/m^2)	25.60 (23.14–28.03)	25.16 (22.96–27.44)	Z = -1.62	0.106[b]
WL (cm)	91.39 ± 7.02	87.19 ± 9.36	t = 22.05	< 0.001[a]
HL (cm)	98.03 ± 6.56	97.23 ± 7.49	t = 5.00	< 0.001[a]
WHR	0.914 (0.867–0.960)	0.867 (0.813–0.922)	Z = -25.66	< 0.001[b]
WHtR	0.533 (0.491–0.572)	0.539 (0.490–0.585)	Z = -3.15	0.002[b]
BFP	25.6 (22.2–28.8)	34.1 (30.6–37.0)	Z = -59.18	< 0.001[b]
BM (kcal)	1626.01 ± 188.68	1304.15 ± 165.55	t = 81.81	< 0.001[a]
VFI	12.43 ± 5.11	8.47 ± 4.51	t = 37.04	< 0.001[a]

Abbreviations, FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 second; VC: Vital capacity; IC: Inspiratory capacity; RV: Residual volume; TV: Tidal volume; ERV: Expiratory reserve volume; IRV: Inspiratory reserve volume; TLC: Total lung capacity; RV/TLV (%): RV divided by TLV; PIF (L/s): Peak inspiratory flow; PEF: Peak expiratory flow; PEFT (s): Peak expiratory flow time; BMI: body mass index; WC: waist circumference; HC: Hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; BFP: Body Fat Percentage; BM: basal metabolism; VFI: visceral fat index. For continuous variables, average range is presented as mean values ± SD (normal distribution data) or median values with interquartile (non-normal distribution data).

[a]Analysis by independent-sample t-test.

[b]Analysis by Manne-Whitney U test.

[c]Analysis by chi-square test.

Prevalence of obesity

The total prevalence of obesity defined by BMI, WL, WHR, WHtR, and BFP were 23.2%, 58.2%, 66.7%, 69.2%, and 56.5%, respectively. In addition to the percentage of obesity defined by BMI, other percentages of several kind obesity were higher in women than those in men (Fig. 3). A total of 1891 (22.8%) participants suffered from both general and central obesity. In particular, the distribution of obesity parameters such as BMI and BFP in men is not higher than those in women (Fig. 3). In a word, the prevalence of obesity both in men and women was at a higher level based on this general rural population (Table S1).

Lung function levels

Both FVC and FEV_1 of and their predicted values were higher in men than those in women (Table 2). In addition, FVC and FEV_1 of participants were higher than their predict values. The ratio of FVC to FEV_1 were higher in women than that in men (Table 2). Similarly, other lung function indices such as VC, IC, RV, TV, ERV, IRV, TLC, PIF, PEF were significantly higher in men than those of women (Table 2). Moreover, FVC and FEV_1 of participants were significantly lower in all different definitions of obesity than their non-obesity groups, respectively (Fig. 4).

Correlation between obesity parameters and lung function indicators

Spearman correlation analyses demonstrated that several obesity parameters were significantly correlated with lung function levels. In particular, BMI, WHtR and BFP were negatively correlated with FVC and FEV_1. However, WC, HC, WHR, BM, and VFI were positively correlated with FVC and FEV_1 (Fig. 5 and Table S2). In addition, BMI, WL, WHR, WHtR, BFP, BM, and VFI were negatively correlated with the ratio FVC to FEV_1 (FEV_1/FVC), while height and hip circumference were positively correlated with FEV_1/FVC (Table 3). In addition, obesity parameters including BMI, WC, HC, WHR, WHtR, BFP, BM, and VFI were significantly correlated most of the other lung function indicators such as VC, IC, RV, TV, ERV, IRV, TLC, PIF, PEF and PEFT (Table S2).

Table 3
Spearman correlation coefficients between obesity parameters and lung function indicators in adult population from in Xinxiang (n = 8284).

	FVC	FEV_1	FEV_1/FVC	Height	Weight	BMI	WC	HC	WHR	WHtR	BFP	BM
FVC		0.976***	0.736***	0.718***	0.166***	-0.172***	-0.234***	0.083*** 107*	-0.377***	-0.429***	-0.470***	0.270***
FEV_1	0.953***		0.844***	0.709***	0.143***	-0.193***	0.265***	0.084***	-0.419***	-0.456***	-0.500***	0.250***
FEV_1/FVC	0.531***	0.738***		0.503***	0.063***	-0.178***	-0.285***	0.074***	-0.436***	-0.412***	-0.469***	-0.165***
Height	0.742***	0.713***	0.357***		0.351***	-0.110***	-0.004	0.213***	-0.153***	-0.277***	-0.262***	0.436***
Weight	0.329***	0.333**	0.210***	0.461***		0.840***	0.762***	0.790***	0.450***	0.621***	0.563***	0.951***
BMI	-0.018	-0.001	-0.051***	-0.002	0.845***		0.838***	0.743***	0.579***	0.835***	0.768***	0.787***
WC	0.033	0.033	0.016	0.161***	0.841***	0.876***		0.660***	0.840***	0.954***	0.760***	0.707***
HC circumference	0.148***	0.185**	0.177***	0.283***	0.797***	0.758***	0.765***		0.189***	0.568***	0.527***	0.779***
WHR	-0.077***	-0.107***	-0.122***	-0.004	0.565***	0.651***	0.819***	0.293***		0.848***	0.629***	0.386***
WHtR	-0.208***	-0.199***	-0.097***	-0.157***	0.676***	0.874***	0.939***	0.668***	0.818***		0.809***	0.544***
BFP	-0.229***	-0.249***	-0.216***	-0.080***	0.571***	0.706***	0.722***	0.528***	0.618***	0.745***		0.450***
BM	0.410***	0.422***	0.291***	0.521***	0.950***	0.783***	0.781***	0.770***	0.502***	0.597***	0.434***	
VFI	-0.233***	-0.240***	-0.184***	-0.112***	0.742***	0.930***	0.847***	0.673***	0.678***	0.884***	0.757***	0.669***

The lower left part of the table is based on men according to Spearman correlation analysis results; The upper right part of the table is based on women acco Spearman correlation analysis results. Abbreviation, FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second; VC: Vital capacity; IC: Inspiratory RV: Residual volume; TV: Tidal volume; ERV: Expiratory reserve volume; IRV: Inspiratory reserve volume; TLC: Total lung capacity; PIF: Peak inspiratory flow; P expiratory flow; PEFT: Peak expiratory flow time; BMI: Body Mass Index; WHR: Waist circumference to hip circumference ratio; WHtR: waist circumference to h ration; BFP: Body fat percentage; BM: Basal metabolism; VFI: Visceral fat index.

Association between obesity and lung function

The association between obesity and lung function are shown in Table 4. After adjusted for their respective confounding factors in the full multiple linear regression model, we found that BMI and WHtR was negatively associated with FVC (β_{BMI} = -0.001, $p < 0.001$; β_{WHtR} = -0.595, $p < 0.001$; β_{BFP} = -0.003, $p < 0.001$) and FEV_1 (β_{BMI} = -0.001, $p < 0.001$; β_{WHtR} = -0.517, $p < 0.001$; β_{BFP} = -0.002, $p < 0.001$), respectively. Whereas WL and WHR was positively associated with FVC (β_{WL} = 0.003, $p < 0.001$; β_{WHR} = 0.168, $p < 0.001$) and FEV_1 (β_{WL} = 0.004, $p < 0.001$; β_{WHR} = 0.133, $p < 0.001$), respectively (Table 4).

Table 4
The association between obesity and lung function (n = 8284).

	FVC			FEV_1		
	B[a]	β[b]	95% CI for B	B[a]	β[b]	95% CI for B
BMI						
Univariate Model	-0.011	-0.054	(-0.015~ -0.006) ***	-0.013	-0.077	(-0.017~ -0.010) ***
Full Model	-0.001	-0.006	(-0.002~ -0.001) ***	-0.001	-0.005	(-0.002~ -0.001) ***
Waist circumference						
Univariate Model	0.008	0.119	(0.006 ~ 0.009) ***	0.003	0.053	(0.002 ~ 0.004) ***
Full Model	0.003	0.049	(0.003 ~ 0.004) ***	0.004	0.060	(0.003 ~ 0.004) ***
WHR						
Univariate Model	0.505	0.062	(0.328 ~ 0.681) ***	0.254	0.035	(0.097 ~ 0.411) ***
Full Model	0.168	0.020	(0.084 ~ 0.252) ***	0.133	0.018	(0.064 ~ 0.202) ***
WHtR						
Univariate Model	-2.510	-0.236	(-2.733~ -2.287) ***	-2.781	-0.294	(-2.976~ -2.586) ***
Full Model	-0.595	-0.056	(-0.700~ -0.489) ***	-0.517	-0.055	(-0.604~ -0.429) ***
BFP						
Univariate Model	-0.068	-0.636	(-0.070~ -0.066) ***	-0.058	-0.619	(-0.060~ -0.057) ***
Full Model	-0.003	-0.028	(-0.004~ -0.002) ***	-0.002	-0.026	(-0.004~ -0.001) ***
Obesity defined by BMI						
Univariate Model	-0.054	-0.032	(-0.090~ -0.017) **	-0.060	-0.040	(-0.093~ -0.028) ***
Full Model	-0.013	-0.005	(-0.020~ -0.006) **	-0.016	-0.006	(-0.026~ -0.006) **
Obesity defined by WHtR						
Univariate Model	-0.226	-0.146	(-0.259~ -0.193) ***	-0.274	-0.198	(-0.303~ -0.245) ***
Full Model	-0.051	-0.033	(-0.066~ -0.036) ***	-0.043	-0.031	(-0.055~ -0.031) ***
Obesity defined by WC						
Univariate Model	-0.256	-0.176	(-0.287~ -0.225) ***	-0.238	-0.185	(-0.266~ -0.211) ***
Full Model	0.064	0.044	(0.050 ~ 0.078) ***	0.068	0.052	(0.056 ~ 0.079) ***
Obesity defined by WHR						
Univariate Model	-0.437	-0.275	(-0.470~ -0.404) ***	-0.422	-0.299	(-0.451~ -0.393) ***
Full Model	0.035	0.022	(0.019 ~ 0.050) ***	0.021	0.015	(0.008 ~ 0.034) **
Obesity defined by BFP						
Univariate Model	-0.068	-0.636	(-0.070~ -0.066) ***	-0.058	-0.619	(-0.060~ -0.057) ***
Full Model	-0.026	-0.018	(-0.041~ -0.012) ***	-0.014	-0.011	(-0.026~ -0.002) ***

Abbreviations, FVC: forced vital capacity; FEV_1: forced expiratory volume in 1 second; BMI: body mass index; WHR: waist circumference to hip circumference ratio; WHtR: waist circumference to height ration; BFP: Body fat percentage; Full Model: Adjusted for age, gender, smoking, drinking, family income, and education level. *: $p < 0.05$; **: $p < 0.01$**; ***: $p < 0.001$.

Similarly, obesity defined by BMI, WHtR and BFP was negatively associated with FVC ($\beta_{\text{obesity defined by BMI}} = -0.013$, $p < 0.001$; $\beta_{\text{obesity defined by WHtR}} = -0.051$, $p < 0.001$; $\beta_{\text{obesity defined by BFP}} = -0.026$, $p < 0.001$) and FEV_1 ($\beta_{\text{obesity defined by BMI}} = -0.016$, $p < 0.001$; $\beta_{\text{obesity defined by WHtR}} = -0.043$, $p < 0.001$; $\beta_{\text{obesity defined by BFP}} = -0.014$, $p < 0.001$), respectively. Whereas obesity defined by WL and WHR was positively associated with FVC ($\beta_{\text{obesity defined by WL}} = 0.064$, $p < 0.001$; $\beta_{\text{obesity defined by WHR}} = 0.035$, $p < 0.001$) and FEV_1 ($\beta_{\text{obesity defined by WL}} = 0.068$, $p < 0.001$; $\beta_{\text{obesity defined by WHR}} = 0.021$, $p < 0.001$), respectively (Table 4).

Discussion

This study investigated the association between obesity parameters and lung function of 8,284 adults from the typical rural areas in central China. Our results show that the prevalence of obesity in this study is in a high level, which is higher than the reported obesity rates in China. Although the prevalence of general obesity defined by BMI was higher in men than that in women, the prevalence of abdominal obesity defined by WL, WHR and BFP were lower in men than those in women. Lung function levels was lower in obesity group when compared with non-obesity group. Spearman correlation analyses showed that these obesity parameters were significantly correlated with the measured lung function indicators. After adjustment for potential confounders, the defined obesity and obesity-related parameters were negatively associated with lung function parameters such as FVC and FEV_1.

Some previous studies have shown that obesity can alter chest wall mechanics, reduces lung volumes and increases airway resistance [4, 11, 13]. Nonetheless, there was inconclusive or inconsistent result about the association between obesity parameters such as BMI and BFP and lung function indicators including FVC and FEV_1 according to previous studies, which may due to their small sample sizes, scattered obesity parameters, and specific groups [19, 21, 44, 45]. In this study, we found several parameters such as BMI, WC, WHR, WHtR, BFP and VFI, representing the incremental degree of obesity, are negatively associated with lung function indicators, which is consistent with results of most previous studies. As we envision according to previous reports, height, HC and BM are positively associated with lung function levels. Our results suggested that obesity group have lower lung function levels compared with non-obesity group. In other words, individual with obesity status trend to have smaller lung capacity and lower lung function.

Recently, some studies have proposed that WC related parameters such as WHR and WHtR might be better indicators than BMI to assess the role of obesity in predicting lung function in general Caucasian population [44–46]. In this study, we investigated the association between several obesity parameters and series of lung function indicators in the general Han Chinese population with a large sample. The results of Spearman correlation analyses and linear regression analyses both showed that elevated BMI, WHR, WHtR, BFP, and individuals with obesity defined by BMI, WHR, WHtR and BFP have lower lung function levels such as FVC and FEV_1. However, increased height, BM, WC, HC, and individuals with obesity defined by WC have a higher FVC and FEV_1.

It seems that there is some conflict between several obesity related parameters mentioned above when linked to lung function in this study. Careful comparison of them provided a reasonable explanation of the differences, that is, both height, weight, WC, and HC are important factors related to lung function. Height related obesity parameters such as BMI, WHtR and obesity defined by BMI and WHtR were negatively associated with lung function because that height is in the denominator position in the formula of BMI and WHtR and a positive relationship between height and lung function. Similarly, HC related WHR and obesity defined by WHR were inversely linked lung function due to that HC is in the denominator position in the formula of WHR and a positive relationship between HC and lung function. WC and obesity defined by WC were positively associated with lung function since there is a positive relationship between WC and lung function.

According to the results of Spearman correlation analyses and linear regression analyses, the order of closeness of obesity parameters to lung function is as follows: (1). Height > Weight > HC > WC; (2). WHtR > BFP > BMI > WHR. It is well known that height of adult individuals remains constant over time. Therefore, weight, HC and WC are the obvious and crucial parameters for obesity condition of individuals in their adulthood. Previous studies shown that BMI and BFP (for general obesity) and WHR and WHtR (for central obesity) are recommended to assess the relationship between obesity and lung function. WC and obesity defined by WC and WHR were positively associated with FVC and FEV_1, which may indicate that lung function improved with the increase of WC to some degree, which is consistent with the results of previous studies [21, 47–49]. However, compared with WC, height, weight and HC have more influence on the lung function, which is manifested by tightly relationship between obesity parameters including WHtR, WHR, BMI and lung function indicators such as FVC and FEV_1.

Our findings indicate that several obesity parameters and obesity defined by them are significantly associated with lung function levels such as FVC and FEV_1. The direction (inverse) of effect for different obesity parameters such as WHtR, WHR, BFP and BMI on lung function is similar from each other, which suggest that obesity condition is significantly associated with lung damage. Systemic/limb/peripheral obesity defined by BMI, WHtR and BFP were negatively associated with FVC and FEV_1, while abdominal/belly/central obesity defined by WC and WHR were positively associated with FVC and FEV_1. These results may suggest that take only WC into account is inappropriate to investigate the relationship between obesity and lung function. In other words, obesity defined by BMI, WHtR and BFP are better than obesity defined by WC and WHR to estimate their relationship with lung function.

There were several strengths in our study. First, we recruited a large population sample of adults across a broad age range from a typical rural area in central China, which let us understand the prevalence of obesity and lung function levels in the rural area. Second, several obesity parameters make it possible to comprehensively investigate their association with lung function to obtain more accurate and detailed information. Third, the large sample size, assessment of potential confounders, and several effect models facilitate investigation of the independent effect of peripheral and central obesity on lung function. However, several limitations should be acknowledged for this study. First, the cross-sectional nature of this study makes it difficult to draw a causal conclusion between obesity and lung function. However, we will re-recruit subject to determine the causal relationship between obesity and lung volume and function in the same adult population. Second, although several important factors have been taken into account in the analyses, residual confounding caused by other unmeasured variables remain possible such as muscle mass and strength, metabolic factors, markers of inflammation, nutritional status, and history or indicators of allergy. Third, it is needed to determine whether these results are generalizable to other ethnic populations in further investigation.

Strengths And Limitations Of This Study

- This is the first study to examine links between several obesity parameters and lung function levels among adult populations in central China with a big sample.
- There is still a lack of comparative study on the relationship between different obesity parameters and lung function within the same study.

- This study had several limitations related to data availability and quality.
- Domestic data on obesity in China are defined differently from international data.
- The findings provide useful suggestions to investigate association between obesity and lung function among Chinese adults.

Conclusion

In summary, both general and central obesity are negatively associated with lung function in general Chinese rural adult population. However, direction of effects for WC and its related WHR on lung function is negative. In particular, height related obesity parameters such as BMI and WHtR have a negative effect on lung function, whereas WC related obesity parameters such as WC and WHR have a positive effect on lung function. Given an inverse association between BFP and lung function, BMI (for general obesity) and WHtR (for central obesity) may be preferred common parameters to assess the relationship between obesity and lung function in general population. However, the underlying mechanism between them needs further investigated.

Abbreviations

FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second; VC: Vital capacity; IC: Inspiratory capacity; RV: Residual volume; TV: Tidal volume; ERV: Expiratory reserve volume; IRV: Inspiratory reserve volume; TLC: Total lung capacity; PIF: Peak inspiratory flow; PEF: Peak expiratory flow; PEFT: Peak expiratory flow time; BMI: Body Mass Index; WC: waist circumference; HC: hip circumference; WHR: the ratio of waist circumference to hip circumference; WHtR: the ratio of WC to height; BFP: Body fat percentage; BM: Basal metabolism; VFI: Visceral fat index.

Declarations

Authors' contributions

XZ and DL participated in the study design, performed the statistical analyses and drafted the manuscript. WW and XZ obtained funding, determined the study design, and participated in the interpretation of data. DL, LG and WW supervised the statistical analyses. DL, AZ, HL, JS, JL, YL, JJ, WL, LG and WW interpreted the results and have written the manuscript. All authors approved the final version of the manuscript.

Acknowledgements

Not applicable.

Funding

This work was supported by the research grants of the National Key Research and Development Program Precision Medicine Initiative of China (2016YFC0900803). Scientific Research Foundation of Xinxiang Medical University (BSKYZZ201706, 300/505233 and BSKYZZ201628, 300/505186). Peak Subject Project of Public Health in Xinxiang Medical University (GWGFXK2018008). The funding sources were not involved in the study design, data collection, analysis and interpretation, or in writing and submitting the manuscript.

Declaration of competing interest

The authors declare that they have no competing interests.

Data availability statement

Data are available upon reasonable request.

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Figures

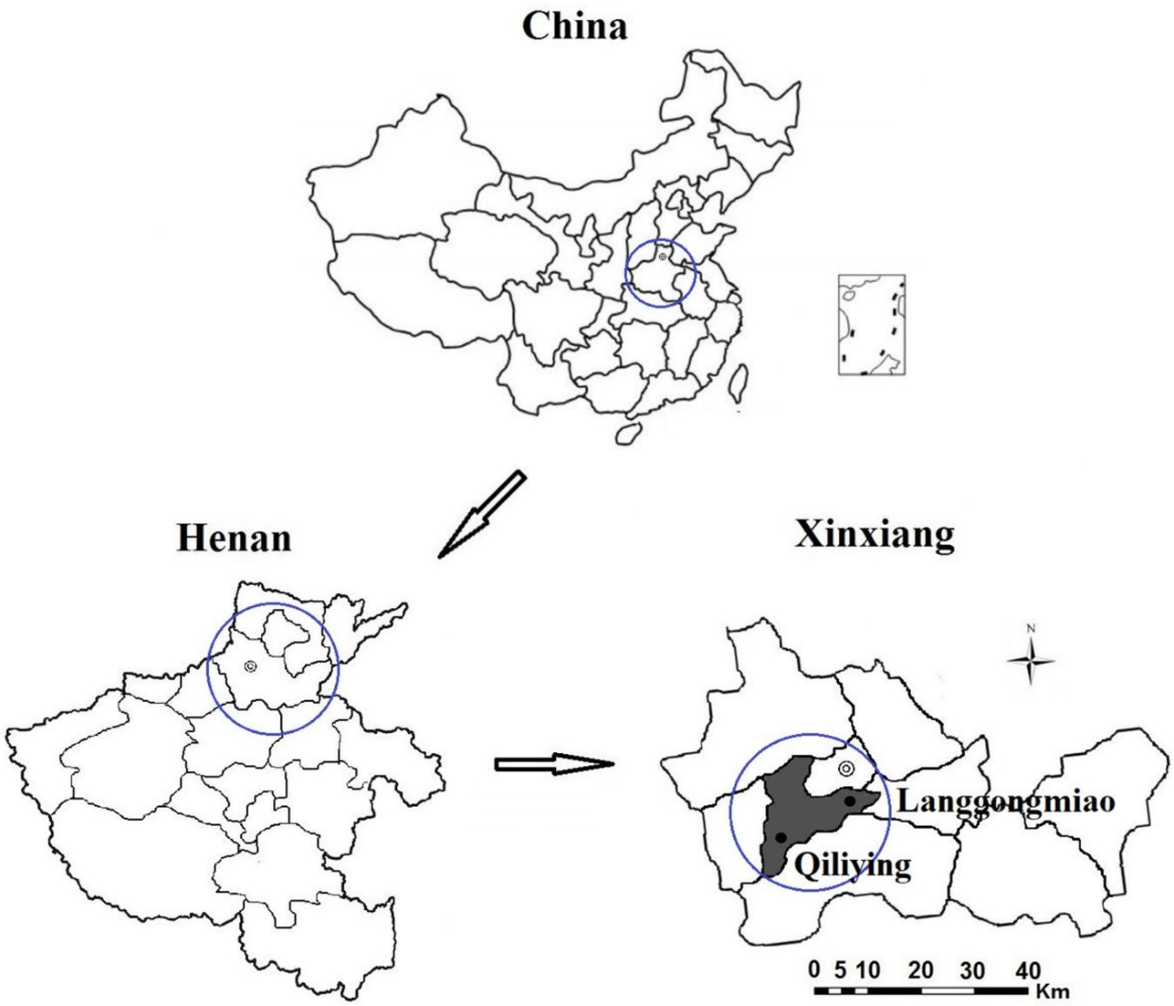

Figure 1

The location of the sampling sites in Xinxiang county. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

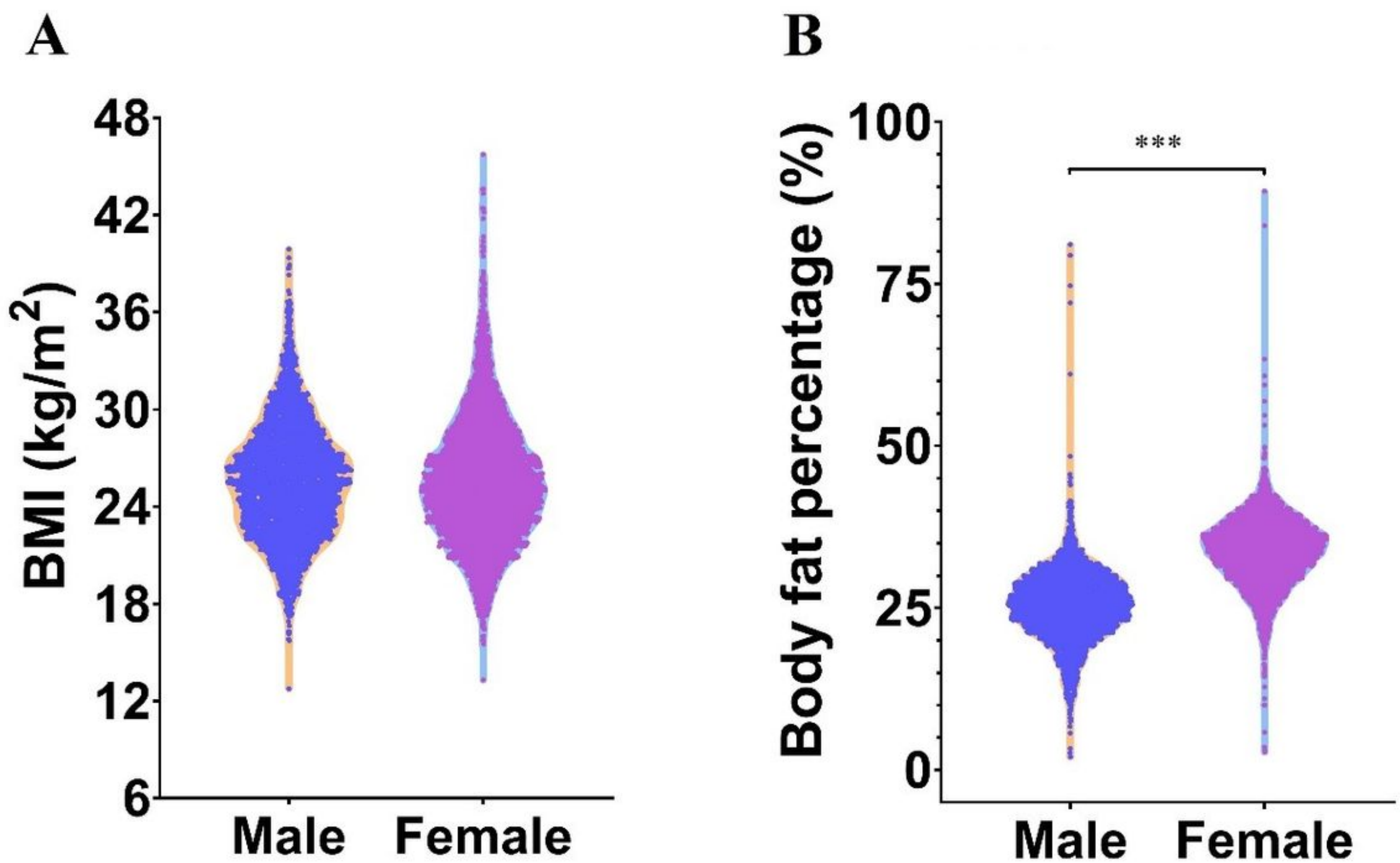

Figure 2

The distribution of BMI and BFP between men and women among the subjects (n = 8,284). BMI: Body mass index. BFP: Body Fat Percentage. ***: P < 0.001.

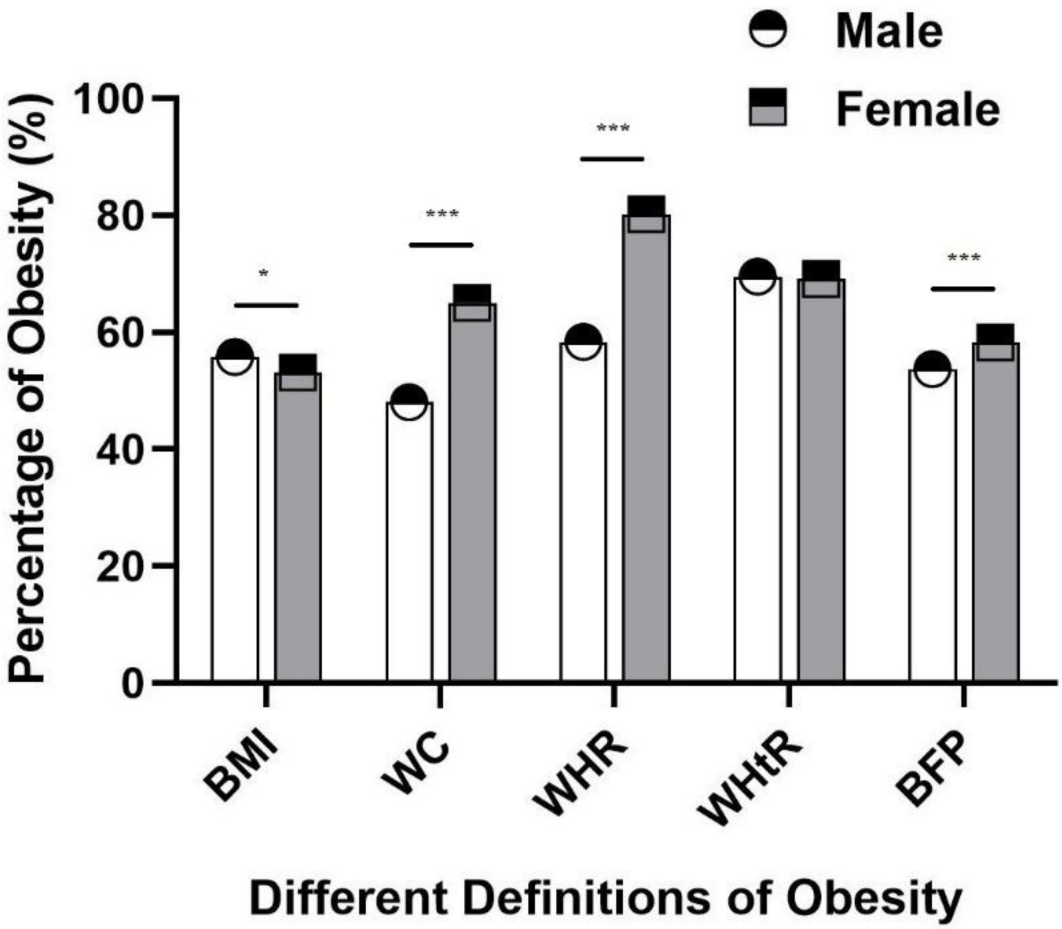

Figure 3

The comparison for percentages of obesity between men (n = 3,327) and women (n = 4,957). BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; BFP: Body Fat Percentage. **: P < 0.010; ***: P < 0.001.

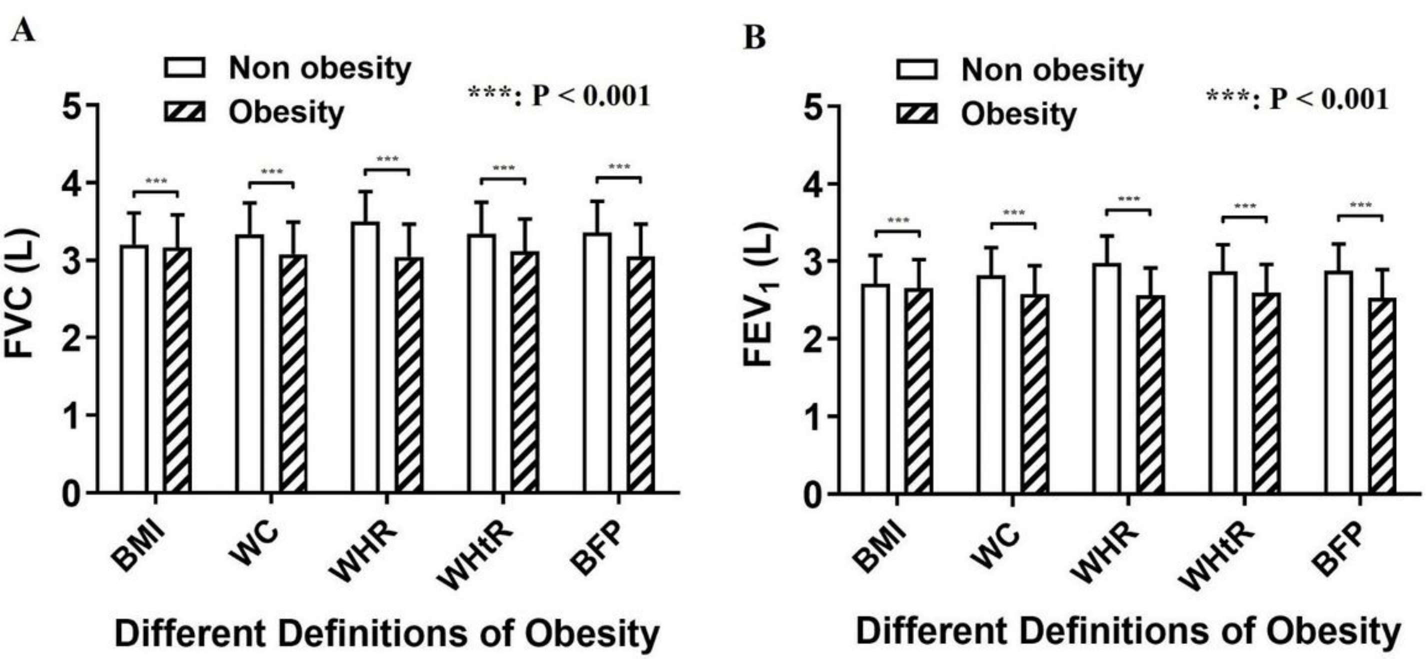

Figure 4

The comparison of FVC (A) and FEV1 (B) between non obesity and obesity subjects. BMI: body mass index; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; BFP: Body Fat Percentage. ***: P < 0.001.

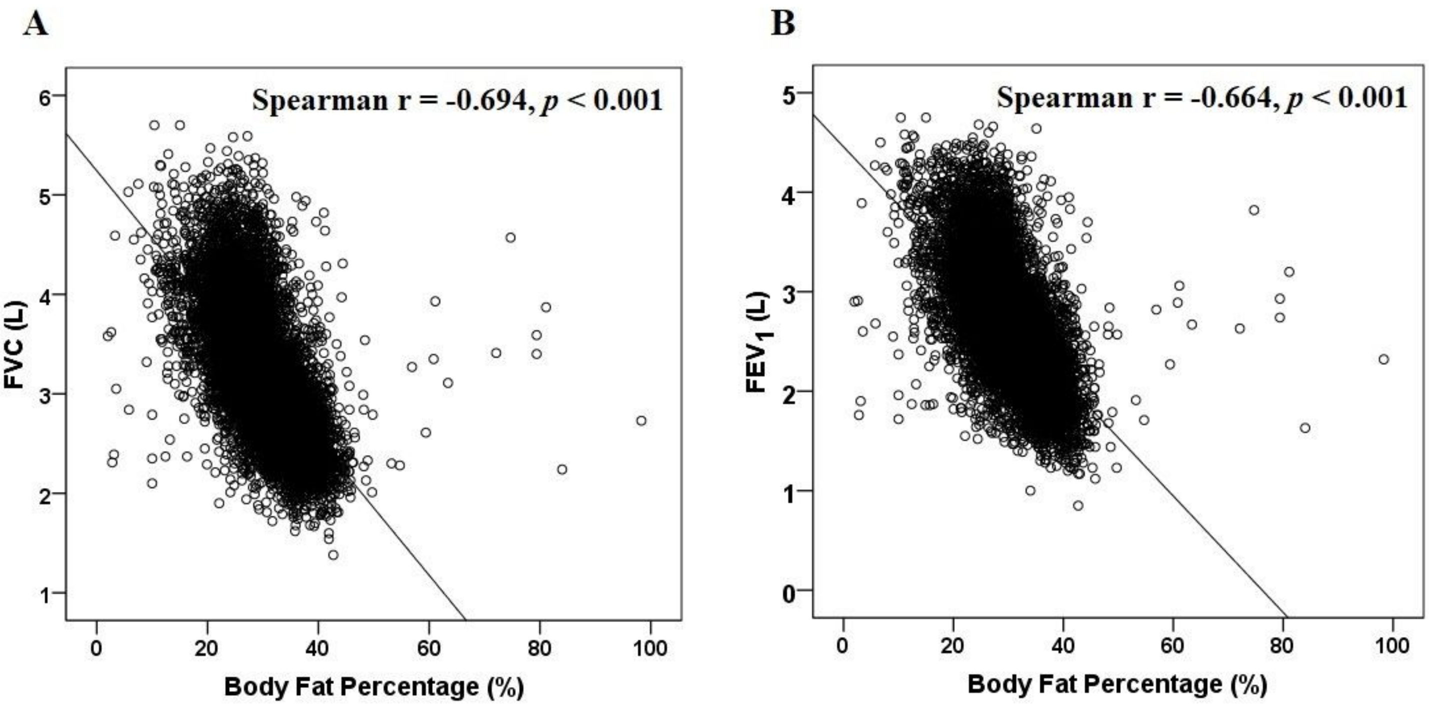

Figure 5

Spearman correlation analyses of the relationship among obesity parameters and lung function in the rural general adult Chinese population (n = 8,284).

Supplementary Files

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- TableS1S2.docx