

The Relationship between Metabolic Syndrome and Pulmonary Function

Original
Article

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Background: Impaired lung function is associated with mortality rate from cardiovascular and all other death causes. There were previous studies on the relationship between lung function impairment and metabolic syndrome, but they are insufficient. This study was conducted on Koreans to analyze each component of metabolic syndrome as well as its variability between sexes.

Methods: 1,370 subjects underwent a health examination at the Eulji General Hospital Health Center. We examined the association between lung function measurement (forced expiratory volume for 1 second [FEV₁], forced vital capacity [FVC], FEV₁/FVC) and metabolic syndrome using Student t-test, Pearson partial correlation coefficient, and analysis of covariance for statistical analysis, and we adopted metabolic syndrome defined by American Heart Association/National Heart, Lung, and Blood Institute in Asia.

Results: Men with metabolic syndrome tended to experience lung function impairment. In terms of association to each metabolic syndrome component, metabolic syndrome components in men were associated with pulmonary function impairment and the more metabolic syndrome diagnostic criteria factors the patients had, the more severe their pulmonary function tended to decline. In women, waist circumference, triglyceride and high-density lipoprotein cholesterol were associated with pulmonary function change.

Conclusion: In men, all metabolic syndrome components were associated with pulmonary function impairment, and the more metabolic syndrome components men had, the more severe their pulmonary functions decline. In women, components of metabolic syndrome were not associated with pulmonary function impairment.

Keywords: Metabolic Syndrome; Forced Expiratory Volume; Forced Vital Capacity; Obesity, Abdominal

INTRODUCTION

As the obese population increases, the incidence of metabolic syndrome is also increasing. There has been a recent report¹⁻⁴⁾ on the relationship between the diagnostic criteria of metabolic syndrome or changes in the pulmonary function and cardiovascular mortality and total mortality. As such, there is increasing interest in changes in metabolic syndrome associated with changes in pulmonary function.

In a number of recent studies, it was reported that among

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the changes in pulmonary function, pulmonary function, deterioration is related to hypertension, type 2 diabetes, low-density lipoprotein cholesterol, overall obesity, abdominal obesity and insulin resistance.⁵⁻⁹⁾ Among the above listed factors, hypertension, diabetes, and abdominal obesity are included as diagnostic criteria for metabolic syndrome, hence it can be inferred that identifying the relationship between metabolic syndrome and pulmonary function deterioration is meaningful.

In a study on the relationship between pulmonary function deterioration and metabolic syndrome, pulmonary function deterioration was detected where there is metabolic syndrome. Even when gender, age, smoking status, alcohol drinking and physical activity factors were reflected, limited pulmonary function deterioration showed independent relevance to increased risk of metabolic syndrome.⁸⁾

Obese people have shown signs of pulmonary function deterioration,⁸⁻⁹⁾ hence, a simple pulmonary function test during health examination can be used as a predictive factor for metabolic syndrome in obese people.

As such, this study will look into the relationship based on the changes in metabolic syndrome diagnostic criteria and pulmonary function indices, like forced expiratory volume for 1 second (FEV₁), forced vital capacity (FVC), and FEV₁/FVC ratio.

METHODS

1. Subjects

This study targeted those who underwent a health examination at the Eulji General Hospital Health Center between January 2, 2008 and August 13, 2008. The age of the subjects ranged from over 20 to under 70 years old, and included 1,370 people out of the total 1,566 patients. The subjects who reported a clinical history on cardiovascular disease (myocardial infarct, angina pectoris) and pulmonary disease (asthma, chronic obstructive pulmonary disease) or cancer, were excluded based on their survey answers. Those with no pulmonary function test results or body measurements (waist circumference, height) were also excluded.

2. Measurements

1) Survey

Prior to conducting the general health examination, patients' consent was attained to conduct a survey. The patients were asked to record specifically their past clinical history, the types of drugs they are taking, their alcohol and smoking history, and physical activity level, etc. Those who found it difficult to fill out the survey were assisted by nurses.

As for physical activity level, subjects were classified into 1) light activity: walking for less than 2 hours a day, working in an office, or working as a housewife with little household chores, 2) medium level activity: walking for 2–4 hours a day, working in manufacturing or service industry, or working as a housewife with a lot of household chores, 3) hard activity: working in agriculture, fishery, civil engineering or construction industry, 4) severe activity: athletes, or those who transport wood or engage in farming work during farming season.

2) Physical measurement

Waist circumference was measured from the center point of the last rib and iliac spine. Height and weight were measured while wearing light clothing (health examination gown). For obesity level, body mass index (BMI) was used, which is the value attained by dividing the body weight (kg) against the height (m²), to classify the subjects into obese (BMI ≥ 25 kg/m²), overweight (23 kg/m² ≤ BMI < 25 kg/m²) and normal weight (BMI < 23 kg/m²) groups. With the blood test, triglyceride, high-density lipoprotein cholesterol (HDL-C), and fasting blood sugar were measured. Blood pressure was measured using an automatic sphygmomanometer after taking over 5 minutes of rest.

3) Pulmonary function test

Pulmonary function was measured between 8 AM and 12 PM using a spirometer (model 2130; SensorMedics Co., Yorba Linda, CA, USA). Subject was in a seated position, and the measurement was taken by an experienced nurse. To reduce any variance in measurement by the person taking the measurement the same nurse measured everyone. The values measured were FEV₁, FVC, FEV₁/FVC.

3. Definition of Metabolic Syndrome

Metabolic syndrome, based on the Asia criteria of the American Heart Association/National Heart, Lung, and Blood Institute,¹⁰⁾ is diagnosed when 3 out of the following 5 categories are satisfied: 1) blood pressure of systolic blood pressure ≥ 130 mm Hg or diastolic blood pressure ≥ 85 mm Hg, or is taking a hypertension drug, 2) fasting blood sugar ≥ 100 mg/dL, or is taking a diabetes drug, 3) triglyceride ≥ 150 mg/dL, or is taking a dyslipidemia drug, 4) low HDL-C (male < 40 mg/dL, female < 50 mg/dL), or is taking a dyslipidemia drug, or 5) the waist circumference applied is male ≥ 90 cm, female ≥ 80 cm. Also, female waist circumference of over 85 cm was also applied based on the Korean Society for the Study of Obesity.¹¹⁾

4. Statistical Analysis

The data was shown as mean \pm standard deviation. For the difference in variables among the groups, Student t-test and χ^2 -test were used. For the relationship between each of the metabolic syndrome factors and pulmonary function, Pierson partial correlation coefficient was used, having modified the age and height factors. For the existence of metabolic syndrome and the relationship with pulmonary function, analysis of covariance was used by controlling the physical activity level and smoking level. This data was analyzed by using SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

1. General Characteristics

Average age of men and women was 44.07 ± 10.12 years old (male) and 43.11 ± 11.50 years old (female), respectively. Pulmonary function figures were higher in women than men. As for BMI, men's average was 24.51 ± 2.97 kg/m² and women's average was 22.77 ± 3.28 kg/m². The ratio of obese people (BMI ≥ 25 kg/m²) was 42.9% and 23.7%, respectively, for men and women. The distribution of metabolic syndrome was statistically higher for men than women at 25.5% versus 17.3%. Women had lower triglyceride and fasting blood sugar levels than men, but HDL-C was statistically higher. In men, systolic blood pressure was 122.09 ± 13.05 mm Hg and diastolic blood pressure was 72.87 ± 9.94 mm Hg, which is statistically higher than women's

systolic blood pressure of 116.33 ± 14.68 mm Hg and diastolic blood pressure of 69.14 ± 9.80 mm Hg.

As for the smoking ratio, current smoker ratio stands at 47.8% for men and 6.3% for women, showing a higher smoking rate in men with higher total smoking volume (Table 1).

2. Relationship between Diagnostic Criteria for Metabolic Syndrome and Pulmonary Function

Among males, there were big differences in FVC according to whether or not he had metabolic syndrome. In fact, the FVC difference was $83.42 \pm 10.08\%$, $87.47 \pm 10.19\%$ ($P < 0.001$). In addition, people with waist circumference of 90 cm or above had FVC of $84.05 \pm 9.99\%$, while for those with waist circumference below 90 cm it was $87.72 \pm 10.26\%$ ($P < 0.001$). Moreover, FVC of people with above 150 mg/dL of triglyceride was $84.66 \pm 9.78\%$ while it was $87.46 \pm 10.58\%$ ($P < 0.001$) for those with triglyceride of below 150 mg/dL. In particular, waist circumference and triglyceride showed the most significant difference of $P < 0.001$. On the other hand, FEV₁ was $97.43 \pm 12.21\%$ for triglyceride levels above 150 mg/dL, while below 150 mg/dL, FEV₁ recorded was $99.87 \pm 12.85\%$ ($P < 0.01$). As such, the difference was only evident between metabolic syndrome and triglyceride level. The FEV₁/FVC ratio difference was found to be correlated only to waist circumference. Among females, FVC didn't show any significant difference in any of these items. FEV₁ showed a difference according to whether or not she had metabolic syndrome and waist circumference of 85 cm and 80 cm, respectively, and whether the HDL-C level was high or low. However, there was no correlation found between FEV₁ and pulmonary function. The FEV₁/FVC ratio difference was found among those females with waist circumference of 85 cm or above and whether or not she had triglyceride and metabolic syndrome (Table 2).

In order to identify correlation between metabolic syndrome and pulmonary function, we have controlled the level of smoking and degree of physical activity, which all have influence on pulmonary function. When smoking and degree of physical activity were controlled, males showed significant correlation between metabolic syndrome and FVC, while females showed significant correlation between metabolic syndrome and FEV₁/FVC (No table was provided).

Table 1. Characteristics of participants.

Variables	Men (n = 715)	Women (n = 655)
Age (y)	44.07 ± 10.12	43.11 ± 11.50
FEV ₁ *	98.93 ± 12.65	101.10 ± 14.91
FVC	86.38 ± 10.37	87.31 ± 11.25
FEV ₁ /FVC (%)*	87.20 ± 6.34	89.15 ± 6.50
Body mass index (kg/m ²)*	24.51 ± 2.97	22.77 ± 3.28
WC (cm)*	87.02 ± 7.75	77.97 ± 8.86
TG (mg/dL)*	152.64 ± 102.04	96.66 ± 63.86
HDL-C (mg/dL)*	50.88 ± 11.40	59.30 ± 12.67
FBG (mg/dL)*	101.75 ± 26.00	93.86 ± 19.36
BP, systolic (mm Hg)*	122.09 ± 13.05	116.33 ± 14.68
BP, diastolic (mm Hg)*	72.87 ± 9.94	69.14 ± 9.80
Smoking status*		
None	229 (32.00)	574 (87.60)
Past	107 (15.00)	7 (1.10)
Current	342 (47.80)	41 (6.30)
Lifetime smoking (pack/y)*	17.07 ± 13.39	8.75 ± 9.92
Alcohol drinking*		
None	100 (14.00)	341 (52.10)
Past	8 (1.10)	6 (1.00)
Current	573 (80.10)	273 (41.70)
Physical activities*		
Stage 1	459 (79.10)	416 (78.30)
Stage 2	82 (14.10)	110 (20.50)
Stage 3	33 (5.70)	10 (1.90)
Stage 4	6 (1.00)	1 (0.20)

Values are presented as mean ± SD or number (%). P-values are for Student's t-test and χ^2 -test.

FEV₁: forced expiratory volume for 1 second, FVC: forced vital capacity, WC: waist circumference, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, FBG: fasting blood sugar, BP: blood pressure.

*Gender comparison (P < 0.001).

3. Correlation between Diagnostic Criteria for Metabolic Syndrome and Pulmonary Function

When age, height as well as total smoking amount were factored in, FVC showed significant negative correlation with waist circumference & triglyceride levels among males, while it showed positive correlation with HDL-C. In particular, waist

circumference with a value of P < 0.001 showed a high level of negative correlation. FEV₁ showed negative correlation with triglyceride levels, while FEV₁/FVC ratio showed positive correlation with waist circumference. Meanwhile, females showed no correlation with pulmonary function measurement value as well as metabolic syndrome component (Table 3).

Table 2. Relationship of metabolic syndrome components and pulmonary functions.

Variables		FEV ₁ (%)	FVC (%)	FEV ₁ /FVC (%)
Men (n = 715)				
MS*	Yes	97.21 ± 12.60 [†]	83.42 ± 10.08 [‡]	87.82 ± 5.90
	No	99.60 ± 12.54 [†]	87.47 ± 10.19 [‡]	86.99 ± 6.48
WC (cm)	≥90 [§]	98.00 ± 12.47	84.05 ± 9.99 [‡]	88.00 ± 5.35 [†]
	<90	99.52 ± 12.63	87.72 ± 10.26 [‡]	86.77 ± 6.79 [†]
TG (cm)	≥150	97.43 ± 12.21 [¶]	84.66 ± 9.78 [‡]	87.51 ± 6.64
	<150	99.87 ± 12.85 [¶]	87.46 ± 10.58 [‡]	87.00 ± 6.14
HDL-C (mg/dL)	<40 ^{**}	97.35 ± 12.00	84.06 ± 10.02 [†]	87.66 ± 5.52
	≥40	99.20 ± 12.75	86.78 ± 10.38 [†]	87.12 ± 6.47
FBS (mg/dL)	≥100 ^{††}	98.75 ± 12.26	85.18 ± 10.43 [†]	87.38 ± 6.04
	<100	99.03 ± 12.87	87.03 ± 10.28 [†]	87.10 ± 6.50
BP (mm Hg)	≥130/85 ^{‡‡}	98.29 ± 13.53	85.06 ± 11.01 [†]	86.89 ± 6.72
	<130/85	99.23 ± 12.22	87.00 ± 10.00 [†]	87.34 ± 6.16
Women (n = 655)				
MS*	Yes	104.09 ± 14.40 [†]	86.40 ± 11.25	90.59 ± 5.23 [¶]
	No	100.50 ± 14.96 [†]	87.53 ± 11.25	88.85 ± 6.71 [¶]
WC (cm)	≥85 [§]	105.61 ± 14.27 [‡]	87.98 ± 11.69	90.55 ± 4.98 [¶]
	<85	99.96 ± 14.87 [‡]	87.13 ± 11.16	88.80 ± 6.79 [¶]
WC (cm)	≥80	103.36 ± 14.80 [¶]	87.63 ± 11.56	89.50 ± 6.02
	<80	99.66 ± 14.82 [¶]	87.09 ± 11.08	88.93 ± 6.79
TG (mg/dL)	≥150	104.24 ± 15.02 [†]	86.70 ± 11.44	90.33 ± 5.51 [†]
	<150	100.56 ± 14.83 [†]	87.42 ± 11.23	88.95 ± 6.64 [†]
HDL-C (mg/dL)	≤50 ^{**}	103.87 ± 13.95 [†]	87.93 ± 11.35	90.00 ± 5.59
	>50	100.31 ± 15.09 [†]	87.13 ± 11.23	88.91 ± 6.73
FBG (mg/dL)	≥100 ^{††}	102.12 ± 13.62	86.17 ± 10.60	89.86 ± 5.39
	<100	100.85 ± 15.21	87.59 ± 11.40	88.98 ± 6.74
BP (mm Hg)	≥130/85 ^{‡‡}	103.17 ± 15.06	86.12 ± 11.57	89.93 ± 6.36
	<130/85	100.60 ± 14.84	87.68 ± 11.15	88.95 ± 6.54

Values are presented as mean ± SD. P-values are for Student's t-test.

FEV₁: forced expiratory volume for 1 second, FVC: forced vital capacity, MS: metabolic syndrome, WC: waist circumference, TG: triglyceride, HDL-C: high-density lipoprotein cholesterol, FBS: fasting blood sugar, BP: blood pressure, AHA/NHLBI: American Heart Association/National Heart, Lung, and Blood Institute.

*Diagnostic criteria of AHA/NHLBI (Asian). [†]P < 0.05. [‡]P < 0.001. [§]Diagnostic criteria of AHA/NHLBI & waist circumference (Korean women). ^{||}TG ≥ 150 or dyslipidemia drug intake. [¶]P < 0.01. ^{**}HDL-C < 40 (men), 50 (women) or dyslipidemia drug intake. ^{††}FBS ≥ 100 or diabetes drug intake. ^{‡‡}BP ≥ 130/85 or hypertension drug intake.

Table 3. Partial correlation coefficients adjusted for age, height, smoking.

	Men (n = 715)			Women (n = 655)		
	FEV ₁	FVC	FEV ₁ /FVC	FEV ₁	FVC	FEV ₁ /FVC
WC	-0.072	-0.189*	0.173 [†]	-0.010	0.001	-0.023
TG	-0.115 [‡]	-0.164 [‡]	0.078	-0.007	-0.121	0.183
HDL-C	0.093	0.125 [‡]	-0.040	-0.058	-0.048	-0.066
BP, systolic	-0.035	-0.065	0.046	-0.210	-0.292	0.081
BP, diastolic	-0.057	-0.089	0.055	-0.173	-0.256	0.075
FBG	-0.036	-0.027	0.008	-0.013	-0.208	0.274

P-values are for Pearson partial correlation coefficients.

FEV₁: forced expiratory volume for 1 second, FVC: forced vital capacity, WC: waist circumference, TG: triglyceride, HDL-C: high density lipoprotein cholesterol, BP: blood pressure, FBG: fasting blood sugar.

*P < 0.001. [†]P < 0.01. [‡]P < 0.05.

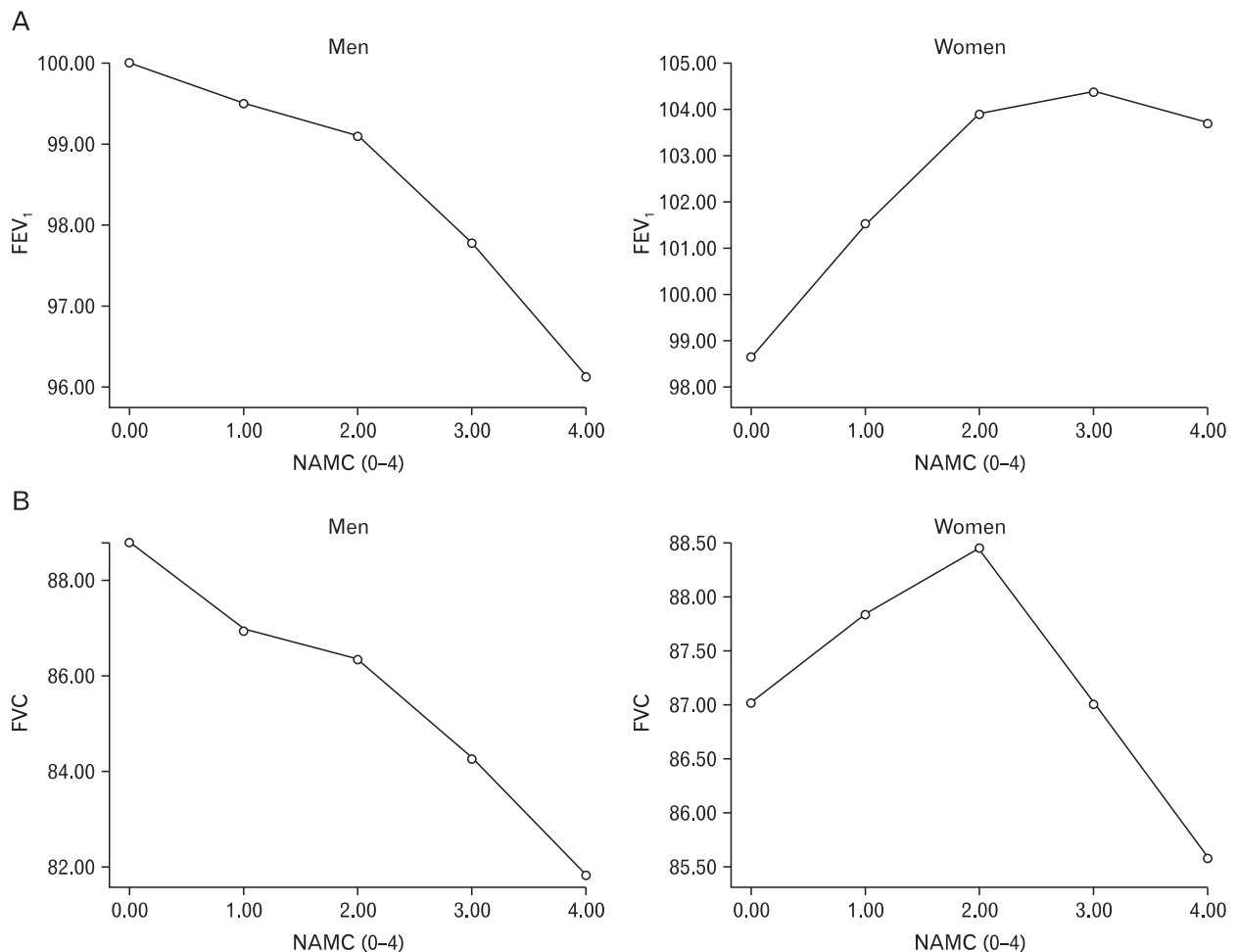


Figure 1. P-values are for analysis of covariance. The relationship between forced vital capacity (FVC) (A), forced expiratory volume for 1 second (FEV₁) (B) and number of American Heart Association/National Heart, Lung, and Blood Institute-number of adult treatment panel III metabolic syndrome components (NAMC). For men FVC and FEV₁ were associated with NAMC. For women, there was no association between FVC, FEV₁ and NAMC.

4. The Relationship between Number of Components That Serve as the Criteria for Diagnosing Metabolic Syndrome and Pulmonary Function

Pulmonary function changed according to the degree of severity of metabolic syndrome. In the case of males, FVC declined as severity of metabolic syndrome increased, while there was no correlative relationship found among females (Figure 1).

DISCUSSION

This study aimed to find relevance between components that serve as the criteria for diagnosing metabolic syndrome and poor performing pulmonary function. Among males, every diagnostic component of metabolic syndrome had significant correlation with poor pulmonary function. On the other hand, among females, FVC had a tendency of poor pulmonary function but with no significant relevance.

Many studies conclude that pulmonary function drops among obese people.^{12,13} Previously, studies have used BMI, waist circumference, waist/hip circumference ratio, abdominal thickness (height) and skin thickness test as the markers that show obesity.¹⁴⁻¹⁶ However, as of recent, studies focus on abdominal obesity as indicative of overall level of obesity. As such, this study tried to examine the waist circumference that demonstrates abdominal obesity as well as the relationship between metabolic syndrome components that are easily found among obese people and effects these factors have on pulmonary function.

According to the study, reverse-correlation was found between diagnostic components of metabolic syndrome and pulmonary function. Among males, while there were significant differences in FVC according to whether or not there were any diagnostics components for metabolic syndrome, there were no FVC differences found among females. However, for both males and females, pulmonary function differed significantly according to waist circumference. For males, there was a significant statistical difference in FVC and FEV₁/FVC. In the case of females, for waist circumference of 85 cm, both FEV₁ and FEV₁/FVC had a significant statistical difference, while waist circumference of 80 cm only showed a significant statistical difference in FEV₁. In

particular, among males, the partial correlation coefficient of waist circumference was FVC -0.189 , FEV₁/FVC 0.173 .

According to a study conducted by Leone et al.,¹⁷ both males and females showed reverse-correlation between all diagnostic components of metabolic syndrome and pulmonary function. As in this study, abdominal obesity was reported as the most powerful predictor of poor pulmonary function.¹⁷ In addition, Chen et al.¹⁸ found out that both males and females showed negative correlation between FEV₁/FVC and waist circumference even after age, height, weight, workload, energy consumption, and smoking were factored in. Thus, the bigger the waist circumference becomes, the greater its impact on pulmonary function, eventually having partial impact on the movements of diaphragm and chest.¹⁸ Canoy et al.¹⁶ took the waist/hip circumference ratio as the indicator of abdominal obesity to verify that both FEV₁ and FVC show reverse correlation both among males and females.

In Australia, Lazarus et al.¹⁴ showed that FVC has negative correlation with males' waist circumference and that no relationship was found among females.¹⁴ Moreover, according to a study conducted by Ochs-Balcom et al.,¹⁹ males' FEV₁ and FVC showed negative correlation in all obesity markers (weight and level of obesity) as well as markers for abdominal obesity (waist circumference, ratio of waist/hip circumference, abdominal height). However, among females, only the abdominal height and waist circumference showed negative correlation with FEV₁, while all markers of obesity showed negative correlation with FVC. In particular, the reverse relationship between FEV₁ and abdominal height was evident only among those obese people with BMI of over 25 kg/m².¹⁹

According to this study, in men, correlation between waist circumference and FVC, FEV₁/FVC ratio was statistically significant in terms of partial correlation coefficient where age, height and total smoking amount was reflected. For women, the correlation was not statistically significant across all respiratory indexes. The results were similar to the research conducted by Harik-Khan et al.,²⁰ which showed that FVC and FEV₁ and waist circumference and hip circumference had negative correlation for men, whereas for women, only FVC had correlation and FEV₁ showed no correlation. To explain such differences by gender, it could be assumed that fat distribution could affect diaphragm and thoracic movements of women more than men and that

waist circumference and hip circumference ratio does not affect pulmonary function.²⁰⁾

Carey et al.²¹⁾ said that changes in weight and obesity are related to FEV₁ and in particular, weight increase of the group with the highest obesity level showed greater FEV₁ reduction. Such results demonstrated a wider gap in men because male abdominal fat accumulated relatively more during the 7-year research period and in women, hip circumference tended to increase more. Thus, their increase in waist/hip circumference ratio was lower than men. Results of this study were also different by sex since males showed a higher level of obesity than women, with a higher ratio of men having abdominal fat.

Nakajima et al.²²⁾ showed correlation between FVC and metabolic syndrome level, such as an increase in the sum of metabolic syndrome diagnostics factors. The research demonstrated that an increase in the severity of metabolic syndrome impairs lung function in men but not in women. The results indicate that in addition to the relationship between each metabolic syndrome factor and weaker pulmonary function, people with more metabolic syndrome factors are more vulnerable to pulmonary function impairment. Therefore, additional studies on how to control these metabolic factors to influence pulmonary function in metabolic patients is necessary.

Not much research has been conducted on the association between metabolic syndrome components and lung function impairment. Since such studies were almost non-existent in Korea, this research regarding pulmonary function impairment in Asians is very significant. It is also meaningful in showing the relationship between pulmonary function, metabolic syndrome, and sex, as such studies had never previously been performed.

However, given that the analysis was conducted on Koreans coming from a certain region and health examinees, it is hard to generalize the outcome of the research to all ethnic groups. Also, since women were not classified into groups before and after menopause, the results may not be statistically significant and should be validated further through additional research. The research had some constraints as a cross-sectional study with not many morbidly obese patients included in the analysis. Further research should be conducted, and in particular, studies on morbidly obese patients are also necessary.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

REFERENCES

1. Mannino DM, Buist AS, Petty TL, Enright PL, Redd SC. Lung function and mortality in the United States: data from the First National Health and Nutrition Examination Survey follow up study. *Thorax* 2003;58:388-93.
2. Schunemann HJ, Dorn J, Grant BJ, Winkelstein W Jr, Trevisan M. Pulmonary function is a long-term predictor of mortality in the general population: 29-year follow-up of the Buffalo Health Study. *Chest* 2000;118:656-64.
3. Sin DD, Wu L, Man SF. The relationship between reduced lung function and cardiovascular mortality: a population-based study and a systematic review of the literature. *Chest* 2005;127:1952-9.
4. Stavem K, Aaser E, Sandvik L, Bjornholt JV, Erikssen G, Thaulow E, et al. Lung function, smoking and mortality in a 26-year follow-up of healthy middle-aged males. *Eur Respir J* 2005;25:618-25.
5. Alberti KG, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabet Med* 1998;15:539-53.
6. Balkau B, Charles MA. Comment on the provisional report from the WHO consultation. European Group for the Study of Insulin Resistance (EGIR). *Diabet Med* 1999;16:442-3.
7. Cheal KL, Abbasi F, Lamendola C, McLaughlin T, Reaven GM, Ford ES. Relationship to insulin resistance of the adult treatment panel III diagnostic criteria for identification of the metabolic syndrome. *Diabetes* 2004;53:1195-200.
8. Lin WY, Yao CA, Wang HC, Huang KC. Impaired lung function is associated with obesity and metabolic syndrome in adults. *Obesity (Silver Spring)* 2006;14:1654-61.
9. Maison P, Byrne CD, Hales CN, Day NE, Wareham NJ. Do different dimensions of the metabolic syndrome change together over time? Evidence supporting obesity as the

- central feature. *Diabetes Care* 2001;24:1758-63.
10. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/ National Heart, Lung, and Blood Institute Scientific Statement. *Circulation* 2005;112:2735-52.
 11. Lee SY, Park HS, Kim DJ, Han JH, Kim SM, Cho GJ, et al. Appropriate waist circumference cutoff points for central obesity in Korean adults. *Diabetes Res Clin Pract* 2007;75:72-80.
 12. Bottai M, Pistelli F, Di Pede F, Carrozzi L, Baldacci S, Matteelli G, et al. Longitudinal changes of body mass index, spirometry and diffusion in a general population. *Eur Respir J* 2002;20:665-73.
 13. McClean KM, Kee F, Young IS, Elborn JS. Obesity and the lung: 1. *Epidemiology. Thorax* 2008;63:649-54.
 14. Lazarus R, Gore CJ, Booth M, Owen N. Effects of body composition and fat distribution on ventilatory function in adults. *Am J Clin Nutr* 1998;68:35-41.
 15. Rossi A, Fantin F, Di Francesco V, Guariento S, Giuliano K, Fontana G, et al. Body composition and pulmonary function in the elderly: a 7-year longitudinal study. *Int J Obes (Lond)* 2008;32:1423-30.
 16. Canoy D, Luben R, Welch A, Bingham S, Wareham N, Day N, et al. Abdominal obesity and respiratory function in men and women in the EPIC-Norfolk Study, United Kingdom. *Am J Epidemiol* 2004;159:1140-9.
 17. Leone N, Courbon D, Thomas F, Bean K, Jegou B, Leynaert B, et al. Lung function impairment and metabolic syndrome: the critical role of abdominal obesity. *Am J Respir Crit Care Med* 2009;179:509-16.
 18. Chen R, Tunstall-Pedoe H, Bolton-Smith C, Hannah MK, Morrison C. Association of dietary antioxidants and waist circumference with pulmonary function and airway obstruction. *Am J Epidemiol* 2001;153:157-63.
 19. Ochs-Balcom HM, Grant BJ, Muti P, Sempos CT, Freudenheim JL, Trevisan M, et al. Pulmonary function and abdominal adiposity in the general population. *Chest* 2006;129:853-62.
 20. Harik-Khan RI, Wise RA, Fleg JL. The effect of gender on the relationship between body fat distribution and lung function. *J Clin Epidemiol* 2001;54:399-406.
 21. Carey IM, Cook DG, Strachan DP. The effects of adiposity and weight change on forced expiratory volume decline in a longitudinal study of adults. *Int J Obes Relat Metab Disord* 1999;23:979-85.
 22. Nakajima K, Kubouchi Y, Muneyuki T, Ebata M, Eguchi S, Munakata H. A possible association between suspected restrictive pattern as assessed by ordinary pulmonary function test and the metabolic syndrome. *Chest* 2008;134:712-8.