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ABOUT COVER

Editorial board member of *World Journal of Diabetes*, Dr. José Carvalheira is an Associate Professor at the Campinas State University (UNICAMP, Brazil). Having received his Bachelor's degree from Pernambuco University College of Medicine in 1994, Dr. Carvalheira undertook his postgraduate training at UNICAMP, receiving his PhD in 2004. He became Chief Physician in the Clinical Oncology Division of the Hospital de Clínicas Affiliated to UNICAMP in 2014 and has held the position since. His ongoing research interests involve investigation of how body composition, energy homeostasis, and the underlying mechanisms of whole-body metabolism are linked to cancer survival outcomes. In particular, his studies aim to elucidate the regulatory role of insulin resistance and its attendant pathophysiological features in determination of cancer-mediated disturbances in systemic homeostasis and cancer prognosis. (L-Editor: Filipodia)

AIMS AND SCOPE

The primary aim of *World Journal of Diabetes* (*WJD*, *World J Diabetes*) is to provide scholars and readers from various fields of diabetes with a platform to publish high-quality basic and clinical research articles and communicate their research findings online.

WJD mainly publishes articles reporting research results and findings obtained in the field of diabetes and covering a wide range of topics including risk factors for diabetes, diabetes complications, experimental diabetes mellitus, gestational diabetes, diabetic angiopathies, diabetic cardiomyopathies, diabetic coma, diabetic ketoacidosis, diabetic nephropathies, diabetic neuropathies, *etc*..

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ORIGINAL ARTICLE

Retrospective Cohort Study

Association between restrictive pulmonary disease and type 2 diabetes in Koreans: A cross-sectional study

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Author contributions: Lee DY performed the experiments, interpreted the results, and wrote the manuscript; Nam SM interpreted the results, wrote and revised the manuscript, and supervised the study.

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Abstract

BACKGROUND

Diabetes is a progressive disease that increases glucose levels in the blood. While studies have shown that patients with pulmonary disease (both obstructive and restrictive pulmonary disease) have a higher prevalence of type 2 diabetes mellitus (T2DM), there have been more studies on restrictive patterns than chronic obstructive pulmonary disease.

AIM

To assess whether restrictive and obstructive pulmonary diseases are associated with T2DM in Koreans.

METHODS

For our analysis, we used data from the Korea National Health and Nutrition Examination Survey. A total of 2830 subjects were included in this study. Spirometry results were categorized into three patterns: Normal, restrictive pulmonary disease (RPD), and obstructive pulmonary disease (OPD).

RESULTS

The factors used as diabetic indicators (*i.e.* homeostatic model assessment of insulin resistance, homeostatic model assessment of beta-cell function, glycated hemoglobin, and fasting insulin) were among the highest in RPD but not in OPD. Based on multivariate logistic regression analysis, subjects with RPD were found with an increased odds ratio [OR: 1.907, 95% confidence interval (CI): 1.110-3.277] for T2DM compared with subjects with normal pulmonary function, whereas in patients with OPD, the OR had not increased. Model 4, which adjusted for the variables that could affect diabetes and pulmonary disease, showed a significant increase in the T2DM OR to RPD (OR: 2.025, 95%CI: 1.264-3.244). On the other hand, no statistically significant difference was shown in OPD (OR: 0.982, 95%CI: 0.634-1.519).

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CONCLUSION
RPD, not OPD, is highly associated with T2DM regardless of the risk factors of various T2DMs that can be confounds.

Key Words: Restrictive pulmonary disease; Obstructive pulmonary disease; Type 2 diabetes mellitus; Insulin resistance; Glycated hemoglobin; Koreans

Core Tip: This study was performed to assess whether restrictive and obstructive patterns of pulmonary disease and type 2 diabetes mellitus (T2DM) are associated with each other in Koreans. For our analysis, we used data from the Korea National Health and Nutrition Examination Survey. A total of 2830 subjects were included in this study. Spirometry results were categorized into three patterns: normal, restrictive, and obstructive pulmonary disease. Restrictive pulmonary disease, not obstructive disease, is highly relevant to T2DM regardless of other risk factors of various T2DMs that can be confounds.

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INTRODUCTION

Diabetes is a progressive disease that increases glucose levels in the blood and has several pathogeneses, including insulin resistance in the liver and dysfunction of pancreas beta cells[1,2]. Type 2 diabetes mellitus(T2DM) is a complex disease associated with increased risk of multiple complications, such as peripheral circulation disease, and cardiovascular diseases such as stroke and coronary artery disease requiring intervention for treatment and prevention[3]. The cause of these cardiovascular diseases has been reported to be the increase in inflammation levels due to hyperglycemia and the weakening of cardiopulmonary functions[4]. Also, an increase of 1% of glycated hemoglobin (HbA1c), a blood sugar control factor, is known to increase the risk of cardiovascular disease by 28%[5]. Moreover, in a recent study, the risk of pulmonary dysfunction was higher in patients with impaired fasting glucose levels[6]. In addition, subjects with T2DM decreased forced expiratory volume in 1 s (FEV1) and forced vital capacity (FVC) regardless of race[7-9].

There are restrictive and obstructive pulmonary diseases in impaired pulmonary function[10]. Restrictive pulmonary disease (RPD) is reduced in both FVC and FEV1, resulting from a defect in thoracic compatibility[11]. On the other hand, obstructive pulmonary disease (OPD) is known to be caused by a significant reduction in FEV1, mainly due to airway blockages associated with smoking[12]. According to previous studies, impaired pulmonary function causes insulin resistance[13-15]. In addition, an increase in the inflammatory response derived from obesity causes insulin resistance and increases the risk of cardiovascular disease associated with obesity[16]. It was shown in previous studies that the prevalence rate of T2DM in chronic OPD patients is high[17,18], whereas it is more related to RPD than chronic OPD[19,20].

As such, the association between T2DM and impaired pulmonary function is not consistently explained. In addition, it is not clear whether this association is mediated by insulin resistance or by other factors. Therefore, based on the cross-sectional data from a large number of Korean subjects, this study examined the association between RPD and OPD with insulin resistance and T2DM.

MATERIALS AND METHODS

Data source and sampling

This study obtained data from the Korea National Health and Nutrition Examination Survey (KNHANES), 2015, a cross-sectional and nationally representative survey

conducted by the Korean Centers for Diseases Control and Prevention. The subjects were designated as those who responded to both the examination and the health survey among adults aged 40 or older who were subjected to the pulmonary function measurement. Among 7380 subjects that participated in KNHANES, 3008 subjects under 40 years of age, 1401 subjects who did not measure pulmonary function, 105 subjects who did not measure T2DM components, and 105 subjects who did not do the health survey were excluded. A total of 2830 participants were eligible for this study (Figure 1).

Measurements of variables

Covariates: Body mass index (BMI) was calculated by dividing weight (kg) by height (m). Waist circumference (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-min rest period. Two measurements were made for all subjects at 5-min 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 non-users. Physical examinations included HbA1c, C-reactive protein (hs-CRP), fasting insulin, fasting glucose, waist circumference, diastolic and systolic blood pressure, total cholesterol, low density lipoprotein, high density lipoprotein-cholesterol, and triglyceride measurement variables.

Measurement of pulmonary function

Pulmonary function was measured using a spirometer (model 2130; SensorMedics, Yorba Linda, CA, Untied States). Participants were classified according to respiratory patterns into a normal group (FEV 1/FVC ≥ 0.70, FVC ≥ 80% predicted), an OPD group (FEV 1/FVC < 0.70), and a RPD group (FVC < 80% predicted, FEV 1 / FVC ≥ 0.70)[21].

T2DM and insulin resistance

Homeostasis model assessment (HOMA) was used to calculate insulin resistance HOMA-IR and beta-cell function HOMA-beta indices using the formula: HOMA-IR = [fasting glucose (mg/dL) × fasting insulin (μU/mL)]/405 (> 2.5 indicating a high index of IR)[22] and HOMA-beta = [fasting insulin (lU/mL) 360]/[fasting glucose (mg/dL)-63][23].

Diabetes mellitus was defined by fasting glucose levels > 126 mg/dL in the health examination. Type 2 diabetes was distinguished from type 1 diabetes based on age at onset and treatment with insulin. Impaired fasting glucose (IFG) was defined as fasting glucose levels ≥ 100 mg/dL and < 125 mg/dL. Also, even if data such as fasting glucose and fasting insulin were normal, those who answered "yes" in the survey on whether they take diabetes drugs were classified as diabetic patients.

Statistical analysis

Since this study uses a complex sampling design, the weight given by the KNHANES has been applied. General characteristics were compared according to the pulmonary function and the prevalence of T2DM through the Chi-square test. A logistic regression analysis was used to analyze the association between pulmonary disease and T2DM, and *P* values < 0.05 were considered statistically significant. Data analysis uses the Statistic Package for Social Science 22.0 window version (Armonk, NY, United States).

RESULTS

In this study, the prevalence of RPD was 8.86% and OPD 14.20%. Significant differences by pulmonary disease were found in all variables except diastolic blood pressure and drinking status. Compared with those in the normal group, RPD and OPD subjects were of older age, with greater waist circumference, higher systolic blood pressure, and higher triglyceride. Also, smokers and men were higher in OPD than in normal and RPD. In terms of T2DM prevalence due to pulmonary disease, RPD accounted for 21.1%, the highest. In addition, the factors used as diabetic indicators, HOMA-IR, HOMA-beta, HbA1c, and fasting insulin, were all among the

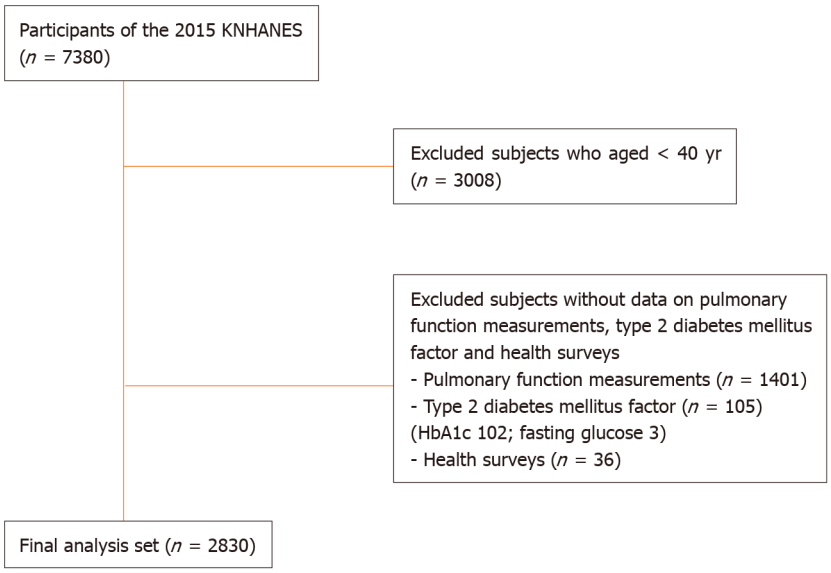

Figure 1 Subject selection from the Korea National Health and Nutrition Examination Survey 2015.

highest in the RPD, not in the OPD, compared to subjects with normal pulmonary function. hs-CRP, which indicates inflammation levels, was also the highest in the RPD (7.80 *vs* 9.84 *vs* 8.07) (Table 1).

Comparing pulmonary disease with fasting glucose levels, subjects with abnormal glucose levels (T2DM or IFG) had a higher prevalence rate of RPD and OPD compared to normal levels. In normal and IFG, the prevalence of RPD was significantly lower than that of OPD, but RPD was higher in T2DM (RPD/OPD: 6.2/11.5 *vs* 8.4/13.3 *vs* 18.1/15.9). In addition, HOMA-IR, HbA1c, and fasting insulin were higher with abnormal glucose levels, while HOMA-beta was significantly lower. The inflammatory factor Hs-CRP also higher in IFG and T2DM compared to normal.

To find out the association between pulmonary disease in subjects who do not have diabetes but are more likely to develop T2DM, multiple regression analyses were performed by dividing levels of normal, IFG, and T2DM groups (Table 2). Model 1, which adjusted for age and sex, showed that the probability of RPD was 1.453 times [95% confidence interval (CI): 1.059-1.995] for IFG and 3.621 times (95%CI: 2.316-5.663) for T2DM. However, Model 4, which adjusted for all variables that could be influential, showed 1.907 times (CI: 1.110-3.277) for T2DM. In contrast, the analysis of the association between OPD and IFG showed no significant association in any model (Table 3). Model 4, which adjusted for the variables that could affect diabetes and pulmonary disease, showed a significant increase in the T2DM odds ratio (OR) to the RPD (OR: 2.025, 95%CI: 1.264–3.244). On the other hand, no statistically significant difference was shown in OPD (OR: 0.982, 95%CI: 0.634–1.519) (Table 4).

DISCUSSION

This cross-sectional study is intended to identify the association of abnormal glucose in pulmonary disease. In particular, RPD was highly associated with increased ORs of T2DM regardless of major potential confounds, such as age and obesity factors. Thus, the main findings of this study are that T2DM is highly related to RPD but not OPD.

Pulmonary disease is associated with T2DM risk factors such as smoking, HbA1c, insulin resistance, hyperglycemia, and abdominal obesity, and these associations are particularly prominent in RPD[24,25]. The results of this study also showed significantly higher indicators of HbA1c, HOMA-IR, fasting glucose, and waist circumference in RPD compared to normal and OPD.

Although smoking is known to be a major cause of reduced pulmonary function[26], the results of this study show that it does not affect RPD. It has been confirmed to influence OPD. Other prior studies have shown that the association between RPD and T2DM prevalence rates is not significantly changed by smoking conditions, indicating that smoking has little influence.

HbA1c, measured for diagnosis of T2DM and monitoring glucose control, is a risk

Table 1 Characteristics of individuals with normal, restrictive, and obstructive pulmonary disease

	Normal, *n* = 2177	RPD, *n* = 251	OPD, *n* = 402
Age (yr)[1]	53.50 ± 0.27[a]	57.79 ± 0.81[b]	62.40 ± 0.65[c]
Male (%)[1]	45.1[a]	50.8[a]	78.5[b]
T2DM (%)[1]	7.9[a]	21.1[b]	12.2[c]
HOMA-IR[1]	2.10 ± 0.07[a]	3.13 ± 0.41[b]	2.21 ± 0.14[a]
HOMA-beta[1]	78.51 ± 2.50[a]	83.13 ± 4.07[b]	76.23 ± 3.83[c]
HbA1c (%)[1]	5.71 ± 0.02[a]	6.14 ± 0.09[b]	5.93 ± 0.06[bc]
Hs-CRP (mg/L)[1]	1.07 ± 0.05[a]	1.79 ± 0.19[b]	1.48 ± 0.17[a]
Fasting insulin (UIU/mL)[1]	7.80 ± 0.16[a]	9.84 ± 0.61[b]	8.07 ± 0.43[a]
BMI (kg/m^2)[1]	24.08 ± 0.07[a]	25.67 ± 0.23[b]	24.08 ± 0.16[a]
Fasting glucose (mg/dL)[1]	101.99 ± 0.67[a]	116.33 ± 3.64[b]	105.85 ± 1.62[c]
Waist circumference (cm)[1]	82.97 ± 0.22[a]	87.59 ± 0.60[b]	86.29 ± 0.45[b]
SBP (mmHg)[1]	119.46 ± 0.42[a]	123.83 ± 1.27[b]	124.47 ± 0.85[b]
DBP (mmHg)[1]	77.22 ± 0.26	76.53 ± 0.86	76.27 ± 0.659
Total cholesterol (mg/dL)[1]	197.35 ± 0.89[a]	190.21 ± 2.59[b]	191.86 ± 2.43[b]
LDL-cholesterol (mg/dL)[1]	118.97 ± 0.81[a]	114.61 ± 2.21[a]	116.41 ± 2.37[b]
HDL-cholesterol (mg/dL)[1]	50.73 ± 0.34[a]	47.97 ± 0.88[b]	46.62 ± 0.68[b]
Triglyceride (mg/dL)[1]	148.73 ± 3.28[a]	155.62 ± 11.25[b]	157.15 ± 7.17[c]
Smoking status (%) (non-/ex-/current smoker)[1]	57.6/24.2/18.3[a]	56.7/25.3/18.0[a]	30.8/40.3/28.9[b]
Drinking alcohol status (%) (non-/current drinking)	25.6/74.4	30.5/69.5	23.3/76.7
FVC (% predicted)[1]	3.69 ± 0.02[a]	2.88 ± 0.04[b]	3.83 ± 0.07[a]
FEV1 (L)[1]	2.93 ± 0.02[a]	2.29 ± 0.04[b]	2.48 ± 0.05[c]
FEV1/FVC[1]	0.80 ± 0.00[a]	0.80 ± 0.00[a]	0.64 ± 0.00[b]
PEF (L/s)[1]	7.75 ± 0.06[a]	6.55 ± 0.12[b]	6.67 ± 0.11[b]

[1]$P < 0.05$ by ANOVA or chi-square test. [a,b,c]The same letters indicate non-significant difference between groups based on Bonferroni multiple comparison test. Data were presented as means ± SD or *n* (%). T2DM: Type 2 diabetes mellitus; Hs-CRP: Hs-C-reactive protein; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; LDL-cholesterol: Low density lipoprotein-cholesterol; HDL-cholesterol: High density lipoprotein-cholesterol. FVC: Forced vital capacity; FEV1: Forced expiratory volume 1.

factor for cardiovascular disease[27]. In this study, the HbA1c level of RPD was the highest compared to normal and OPD (5.71 *vs* 6.14 *vs* 5.93). These results are consistent with the results of a prior study that showed a link between HbA1c and reduced pulmonary function in diabetics[28]. Moreover, the high level of HbA1c in healthy individuals means poor lung capacity, especially RPD[25].

Although pathological mechanisms for explaining the association between reduced pulmonary function and insulin resistance and T2DM have not been identified, there may be several common underlying causes. First, insulin resistance and hyperglycemia, the main risk factors for T2DM, caused decreased pulmonary function[29]. One study reported that insulin receptors exist in the lung pleura[30], and this insulin can change the physiology, which can promote deterioration of the respiratory muscle due to changes in glucose absorption in the thoracic muscle[31]. The results of this study indicate that HOMA-IR and fasting glucose figures are significantly higher in the RPD compared to normal and OPD, consistent with this hypothesis.

Second, the accumulation of fat in the abdominal cavity reduces lung volume and decreases the motion of the diaphragm, so pulmonary function is likely to be reduced[32,33]. The results of this study show that WC and BMI are significantly higher in RPD and OPD than in normal groups, supporting this hypothesis. However, there is

Table 2 Characteristics of individuals with pulmonary function in normal, impaired fasting glucose, and type 2 diabetic subjects

	Normal, *n* = 1608	IFG, *n* = 934	T2DM, *n* = 288
Age (yr)[1]	53.63 ± 0.31[a]	56.23 ± 0.40[b]	58.95 ± 0.71[c]
Male (%)[1]	42.9 ± 1.3[a]	58.2 ± 1.7[b]	62.0 ± 3.5[b]
RPD/OPD (%)[1]	6.2/11.5[a]	8.4/13.3[b]	18.1/15.9[c]
HOMA-IR[1]	1.45 ± 0.03[a]	2.49 ± 0.06[b]	5.52 ± 0.58[c]
HOMA-beta[1]	84.75 ± 1.58[a]	76.38 ± 1.93[b]	48.56 ± 3.96[c]
HbA1c (%)[1]	5.47 ± 0.01[a]	5.79 ± 0.02[b]	7.61 ± 0.12[c]
Hs-CRP (mg/L)[1]	0.94 ± 0.04[a]	1.34 ± 0.09[b]	2.04 ± 0.30[c]
Fasting insulin (UIU/mL)[1]	6.42 ± 0.12[a]	9.35 ± 0.24[b]	13.02 ± 1.05[c]
BMI (kg/m^2)[1]	23.63 ± 0.08[a]	24.97 ± 0.11[b]	25.19 ± 0.22[b]
Fasting glucose (mg/dL)[1]	90.84 ± 0.16[a]	107.44 ± 0.26[b]	168.79 ± 3.34[c]
Waist circumference (cm)[1]	81.52 ± 0.24[a]	86.44 ± 0.31[b]	88.32 ± 0.57[c]
SBP (mmHg)[1]	117.92 ± 0.46[a]	123.00 ± 0.58[b]	126.55 ± 1.14[c]
DBP (mmHg)[1]	76.39 ± 0.32[a]	78.18 ± 0.39[b]	77.10 ± 0.75[a]
Total cholesterol (mg/dL)[1]	196.00 ± 0.96[a]	198.67 ± 1.46[a]	186.82 ± 2.73[b]
LDL-cholesterol (mg/dL)[1]	118.77 ± 0.91[a]	120.50 ± 1.30[a]	107.90 ± 2.26[b]
HDL-cholesterol (mg/dL)[1]	51.71 ± 0.39[a]	48.25 ± 0.46[b]	45.30 ± 0.72[c]
Triglyceride (mg/dL)[1]	130.65 ± 3.08[a]	166.09 ± 5.44[b]	216.02 ± 15.20[c]
Smoking status (%) (non-/ex-/current smoker)[1]	59.9/22.1/18.0[a]	46.6/32.0/21.4[b]	45.6/31.7/22.8[b]
Drinking alcohol status (%) (non-/current drinking)	26.4/73.6	23.6/76.4	28.9/71.1
FVC (% predicted)[1]	3.61 ± 0.26[a]	3.72 ± 0.04[b]	3.56 ± 0.07[a]
FEV1 (L)[1]	2.81 ± 0.02[a]	2.86 ± 0.03[ab]	2.72 ± 0.05[ac]
FEV1/FVC[1]	0.78 ± 0.00[a]	0.77 ± 0.00[b]	0.77 ± 0.01[b]
PEF (L/sec)[1]	7.42 ± 0.06[a]	7.73 ± 0.09[b]	7.48 ± 0.15[ab]

[1]$P < 0.05$ by ANOVA or chi-square test. [a,b,c]The same letters indicate non-significant difference between groups based on Bonferroni multiple comparison test. Data were presented as means ± SD or *n* (%). IFG: Impaired fasting glucose; T2DM: Type 2 diabetes mellitus; Hs-CRP: Hs-C-reactive protein; BMI: Body mass index; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; LDL-cholesterol: Low density lipoprotein-cholesterol; HDL-cholesterol: High density lipoprotein-cholesterol; FVC: Forced vital capacity; FEV1: Forced expiratory volume 1.

no statistically significant difference between the WC and BMI of RPD and OPD. In other words, abdominal obesity may be the basis for explaining the association between decreased pulmonary function and T2DM, but it does not seem to explain fully the relationship between RPD and T2DM.

Third, systemic inflammatory responses with insulin resistance lead to reduced pulmonary function and the development of diabetes[34]. Visceral fat, one of the risk factors for diabetes, affects the concentration of cytokines in the blood such as interleukin-6, adiponectin, leptin, and tumor necrosis factor-α, causing systemic inflammatory reactions and chronic low-grade inflammation reduced pulmonary function[35,36]. In this study, the hs-CRP, an indicator of systemic inflammatory reactions, was the highest in RPD, and the prior study is consistent with the findings that the increase in hs-CRP is highly related to pulmonary disease[37-39].

To summarize, there was a significant association between RPD and T2DM, whereas IFG was weak or not present. This suggests that T2DM is not a result of RPD, rather the cause of T2DM. Thus, it can be seen that risk factors, such as HOMA-IR, HbA1c, hyperglycemia, abdominal fat, and inflammatory index hs-CRP, are not sufficient in IFG to cause RPD compared to T2DM. Therefore, it would be worthwhile to examine the pulmonary function of IFG patients in future longitudinal studies according to the pattern of their T2DM progression.

Table 3 Odds ratios for pulmonary function according to the fasting glucose level by multivariate logistic regression analysis

	Pulmonary disease	Fasting glucose odds ratio (95%CI)	
		IFG (100-125)	T2DM (≥ 126)
Model 1	RPD	1.453 (1.059-1.995)[a]	3.621 (2.316-5.663)[b]
	OPD	1.199 (0.888-1.619)	1.744 (1.164-2.614)[a]
Model 2	RPD	1.282 (0.939-1.749)	2.890 (1.810-4.616)[b]
	OPD	0.725 (0.518-1.014)	0.821 (0.525-1.284)
Model 3	RPD	1.074 (0.781-1.476)	2.316 (1.438-3.729)[b]
	OPD	0.699 (0.498-0.982)	0.796 (0.501-1.267)
Model 4	RPD	0.934 (0.638-1.369)	1.907 (1.110-3.277)[a]
	OPD	0.722 (0.512-1.019)	0.782 (0.484-1.263)

[a]$P < 0.01$.

[b]$P < 0.001$. Model 1: Crude; Model 2: Adjusted for age, sex; Model 3: Adjusted for variables in Model 2 + body mass index, waist circumference, smoking status; Model 4: Adjusted for variables in Model 3 + C-reactive protein, homeostasis model assessment-IR. Reference category: Individuals with normal. RPD: Restrictive pulmonary disease; OPD: Obstructive pulmonary disease; IFG: Impaired fasting glucose; T2DM: Type 2 diabetes mellitus.

Table 4 Odds ratios for type 2 diabetes mellitus according to the pulmonary function by multivariate logistic regression analysis

	Pulmonary disease	Odds ratio	95%CI
Model 1	RPD	3.127[b]	2.056-4.756
	OPD	1.631[a]	1.103-2.412
Model 2	RPD	2.580[b]	1.670-3.988
	OPD	1.033	0.673-1.584
Model 3	RPD	2.257[b]	1.465-3.475
	OPD	0.984	0.633-1.531
Model 4	RPD	2.025[a]	1.264-3.244
	OPD	0.982	0.634-1.519

[a]$P < 0.01$.

[b]$P < 0.001$. Model 1: Crude; Model 2: Adjusted for age, sex; Model 3: Adjusted for variables in model 2 + body mass index, waist circumference, smoking status; Model 4: Adjusted for variables in model 3 + C-reactive protein, homeostasis model assessment -IR. Reference category: Individuals with normal. RPD: Restrictive pulmonary disease; OPD: Obstructive pulmonary disease.

Despite several meaningful findings of this study, there are several limitations. First, we could not use a specialized method to measure insulin resistance. However, it is reported that there is a high correlation between HOMA-IR and whole-body glucose absorption, measured using the euglycemic hyperinsulinemic clamp method. Second, because KNHANES's individuals who participated in this survey have relatively mild levels of comorbidities, a small number of severe-stage diabetics or pulmonary disease patients may affect the outcome analysis. In addition, the proportion of IFG or T2DM may have been somewhat high only for those aged 40 or older who conducted the pulmonary function tests. However, the strength of this data is that there is a high response rate, and it is thought that potential confounds will not have a significant impact on the results because it has been obtained from the representative information of a Korean population. Third, this study could not determine the temporal relationship because it was a cross-sectional design. This made it impossible to pinpoint the sequence of fundamental causes between pulmonary disease and T2DM. Therefore, it would be worthwhile to identify the mechanism between the two through future longitudinal studies.

CONCLUSION

This study was conducted to determine the association between pulmonary disease and T2DM. It was found that restrictive pulmonary function, not obstructive, is highly relevant to T2DM regardless of the various risk factors of T2DM that can be confounds.

ARTICLE HIGHLIGHTS

Research background

Previously, the association between type 2 diabetes mellitus (T2DM) and pulmonary disease was confirmed. Some studies found that T2DM is related to obstructive pulmonary disease (OPD), and others have shown that it is related to restrictive pulmonary disease (RPD).

Research motivation

T2DM and RPD are highly connected with T2DM, but research on causality between them is insufficient. Therefore, it is important to study this.

Research objectives

To find out the association between T2DM and pulmonary disease and to reveal its causal relationship.

Research methods

Korea National Health and Nutrition Examination Survey (KNHANES) is a survey research program conducted by the Korean Centers for Diseases Control and Prevention to assess the health and nutritional status of adults and children in Korea and to track changes over time. The survey combines interviews, physical examinations, and laboratory tests. KNHANES interview includes demographic, socioeconomic, dietary, and health-related questions. The examination component consists of medical, dental, and physiological measurements as well as laboratory tests administered by medical personnel, and all data are made anonymous and can be officially downloaded from the website. The KNHANES data are the official national disclosure data conducted annually. The data in this study are complex sampling design, using logistic regression analysis that is most appropriate to view the association between the variables recommended by the Korean Centers for Diseases Control.

Research results

Compared to OPD, the ratio of T2DM and its risk factors in restrictive RPD was very high. In addition, the analysis of pulmonary disease by fasting glucose level showed no significant difference in impaired fasting glucose group, and in T2DM, the probability of RPD occurring was 1.907 times higher than that of OPD. Also, the results of this study have significant association between RPD and T2DM, whereas impaired fasting glucose was weak or not present.

Research conclusions

RPD is highly relevant to T2DM regardless of risk factors. To summarize, this study suggests that RPD is not a cause of T2DM but rather a consequence of T2DM.

Research perspectives

In the future, a longitudinal study should identify changes in pulmonary function of impaired fasting glucose as it progresses.

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