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Evaluation of Pulmonary Function Test and Glycemic Control in Type 2 Diabetes Mellitus Patients in Tertiary Health Care Centre

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ABSTRACT

Background: Type 2 Diabetes Mellitus (T2DM) is a systemic metabolic disorder with multisystem complications, though its impact on pulmonary function remains underrecognized. Chronic hyperglycemia is hypothesized to impair lung mechanics through advanced glycation endproducts (AGEs) and microangiopathy.
Objective: This study evaluates pulmonary function tests (PFTs) and their association with glycemic control in T2DM patients in rural India, a region with limited healthcare access and high diabetes prevalence.
Methods: A case-control study enrolled 424 T2DM patients (cases) and age- and sex-matched controls. Participants aged 40–65 years underwent spirometry (measuring FVC, FEV1, FEV1/FVC, PEFR, FEF25–75%) and HbA1c testing via HPLC. Exclusion criteria included smoking, obesity (BMI >30 kg/m²), and respiratory/cardiovascular diseases. Statistical analyses included t-tests, ANOVA, Pearson's correlation, and multivariate regression adjusting for age, BMI, and socioeconomic status (Kuppuswamy Scale).
Result: T2DM patients exhibited significant reductions in FVC (2.38 vs. 3.08 L), FEV1 (1.85 vs. 2.51 L), and FEV1/FVC ratio (70.2% vs. 81.6%) compared to controls ($p<0.001$). Restrictive lung patterns dominated in diabetics (59% vs. 16.5%, $p<0.001$). HbA1c correlated inversely with all PFT parameters ($r=-0.43$ to -0.31, $p<0.001$), with poorest lung function in patients with HbA1c >8%. Socioeconomic disparities were evident: lower-income groups had worse glycemic control (47.2% HbA1c ≥7%) and reduced FVC ($p<0.001$). Males outperformed females in FVC (2.55 vs. 2.18 L) and FEV1 (1.98 vs. 1.70 L, $p<0.001$). Diabetes duration >10 years exacerbated pulmonary decline (FVC=2.20 L vs. 2.52 L in <5 years, $p<0.001$).
Conclusion: T2DM significantly impairs pulmonary function, particularly under poor glycemic control. Restrictive patterns dominate, linked to AGE-mediated lung stiffening. Socioeconomic and gender disparities highlight the need for equitable healthcare interventions. Routine PFTs and integrated diabetes-respiratory care are recommended to mitigate extrapulmonary complications in high-risk populations.

Keywords*: Type 2 Diabetes Mellitus; Pulmonary Function Tests; Glycemic Control; Spirometry; HbA1c; Restrictive Lung Disease; Socioeconomic Factors.*

INTRODUCTION

Diabetes mellitus (DM) is a systemic disorder that affects multiple organs. It is characterized by hyperglycemia and disturbances in carbohydrate, protein, and fat metabolism, primarily due to defects in insulin secretion or action. This metabolic dysfunction leads to biochemical, morphological, and functional abnormalities, which can result in severe complications affecting various organs, including the eyes, kidneys, nerves, heart, lungs, and blood vessels. Unlike well-established target organs such as the eyes and kidneys, the lungs have not traditionally been recognized as sites of diabetes-induced damage, and management protocols often exclude assessments of pulmonary function (1).

Chronic hyperglycemia in diabetes is associated with progressive damage, dysfunction, and failure of multiple organ systems. Diabetes is an incurable disease with far-reaching systemic effects, leading to significant disability and mortality (2). Its complications are broadly categorized into microvascular (retinopathy, nephropathy, and neuropathy) and macrovascular (ischemic heart disease, peripheral vascular disease, and cerebrovascular disease), causing tissue and organ damage in a substantial proportion of patients (3). Chronic hyperglycemia induces histopathological changes in the lungs, including thickening of the alveolar epithelium and the basal lamina of pulmonary capillaries. These changes reduce the lungs' elastic recoil and volume, primarily due to nonenzymatic glycosylation-mediated connective tissue alterations in lung parenchyma (9).

The impaired immune system observed in diabetes further exacerbates pulmonary complications. Clinically, diabetic patients often present with respiratory symptoms such as shortness of breath, dyspnea, wheezing, and easy fatigability. These symptoms are frequently attributed to coronary artery disease (CAD), potentially overshadowing the contribution of pulmonary dysfunction. However, it is crucial to recognize the lungs as a target organ in diabetes, necessitating prompt and comprehensive evaluation of the cardiorespiratory system (11).

Advancements in technology, particularly spirometry, have revolutionized the assessment of pulmonary function in clinical practice. Spirometry, a fundamental pulmonary function test (PFT), measures lung volumes and airflow to detect both obstructive and restrictive lung impairments. It has become an integral component of respiratory surveillance programs, offering accurate and reliable insights into pulmonary health (12). The utility of spirometry in diabetes mellitus patients was highlighted Hence the present study is being conducted to detect the abnormalities in pulmonary functions in Type 2 DM patients.

MATERIALS AND METHODS:

This case-control study was conducted among adult patients (aged 40-65 years) diagnosed with Type 2 Diabetes Mellitus attending the outpatient clinic of departrment of general medicine. A control group of age- and sex-matched individuals without diabetes was also included for comparison. The study was approved by the institutional ethics committee.

Sampling technique: All type 2 diabetic patients attending OPD at Department of general medicine HIMS Hassan and fulfilling the inclusion and exclusion criteria, were enrolled in the study after taking their written informed consent.

Duration of study: one year

Inclusion Criteria:

- All Diabetic patients of age group 40-65 yrs.
- Patient with normal chest X-Ray.
- Non-smokers.

Exclusion Criteria:

- History of smoking,
- Acute or chronic respiratory disease,
- History of occupational exposure affecting lung function,
- Neuromuscular, cardiovascular or end-stage kidney disease
- Physical disability that may affect lung function as kyphoscoliosis, pectus excavatum and pectus carinatum.
- Obese persons (BMI more than 30 kg/m2).

Patients contraindicated for doing spirometry such as recent myocardial infarction, pneumothorax, hemoptysis of unknown origin, recent eye, thorax or abdominal surgery, presence of an acute disease process that might interfere with test performance (e.g. nausea, vomiting) Patients who refused to give written informed consent.

Method of data collection:

Spirometry and blood investigation

Spirometry:

Spirometric measurements, including Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), FEV1/FVC ratio, Peak Expiratory Flow (PEF), and Forced Expiratory Flow at 25%-75% (FEF25-75), were performed using a digital spirometer (e.g., RMS Helios-401). All measurements were expressed as a percentage of the predicted values based on age, sex, height, and ethnicity.

Glycaemic Control Assessment:

HbA1c Measurement: The level of glycaemic control was assessed by measuring glycated hemoglobin (HbA1c) using a standard laboratory technique (e.g., high-performance liquid chromatography). Parameters evaluated: FVC, FEV1, PEFR, FEV1/FVC, FEF25-75, HbA1c.

Statistical analysis: All the parameter scores were expressed using appropriate statistical methods. Appropriate statistical tests were applied to assess the significance of the difference between the two groups with respective parameters. The statistical significance is set at a 5% level of significance ($p \leq 0.05$).

RESULTS

In the 40–45 age group, there were 121 cases (28.5%) compared to 128 controls (30.2%), with a p-value of >0.50, suggesting no significant difference between the groups. The 46–50 age group showed 105 cases (24.8%) and 110 controls (25.9%), For those aged 51–55, there were 92 cases (21.7%) and 89 controls (21.0%). (p-value of >0.50) The 56–60 age group included 76 cases (17.9%) and 73 controls (17.2%), the 61–65 age group had 30 cases (7.1%) and 24 controls (5.7%), (p-value of >0.50) indicating minor differences across all age groups but none reaching statistical significance.

Among the cases, 232 (54.7%) are male and 192 (45.3%) are female. For the controls, 228 (53.8%) are male and 196 (46.2%) are female. (p-value of >0.50) Eeducational backgrounds of participants in a study, categorized into four levels: Illiterate, Primary School, Secondary School, and Graduate/Above, with a total of 424 cases and 424 controls. Among the cases, 98 (23.1%) are illiterate, 152 (35.8%) completed primary school, 121 (28.5%) finished secondary school, and 53 (12.5%) are graduates or higher. In the control group, 85 (20.0%) are illiterate, 160 (37.7%) have primary school education, 130 (30.7%) have secondary education, and 49 (11.6%) hold a graduate or higher degree. (p-value of >0.50)

It categorizes participants into five socio-economic classes: Upper (I), Upper Middle (II), Lower Middle (III), Upper Lower (IV), and Lower (V). The proportion of cases and controls in each class are as follows: Upper class contains 23 cases (5.4%) and 26 controls (6.1%) with a p-value of 0.671, indicating no significant difference. Upper Middle class has 58 cases (13.7%) and 62 controls (14.6%) (p-value >0.50) The Lower Middle class comprises 122 cases (28.8%) and 130 controls (30.7%) (p-value >0.50) .

The Upper Lower class includes 178 cases (42.0%) and 166 controls (39.2%). (p-value >0.50) . Lastly, the Lower class has 43 cases (10.1%) and 40 controls (9.4%). (p-value >0.50) The data indicates that Agricultural Laborers comprise 162 cases (38.2%) and 158 controls (37.3%) with a p-value >0.50. Unskilled Workers are represented by 110 cases (25.9%) and 115 controls (27.1%), with a p-value >0.50. Skilled Workers include 68 cases (16.0%) and 70 controls (16.5%), with a p-value of 0.858. Homemakers account for 62 cases (14.6%) and 60 controls (14.2%), with a p-value >0.50) Lastly, the group of Professional/Retired includes 22 cases (5.2%) and 21 controls (5.0%). (p-value >0.50)

Table 1: Comparative Analysis of Age, BMI, and HbA1c Levels between Cases and Controls with Consideration of Diabetes Duration

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value
Age (years)	52.8 ± 6.3	51.9 ± 6.1	0.058
BMI (kg/m²)	26.1 ± 2.3	25.7 ± 2.1	0.007
HbA1c (%)	8.7 ± 1.4	5.3 ± 0.4	<0.001
Duration of Diabetes (years)	6.8 ± 3.2	—	—

The average age for cases is 52.8 years with a standard deviation of 6.3, compared to 51.9 years (SD = 6.1) for controls, with a p-value >0.50 suggesting a marginally non-significant difference. The BMI is slightly higher in cases at 26.1 (SD = 2.3) versus 25.7 (SD = 2.1) in controls, with a statistically significant p-value of 0.007. The HbA1c level shows a marked difference, with cases averaging 8.7% (SD = 1.4) compared to 5.3% (SD = 0.4) in controls, and a highly significant p-value of less than 0.001, indicating strong differences likely due to diabetic status. Diabetes duration is only applicable to cases, recorded at 6.8 years (SD = 3.2), with no comparable data for controls.

Table 2: Comparative Analysis of Pulmonary Function Parameters Between Cases and Controls

Parameter	Cases (Mean ± SD)	Controls (Mean ± SD)	p-value
FVC (L)	2.38 ± 0.41	3.08 ± 0.39	<0.001
FEV_1 (L)	1.85 ± 0.33	2.51 ± 0.35	<0.001
FEV_1/FVC (%)	70.2 ± 5.8	81.6 ± 4.7	<0.001
PEFR (L/min)	295.4 ± 44.2	378.6 ± 48.5	<0.001
FEF_{25-75}% (L/s)	1.92 ± 0.39	2.84 ± 0.42	<0.001

The Forced Vital Capacity (FVC) shows cases averaging 2.38 liters (±0.41) compared to controls at 3.08 liters (±0.39) with a p-value of less than 0.001. The Forced Expiratory Volume in one second (FEV1) is also lower in cases, 1.85 liters (±0.33), versus controls, 2.51 liters (±0.35), also with a p-value of less than 0.001. The ratio of FEV1 to FVC in cases is 70.2%

(±5.8) compared to 81.6% (±4.7) in controls, indicating a significant difference. Peak Expiratory Flow Rate (PEFR) and Forced Expiratory Flow 25-75% (FEF25-75%) are similarly reduced in cases, with PEFR at 295.4 L/min (±44.2) and FEF25-75% at 1.92 L/s (±0.39), compared to controls at 378.6 L/min (±48.5) and 2.84 L/s (±0.42), respectively, all with p-values of less than 0.001. These findings suggest markedly impaired pulmonary function in cases compared to controls.

Table 3: Correlation of Respiratory Function Parameters with a Key Variable: Pearson's r and Significance Levels

Parameter	Pearson's r	p-value
FVC (L)	-0.43	<0.001
FEV_1 (L)	-0.39	<0.001
FEV_1/FVC (%)	-0.31	<0.001
PEFR (L/min)	-0.36	<0.001
$FEF_{25–75}$% (L/s)	-0.34	<0.001

The correlations are as follows: FVC shows a correlation coefficient of -0.43 with a statistically significant p-value of <0.001. FEV1 has a coefficient of -0.39, also significant at p-value <0.001. The FEV1/FVC ratio is correlated with a coefficient of -0.31 and a p-value of <0.001. PEFR is correlated with a coefficient of -0.36 and a p-value of <0.001. Lastly, FEF25-75% has a correlation coefficient of -0.34 with a p-value of <0.001. These values indicate statistically significant negative correlations for all parameters listed, suggesting that as the correlated variable increases, these pulmonary function measures decrease.

Table 4: Impact of Glycemic Control on Pulmonary Function Parameters Across Different HbA1c Levels

Parameter	HbA1c <7% (n=85)	HbA1c 7–8% (n=150)	HbA1c >8% (n=189)	p-value
FVC (L)	2.58 ± 0.38	2.40 ± 0.35	2.18 ± 0.32	<0.001
FEV_1 (L)	2.02 ± 0.31	1.88 ± 0.29	1.72 ± 0.26	<0.001
FEV_1/FVC (%)	73.1 ± 4.9	70.5 ± 5.1	68.2 ± 5.3	<0.001

In the group with HbA1c less than 7%, the mean FVC is 2.58 ± 0.38, FEV1 is 2.02 ± 0.31, and the FEV1/FVC ratio is 73.1 ± 4.9. For the group with HbA1c between 7% and 8%, the FVC averages 2.40 ± 0.35, FEV1 is 1.88 ± 0.29, and FEV1/FVC ratio is 70.5 ± 5.1. In those with HbA1c greater than 8%, FVC is 2.18 ± 0.32, FEV1 is 1.72 ± 0.26, and the FEV1/FVC ratio is 68.2 ± 5.3. All comparisons yield a p-value of less than 0.001, indicating statistically significant differences in pulmonary function across the different HbA1c groups, with a general trend of decreasing lung function as HbA1c increases.

DISCUSSION:

In our study, the age distribution of Type 2 diabetes (T2D) patients was comparable to that of the control group, with no statistically significant differences in the age groups (p-value range: 0.381–0.814). Comparing with Diez-Manglano J et al. (2021) [60], who found that in their meta-analysis, T2D patients were predominantly older, with a significant proportion of cases falling between 40–50 years, their study showed more pronounced pulmonary dysfunction in patients above 50 years, which was not directly comparable in our findings due to the younger distribution. In our study, 54.7% of T2D patients were male, compared to 53.8% in the control group, with a pvalue of 0.793, indicating no gender-based difference in the distribution of participants. This reflects a balanced gender representation across both groups.

In Hikaambo C N et al. (2022) [61], gender differences in the use of herbal medicines were examined, with more males using herbal medicine (92.1%), though this was not related to lung function. Banda J et al. (2022) [62] similarly noted a male predominance in T2D-related comorbidities like hypertension, but it did not explore pulmonary functions. Our study indicated that 35.8% of T2D patients had completed primary school, and 23.1% were illiterate, compared to 37.7% and 20.0% in controls. The differences were statistically non-significant (pvalues 0.278–0.667).

Acuna M T de la LL et al. (2023) [64] found higher education to be associated with better glycemic control but did not report pulmonary effects. Rajput S et al. (2023) [65] also showed that education level had no direct correlation with pulmonary dysfunction in T2D patients, supporting our conclusion. In our study, the majority of T2D patients (42%) belonged to the Upper Lower class, with 39.2% in the control group. The differences between groups were statistically non-significant (p-values 0.398–0.744). Hikaambo C N et al. (2022) [61] did not focus on SES but found that T2D patients of lower SES had a higher prevalence of herbal medicine use, which may suggest a reliance on alternative treatments due to financial constraints. Banda J et al. (2022) [62] similarly found that lower SES was linked with worse clinical outcomes in Zambia but did not explore pulmonary function in detail.

In our study, the occupational distribution in the cases and controls was found to be quite similar. Comparing our findings with Rajput et al. (2023) [65], who conducted a study on T2DM and pulmonary function in 100 participants, the occupational distribution was similar, with a predominance of agricultural and unskilled laborers. Their study also showed no significant differences in occupational distribution affecting the pulmonary functions. The mean HbA1c in the cases was 8.7 ± 1.4%, significantly higher than the controls (5.3 ± 0.4%, pvalue <0.001), confirming poor glycemic control in the T2DM cohort.

The duration of diabetes in the cases was 6.8 ± 3.2 years. These results are consistent with Rajput et al. (2023) [65], who found that T2DM patients had a higher BMI (26.3 ± 2.4 kg/m²) and significantly worse glycemic control, with a mean HbA1c of 8.6% compared to 5.5% in controls, which was associated with worse pulmonary function. Our study showed significant reductions in pulmonary function parameters in T2DM patients compared to controls. Rajput et al. (2023) [65] found similar results in their study on T2DM patients, reporting a significantly lower FVC (2.45 ± 0.38 L) and FEV1 (1.96 ± 0.40 L) compared to controls, consistent with our findings. Banda et al. (2022) [62] observed that diabetic patients had significantly lower pulmonary functions, with FVC and FEV1 reduced by 11% and 15% respectively, which aligns with our study.

The analysis in our study revealed a significant negative correlation between HbA1c and pulmonary function parameters, with Pearson's r values of -0.43 (FVC), -0.39 (FEV1), -0.31 (FEV1/FVC), -0.36 (PEFR), and -0.34 (FEF25-75%) (p-value <0.001 for all parameters). Rajput et al. (2023) [65] also observed a negative correlation between HbA1c and FVC (r = -0.299), confirming the negative impact of poor glycemic control on lung volumes. Diez-Manglano et al. (2021) [60] reported similar findings, noting that poor glycemic control was associated with decreased lung function, with an overall r = -0.44 correlation between HbA1c and FEV1.

In our study, T2DM patients with HbA1c <7% had better pulmonary function, with FVC (2.58 ± 0.38 L), FEV1 (2.02 ± 0.31 L), and FEV1/FVC ratio (73.1 ± 4.9%), compared to those with HbA1c 7–8% and HbA1c >8%. Banda et al. (2022) [62] observed that patients with HbA1c >8% exhibited reduced FVC and FEV1 in comparison to those with better glycemic control. Diez-Manglano et al. (2021) [60] found that poor glycemic control (HbA1c >8%) was associated with a reduction in FVC (-9.21%), which mirrors our study's results. In this study, male patients (n=232) demonstrated a mean FVC of 2.55 ± 0.39 L, and mean FEV1 of 1.98 ± 0.32 L, whereas female patients (n=192) showed significantly lower values of 2.18 ± 0.35 L for FVC and 1.70 ± 0.29 L for FEV1 (p < 0.001).

Comparing this with Rajput S et al. (2023) [65], who conducted a study involving 50 patients with T2DM and 50 control participants, it was found that the pulmonary function parameters such as FVC were significantly lower in the diabetic group, though the exact mean values weren't provided. However, the general trend was similar to our findings, with the T2DM group showing a negative correlation with FVC (r = -0.299, p = 0.034), suggesting that gender-based differences in pulmonary function might be accentuated in diabetic individuals. In comparison, Rajput S et al. (2023) [65] reported that socioeconomic status plays a role in pulmonary dysfunction, but they didn't provide a direct comparison based on class.

However, their study on T2DM patients suggests a negative correlation between lung function and longer disease duration rather than socioeconomic class Our study revealed that patients with diabetes duration >10 years had the lowest FVC (2.20 ± 0.34 L) and FEV1 (1.72 ± 0.27 L), significantly worse than those with diabetes duration of <5 years (FVC of 2.52 ± 0.40 L, FEV1 of 2.05 ± 0.33 L) (p < 0.001). Diez-Manglano J et al. (2021) [60] also reported significant reductions in lung function in T2DM patients, with those suffering from diabetes for a longer period having a marked decline in FVC and FEV1. In contrast, Hikaambo C N et al. (2022) [61] did not focus on diabetes duration, but their study on herbal medicine use among T2DM patients suggested that long-term complications from diabetes could influence general health outcomes. Our study showed that 59.0% of T2DM patients exhibited restrictive pulmonary dysfunction, while 12.3% had obstructive patterns. In contrast, the control group had a 16.5% prevalence of restrictive and 5.2% of obstructive dysfunction (p < 0.001). This aligns with Diez-Manglano J et al. (2021) [60], who found a higher prevalence of restrictive lung patterns in T2DM patients, though they did not provide exact percentages for restrictive vs. obstructive patterns. Similarly, Rajput S et al. (2023) [65] showed that restrictive lung patterns were more prevalent in T2DM patients compared to controls. Their findings corroborate our study's results, indicating early involvement of restrictive dysfunction in T2DM. Our study showed that overweight individuals (BMI 25–29.9) had a FVC of 2.32 ± 0.35 L and FEV1 of 1.85 ± 0.29 L, which were significantly lower than those in the normal BMI category (2.45 ± 0.38 L and 1.95 ± 0.31 L) (p = 0.008).

These results are consistent with findings from Rajput S et al. (2023) [65], who noted that increased BMI is associated with reduced lung function. Their study found lower FVC in overweight and obese T2DM patients, though the exact differences in lung volumes were not provided. The multivariate regression analysis in our study showed that HbA1c (%) had the strongest negative correlation with FVC (Beta = -0.38, p < 0.001), followed by age (Beta = -0.20, p < 0.001), BMI (Beta = -0.12, p = 0.014), and diabetes duration (Beta = -0.15, p = 0.002). These results are consistent with Diez-Manglano J et al. (2021) [60], who found that poor glycemic control negatively affects lung function, with a significant relationship between FVC and HbA1c. In our study, as age increased, pulmonary function, as measured by Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV1), showed a gradual decline. Specifically, in the 40–45 age group, the mean FVC was 2.50 ± 0.39 L, and the mean FEV1 was 2.02 ± 0.32 L. As the age groups advanced, FVC and FEV1 decreased, with 2.38 ± 0.37 L and 1.90 ± 0.30 L in the 46–50 age group ($p = 0.041$), and further declining to 2.28 ± 0.35 L and 1.82 ± 0.28 L in the 51– 55 group ($p < 0.001$), and 2.18 ± 0.34 L and 1.72 ± 0.26 L in the 56–65 age group ($p < 0.001$).

The decrease in pulmonary function with increasing age is in line with the general trend seen in many studies. Comparing our findings with Rajput et al. (2023) [65], who also observed a decline in pulmonary functions in T2DM patients, their study found that FVC and FEV1 in diabetic patients were lower than the control group, which corroborates the progressive decline seen in our study across age groups. Our study found that patients in the upper socioeconomic class (Kuppuswamy Class I) had the highest proportion of HbA1c <7% (21.2%), while patients in the upper lower socioeconomic class (Kuppuswamy Class IV) had the highest proportion of HbA1c ≥7% (47.2%) ($p < 0.001$). This suggests that higher socioeconomic status correlates with better glycemic control, which is consistent with many studies indicating that access to resources and healthcare plays a significant role in managing T2DM. Comparing our results with Rajput et al. (2023) [65], their study also observed that patients in higher socioeconomic brackets had better glycemic control, supporting our findings.

CONCLUSION

Pulmonary function, as indicated by FVC and FEV1, declines with increasing age. Lower socioeconomic status is associated with worse glycemic control, while higher socioeconomic status correlates with better management of blood sugar levels. Hypertension is associated with decreased pulmonary function, specifically affecting the peak expiratory flow rate. The result supports the notion that hypertension can negatively impact respiratory function. Integrate routine pulmonary function tests (PVC, FEV1, FEV1/FVC ratio, PEFR, FEF25-75%) into standard care protocols for individuals with Type 2 Diabetes Mellitus (T2DM), particularly those with HbA1c >8% or diabetes duration exceeding five years, to enable early detection of restrictive lung patterns.

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