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Original Article

The Association between Pulmonary Function and Metabolic Syndrome in Koreans: A Cross-Sectional Study

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SUMMARY

Background: This study was performed to establish the relationship between these diseases by analysing the prevalence of metabolic syndrome and its link to pulmonary dysfunction.
Material and Methods: This study obtained data from the 6th Korea National Health and Nutrition Examination Survey (KNHANES, 2013–2015), a cross-sectional and nationally representative survey conducted by the Korean Centres for Diseases Control and Prevention.
Results: Of the 8,156 participants included in this study, the prevalence rate of restrictive pattern in the subjects of this study was 8.71% and 14.39% in the obstructive pattern. The prevalence of metabolic syndrome was 29.38%. The results of the relationship between pulmonary function and metabolic syndrome through logistic regression analysis showed a significant difference in the restrictive pattern, but no difference in the obstructive pattern, in odds ratio corrected for variables that could affect metabolic syndrome and pulmonary dysfunction (restrictive: OR 1.308, 95% CI 1.024–1.671; obstructive: OR 0.928, 95% CI 0.739–1.166).
Conclusion: The conclusion of this study found that, rather than obstructive pattern, the restrictive pattern was highly correlated with metabolic syndrome regardless of the confounding variables or risk factors of various metabolic syndromes that could be mediated.

1. Introduction

Metabolic syndrome is a series of a syndrome with clinical characteristics such as hypertension, abdominal obesity, hyperglycemia, dyslipidemia, and the prevalence rate is increasing rapidly with the increase of the world's obese population.[1,2] Also, studies on the effects on whole-body organs, such as cardiovascular disease and type 2 diabetes,[3,4] have been reported to increase the risk of pulmonary dysfunction, particularly in recent years.[5,6]

Pulmonary dysfunction, which means that there is an obstructive and restrictive pattern, has a significant correlation with ischemic coronary disease and stroke,[7,8] resulting in an increase in mortality due to the risk of these cardiovascular diseases.[9] The obstructive pattern represents a significant decrease in forced expiratory volume in one second (FEV_1) due to airway disorders and is a major cause of chronic obstructive pulmonary disease (COPD).[10] Conversely, a restrictive pattern is reduced in both forced vital capacity (FVC) and FEV_1 due to defects of chest conformity.[11]

Some studies have shown that metabolic syndrome and COPD are related,[12,13] while others have more to do with restrictive pulmonary disease than COPD.[14,15] This reduced pulmonary function is reported to occur before the progression of metabolic syndrome,[16] but the correlation between reduced pulmonary function and metabolic syndrome is not consistently explained, and there are no clear results for potential mechanisms.

Moreover, information on the association between pulmonary function and metabolic syndrome from population-based studies in Korea is relatively scarce, and further research on the link between pulmonary function disorders and metabolic syndrome is needed because improved understanding of the lung function of the metabolic syndrome patients can affect their clinical management. To this end, the study aims to establish the relationship between these diseases by analyzing the prevalence of metabolic syndrome and its link to the pulmonary dysfunction using data from the Korea National Health and Nutrition Survey (KNHANES) data.

2. Methods

2.1. Data source and sampling

This study obtained data from the 6th KNHANES (2013–2015), a cross-sectional and nationally representative survey conducted by the Korean Centers for Diseases Control and Prevention (KCDC). The subjects were designated as those who responded to both the examination and the health survey among adults aged 40 or older who were subject to the pulmonary function measurement. Among 22,948 subjects that participated in KNHANES, 10,110 subjects under 40 years of age, 4,008 subjects who did not measure pulmonary function, 464 subjects who did not measure metabolic syndrome

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components, and 210 subjects who did not do the health survey were excluded. A total of 8,156 participants were eligible for this study (Figure 1). KNHANES was conducted without deliberation by the Research Ethics Review Committee, which is a study conducted by the state for public welfare under the Bioethics Act.

2.1.1. Covariates

General characteristic information such as sex, age, body mass index (BMI), waist circumference (WC), total cholesterol, triglyceride, HDL-cholesterol, systolic blood pressure, diastolic blood pressure, fasting glucose, smoking and drinking condition was included as covariates in the analysis model.

BMI was calculated by dividing [weight (Kg)/height (m^2)]. WC was measured at the midpoint between the bottom of the rib cage and the top of the lateral border of the iliac crest with full expiration. Blood samples were collected from subjects in the morning after overnight fasting and analyzed at a national central laboratory. Blood pressure was measured using a mercury sphygmomanometer in a seated position after a 10-minute rest period. Two measurements were made for all subjects at 5-minute intervals. An average of two measurements was used for the data analyses. Cigarette smoking condition was categorized as never smokers, ex-smokers and current smokers, and drinking condition was dichotomized as current users and nonusers.

2.1.2. Measurement of pulmonary function

Pulmonary function was measured using a spirometer (model 2130; SensorMedics, Yorba Linda, California). Participants were classified according to respiratory patterns into a normal group (FEV_1 / FVC ≥ .70, FVC ≥ .80% predicted), an obstructive pulmonary dysfunction group (FEV_1 / FVC < .70), and a restrictive pulmonary dysfunction group (FVC < 80% predicted, FEV_1 / FVC ≥ .70).[17]

2.1.3. Metabolic syndrome

The definition of metabolic syndrome in the study was diagnosed with metabolic syndrome if three or more of the five or more components were satisfied using the guidelines of the National Cholesterol Education Program Adult Treatment Panel III; (1) abdominal obesity: waist circumference > 90 cm in men and > 85 cm in women; (2) hypertriglyceridemia: ≥ 150 mg/dL; (3) reduced HDL cholesterol: < 40 mg/dL for men and, < 50 mg/dL for women; (4) hypertension: systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg; and (5) elevated fasting glucose: ≥ 100 mg/dL. If participants were using anti-hypertension or diabetes or dyslipidemia treatment medication, they were considered to be present.[18]

2.2. Ethical considerations

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

2.3. Data analysis

Since this study uses complex samples data, the weight given by the KNHANES has been applied. General characteristics were compared according to the pulmonary function and the prevalence of metabolic syndrome through the Chai-square test. A logistic regression analysis was used to analyze the association between pulmonary dysfunction and metabolic syndrome, and p-values < 0.05 were considered statistically significant. Data analysis uses the SPSS 22.0 window version.

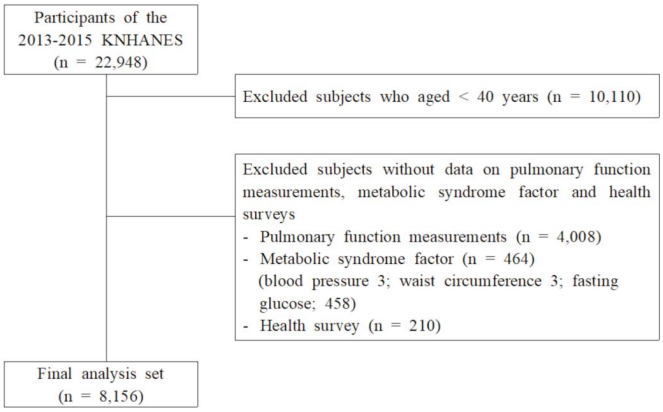

Figure 1. Subject selection from the Korea National Health and Nutrition Examination Survey 2013–2015.

3. Results

3.1. Characteristics of subjects according to the pulmonary function

The prevalence rate of restrictive pattern in the subjects of this study was 8.71% and 14.39% in obstructive pattern. In the characteristics of the subjects with pulmonary function, there was a significant difference in pulmonary dysfunction in all variables except the drinking condition. The prevalence of metabolic syndrome according to pulmonary dysfunction was the highest with a restrictive pattern of 45.0%. Also, male, and current smokers were highest in obstructive pattern than those normal and restrictive patterns. In addition, FVC and FEV1 were the lowest in a restrictive pattern (2.86; 2.28), and FEV1/FVC was the lowest in an obstructive pattern (Table 1).

3.2. Characteristics of subjects according to the metabolic syndrome

The prevalence of metabolic syndrome was 29.38%. In the characteristics of the subjects with the metabolic syndrome, there were statistically significant differences in all variables except drinking condition. The restrictive and obstructive dysfunction pattern of the metabolic syndrome subjects was 12.4% and 14.7%, respectively, which was significantly higher than the 6.4% and 12.7% of the non-metabolic syndrome subjects (Table 2).

3.3. Odds ratios for metabolic syndrome according to the pulmonary function

To find out the association between metabolic syndrome and pulmonary dysfunction, logistic regression analyses were performed. In crude, which no covariates have been adjusted, both restrictive and obstructive pattern showed significant differences comparing to the normal group (restrictive: OR 2.156, 95% CI 1.792–2.593; obstructive: OR 1.275, 95% CI 1.100–1.478). However, Model 1 to Model 3, which adjusted for variables that could affect metabolic syndrome and pulmonary dysfunction, showed a significant difference in the restrictive pattern, but no difference in the obstructive pattern (Model 3, restrictive: OR 1.308, 95% CI 1.024–1.671; obstructive: OR 0.928, 95% CI 0.739–1.166) (Table 3).

4. Discussion

This study was conducted to investigate the relationship be-

Table 1
Characteristics of subjects according to the pulmonary function.

	Normal (n = 6,272)	Restrictive (n = 710)	Obstructive (n = 1,174)
MetS (%)*	27.5[a]	45.0[b]	32.9[c]
Male (%)*	42.8[a]	51.5[b]	74.0[c]
age (y)*	54.13 ± 0.18[a]	58.14 ± 0.48[b]	63.74 ± 0.36[c]
BMI (kg/m^2)*	24.09 ± 0.05[a]	25.56 ± 0.17[b]	23.99 ± 0.10[a,c]
WC (cm)*	82.10 ± 0.16[a]	86.96 ± 0.45[b]	85.15 ± 0.31[c]
Total cholesterol (mg/dL)*	194.64 ± 0.54[a]	191.86 ± 1.49[a,b]	188.46 ± 1.25[b,c]
Triglyceride (mg/dL)	147.60 ± 1.96	159.26 ± 5.14	149.18 ± 3.44
HDL-C (mg/dL)*	50.56 ± 0.18[a]	47.65 ± 0.51[b]	47.39 ± 0.41[b,c]
SBP (mmHg)*	119.28 ± 0.27[a]	123.87 ± 0.75[b]	123.91 ± 0.52[b,c]
DBP (mmHg)*	76.72 ± 0.17[a]	77.38 ± 0.52[a,b]	75.25 ± 0.37[a,c]
Fasting glucose (mg/dL)*	101.84 ± 0.38[a]	112.25 ± 1.77[b]	104.97 ± 0.80[c]
Smoking (%)* (non-/ex-/current)	60.8/20.8/18.4	55.5/26.1/18.4	33.6/36.2/30.3
Drinking (%) (non-/current)	28.1/71.9	31.5/68.5	29.3/70.7
FVC (L)*	3.64 ± 0.01[a]	2.86 ± 0.03[b]	3.70 ± 0.03[a,c]
FEV_1 (L)*	2.89 ± 0.01[a]	2.28 ± 0.02[b]	2.37 ± 0.02[c]
FEV_1/FVC (ratio, %)*	0.79 ± 0.00[a]	0.80 ± 0.00[a,b]	0.64 ± 0.00[c]

Data were presented as means ± SD or number (%).
[a,b,c] The same letters indicate non-significant difference between groups based on Bonferoni multiple comparison test.
MetS, metabolic syndrome; BMI, body mass index; WC, waist circumference; HDL-C, high density lipoprotein-cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure.
* $p < 0.05$ by chi-square test.

Table 2
Characteristics of subjects according to the metabolic syndrome.

	MetS (n = 2,396)	Non-MetS (n = 5,760)	*p*
Restrictive (%)	12.4	6.4	< 0.0001
Obstructive (%)	14.7	12.7	0.021
Male (%)	53.3	45.3	< 0.0001
age (y)	57.98 ± 0.26	54.86 ± 0.20	< 0.0001
BMI (kg/m^2)	26.17 ± 0.07	23.37 ± 0.04	< 0.0001
WC (cm)	89.38 ± 0.19	80.17 ± 0.14	< 0.0001
Total cholesterol (mg/dL)	195.98 ± 0.87	192.58 ± 0.53	< 0.0001
Triglyceride (mg/dL)	229.30 ± 4.03	114.78 ± 1.17	< 0.0001
HDL-C (mg/dL)	42.51 ± 0.22	53.02 ± 0.18	< 0.0001
SBP (mmHg)	128.73 ± 0.39	116.70 ± 0.26	< 0.0001
DBP (mmHg)	80.65 ± 0.27	74.91 ± 0.16	< 0.0001
Fasting glucose (mg/dL)	116.12 ± 0.84	97.62 ± 0.31	< 0.0001
Smoking (%) (non-/ex-/current)	50.5/25.5/24.0	59.3/22.4/18.3	< 0.0001
Drinking (%) (non-/current)	29.6/70.4	28.1/71.9	0.225
FVC (L)*	3.54 ± 0.02	3.61 ± 0.01	0.002
FEV_1 (L)*	2.71 ± 0.02	2.79 ± 0.01	< 0.0001
FEV_1/FVC (ratio, %)*	0.77 ± 0.00	0.78 ± 0.00	< 0.0001

Data were presented as means ± SD or number (%).
[a,b,c] The same letters indicate non-significant difference between groups based on Bonferoni multiple comparison test.
MetS, metabolic syndrome; BMI, body mass index; WC, waist circumference; HDL-C, high density lipoprotein-cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure.
* $p < 0.05$ by chi-square test.

Table 3
The adjusted odds ratios for metabolic syndrome according to the pulmonary function by logistic regression analysis.

Pulmonary dysfunction	Odds ratio	95% CI	p-value
Crude			
Normal	1 (reference)		
Restrictive	2.156**	1.792–2.593	< 0.0001
Obstructive	1.275*	1.100–1.478	0.001
Model 1			
Normal	1 (reference)		
Restrictive	2.111**	1.758–2.534	< 0.0001
Obstructive	1.166	0.999–1.361	0.051
Model 2			
Normal	1 (reference)		
Restrictive	1.893**	1.563–2.293	< 0.0001
Obstructive	0.976	0.824–1.157	0.781
Model 3			
Normal	1 (reference)		
Restrictive	1.308*	1.024–1.671	0.032
Obstructive	0.928	0.739–1.166	0.522

Model 1: adjusted for sex.
Model 2: adjusted for variables in model 1 + age, smoking condition.
Model 3: adjusted for variables in model 2 + body mass index, waist circumference, total cholesterol, systolic blood pressure, diastolic blood pressure, triglyceride, HDL-cholesterol.
Reference category: subjects with non-metabolic syndrome.
* $p < 0.05$, ** $p < 0.0001$.

tween pulmonary dysfunction and metabolic syndrome. The main finding of this study is that metabolic syndrome is highly associated with a restrictive pattern, not obstructive ventilation disorder. These results are consistent with recent studies suggesting a high risk of diabetes in a restrictive pulmonary pattern, but not in obstructive pulmonary disease.[19]

The prevalence of metabolic syndrome among pulmonary dysfunction was 32.9% in patients with the obstructive group, which showed a significant difference compared to 27.5% in the normal group ($p = 0.002$). These results are consistent with the results of a meta-analysis study that had a significant difference (p = 0.001) compared to 30.0% of the control group with normal pulmonary function, with a prevalence of metabolic syndrome of 32.0% among patients with COPD.[20] The prevalence of metabolic syndrome (45.0%) in patients with the restrictive pattern was significantly higher than that of an obstructive pattern (32.9%). This is consistent with the results of a study that showed statistically higher statistical significance in restrictive lung disease than in obstructive lung disease in both men and women in comparing the prevalence of metabolic syndrome of pulmonary dysfunction according to gender.[21]

Pulmonary dysfunction is known to be severely affected by smoking.[22] Some prior studies show that the influence of smoking conditions on the association between restrictive pattern and metabolic syndrome is low, while the effect on obstructive pattern is

significant.[23,24] The results of this study also showed that the current smoking rate due to obstructive pattern was 30.3%, significantly higher than 18.4% of the restrictive pattern. Therefore, it seems that smoking status is related to pulmonary dysfunction and airway obstruction. These findings are consistent with the results of prior research that smoking affects obstructive pattern more than restrictive pattern.

Pulmonary dysfunction is associated with risk factors for metabolic syndrome, such as type 2 diabetes, insulin resistance, abdominal obesity, and high blood pressure, especially in restrictive pulmonary dysfunction.[15,25,26] In this study, fasting glucose and WC were significantly higher in the restrictive than normal and obstructive (Table 1). In addition, metabolic syndrome showed significantly lower FVC, FEV_1 and FEV_1/FVC indicators than non-metabolism syndrome (Table 2). Previous studies have shown that middle-aged people with reduced lung function have a greater risk of diabetes, insulin resistance, hypertension, and cardiovascular disease within 10 years.[27–29] The results of these studies indicate that restrictive pulmonary dysfunction is closely related to metabolic syndrome and may increase the risk of diabetes.

There was a significant difference in both restrictive and obstructive patterns without any variables adjusting in the pulmonary function odds ratio according to the prevalence of metabolic syndrome (restrictive: OR 2.156, obstructive: OR 1.275). In contrast, when the variables that could affect metabolic syndrome and pulmonary dysfunction were adjusted, significant differences were found only in the restrictive pattern (Model 1: OR 2.111; Model 2: OR 1.893; Model 3: OR 1.308). However, the exact pathological mechanism for explaining this association has not been established.

One possible explanation is that pulmonary function is likely to be reduced because abdominal obesity reduces the movement of the diaphragm and restricts lung volume with fat accumulation in the abdominal cavity.[30] The results of this study also showed that the waist circumference was the highest in the restrictive pattern, consistent with previous studies. The chemical mechanism associated with this is thought to be a decrease in pulmonary function due to systemic inflammatory reactions caused by visceral fat affecting blood cytokines such as TNF-α (tumor necrosis factor-α), interleukin-6, leptin, and adiponectin.[31] Studies have shown that an increase in C-reactive protein (CRP), an indicator of the systemic inflammatory response, is highly associated with pulmonary dysfunction,[32] and chronic low-grade tissue inflammation decreases lung function.[33] As such, the inflammatory response seems to contribute to the decline in lung function and the relationship between metabolic syndrome.

Another potential explanation is that pulmonary dysfunction may be related to insulin resistance. Several previous studies have shown that the parameters of restrictive pulmonary disease predict the incidence of type 2 diabetes and are associated with basic insulin resistance.[34,35] Insulin resistance, a major etiology of diabetes, can alter the absorption of glucose in the chest muscles, thereby reducing the function of the respiratory muscles and contributing to the restrictive pattern.[36]

There are some limitations when evaluating the results of this study. First, although this study could help provide more information on the nature of this relationship, it was a cross-sectional study of measuring pulmonary function and metabolic syndrome factors at once. Because the cross-sectional study design tends to leave uncertainty about the time sequence, it was impossible to pinpoint the order of the underlying causes of pulmonary disease. Therefore, it will be worthwhile to find a mechanism to clarify the causal relationship between pulmonary function and metabolic syndrome through longitudinal studies in the future. Second, draw recall bias can be caused because socio-statistical characteristics of the research population are collected through surveys. Third, the overall prevalence of metabolic syndrome may have been underestimated because information on the components of metabolic syndrome excluded incomplete topics. However, this process is likely to have been randomly excluded, so it is unlikely that it will have a significant impact on this study results. Despite these limitations, this study has significant research and clinical implications. The strength of this study is that it obtains data from representative information of a large Korean population with a high response rate, allowing multiple statistical adjustments by potential disturbance factors.

This study was conducted to investigate the association between pulmonary function and metabolic syndrome in Koreans. The results of this study found that, rather than obstructive pattern, the restrictive pattern was highly correlated with metabolic syndrome regardless of the confounding variables or risk factors of various metabolic syndromes that could be mediated.

Conflict of interest

There are no conflicts of interest regarding this research.

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