Association Between Metabolic Syndrome and Lung Function in Rural Areas in China

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Research

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Abstract

Background

There remains considerable uncertainty about the association between adult metabolic syndrome (MetS) and obstructive lung disease (OLD) possibly through generalized systemic inflammation. The purpose of this study was to investigate the relationship between MetS and its components and lung function patterns.

Methods

Participants (n = 3978) were drawn from Pingluo and Qingtongxia residents at baseline from the Ningxia Cohort Study. The MetS was assessed according to the criteria of National Cholesterol Education Program III. Spirometric parameters were measured to define lung function. Through multiple linear regression and logistic regression analysis, these relationships were tested.

Results

The prevalence of obstructive lung disease (OLD) was comparable between genders (15.9% and 14.2%). The prevalence of obstructive pulmonary disease (OLD) was comparable between genders (15.9% and 14.2%), but the prevalence of MetS in males with co-existent OLD was lower than that in females (32.9% and 40.8%). After adjusting for potential confounders such as age and family income group, impaired lung function was associated with individual components of the metabolic syndrome, such as abdominal obesity, hypertension, and low HDL -C(all parameters were $p < 0.05$).

Conclusions

As an important component of MetS, abdominal obesity is associated with impaired lung function. Surprisingly, there is a negative correlation between HDL-C and lung function, and the presence of this relationship suggests a new understanding of the role of HDL-C.

Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by an incomplete reversible limitation of airflow, which usually develops progressively and is associated with an abnormal inflammatory response of the lungs to harmful particles or gases. COPD is the leading cause of morbidity and mortality worldwide [1]. In addition, COPD is projected to become the third leading cause of death globally by 2020 [2]. In China, the prevalence of COPD among people over 40 years old was 8.2%, which was the fifth leading cause of death in the country [3, 4]. Therefore, it was important to identify and assess the impact of COPD and related diseases on disease progression.

The diagnosis of COPD considering its inflammatory nature and comorbidity adds to the term chronic systemic inflammatory syndrome [5, 6]. Metabolic syndrome (MetS), which is characterized by abdominal obesity, hypertension, insulin resistance, and dyslipidaemia, is one of its comorbidities and can increase the risk of cardiovascular disease and type 2 diabetes [7, 8]. Pulmonary dysfunction is a symptom of COPD, and recent studies on the role of MetS and its components in the prediction of lung dysfunction had received particular attention [9–11].

Findings from studies in Italy, Taiwan and Japan have shown that MetS are independently associated with restrictive patterns of impaired lung function [12–14], and other reported results have also suggested that restricted pulmonary disease (RLD) was associated with MetS. However, the Guangzhou Biobank Cohort Study has found that air obstruction was associated with MetS [15]. Meanwhile, the Japanese study found that airflow obstruction of the Global Initiative for Chronic Obstructive Lung Disease (GOLD) stage II-IV might be related to MetS in men [16]. However, large-scale studies on obstructive pulmonary disease and MetS are scarce at present. Therefore, the purpose of this study was to explore the relationship between MetS and its components and lung function, and to compare the differences in MetS components among adults of different genders and ages in rural areas in China.

Methods

Study setting

Figure 1 shows the locations of Pingluo and Qingtongxia, which are in the north and the middle of Ningxia Hui Autonomous Region, respectively. Pingluo county and Qingtongxia county covers areas about 1,568 and 2,445 square kilometers, respectively. These two counties have a temperate continental monsoon climate, i.e. which is characterized by long duration of cold weather in winter, short duration of hot weather in summer, dry climate and little rain and snow.

Study design and Participants

The study data were the baseline of a population-based cohort study conducted by Ningxia Medical University between March 2018 and May 2019 in Pingluo and Qingtongxia, which included 3,978 residents. All participants must meet the following inclusion criteria to be formally enrolled in the study : (i) male and female adults aged between 35 and 74, (ii) the registered permanent residents in the selected investigation sites (those who stay at home for more than five months throughout the year), (iii) have no serious physical disability and are able to communicate normally, (iv) registration report of morbidity and death of the disease belongs to the administrator of the local health department. The specific process is shown in Fig. 2.

Data collection and measurement

Questionnaires were collected from each subject by trained college students and village doctors. Lifestyle (smoking and drinking), medical history (disease and medication histories), and physiological conditions (including pregnancy and fasting time) information were collected during health examination via face by face interview. Estimates of self-reported smoking, alcohol drinking, educational level and family income were obtained from questionnaire responses. The participants were classified as current, former and never smokers. Current smokers were defined as smoking more than one cigarette a day for more than six months. Never smokers included not smoking more than one cigarette per day and for no more than six months. Alcohol drinking was divided into two levels. Current drinkers include those who drink alcohol at least once a week for more than six months.

Never drinkers were defined as drinking less than once a week on average. Education level is divided into primary school and no formal school education, Junior high school, Senior high school or above. Family income group: Calculated by quartiles. ‘Quartile 1’ represents the lowest family finance status, while ‘Quartile 4’ is the highest family finance status.

Blood samples included fasting plasma glucose (FPG), triglycerides (TG), and HDL cholesterol (HDL-C) were tested by the laboratory at the local community hospital. Anthropometric measurements, including height, weight and waist

circumference (WC) were evaluated by trained personnel using a bioelectrical impedance analyzer with 8-point tactile electrodes (InBody 720, Biospace Co, Seoul, Korea). The bioelectrical impedance analyzer was calibrated every morning before the examination and was validated for reproducibility and accuracy of body composition. Blood pressure was measured three times using an automated sphygmomanometer after the participant was in the seated position for at least 15 min. Height and weight were measured to the nearest 0.1 cm and 0.1 kg. Body mass index (BMI) was calculated as weight divided by height squared (kg/m 2).

All investigations were performed in accordance with the Declaration of Helsinki and approved by the Ethical Committee of Ningxia Medical University (No. 2018–012). All patients gave their consent for participation in the study, or if that was not possible, consent was provided by appropriate family members.

Assessment of lung function

Forced expiratory volume in one second (FEV1), forced vital capacity (FVC) and the ratio of FEV1 to FVC were determined by spirometry using a digital spirometer interfaced to a computer (Chestgraph HI-101, CHEST MI, Inc., Tokyo, Japan). This spirometer can be used to determine the predicted FEV1 and FVC values based on the predictive equation. The predicted FVC and FEV1 values vary with the characteristics of a given population (age, height, gender, and race/ethnicity). All spirometric examinations were performed when the participants were in sitting position with a nose clip. Each participant was required to perform three satisfactory curves according to the recommendations of the American Thoracic Society [17], and the highest values were used in analyses. The lung function results were expressed as expiratory volume (L) and percentage of the predicted values of individuals with similar characteristics (sex, age and height). Calibrations were performed each morning according to the manufacturer's instruction. Restrictive lung disease (RLD) was defined as FVC < 80% and FEV1/FVC > 70% of predicted value. Participants with FEV1/FVC < 70% of predicted values were assigned as having obstructive lung disease (OLD).

Assessment of metabolic syndrome

We classified participants as having MetS if they have abdominal obesity as defined by Asia-Pacific cut-off limits [18] (waist circumference ≥ 90 cm for males and ≥ 80 cm for females) plus any two of the following four factors according to the National Cholesterol Education Program (NCEP) Adult Treatment Panel III [19] definition: a. fasting plasma glucose (FPG) ≥ 5.6 mmol/L or previously diagnosed type 2 diabetes; b. triglycerides (TG) ≥ 1.7 mmol/L or specific treatment for this lipid abnormality; c. high-density lipoprotein cholesterol (HDL-C) < 1.03 mmol/L in males or < 1.29 mmol/L in females or specific treatment for this lipid abnormality; d. systolic blood pressure (SBP) ≥ 130 mmHg or diastolic blood pressure (DBP) ≥ 85 mm Hg or treatment of previously diagnosed hypertension. Subjects without any of the five risk factors received an MetS score 0, and those with one, two, three and four or more of the risk factors received an MetS score of 1, 2, 3 and ≥ 4, respectively.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD). Frequencies and percentages were used to report categorical variables. Gender differences were evaluated by chi-square test for categorical variables and by one-way analysis of variance (ANOVA) for continuous variables. By gradually adjusting the latent variables, the relationship between lung function and metabolic equivalent and its composition was established by multiple linear regression analysis. The relationships between OLD and scores of MetS were determined using binary logistic regression. Potential confounding factors, including age, smoking, alcohol drinking, educational level, family income group and body mass index were adjusted to assess the associations. All analyses were conducted using SPSS for Windows software, version 23.0 (SPSS Inc., Chicago, Illinois, USA). A two-sided p value < 0.05 was considered statistically significant.

Results

A total of 3978 subjects (1760 males and 2218 females) were included for analysis (Table 1). Females were significantly younger than males (mean ages, 53.6 ± 8.3 vs. 58.1 ± 8.8, p values < 0.001). Males were better educated and less family income than females, but had higher frequency of current smoking and alcohol drinking, and there is no statistical difference in family income between males and females. Significant differences in other clinical characteristics were observed between genders (p values < 0.001), except of TG (p values = 0.493). Compared to females, males had greater WC (88.9 ± 10.2 vs. 86.2 ± 8.8 cm), higher levels of SBP (135.1 ± 18.3 vs. 133.3 ± 18.5 mmHg), DBP (83.8 ± 12.4 vs. 82.2 ± 11.7 mmHg), and FPG (5.5 ± 0.8 vs. 5.4 ± 0.8 mmol/L), but lower HDL-C (1.3 ± 0.3 vs. 1.4 ± 0.3 mmol/L). The prevalence of MetS was significantly higher in females than males. Despite there was no gender difference in the mean estimates of FEV1 (% predicted) and FEV1/FVC ratio, males had a significantly higher mean FEV1. There were not significant differences between the genders of OLD and RLD, with the former being more males than females and the latter being the opposite.

Table 1
Basic characteristic of the study objects.

	Males (n = 1760)	Females (n = 2218)	All (n = 3978)	P Value
Age (years)	58.1 ± 8.8	53.6 ± 8.3	55.6 ± 8.8	< 0.001
Educational level (%)				< 0.001
Primary school and no formal school education	1026 (58.3)	1463 (66.0)	2489 (62.6)	
Junior high school	625 (35.5)	672 (30.3)	1297 (32.6)	
Senior high school or above	109 (6.2)	83 (3.7)	192 (4.8)	
Family income group (%)				0.087
Quartile 1 (<¥10,000)	400 (22.7)	449 (20.2)	849 (21.3)	
Quartile 2 (¥10,000–¥20,000)	507 (28.8)	610 (27.5)	1117 (28.1)	
Quartile 3 (¥20,000–50,000)	398 (22.6)	525 (23.7)	923 (23.2)	
Quartile 4 (>¥50,000)	455 (25.9)	634 (28.6)	1089 (27.4)	
Smoking				< 0.001
Current (%)	498 (28.3)	11 (0.5)	509 (12.8)	
Never (%)	1262 (71.7)	2207 (99.5)	3469 (87.2)	
Alcohol drinking				< 0.001
Current (%)	261 (14.8)	21 (0.9)	282 (7.1)	
Never (%)	1499 (85.2)	2197 (99.1)	3696 (92.9)	
BMI (kg/m ^{2})	25.0 ± 3.3	24.8 ± 3.2	24.9 ± 3.3	0.148
WC (cm)	88.9 ± 10.2	86.2 ± 8.8	87.4 ± 9.5	< 0.001
SBP (mmHg)	135.1 ± 18.3	133.3 ± 18.5	134.1 ± 18.4	0.002
DBP (mmHg)	83.8 ± 12.4	82.2 ± 11.7	82.9 ± 12.1	< 0.001
FPG (mmol/L)	5.5 ± 0.8	5.4 ± 0.8	5.5 ± 0.8	< 0.001
TG (mmol/L)	1.5 ± 0.8	1.5 ± 0.7	1.5 ± 0.7	0.493
HDL-C (mmol/L)	1.3 ± 0.3	1.4 ± 0.3	1.3 ± 0.3	< 0.001
MetS (%)	664 (37.7)	1075 (48.5)	1739 (43.7)	< 0.001
abdominal obesity	768 (43.6)	1680 (75.7)	2448 (61.5)	< 0.001

Continuous data are shown as mean ± SD and compared using independent sample t tests. Categorical data are shown as n (%) and compared using the chi-square test.

BMI body mass index, WC waist circumference, SBP systolic blood pressure, DBP diastolic blood pressure, FPG fasting plasma glucose, TG triglycerides, HDL-C high-density lipoprotein cholesterol, MetS metabolic syndrome, FVC forced vital capacity, FEV1 forced expiratory volume in 1 s, OLD obstructive lung disease, RLD restrictive lung disease.

	Males (n = 1760)	Females (n = 2218)	All (n = 3978)	P Value
High blood pressure	1187 (67.4)	1324 (59.7)	2511 (63.1)	< 0.001
High glucose	727 (41.3)	780 (35.2)	1507 (37.9)	< 0.001
High triglycerides	624 (35.4)	802 (36.2)	1426 (35.8)	0.646
Low HDL-C	372 (21.1)	849 (38.3)	1221 (30.7)	< 0.001
FVC %predicted	75.5 ± 15.5	77.5 ± 15.4	76.6 ± 15.5	< 0.001
FVC (L)	2.7 ± 0.6	2.1 ± 0.5	2.4 ± 0.6	< 0.001
FEV1%predicted	75.2 ± 15.2	74.2 ± 14.9	74.6 ± 15.0	0.043
FEV1 (L)	2.1 ± 0.5	1.7 ± 0.4	1.9 ± 0.5	< 0.001
FEV1/ FVC ratio	80.1 ± 11.8	80.9 ± 11.5	80.6 ± 11.7	0.198
OLD (%)	280 (15.9)	314 (14.2)	594 (14.9)	0.068
RLD (%)	883 (50.2)	1071 (48.3)	1954 (49.1)	0.125

Continuous data are shown as mean ± SD and compared using independent sample t tests. Categorical data are shown as n (%) and compared using the chi-square test.

BMI body mass index, WC waist circumference, SBP systolic blood pressure, DBP diastolic blood pressure, FPG fasting plasma glucose, TG triglycerides, HDL-C high-density lipoprotein cholesterol, MetS metabolic syndrome, FVC forced vital capacity, FEV1 forced expiratory volume in 1 s, OLD obstructive lung disease, RLD restrictive lung disease.

Table 2 shows the independent relationships between each component of MetS and FVC (% predicted), FEV1 (% predicted) and FEV1/FVC ratio by multiple linear regression analyses. In males, WC and SBP were significantly negatively correlated with FVC, while DBP and FPG were opposite. DBP was weakly related FVC in females. A significant negative correlation between HDL-C and FVC was observed in females and males. The relationship between WC, SBP and DBP and FEV1 was similar to that of FVC in males. There was a strong negative correlation between HDL and FEV1 in females, while the remaining variables were not related. Otherwise, HDL-C was weakly correlation with FEV1/FVC ratios in males. None of the variables were associated with FEV1 in females.

Table 2
Regression coefficients of each metabolic component individually entered into adjust model predicting FVC (%predicted), FEV1 (%predicted) and FEV1/FVC ratios.

	FVC (%predicted)		FEV1 (%predicted)		FEV1/FVC ratio	
	Males	Females	Males	Females	Males	Females
Variables	β (SE)	β (SE)	β (SE)	β (SE)	β (SE)	β (SE)
WC (cm)	-0.067 (0.038)**	0.041 (0.039)	-0.057 (0.039)*	0.037 (0.038)	0.041 (0.030)	0.007 (0.030)
SBP (mmHg)	-0.070 (0.028)*	-0.058 (0.028)	-0.080 (0.029)*	-0.017 (0.028)	-0.005 (0.023)	0.030 (0.022)
DBP (mmHg)	0.100 (0.040)**	0.068 (0.042)*	0.068 (0.041)*	0.037 (0.042)	-0.028 (0.032)	-0.014 (0.032)
FPG (mmol/L)	0.056 (0.450)*	0.034 (0.429)	0.028 (0.459)	0.007 (0.424)	-0.032 (0.359)	-0.014 (0.329)
TG (mmol/L)	-0.003 (0.499)	-0.028 (0.464)	0.032 (0.509)	-0.007 (0.459)	0.038 (0.398)	0.021 (0.357)
HDL-C (mmol/L)	-0.068 (1.233)**	-0.136 (1.120)***	-0.029 (1.257)	-0.100 (1.109)***	0.054 (0.984)*	0.013 (0.861)
Data were calculated using multiple linear regression. Adjustments were made for age and family income group.						
WC waist circumference, SBP systolic blood pressure, DBP diastolic blood pressure, FPG fast plasma glucose, TChol total cholesterol, HDL-C HDL cholesterol, TG triglycerides, FVC forced vital capacity, SE standard error						
*p < 0.05, **p < 0.01, ***p < 0.001						

The prevalence of RLD and OLD with coexistent MetS were significant differences in males and females (38.2% vs. 32.9%) (48.7% vs. 40.8%) (Table 3). The ORs of MetS for RLD were not significantly different in all participants was observed in crude model and after adjust model 1, 2. The ORs of OLD of MetS in males showed no significant difference for crude model and after adjust model 1, 2. In addition, the ORs of OLD of MetS were significant different in male was observed in crude model [0.695 (95% confidence interval CI, 0.546–0.886)], after adjust model 1 [0.682 (95% CI, 0.534–0.872)] and model 2 [0.738 (95% CI, 0.568–0.959)].

Table 3
Odds ratios for restrictive lung disease (RLD) and obstructive lung disease (OLD) in metabolic syndrome

Variable	RLD		OLD	
	Males	Females	Males	Females
MetS (%)	38.2	48.7	32.9	40.8
Crude OR (95% CI)	1.038 (0.856–1.259)	1.021 (0.865–1.207)	0.777 (0.593–1.018)	0.695 (0.546–0.886)
Adjust OR (95% CI)				
Model 1	1.043 (0.858–1.268)	0.942 (0.794–1.116)	0.772 (0.589–1.013)	0.682 (0.534–0.872)
Model 2	0.968 (0.777–1.206)	0.927 (0.773–1.111)	0.825 (0.609–1.117)	0.738 (0.568–0.959)
Data were calculated using multiple logistic regression.				
Adjustments for model 1 were age smoking and alcohol drinking.				
Adjustments for model 2 were age, smoking, alcohol drinking, educational level, family income group and body mass index.				

The correlation results of OLD and MetS Score in males and females are shown in Table 4. The numbers of males with OLD and 1, 2, 3 and 4 + MetS scores were 74, 87, 61 and 31; females, 65, 98, 80, 48, respectively. In females, OLD and MetS score 4 were statistically significant in crude model [0.539 (95% CI, 0.314–0.925)] and adjusted model 1 [0.507 (95% CI, 0.294–0.873)]. The relationships were not statistically significant between OLD and MetS scores after adjusting confounding factors in males.

Table 4
Association between OLD and MetS Score in males and females according to odd ratios (OR).

	Males				Females			
		Crude model	Model 1	Model 2		Crude model	Model 1	Model 2
MetS Score	n (%)	OR (95% CI)	OR(95% CI)	OR(95% CI)	n (%)	OR (95% CI)	OR (95% CI)	OR (95% CI)
0	27 (9.6)	Reference	Reference	Reference	23 (7.3)	Reference	Reference	Reference
1	74 (26.4)	1.253 (0.776–2.025)	1.259 (0.778–2.039)	1.284 (0.791–2.084)	65 (20.7)	0.972 (0.576–1.639)	0.936 (0.554–1.582)	0.984 (0.578–1.675)
2	87 (31.7)	1.206 (0.754–1.929)	1.211 (0.754–1.943)	1.285 (0.786–2.101)	98 (31.2)	0.875 (0.531–1.440)	0.837 (0.507–1.381)	0.920 (0.544–1.556)
3	61 (21.8)	0.936 (0.573–1.529)	0.935 (0.572–1.530)	1.035(0.608–1.762)	80 (25.5)	0.722 (0.435-1.200)	0.699 (0.420–1.163)	0.792 (0.457–1.372)
≥ 4	31 (11.1)	0.899 (0.515–1.569)	1.091 (0.820–1.452)	1.029 (0.557–1.901)	48 (15.3)	0.539 (0.314–0.925)	0.507 (0.294–0.873)	0.577 (0.321–1.037)
Data were calculated using multiple logistic regression.								
Adjustments for model 1 were smoking and family income group.								
Adjustments for model 2 were age, smoking, alcohol drinking, educational level, family income group and body mass index.								

Discussion

The current analysis indicated a high prevalence of metabolic syndrome, and it was noteworthy that in both men and women, individual composition of abdominal obesity, low HDL-C, and high blood pressure was significantly associated with decreasing FVC and FEV1. In addition, MetS and MetS score 4 were negatively correlated with OLD in women.

When we independently predicted FVC, FEV1 and FEV1/FVC ratio for each metabolic component, we found that after adjusting for age and family income group, WC was one of the MetS components associated with the decrease of FVC and FEV1 in males. This was consistent with some studies [13, 20, 21]. At present, it was believed that central obesity (abdominal obesity) was the source of common metabolic diseases and cardiovascular diseases in adults, such as hyperglycemia, hypertension, dyslipidemia and so on, and was the core component of MetS [22]. Most of the current data support the link between MetS and impaired lung function mainly through abdominal obesity. WC, as one of the indicators of abdominal obesity, was related to the deterioration of lung function [23]. Central obesity may affect the mechanical performance of the ventilator because it limits the expansion of the diaphragm. The gender difference may be related to the respiratory movement and fat distribution of the chest wall and abdominal wall, and have different effects on the lung function of women and men [24]. Furthermore, MetS is characterized by systemic inflammation, and endothelial dysfunction caused by this systemic inflammation leads to impaired organ system function [25, 26]. Notably, our study found that males smoke more than females, and that long-term exposure to cigarette smoke causes systemic inflammation [27]. Thus, in active smokers with Mets, since it comes from two

sources, visceral fat and lung exposure to cigarette smoke, it may increase systemic inflammation. This may lead to increased endothelial dysfunction and a rapid decline in lung function.

It was worth noting that an important component in our study was HDL-C, and its increase was significantly correlated with decreased FVC and FEV1 in all participants. Consistent with this observation, a representative US sample study found that low HDL-C were associated with impaired lung function [11]. A small case-control study reported that HDL levels in the COPD group were significantly lower than those in the control group (47.1% vs 58%)[28]. A small population study in Mexico [29] observed that subjects with normal or elevated high-density lipoprotein cholesterol had lower FVC than subjects with low-density lipoprotein cholesterol. The pathophysiological role of this link is unknown. Usually chronic inflammation accelerates atherosclerosis in part by altering HDL and its ability to promote reverse cholesterol transport [30, 31]. Since this lipoprotein has anti-fungal, anti-inflammatory, antioxidant and even anti-apoptotic functions, we hope that its high value will have a beneficial effect on lung function [32–34]. But in recent years, the role of high density lipoprotein cholesterol as an atherosclerotic protective agent is changing.

In fact, it has been recognized that their ability to fight inflammation and mobilize cholesterol is severely affected by the oxidation of HDL-related proteins, and even this dysfunctional HDL may have a pro-inflammatory effect. This new approach to the physiology of high-density lipoprotein cholesterol may partly explain our finding that subjects with high cholesterol have a smaller lung volume [35]. At the same time, a genetic and molecular study reported two polymorphisms in apolipoprotein M (APOM)-related genes associated with decreased lung function in two ethnic groups (African-American and European-American). APOM is a kind of lipoprotein associated with high density lipoprotein cholesterol. The change of its gene expression will change the quality and function of high density lipoprotein cholesterol. In fact, the same study found that high levels of high-density lipoprotein cholesterol were associated with a decrease in the FEV1/FVC ratio [36].

In this study, MetS was associated with decreased prediction ability of OLD in females, and MetS score was negatively correlated with the incidence of OLD. This contradicts previous research [15, 37, 38]. However, after careful observation, we found that HDL-C played a crucial role in our study, and it was significantly negatively correlated with FVC and FEV1 in females, while other MetS components had relatively little effect on OLD. Our results are consistent with a previous study that found that in the Japanese population, patients with stage I airflow obstruction (FEV1/FVC < 70% and FEV1 ≥ 80% predicted values) had a lower risk of MetS than patients with normal lung function in the crude model [16].

There are limitations in this study. First of all, our study showed that MetS and its components were associated with decreased lung function, or even a negative correlation. However, due to the limitations of the study design, the causal relationship between the two has not been determined. Second, we also found that HDL, as an important metabolic component, is negatively correlated with impaired lung function, and the pathophysiological relationship between them is still unclear. Studies have shown that the incidence of lung function impairment itself is not clear. Although HDL-C is negatively correlated with FEV1 and FVC, it is statistically significant, but it does not represent lung involvement [39]. Therefore, it is necessary to further study these links.

Conclusions

In conclusion, our findings highlight the correlation between MetS and their components (especially abdominal obesity and low HDL-C) in the Chinese population. Thus, in the case of impaired lung function, the possibility of this relationship should not be easily overlooked.

Abbreviations

COPD
Chronic obstructive pulmonary disease
MetS
Metabolic syndrome
GOLD
Global Initiative for Chronic Obstructive Lung Disease
OLD
Obstructive lung disease
RLD
Restrictive lung disease
NCEP ATP III
National Cholesterol Education Program Adult Treatment Panel III
BMI
Body mass index
WC
Waist circumference
SBP
Systolic blood pressure
DBP
Diastolic blood pressure
FPG
Fasting plasma glucose
TG
Triglycerides
HDL-C
High-density lipoprotein cholesterol
FVC
Forced vital capacity
FEV1
Forced expiratory volume in 1 s

Declarations

Ethics approval and consent to participate

Allstudy investigations were performed in accordance with the Declaration of Helsinki and approved by the Ethical Committee of Ningxia Medical University(No.2018–012).

Consent for publication

Not applicable.

Availability of data and materials

The data used to support the findings of this study are available from thecorresponding author upon request.Yuhong Zhang: zhabour@163.com.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

FW and YH designed the study and drafted an outline.YZ,FW, DTand XC involved in collecting data.DTand JLanalyzed the data,wrote the original draft, and reviewed andedited the manuscript.JY and YZ critically reviewed and revised themanuscript. Finally, all authors read and approved the manuscript content.

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Figures

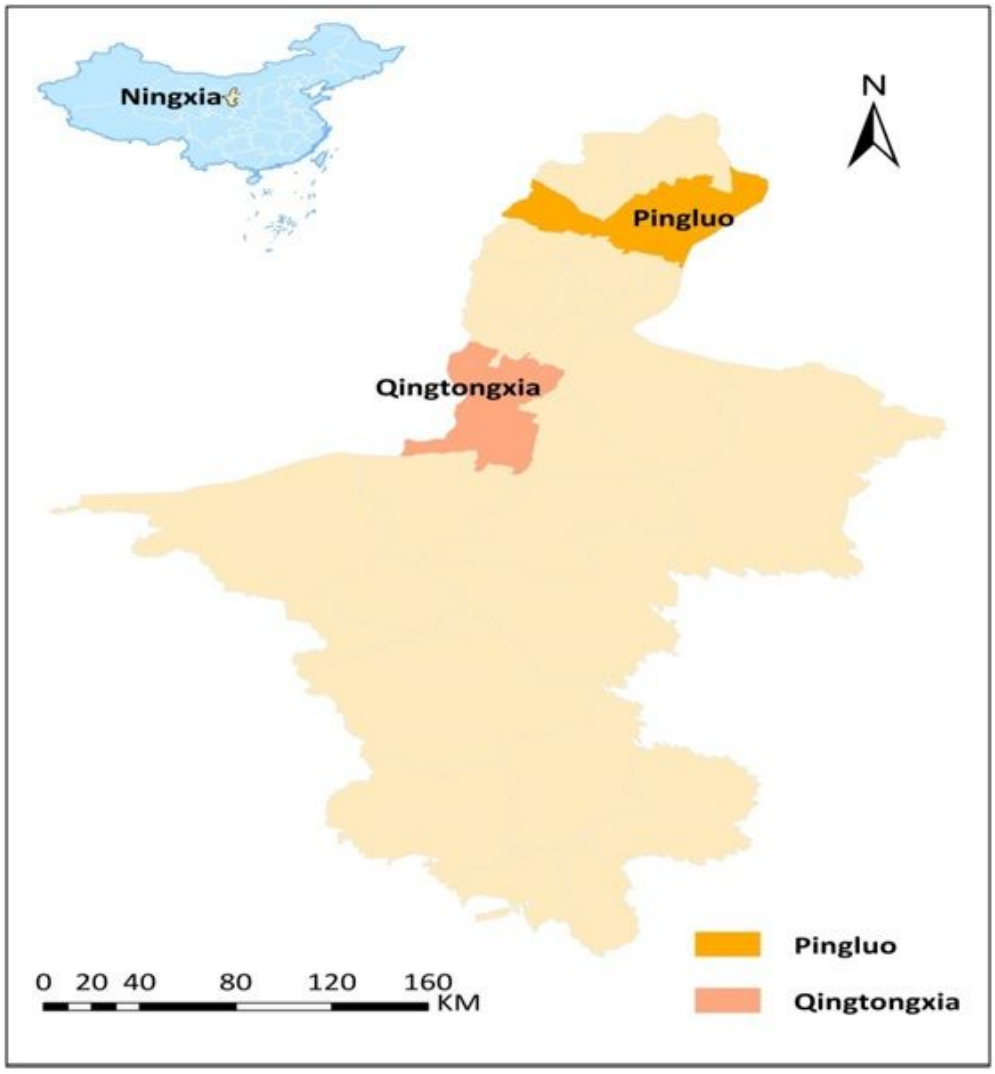

Figure 1

Location of Pingluo and Qingtongxia counties in Ningxia Hui Autonomous Region, China. 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.

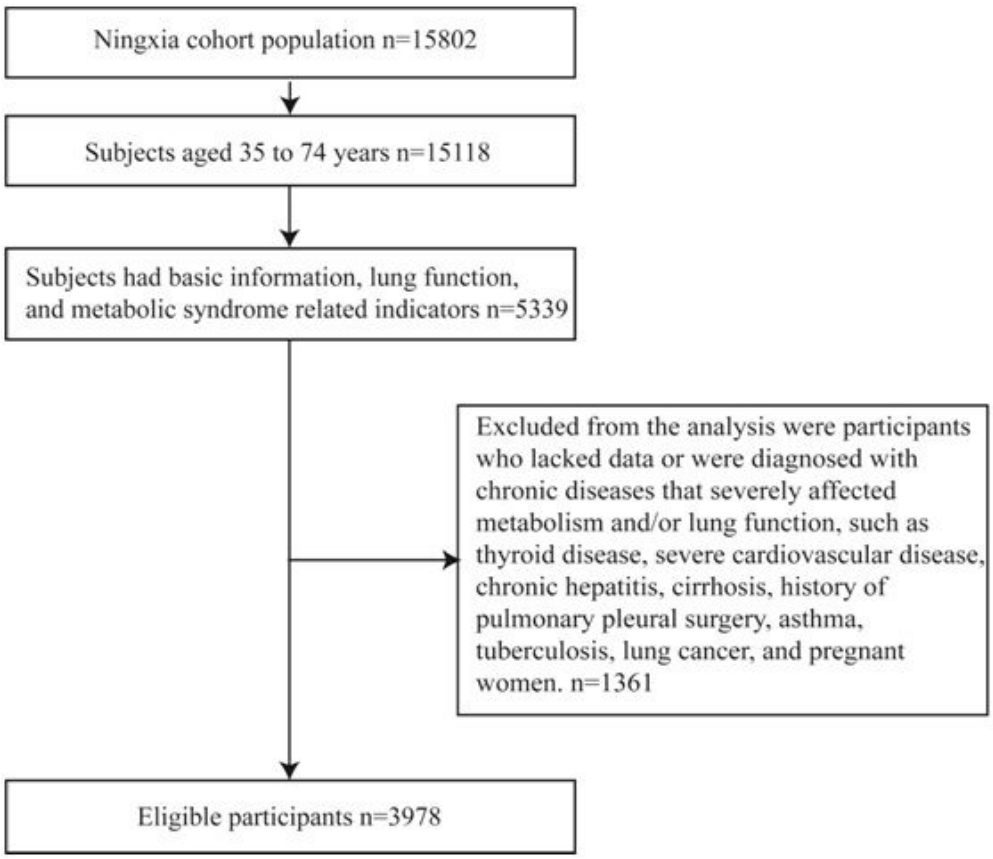

Figure 2

Selection of participants for inclusion in the study.