

Spirometry-Based Airflow Obstruction and Pulmonary Function in Type 2 Diabetes: A Cross-Sectional Study

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Citation: Torkian S, Ahmadi A, Kiani FZ, Rouhi H, Soleymani Babadi A. Spirometry-Based Airflow Obstruction and Pulmonary Function in Type 2 Diabetes: A Cross-Sectional Study. J Occup Health Epidemiol. 2026;15(2):93-101.

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Article Info

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Article history
Received: Dec 2025
Accepted: May 2026

 10.61882/johe.15.2.93

Print ISSN: 2251-8096
Online ISSN: 2252-0902

Peer review under responsibility of
Journal of Occupational Health
and Epidemiology

Abstract

Background: Systemic inflammation, oxidative stress, and microvascular dysfunction may predispose individuals with diabetes to impaired lung function. This cross-sectional study aimed to ascertain pulmonary function, the prevalence of spirometric airflow obstruction consistent with COPD, as well as associated factors among adults with type 2 diabetes in Southwest Iran.

Materials & Methods: This cross-sectional study included 732 adults with type 2 diabetes, aged 35–70 years, enrolled in the Shahrekord PERSIAN Cohort Study. Demographic, comorbidities, anthropometric measurements, and spirometry findings were collected according to the standardized cohort protocol. Chi-square test, Fisher's exact test, and multivariable logistic regression analyses were undertaken to identify factors related to spirometric airflow obstruction. Spirometric patterns were classified as obstructive, restrictive, mixed, and normal based on standard criteria.

Results: The prevalence of spirometric airflow obstruction was 8.5% (62/732). The most common pattern was restrictive (467, 63.8%), followed by mixed (47, 6.4%) and obstructive (15, 2.0%). In the multivariable logistic regression model, alcohol use (OR = 2.23; 95% CI: 1.09, 4.56), marital status (OR = 2.62; 95% CI: 1.14, 6.00), and chronic pulmonary disease (OR = 2.59; 95% CI: 1.21, 5.53) were independently linked to airflow obstruction.

Conclusions: This study indicated a notable prevalence of spirometric airflow obstruction among adults with type 2 diabetes, with restrictive abnormalities being the predominant pattern. These findings offer preliminary epidemiological evidence for respiratory impairment in this population and establish a baseline for future longitudinal as well as interventional studies.

Keywords: Chronic Obstructive Pulmonary Disease, Type 2 Diabetes Mellitus, Pulmonary Function, Spirometry, Respiratory Function Test.

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent hyperglycemia arising from insulin resistance and/or impaired insulin secretion [1]. Type 2 diabetes mellitus (T2DM) constitutes the predominant form of the disease and remains a major global health challenge in spite of significant therapeutic advances, with no definitive cure being

currently available [2]. According to recent reports, an estimated 537 million adults worldwide (10.5% of the population aged 20–79 years) are living with diabetes [3, 4]. This number is projected to grow to 643 million by 2030 and to 783 million by 2045 (3, 4). In 2019, approximately 463 million individuals were affected by diabetes, with projections revealing a rise to 578 million by 2030 and 700 million by 2045. Note that nearly half

of all people with diabetes (50.1%) remain undiagnosed [5].

Chronic hyperglycemia induces widespread vascular damage involving both macrovascular and microvascular systems. These abnormalities contribute to serious long-term complications, including cardiovascular disease, nephropathy, retinopathy, and peripheral neuropathy [6]. Increasing evidence implies that the lungs may also be a target organ affected by the systemic consequences of diabetes. Several studies have reported measurable reductions in pulmonary function among those with T2DM, together with an accelerated decline in spirometry indices. All these indicate that pulmonary impairment represents an underrecognized complication of the disease [7].

Spirometry is the primary tool for appraising pulmonary function and detecting ventilatory abnormalities. The European Respiratory Society (ERS) and American Thoracic Society (ATS) 2022 technical standards provide comprehensive guidance for routine lung function test interpretation, highlighting the importance of applying population-appropriate reference equations and distinguishing between obstructive, restrictive, and mixed ventilatory defects [8]. Among these, spirometric airflow obstruction, defined as a diminished FEV_1/FVC ratio, is a key finding that may signal underlying airway disease [9]. Importantly, pre-bronchodilator spirometry alone can result in overdiagnosis of airflow obstruction in a considerable proportion of cases, necessitating post-bronchodilator testing to confirm the presence of fixed obstruction [10].

The relationship between T2DM and pulmonary function abnormalities has gained increasing attention. Insulin resistance has been inversely linked to key spirometry indices. Those with high insulin resistance exhibit significantly lowered forced expiratory volume in one second (FEV_1) and FEV_1/FVC ratios, suggesting impaired ventilatory function [11]. Chronic systemic inflammation, which is common to both T2DM and pulmonary diseases, may serve as a biological link between the two conditions. Prolonged hyperglycemia promotes oxidative stress and endothelial dysfunction within the lungs, potentially accelerating pulmonary decline [12]. Emerging evidence also suggests that antidiabetic medications, particularly metformin, may influence respiratory outcomes through anti-inflammatory effects and modulation of airway physiology [13]. These interactions highlight the clinical importance of ascertaining pulmonary function in those with T2DM [14].

In spite of the growing body of evidence linking diabetes to pulmonary impairment, routine lung function testing is not currently included as a standard recommendation in the American Diabetes Association (ADA) 2025 Standards of Care in Diabetes. This highlights a potential gap in comprehensive comorbidity assessment for this population [15].

Given the growing prevalence of diabetes in Iran, estimated at approximately 10–15% of the adult population, as well as the potential respiratory complications associated with the disease, examination of pulmonary function abnormalities in diabetic individuals is a national health priority [16]. Nevertheless, limited data exist regarding the prevalence and patterns of spirometric abnormalities in patients with T2DM within the Iranian population [17]. While previous studies have documented isolated spirometric findings, none have comprehensively characterized the full spectrum of ventilatory patterns including obstructive, restrictive, and mixed defects using standardized criteria across this specific population [15].

Thus, the present study, undertaken within the Shahrekord PERSIAN Cohort Study (SCS), was designed to: (a) evaluate pulmonary function test parameters among those with T2DM; (b) determine the prevalence of spirometric airflow obstruction and other ventilatory patterns, including restrictive and mixed defects, using standardized criteria; and (c) identify factors linked to these spirometric abnormalities. The novelty of this study lies in its population-based design, its focus on an understudied Iranian population in southwestern Iran, and its potential to establish baseline epidemiological evidence for future longitudinal investigations inspecting the progression of pulmonary impairment in diabetic patients.

Materials and Methods

This cross-sectional study employed baseline data from the Shahrekord Cohort Study (SCS), a population-based cohort within the PERSIAN (Prospective Epidemiological Research Studies in Iran) framework [18]. The SCS recruited 10,075 adults aged 35–70 years from Shahrekord, southwestern Iran, to examine the incidence and prevalence of non-communicable diseases. Detailed protocols concerning study design, sampling, and assessments have been previously published [18]. Comprehensive data including demographic characteristics, comorbidities, anthropometric measurements, and spirometry were collected following the standardized cohort protocol. A total of 732 individuals with T2DM were included for the present analysis.

Demographic variables included age (<45, 45–65, >65 years), sex (male, female), marital status (single, married, divorced, widowed; dichotomized as married vs. others for regression analyses), place of residence (urban vs. rural), employment status (employed vs. unemployed), and ethnicity (Fars, Lor, other). Anthropometric variables consisted of body mass index (BMI; ≤ 30 vs. > 30 kg/m²). Other variables considered in the analysis were smoking (yes/no), alcohol consumption (yes/no), history of myocardial infarction

(yes/no), cardiac ischemia (yes/no), and chronic pulmonary disease (yes/no). Chronic pulmonary disease was defined as chronic respiratory conditions other than COPD (asthma, chronic bronchitis, emphysema, or pulmonary fibrosis) based on self-reported physician diagnosis.

DM was defined based on the American Diabetes Association criteria: fasting blood glucose ≥ 126 mg/dL, 2-hour postprandial glucose ≥ 200 mg/dL, prior physician diagnosis, or current use of antihyperglycemic medications [19].

Pulmonary function tests (PFTs) were performed using a calibrated Italian-made spirometer under strict daily quality control procedures. The spirometer was calibrated daily according to the manufacturer's instructions, with all tests conducted by trained technicians following standardized protocols. Measured indices included forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), forced expiratory volume in 6 seconds (FEV_6), peak expiratory flow (PEF), forced expiratory flow at 25%, 50%, and 75% of pulmonary volume (FEF_{25} , FEF_{50} , FEF_{75}), FEF_{25-75} , as well as maximum voluntary ventilation (MVV). All values were expressed as percentages of predicted values based on reference equations appropriate for the Iranian population [20].

Spirometric airflow obstruction was defined as pre-bronchodilator $FEV_1/FVC < 0.70$, in accordance with the fixed-ratio criterion recommended by GOLD guidelines [20]. This criterion was chosen to allow direct comparison with previous epidemiological studies, including the Shahrekord PERSIAN cohort study [21], and since it is practical for large-scale population-based studies. Nevertheless, it is important to note that this approach may overdiagnose airflow obstruction in older adults and underdiagnose in younger individuals compared to the Lower Limit of Normal (LLN) approach recommended by ATS/ERS guidelines [8].

Based on standard spirometry criteria [8] together with the definitions employed in the Shahrekord PERSIAN cohort study [21], participants were classified into the following patterns:

Obstructive pattern: $FEV_1/FVC < 70\%$, $FVC \geq 80\%$, and $FEV_1 \leq 80\%$

Restrictive pattern: $FEV_1/FVC \geq 70\%$, $FVC \leq 80\%$, and $FEV_1 \leq 80\%$ or $FEV_1 \geq 80\%$

Mixed pattern: $FEV_1/FVC < 70\%$, $FVC \leq 80\%$, and $FEV_1 \leq 80\%$

Descriptive statistics were presented as mean $\pm$ standard deviation (SD) for continuous variables and as frequency (%) for categorical variables. Differences across subgroups were appraised using the Chi-square

test or Fisher's exact test, as appropriate.

Logistic regression analyses were undertaken to identify factors linked to spirometric airflow obstruction. All independent variables were first entered into univariable models. Variables with p-values < 0.2 in univariable analysis were subsequently included in multivariable logistic regression models. The selection of variables was based on clinical relevance and previous literature, in addition to statistical significance. Odds ratios (ORs), adjusted odds ratios (AORs), and 95% confidence intervals (CIs) were also reported. A two-sided p-value < 0.05 was considered statistically significant.

Overfitting: To appraise the potential for overfitting in the multivariable logistic regression model, the events-per-variable (EPV) statistic was utilized. This was calculated as the ratio of the number of outcome events (cases with spirometric airflow obstruction) to the number of predictor variables entered into the final model. A minimum EPV of 10 was deemed appropriate to ensure reliable estimates and lower the risk of overfitting, in line with established recommendations for logistic regression modeling [22].

Multicollinearity among independent variables was ascertained using the variance inflation factor (VIF), with values exceeding 10 signaling significant collinearity. Model calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Interaction terms were not included in the final model owing to the limited number of outcome events and to avoid overfitting. The linearity assumption for continuous variables was explored using the Box–Tidwell test. All analyses were performed using SPSS and Stata.

Results

A total of 732 adults with T2DM were included in the analysis. Among them, 62 individuals (8.5%) had spirometric airflow obstruction ($FEV_1/FVC < 0.70$), while 670 (91.5%) had no evidence of airflow obstruction. The characteristics of participants according to airflow obstruction status are reported in Table 1.

No significant differences were noted in the prevalence of spirometric airflow obstruction by gender, age, marital status, place of residence, employment status, ethnicity, BMI, alcohol use, smoking, history of myocardial infarction, or cardiac ischemia (all $P > 0.05$). Nevertheless, the presence of chronic pulmonary disease was significantly linked to spirometric airflow obstruction (16.1% vs. 6.7%, $P = 0.019$).

Table 1. Prevalence of spirometric airflow obstruction across demographic and clinical subgroups in type 2 diabetes patients (n = 732)

Variable	Category	Airflow Obstruction* n (%) (n=62)	No Airflow Obstruction n (%) (n=670)	Total (N=732)	P-value†
Gender	Female	32 (51.6)	383 (57.2)	415 (56.7)	0.399
	Male	30 (48.4)	287 (42.8)	317 (43.3)	
Age (years)	<45	5 (8.1)	67 (10.0)	72 (9.8)	0.336
	45–65	53 (85.5)	522 (77.9)	575 (78.6)	
	>65	4 (6.5)	81 (12.1)	85 (11.6)	
Marital Status	Single	8 (12.9)	41 (6.1)	49 (6.7)	0.070
	Divorced/Widowed	8 (12.9)	37 (5.5)	45 (6.1)	
	Married	46 (74.2)	592 (88.4)	638 (87.2)	
Residence	Urban	56 (90.3)	578 (86.3)	634 (86.6)	0.370
	Village	6 (9.7)	92 (13.7)	98 (13.4)	
Employment	Employed	23 (37.1)	229 (34.2)	252 (34.4)	0.644
	Unemployed	39 (62.9)	441 (65.8)	480 (65.6)	
Ethnicity	Fars	37 (59.7)	320 (47.8)	357 (48.8)	0.195
	Lor	19 (30.6)	273 (40.7)	292 (39.9)	
	Other	6 (9.7)	77 (11.5)	83 (11.3)	
BMI	≤30	35 (56.5)	421 (62.8)	456 (62.3)	0.321
	>30	27 (43.5)	249 (37.2)	276 (37.7)	
Alcohol Use	Yes	12 (19.4)	82 (12.2)	94 (12.8)	0.109
	No	50 (80.6)	588 (87.8)	638 (87.2)	
Smoking	Yes	4 (6.5)	82 (12.2)	86 (11.7)	0.176
	No	58 (93.5)	588 (87.8)	646 (88.3)	
Myocardial Infarction	Yes	1 (1.6)	22 (3.3)	23 (3.1)	0.712
	No	61 (98.4)	648 (96.7)	709 (96.9)	
Cardiac Ischemia	Yes	9 (14.5)	82 (12.2)	91 (12.4)	0.603
	No	53 (85.5)	588 (87.8)	641 (87.6)	
Chronic Pulmonary Disease	Yes	10 (16.1)	45 (6.7)	55 (7.5)	0.019**
	No	52 (83.9)	625 (93.3)	677 (92.5)	

*Spirometric airflow obstruction defined as pre-bronchodilator FEV₁/FVC < 0.70
†P-value from Chi-square test or Fisher's exact test (**) Abbreviations: BMI, body mass index (kg/m²); DM, diabetes mellitus

Factors Associated with Spirometric Airflow Obstruction: Univariable logistic regression analyses identified marital status (married) and history of chronic pulmonary disease as significantly correlated with spirometric airflow obstruction (P < 0.05). In multivariable logistic regression models, alcohol use

(OR = 2.23; 95% CI: 1.09, 4.56), marital status (OR = 2.62; 95% CI: 1.14, 6.00), and chronic pulmonary disease (OR = 2.59; 95% CI: 1.21, 5.53) remained independent associated factors of spirometric airflow obstruction in adults with T2DM (Table 2). No other variables revealed significant associations.

Table 2. Univariable and multivariable logistic regression analysis of factors associated with spirometric airflow obstruction in T2DM patients (n = 732)

Variables		Univariable Multivariable			
		OR (95% CI)	P-value	AOR* (95% CI)	P-value
Gender	Male	0.79 (0.47, 1.34)	0.399	-	-
	Female	1.00 (Reference)		-	-
Age	45–65	0.73 (0.28, 1.90)	0.526	0.72 (0.27, 1.90)	0.518
	>65	1.51 (0.39, 5.85)	0.176*	1.61 (0.40, 6.39)	0.493
	<45	1.00 (Reference)		1.00 (Reference)	
Marital Status	Married	2.27 (1.01, 5.09)	0.046*	2.62 (1.14, 6.00)	0.022
	Others	1.00 (Reference)		1.00 (Reference)	
Residence	Village	0.67 (0.28, 1.60)	0.373	-	-
	Urban	1.00 (Reference)		-	-
Employment	Employed	1.13 (0.62, 4.07)	0.644	-	-
	Unemployed	1.00 (Reference)		-	-
Ethnicity	Fars	0.67 (0.27, 1.65)	0.389	-	-
	Lor	1.12 (0.43, 2.90)	0.816	-	-
	Other	1.00 (Reference)		-	-

BMI	>30	1.30 (0.77, 2.20)	0.322	-	-
	≤30	1.00 (Reference)		-	-
Alcohol Use	Yes	1.72 (0.88, 3.36)	0.113*	2.23 (1.09, 4.56)	0.027
	No	1.00 (Reference)		1.00 (Reference)	
Smoking	Yes	2.02 (0.75, 5.71)	0.184*	2.91 (0.97, 8.68)	0.055
	No	1.00 (Reference)		1.00 (Reference)	
Myocardial Infarction	Yes	0.48 (0.06, 3.64)	0.480	-	-
	No	1.00 (Reference)		-	-
Cardiac Ischemia	Yes	1.21 (0.57, 2.56)	0.604	-	-
	No	1.00 (Reference)		-	-
Chronic Pulmonary Disease	Yes	2.67 (1.27, 5.60)	0.009*	2.59 (1.21, 5.53)	0.013
	No	1.00 (Reference)		1.00 (Reference)	

*AOR: Adjusted odds ratio (adjusted for all variables with P < 0.2 in univariable analysis) Abbreviations: BMI, body mass index (kg/m²); CI, confidence interval; OR, odds ratio; DM, diabetes mellitus

The VIF values for the included variables ranged within 1.00 to 1.10, demonstrating no significant multicollinearity. The Hosmer–Lemeshow test yielded a non-significant result ($\chi^2 = 0.14$, $df = 4$, $P = 0.997$), implying adequate model calibration. The Box–Tidwell test revealed no significant departures from linearity for continuous variables.

Pulmonary Function Test Comparisons: Comparisons of spirometry indices between participants with and without spirometric airflow obstruction are

summarized in Table 3. Those with airflow obstruction had significantly lower FEV₁, PEF, FEF₂₅, FEF₅₀, FEF₇₅, FEF_{25–75}, FEV₁/FEV₆, and MVV compared to those without airflow obstruction (all P < 0.001). No significant differences were noted for FVC or FEV₆ (P = 0.157 and P = 0.357, respectively). These results reflect marked airflow limitation and diminished expiratory flow rates among T2DM participants with spirometric airflow obstruction.

Table 3. Comparison of spirometry indices between participants with and without spirometric airflow obstruction in type 2 diabetes patients

Variables (% Predicted)	Overall (n = 732) Mean ± SD	Airflow Obstruction* (n = 62) Mean ± SD	No Airflow Obstruction (n = 670) Mean ± SD	P-value†
FVC	87.52 ± 18.43	92.81 ± 20.94	87.34 ± 18.32	0.157
FEV ₁	97.91 ± 21.96	78.72 ± 19.03	98.57 ± 21.77	<0.001
PEF	68.67 ± 22.54	39.48 ± 16.08	69.66 ± 22.07	<0.001
FEF ₂₅	70.30 ± 23.86	39.54 ± 17.69	71.35 ± 23.35	<0.001
FEF ₅₀	98.98 ± 38.25	54.72 ± 17.18	100.48 ± 37.87	<0.001
FEF ₇₅	166.08 ± 65.06	99.49 ± 51.59	168.34 ± 64.30	<0.001
FEF _{25–75}	114.80 ± 45.25	61.02 ± 19.00	116.62 ± 44.76	<0.001
FEV ₆	87.33 ± 18.34	90.78 ± 19.88	87.22 ± 18.29	0.357
FEV ₁ /FEV ₆	112.28 ± 9.48	86.65 ± 9.45	113.15 ± 8.18	<0.001
MVV	88.63 ± 16.54	72.26 ± 17.37	89.19 ± 16.24	<0.001

*Spirometric airflow obstruction defined as pre-bronchodilator FEV₁/FVC < 0.70
†P-value from Mann-Whitney U test Abbreviations: FEV₁, forced expiratory volume in 1 second; FEV₆, forced expiratory volume in 6 seconds; FVC, forced vital capacity; PEF, peak expiratory flow; FEF, forced expiratory flow; MVV, maximum voluntary ventilation; SD, standard deviation

Type of Respiratory Disease: Based on the fixed-ratio algorithm using spirometry criteria (Table 4), restrictive patterns were the most prevalent form of pulmonary dysfunction (467/732, 63.8%), followed by mixed

patterns (47/732, 6.4%) and obstructive patterns (15/732, 2.0%). This classification highlights that the majority of pulmonary impairments in this population were restrictive as compared to obstructive in nature.

Table 4. Frequency of spirometric patterns based on the fixed-ratio algorithm in type 2 diabetes patients

Type of Respiratory Disease	Criteria	N (%)
Obstructive	FEV ₁ /FVC < 0.70, FVC ≥ 80% predicted, and FEV ₁ ≤ 80% predicted	15 (2.0)
Restrictive	FEV ₁ /FVC ≥ 0.70, FVC < 80% predicted, and (FEV ₁ ≤ 80% predicted or FEV ₁ ≥ 80% predicted) *	467 (63.8)
Mixed	FEV ₁ /FVC < 0.70, FVC < 80% predicted, and FEV ₁ ≤ 80% predicted	47 (6.4)
Normal	FEV ₁ /FVC ≥ 0.70 and FVC ≥ 80% predicted	203 (27.8) †

*Restrictive patterns were classified based on spirometry alone without lung volume measurements; these should be interpreted as possible restrictive spirometry pattern
†Calculated as 732 – (15 + 467 + 47) = 203 Abbreviation: DM, diabetes mellitus

Discussion

Restrictive spirometric patterns were the most frequent abnormality among adults with type 2 diabetes mellitus (T2DM), followed by mixed and obstructive patterns. Alcohol consumption, marital status, and chronic pulmonary disease were independently linked to airflow obstruction, whereas smoking, age, and sex were not significant after adjustment [23].

Alcohol consumption was tied to airflow obstruction following adjustment for other covariates. Previous studies have documented different associations according to the amount of alcohol consumed and the pulmonary outcome appraised. In NHANES III, Sisson et al. found higher odds of an obstructive pattern among former heavy drinkers, while low-to-moderate consumption was not associated with obstruction [23]. In a prospective analysis of 16,268 Chinese adults, moderate alcohol consumption was linked to higher FEV₁ and FVC, with the associations varying according to drinking pattern [24]. Another population-based study using both self-reported alcohol intake and carbohydrate-deficient transferrin found no consistent relationship between alcohol exposure and pulmonary function after accounting for smoking and other factors [25]. In contrast, a recent longitudinal study reported greater annual reductions in FVC and FEV₁ among participants with heavy alcohol consumption [26].

The association observed in this population thus agrees more closely with studies of high alcohol exposure than with studies reporting neutral or favorable associations for moderate intake [23]. Differences in the quantity and pattern of drinking, smoking exposure, population characteristics, and definitions of pulmonary impairment may account for the variations among studies [24]. Alcohol exposure may also be accompanied by other behavioral factors linked to respiratory impairment, making residual confounding possible [25].

Marital status was independently associated with airflow obstruction. Even though the crude prevalence of spirometric airflow obstruction was higher among unmarried, divorced, or widowed individuals compared to married individuals, following adjustment for potential confounders including age, smoking, BMI, and chronic pulmonary disease, married status was independently linked to elevated odds of airflow obstruction. This paradoxical finding may be explained by the distribution of confounding factors across marital status groups.

There is limited direct evidence linking marital status to spirometric obstruction. Studies examining social factors in respiratory disease have generally focused on education, income, occupation, and access to healthcare rather than marital status [27]. In patients hospitalized for COPD exacerbation, marital status was inspected as

a social determinant of discharge outcomes, suggesting that social characteristics may influence the course of respiratory disease [28]. Population-based research has also noted associations between socioeconomic and occupational characteristics as well as airflow limitation after adjustment for smoking and other factors [27]. Studies of COPD prognosis have similarly reported differences according to social and demographic characteristics, though the direction and magnitude of associations have varied across populations.

Marital status may therefore reflect socioeconomic circumstances, occupational conditions, household responsibilities, or access to healthcare rather than exerting a direct impact on pulmonary function. These factors were not fully appraised in the present analysis. The association should consequently be interpreted cautiously, particularly since the available literature does not provide consistent evidence for an independent relationship between marital status and spirometric airflow obstruction.

The association between chronic pulmonary disease and airflow obstruction is compatible with the established relationship between chronic respiratory disorders and impaired airflow. The predominance of restrictive abnormalities also aligns with several studies examining pulmonary function in T2DM. A meta-analysis of 93 studies reported lower FEV₁ and FVC among those with diabetes as well as an association between diabetes and restrictive spirometry [29]. In the Korean National Health and Nutrition Examination Survey, restrictive impairment was more frequent among participants with diabetes than among those without diabetes, with diabetes remaining associated with restrictive impairment after adjustment [30]. Another Korean population-based analysis found that restrictive, but not obstructive, ventilatory dysfunction was independently linked to T2DM [31]. A separate Korean cross-sectional study reported a similar association between restrictive pulmonary disease and T2DM, while no significant association was observed for obstructive disease [32]. Smaller comparative studies have also reported lower FVC and FEV₁ among patients with T2DM, with the pattern tending toward restriction [33, 34].

Several mechanisms have been proposed for diminished lung volumes in diabetes. Pulmonary microangiopathy, chronic inflammation, autonomic dysfunction, and glycation of connective-tissue proteins may alter pulmonary vascular and mechanical properties [35]. The association between diabetes-related microvascular complications and poorer pulmonary function has also been documented in meta-analytic evidence [29]. If total lung capacity was not measured, however, the pattern identified by spirometry should be reported as a “restrictive spirometric pattern” rather than confirmed restrictive lung disease since confirmation requires measurement of total lung capacity [36].

Smoking was not independently linked to airflow obstruction after adjustment. This differs from population-based evidence exhibiting a clear association between smoking and airflow limitation. In the Korean diabetes population, ever-smoking was independently tied to obstructive impairment [30]. UK Biobank data revealed a strong association between both current and former smoking and airflow obstruction, with the association being stronger among women [37]. Studies of young European adults have also noted higher prevalence of airflow obstruction among ever-smokers than never-smokers [38]. In a large Canadian population study, smoking remained an important determinant of airflow obstruction even among relatively young adults [39].

Age and sex were again not significant in the adjusted model. In contrast, older age and male sex were linked to lowered pulmonary function among Korean adults with diabetes [30], while UK Biobank data indicated sex differences in the relationship between smoking and airflow obstruction [37]. Differences in smoking exposure, age distribution, sample size, and the clinical characteristics of adults with T2DM may account for the lack of significant associations in this population.

The main strengths included standardized spirometry, a well-characterized diabetic population, as well as multivariable adjustment for major confounders. Limitations included the cross-sectional design, which precludes causal inference; absence of post-bronchodilator testing and lung volume measurements, preventing confirmation of COPD and restrictive defects, respectively; the small number of participants with airflow obstruction ($n=62$), which may have lowered statistical power; unavailable data on diabetes duration, HbA1c, and antidiabetic medications; potential residual confounding; and limited generalizability.

Conclusion

Spirometric airflow obstruction ($FEV_1/FVC < 0.70$) was present in 8.5% of adults with type 2 diabetes. Alcohol consumption, marital status, and chronic pulmonary disease were independently linked to airflow obstruction. Restrictive spirometric patterns were more frequent than obstructive patterns. Longitudinal studies with comprehensive pulmonary and diabetes-related assessments are warranted to clarify these associations.

Acknowledgments

We would like to acknowledge Shahrekord University of Medical Sciences for financially supporting this project.

Conflict of interest

None declared.

Funding

The SCS was funded by the Ministry of Health and Medical Education of Iran (Grant number 700/120) to develop cohort studies across Chaharmahal and Bakhtiari Province, and was financially and logistically supported by Shahrekord University of Medical Sciences (Grant numbers 2763 and 3366).

Ethical Considerations

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki for research involving human participants. Prior to the initiation of the study, the research protocol was reviewed and approved by the Ethics Committee of Shahrekord University of Medical Sciences. Written informed consent had been obtained from all participants upon their entry into the Persian Cohort Study. Participants were assured that their personal information would remain confidential and that all collected data would be anonymized and used solely for research purposes. Participants had the right to withdraw from the study at any stage without consequences.

Code of Ethics

The study protocol was reviewed and approved by the Ethics Committee of Shahrekord University of Medical Sciences (Ethics Code: IR.SKUMS.REC.1396.110).

Authors' Contributions

Samaneh Torkian and Ali Ahmadi: designed and supervised the study. Data analysis and interpretation were carried out; Fatemeh Zeynab Kiani: was responsible for spirometry testing and field investigations; Hamid Rouhi and Akbar Soleymani Babadi Karimi: contributed to data acquisition. All authors contributed to drafting and revising the manuscript and approved the final version for publication.

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