Section: Medicine

Original Research Article

LUNG FUNCTION DECLINE IN TYPE2 DIABETES MELLITUS: INSIGHTS FROM FVC AND FEV_1

Sanah Ali Sayed[1], Nyaz Mohammad Khan[2], Rani vijayan[3]

[1]*Assistant professor, Department of Physiology, JIET Medical College and Hospital, Jodhpur, Rajasthan, India*
[2]*Assistant professor, Department of Physiology, Dr SN Medical College, Jodhpur, Rajasthan, India*
[3]*MBBS, SSR Medical College, Phoenix, Mauritius*

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Corresponding Author:
Dr. Sanah Ali Sayed,
Assistant professor, Department of Physiology, JIET Medical College And Hospital, Jodhpur, Rajasthan, India.
Email: sayedsanah86@gmail.com

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ABSTRACT

Background: Diabetes mellitus (DM) is a metabolic disorder characterized by chronic hyperglycemia due to impaired insulin secretion or action. It is highly prevalent in India and is associated with multiple systemic complications. Emerging evidence indicates that the lungs may act as a target organ in DM, with hyperglycemia-induced microangiopathy and non-enzymatic glycosylation leading to reduced pulmonary elasticity and function. The objectives are to evaluate pulmonary function (FVC {forced vital capacity}, FEV_1 {forced expiratory volume in 1 second}) in type 2 diabetes mellitus (T2DM) patients using computerized spirometry and compare with age-matched healthy controls. To assess the relationship between duration of diabetes and pulmonary function in T2DM patients.

Materials and Methods: This cross-sectional observational study was conducted at a tertiary care hospital in Western Rajasthan over one year after ethical approval. It included T2DM patients aged 40–65 years and age- and sex-matched healthy controls. Subjects with conditions affecting lung function or history of tobacco/betel nut use were excluded. Participants underwent detailed history, clinical examination, and assessment of anthropometric and cardiovascular parameters. Diagnosis of diabetes was based on American Diabetes Association (ADA) criteria. Diabetic patients were categorized by disease duration: <5 years, 6–10 years, and >10 years. Pulmonary function tests were performed using a computerized spirometer following standard guidelines. Tests were conducted in a sitting position with a nose clip, repeated three times, and the best value was recorded. Data were expressed as mean ± SD and analyzed using Student's t-test, ANOVA, Tukey's post hoc test, and Spearman's correlation.

Results: Among diabetic subjects, most were aged 40–60 years, with comparable gender distribution between cases and controls. Pulmonary function (FVC and % predicted FVC) was significantly reduced in T2DM patients compared to healthy controls and showed a progressive decline with increasing duration of diabetes. ANOVA revealed statistically significant differences across groups, with post hoc analysis confirming significant reductions between controls and all diabetic subgroups. A significant negative correlation was observed between duration of diabetes and FVC, indicating worsening lung function with longer disease duration. FEV_1 and % predicted FEV_1 were reduced in T2DM patients compared to controls, with a progressive decline observed with increasing duration of diabetes. ANOVA showed statistically significant differences among groups, and post hoc analysis revealed significant reductions between controls and most diabetic subgroups. A significant negative correlation was observed between duration of diabetes and FEV_1 , indicating deterioration of pulmonary function with longer disease duration.

Conclusion: FVC and FEV_1 were significantly reduced in T2DM patients compared to controls ($p < 0.001$) and declined further with increasing disease

duration. A negative correlation with duration indicates progressive deterioration of pulmonary function, suggesting a restrictive pattern in diabetes.
Keywords: Pulmonary function tests, type 2 diabetes mellitus, forced vital capacity, forced expiratory volume in 1 second.

INTRODUCTION

Diabetes Mellitus (DM) is considered as a metabolic disorder of multiple etiologies (genetic and environmental). It is characterized by chronic hyperglycemia with disturbances of carbohydrate, protein and fat metabolism due to absolute or relative insulin deficiencies (i.e. defects in either insulin secretion or insulin action or both). Type 1 or Insulin Dependent Diabetes Mellitus (IDDM) is due to insulin deficiency caused by autoimmune destruction of beta cells in the islets of pancreas.

About 422 million people worldwide have diabetes. There has been an alarming increase in the incidence and prevalence of this condition in India in last few decades. India is often referred to as the "Diabetic Capital of the World".

In 2021, it is estimated that 537 million people have diabetes, and this number is projected to reach 643 million by 2030, and 783 million by 2045 (IDF, 2021).[1]

DM is accompanied by wide spread biochemical, morphological, and functional abnormalities which may precipitate certain complications that affect the neural, cardiovascular, renal systems, and also organs and tissues like skin, liver, collagen, and elastic fibers. It is indeed a multisystem disorder that affects many organs of the body (Kaur S& Agarwal N, 2016).[2]

The complications associated with diabetes impose a substantial healthcare burden and significantly impair quality of life. Several mechanisms have been proposed to explain hyperglycemia-induced end-organ damage, including the formation of advanced glycation end products, increased glucose metabolism through the sorbitol pathway, activation of protein kinase C, and enhanced flux through the hexosamine pathway. Collectively, these processes contribute to altered collagen and elastin cross-linking, leading to reduced elasticity of connective tissues ({Marvisi M et al., 2001}, {Ljubic S et al.,1998}).[3,4]

The presence of an extensive micro vascular circulation and abundant connective tissue in the lungs raises the possibility that lung tissue may be affected by micro - angiopathy process and non-enzymatic glycosylation of tissue proteins, induced by chronic hyperglycemia, thereby rendering the lung a "target organ" in diabetic patients.

The non-enzymatic glycosylation of proteins in the lungs and chest wall makes the collagen less susceptible to proteolysis and leads to its accumulation in lung connective tissue. This process is mainly driven by hyperglycemia, and thus it is more pronounced in patients with poor metabolic control (Cavan DA et al., 1991).[5]

Animal studies have provided evidence for leptin as a stimulant of ventilation, whereas researchers have also proposed an important role of leptin in lung maturation and development (Hsia CC & Raskin P, 2007).[6]

Objectives

1. To evaluate the Pulmonary Function Tests - FVC, FEV1 using computerized spirometry in type2 Diabetes Mellitus patients and compare the mean with the age matched healthy controls.
2. To assess the relation of duration of the disease with Pulmonary Function Tests in type 2 DM patients.

MATERIALS AND METHODS

This cross-sectional observational study was conducted at a tertiary care hospital in Western Rajasthan over one year after ethics approval. It included type 2 diabetic patients aged 40–65 years and age- and sex-matched healthy controls. Participants with conditions affecting lung function—such as structural chest abnormalities, respiratory diseases, neuromuscular disorders, malignancy, cardiopulmonary disease, prior major thoracic or abdominal surgery, or any history of tobacco or betel nut use—were excluded.

Participants were informed about the study and provided consent. A detailed history (personal, family, socioeconomic, drug, and medical) was recorded using a predesigned proforma, followed by clinical examination. Anthropometric measurements (height, weight, BMI) and cardiovascular parameters (pulse rate, blood pressure) were assessed. Subjects were divided into two groups: Group 1—type 2 diabetes mellitus (T2DM) cases and Group 2—age- and BMI-matched healthy controls.

American Diabetes Association Criteria for diagnosis of diabetes:[7]

1. HbA1C ≥ 6.5%. The test should be performed in a laboratory using a method that is National Glycohemoglobin Standardization Program (NGSP) certified and standardized to the Diabetes Control and Complications Trial (DCCT) assay.
2. Fasting Blood Glucose (FBG) ≥ 126 mg/dl (7mmol/L). Fasting is defined as no caloric intake for at least 8 hours.
3. 2-hour plasma glucose ≥200mg/dl (11.1 mmol/L) during an Oral Glucose Tolerance Test (OGTT). The test should be performed as described by WHO, using a glucose load containing the equivalent of 75g anhydrous glucose dissolved in water.
4. In a patient with classic symptoms of hyperglycemia or hyperglycemic crisis, a random plasma glucose ≥200 mg/dl (11.1 mmol/L).

Based on the duration of diabetes, diabetic patients will be divided into groups

Group A – Duration of diabetes < 5 years, Group B – Duration of diabetes 6 – 10 years, Group C – Duration of diabetes >10 years.

Pulmonary function tests were performed using a computerized spirometer following American Thoracic Society guidelines. Tests were conducted between 10:00–14:00 hours to minimize diurnal variation, with daily calibration of the instrument and ambient temperature maintained at 30–40°C. Subjects were trained prior to testing, and the procedure was carried out in a sitting position using a nose clip. Each test was repeated three times with adequate rest, and the best result was recorded.

Spirometry was performed following standard guidelines, consisting of three phases: maximal inspiration, forceful ("blast") exhalation, and continued complete exhalation. Subjects were instructed and allowed practice trials, then tested in a sitting position with a nose clip. After a rapid full inspiration, they sealed the mouthpiece properly and exhaled as forcefully and completely as possible without hesitation or coughing, followed by a maximal inspiration. Each maneuver lasted at least 6 seconds with a visible plateau. A minimum of three acceptable readings (FVC, FEV1) were obtained with adequate rest between trials, and the highest value was considered for analysis. Results were displayed digitally on a laptop.

Spirometry parameters were expressed as mean ± standard deviation. Data were analyzed using Student's t-test, test of homogeneity of variances, ANOVA, Tukey's HSD post hoc test, and Spearman's rho correlation.

RESULTS

A- Anthropometric Parameters

[Table 1] shows age distribution in type 2 diabetes mellitus patients and control subjects. The mean age of diabetic patients was 53.32±8.19 years and that of control was 47.78±6.80 years. On statistical analysis by student t test the result obtain was non-significant (p >0.05), hence the groups were comparable.

Table 1: Distribution of age in type 2 diabetic patients and healthy controls

Characteristic	Type 2 diabetic Mean ± SD (n = 60)	Healthy control Mean ± SD (n = 60)	P-value
Age	53.32±8.19	47.78±6.80	0.15

Table 1a: Distribution of type 2 diabetic patients on basis of duration of diabetes in different age group

		Control (1)	DM Group			Total Diabetic (2)	Total (1+2)
			Diabetic 1-5 Year	Diabetic 6-10 Year	Diabetic >10 Year		
Age Group	40-50 Year	36	9	10	7	26	62
	51-60 Year	21	9	7	7	23	44
	61-70 Year	3	2	4	5	11	14
Total		60	20	21	19	60	120

[Table 1 (a) and Figure 1] shows distribution of type 2 diabetic patients on the basis of duration of diabetes in different age groups. The data obtained shows that out of total diabetic subjects, 26 subjects were in age group 40-50 years, 23 subjects in the age group 51 – 60 years and 11 subjects in the age group 61-70 years.

Table 2: Distribution of gender in type 2 diabetic and healthy controls

		DM Group				Total
		Control	Diabetic 1-5 Year	Diabetic 6-10 Year	Diabetic >10 Year	
Gender	Male	38	12	9	10	69
	Female	22	8	12	9	51
Total		60	20	21	19	120

Pulmonary Function Tests Parameters

Table 3: FVC in type 2 diabetic and healthy controls

FVC actual								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	60	2.848	0.59043	0.07622	2.6963	3.0014	1.22	4.15
Diabetic 1-5 Year	20	2.177	0.76597	0.17128	1.8185	2.5355	0.59	3.84

Diabetic 6-10 Year	21	1.683	0.62475	0.13633	1.3990	1.9677	0.67	3.05
Diabetic >10 Year	19	1.513	0.70076	0.16076	1.1759	1.8514	0.52	3.07
Total	120	2.321	0.85215	0.07779	2.1675	2.4755	0.52	4.15

[Table 2] shows distribution of gender in type 2 diabetic and healthy controls. Out of total 60 control subjects 38 were healthy males and 22 were healthy females while out of total 60 type 2 diabetic patients 31 were diabetic males and 29 were diabetic females.

[Table 3] a shows descriptives of FVC actual in type 2 diabetic and healthy controls. The mean of FVC in controls was 2.84±0.59, while in 1–5-year diabetic it was 2.17±0.76, in 6-10 year 1.68 ±0.62, and in >10 year 1.51±0.70. The result shows that the FVC values were decreased with increased duration of diabetes.

Table 3b: Test of homogeneity of variances

		Levene Statistic	df1	df2	Sig.
FVC actual	Based on Mean	0.734	3	116	0.534
	Based on Median	0.641	3	116	0.590
	Based on Median and with adjusted df(Degrees of Freedom)	0.641	3	107.230	0.590
	Based on trimmed mean	0.736	3	116	0.533

[Table 3b] shows test of homogeneity of variances of FVC actual based on mean, median, median with adjusted df and trimmed mean. On statistical analysis the result was non-significant it shows that our data is valid for analysis by ANOVA.

Table 3c: Anova

FVC actual					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38.054	3	12.685	30.426	0.000
Within Groups	48.360	116	0.417		
Total	86.414	119			

[Table 3c] shows ANOVA of FVC actual between groups and within groups of control and type 2 diabetics. On statistical analysis the result was statistically significant, showing that we can apply multiple comparisons using turkey HSD test.

Table 3d: Multiple Comparisons

Dependent Variable:						
Tukey HSD						
(I) DM Group		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	Diabetic 1-5 Year	.67183*	0.16671	0.001	0.2373	1.1064
	Diabetic 6-10 Year	1.16550*	0.16371	0.000	0.7388	1.5922
	Diabetic >10 Year	1.33515*	0.16997	0.000	0.8921	1.7782
Diabetic 1-5 Year	Control	-.67183*	0.16671	0.001	-1.1064	-0.2373
	Diabetic 6-10 Year	0.49367	0.20174	0.074	-0.0322	1.0195
	Diabetic >10 Year	.66332*	0.20685	0.009	0.1241	1.2025
Diabetic 6-10 Year	Control	-1.16550*	0.16371	0.000	-1.5922	-0.7388
	Diabetic 1-5 Year	-0.49367	0.20174	0.074	-1.0195	0.0322
	Diabetic >10 Year	0.16965	0.20444	0.840	-0.3632	0.7025
Diabetic >10 Year	Control	-1.33515*	0.16997	0.000	-1.7782	-0.8921
	Diabetic 1-5 Year	-.66332*	0.20685	0.009	-1.2025	-0.1241
	Diabetic 6-10 Year	-0.16965	0.20444	0.840	-0.7025	0.3632
*. The mean difference is significant at the 0.05 level.						

[Table 3d] shows multiple comparisons using turkey HSD of FVC actual in controls and type 2 diabetics. Comparisons of FVC actual between control and diabetics 1–5-year, 6-10 year and >10 year was statistically significant. Between diabetic 1-5 year and 6-10 year was non-significant and between diabetic 1-5 year and >10 year was significant, while comparisons between diabetic 6-10 and >10 year was non – significant.

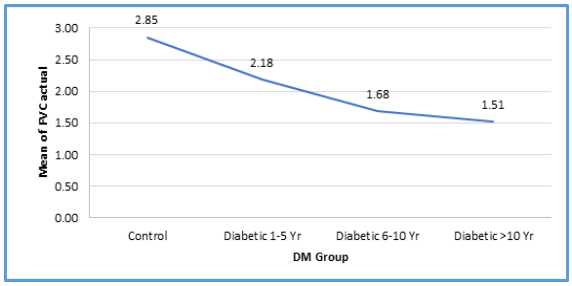

Figure 1: graph showing mean of FVC actual in control and type 2 diabetics.

Table 3e: Correlations

			FVC actual	DM Group
Spearman's rho	FVC actual	Correlation Coefficient	1.000	-.677**
		Sig. (2-tailed)		0.000
		N	120	120
	DM Group	Correlation Coefficient	-.677**	1.000
		Sig. (2-tailed)	0.000	
		N	120	120
**. Correlation is significant at the 0.01 level (2-tailed).				

[Table 3e] shows correlation of FVC actual among diabetic groups. The result of spearman's rho shows negative correlation among FVC actual and diabetes. This shows that with increasing duration of diabetes the FVC actual was decreasing.

Table 4: %Pred FVC in type 2 diabetic and healthy controls

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	60	95.53	16.094	2.078	91.38	99.69	43	137
Diabetic 1-5 Year	20	79.15	18.363	4.106	70.56	87.74	38	112
Diabetic 6-10 Year	21	59.48	15.108	3.297	52.60	66.35	26	84
Diabetic >10 Year	19	53.89	20.174	4.628	44.17	63.62	22	92
Total	120	79.90	24.230	2.212	75.52	84.28	22	137

[Table 4a] showing descriptives of %Pred FVC in type 2 diabetic and healthy controls. The mean %pred FVC in control was 95.53±16.09, in 1–5-year diabetic was 79.15±18.36, in 6-10- year diabetic was 59.48 ±15.11, in >10 year was 53.89 ± 20.17. The result shows that the mean %pred FVC value was decreasing with increasing duration of diabetes.

Table 4b: Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
%Pred FVC	Based on Mean	1.159	3	116	0.328
	Based on Median	1.170	3	116	0.324
	Based on Median and with adjusted df	1.170	3	110.966	0.324
	Based on trimmed mean	1.166	3	116	0.326

[Table 4b] shows Test of homogeneity of variances of %pred FVC based on mean, median, median with adjusted df and trimmed mean in type 2 diabetics and healthy controls. On statistical analysis the result was non-significant. This shows that our data is valid for analysis by ANOVA.

Table 4c: ANOVA

%Pred FVC					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	36284.289	3	12094.763	41.780	0.000
Within Groups	33580.511	116	289.487		
Total	69864.800	119			

[Table 4c] shows ANOVA of % pred FVC between and within groups of type 2 diabetic and healthy controls. On statistical analysis the result was statistically significant, showing that we can apply multiple comparisons using turkey HSD test.

Table 4d: Multiple Comparisons

Dependent Variable:						
Tukey HSD						
(I) DM Group		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	Diabetic 1-5 Year	16.383*	4.393	0.002	4.93	27.83
	Diabetic 6-10 Year	36.057*	4.314	0.000	24.81	47.30
	Diabetic >10 Year	41.639*	4.479	0.000	29.96	53.31
Diabetic 1-5 Year	Control	-16.383*	4.393	0.002	-27.83	-4.93
	Diabetic 6-10 Year	19.674*	5.316	0.002	5.82	33.53
	Diabetic >10 Year	25.255*	5.451	0.000	11.05	39.46
Diabetic 6-10 Year	Control	-36.057*	4.314	0.000	-47.30	-24.81
	Diabetic 1-5 Year	-19.674*	5.316	0.002	-33.53	-5.82

	Diabetic >10 Year	5.581	5.387	0.729	-8.46	19.62
Diabetic >10 Year	Control	-41.639*	4.479	0.000	-53.31	-29.96
	Diabetic 1-5 Year	-25.255*	5.451	0.000	-39.46	-11.05
	Diabetic 6-10 Year	-5.581	5.387	0.729	-19.62	8.46
*. The mean difference is significant at the 0.05 level.						

[Table 4d] shows multiple comparisons using turkey HSD of %pred FVC in controls and type2 diabetics. Comparisons of %pred FVC between control and diabetics 1-5 year, 6-10 year and >10 year was statistically significant. Between diabetic 1-5 year with 6-10 year and >10 year was significant, while comparisons between diabetic 6-10 and >10 year was non –significant.

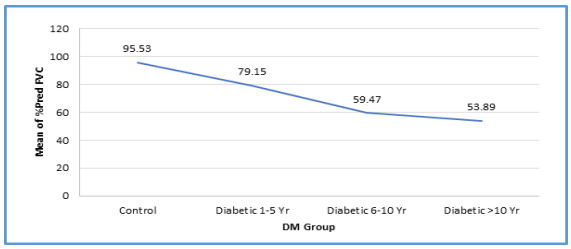

Figure 2: graph showing mean of %pred FVC in controls and type 2 diabetics.

Table 5: FEV1 in type 2 diabetic and healthy control

Table 5a: Descriptives of FEV1 in type 2 diabetic and healthy controls

FEV1(L) actual								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	60	2.434	0.51706	0.0667	2.3011	2.5682	1.02	3.45
Diabetic 1-5 Year	20	1.911	0.76220	0.1704	1.5543	2.2677	0.46	3.25
Diabetic 6-10 Year	21	1.497	0.58884	0.1285	1.2291	1.7652	0.52	2.80
Diabetic >10 Year	19	1.295	0.63263	0.1451	0.9903	1.6002	0.16	2.69
Total	120	2.002	0.75142	0.0685	1.8671	2.1387	0.16	3.45

[Table 5a] shows descriptives of FEV1 in type 2 diabetic and healthy controls. The mean of FEV1 actual in control was 2.43±0.51, in 1–5-year diabetic was 1.91±0.76, in 6–10-year diabetic was 1.49±0.58, in >10-year diabetic was 1.29±0.63.

Table 5b: Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
FEV1(L) actual	Based on Mean	2.037	3	116	0.113
	Based on Median	1.846	3	116	0.143
	Based on Median and with adjusted df	1.846	3	110.496	0.143
	Based on trimmed mean	2.024	3	116	0.114

[Table 5b] shows test of homogeneity of variances based on mean, median, median with adjusted df and trimmed mean in type 2 diabetic and healthy control. On statistical analysis the result was non-significant. This shows that our data is valid for analysis by ANOVA.

Table 5c: ANOVA

FEV1(L) actual					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.240	3	8.747	24.777	0.000
Within Groups	40.950	116	0.353		
Total	67.190	119			

[Table 5c] shows ANOVA of FEV1 actual between groups and within groups of type 2 diabetic and healthy controls. On statistical analysis the result was statistically significant, showing that we can apply multiple comparisons using turkey HSD test.

Table 5d: Multiple Comparisons

Dependent Variable:						
Tukey HSD						
(I) DM Group		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Control	Diabetic 1-5 Year	.52367*	0.15341	0.005	0.1238	0.9236
	Diabetic 6-10 Year	.93752*	0.15065	0.000	0.5448	1.3302
	Diabetic >10 Year	1.13940*	0.15641	0.000	0.7317	1.5471

Diabetic 1-5 Year	Control	-.52367*	0.15341	0.005	-0.9236	-0.1238
	Diabetic 6-10 Year	0.41386	0.18564	0.121	-0.0700	0.8978
	Diabetic >10 Year	.61574*	0.19034	0.009	0.1196	1.1119
Diabetic 6-10 Year	Control	-.93752*	0.15065	0.000	-1.3302	-0.5448
	Diabetic 1-5 Year	-0.41386	0.18564	0.121	-0.8978	0.0700
	Diabetic >10 Year	0.20188	0.18812	0.707	-0.2885	0.6923
Diabetic >10 Year	Control	-1.13940*	0.15641	0.000	-1.5471	-0.7317
	Diabetic 1-5 Year	-.61574*	0.19034	0.009	-1.1119	-0.1196
	Diabetic 6-10 Year	-0.20188	0.18812	0.707	-0.6923	0.2885
*. The mean difference is significant at the 0.05 level.						

[Table 5d] shows multiple comparisons using turkey HSD of actual FEV1 in type 2 diabetic and healthy controls. Comparisons of actual FEV1 between control and diabetics 1-5- year, 6-10- year and >10 year was statistically significant. Between diabetic 1-5 year with 6-10 year was statistically non – significant and with >10 year was significant, while comparisons between diabetic 6-10 and >10 year was non – significant.

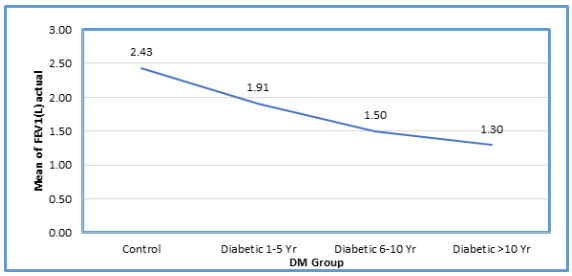

Figure 3: graph showing mean of FEV1 actual in control and type 2 diabetic

Table 5e: Correlations

			FEV1(L) actual	DM Group
Spearman's rho	FEV1(L) actual	Correlation Coefficient	1.000	-.622**
		Sig. (2-tailed)		0.000
		N	120	120
	DM Group	Correlation Coefficient	-.622**	1.000
		Sig. (2-tailed)	0.000	
		N	120	120
**. Correlation is significant at the 0.01 level (2-tailed).				

[Table 5e] shows correlation of FEV1 actual among diabetic groups. The result of spearman's rho shows negative correlation between FEV1 actual and diabetes. This shows that with increasing duration of diabetes FEV1 was decreasing.

Table 6: % PRED FEV1 in type 2 Diabetic and healthy controls

Table 6a: Descriptives

%Pred FEV1								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Control	60	101.03	18.901	2.440	96.15	105.92	46	138
Diabetic 1-5 Year	20	89.20	29.721	6.646	75.29	103.11	24	171
Diabetic 6-10 Year	21	67.86	18.175	3.966	59.58	76.13	28	96
Diabetic >10 Year	19	60.37	23.660	5.428	48.96	71.77	9	94
Total	120	86.82	27.136	2.477	81.91	91.72	9	171

[Table 6a] shows descriptives of %pred FEV1 in type 2 diabetic and healthy controls. The mean of %pred FEV1 in control was 101.03±18.90, in 1–5-year diabetic was 89.20±29.72, in 6–10-year diabetic 67.86±18.17, in >10-year diabetic was 60.37±23.66.

Table 6b: Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
%Pred FEV1	Based on Mean	0.858	3	116	0.465
	Based on Median	0.832	3	116	0.479
	Based on Median and with adjusted df	0.832	3	80.829	0.480
	Based on trimmed mean	0.851	3	116	0.469

[Table 6b] shows test of homogeneity of variances of %pred FEV1 based on mean, median, median with adjusted df and trimmed mean in type 2 diabetic and healthy controls. On statistical analysis the result was non - significant. This shows that our data is valid for analysis by ANOVA

Table 6c: ANOVA

%Pred FEV1					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	33079.841	3	11026.614	23.451	0.000
Within Groups	54544.126	116	470.208		
Total	87623.967	119			

[Table 6c] shows ANOVA of %pred FEV1 between and within groups of type 2 diabetics and healthy controls. On statistical analysis the result was statistically significant, showing that we can apply multiple comparisons using turkey HSD test.

Table 6d: Multiple Comparisons

Dependent Variable:						
Tukey HSD						
(I) DM Group		**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Control	Diabetic 1-5 Year	11.833	5.599	0.155	-2.76	26.43
	Diabetic 6-10 Year	33.176*	5.498	0.000	18.84	47.51
	Diabetic >10 Year	40.665*	5.708	0.000	25.79	55.54
Diabetic 1-5 Year	Control	-11.833	5.599	0.155	-26.43	2.76
	Diabetic 6-10 Year	21.343*	6.775	0.011	3.68	39.00
	Diabetic >10 Year	28.832*	6.947	0.000	10.72	46.94
Diabetic 6-10 Year	Control	-33.176*	5.498	0.000	-47.51	-18.84
	Diabetic 1-5 Year	-21.343*	6.775	0.011	-39.00	-3.68
	Diabetic >10 Year	7.489	6.866	0.696	-10.41	25.39
Diabetic >10 Year	Control	-40.665*	5.708	0.000	-55.54	-25.79
	Diabetic 1-5 Year	-28.832*	6.947	0.000	-46.94	-10.72
	Diabetic 6-10 Year	-7.489	6.866	0.696	-25.39	10.41
*. The mean difference is significant at the 0.05 level.						

[Table 6d] shows multiple comparisons using turkey HSD of %pred FEV1 in type 2 diabetic and healthy controls. Comparisons of %pred FEV1 between control and diabetics 1-5 year was statistically non – significant, between control and diabetic 6-10 year and >10 year was statistically significant. Between diabetic 1-5 year with 6-10 year was statistically non – significant and with >10 year was significant, while comparisons between diabetic 6-10 and >10 year was non – significant.

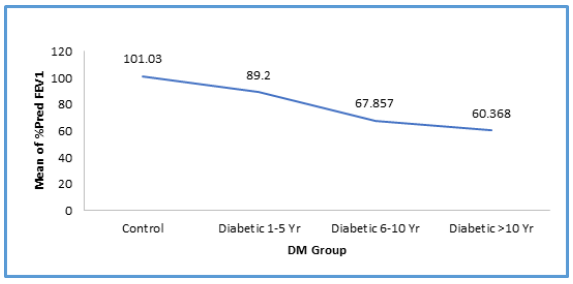

Figure 4: mean of %pred FEV1 in control and type 2 diabetic

DISCUSSION

Mean age of our patients was 53.32±8.19. This pattern of age distribution was more or less same among control also. We excluded the older patients, the possibility of senile changes in lungs as there are reports indicating similarity between diabetic pulmonary changes and senile lung changes.

The student t test was statistically significant between the groups showing that FVC and FEV1 lung function parameters were reduced.

Pulmonary function parameters showed a progressive decline in diabetic patients compared to controls. Both FVC and FEV_1 values decreased with increasing duration of diabetes, with the lowest values observed in patients with >10 years of disease. The differences across groups were highly statistically significant, indicating a strong association between longer diabetes duration and reduced lung function.

Comparing the PFT parameters FVC and FEV1 among control and diabetic groups, our test was significant for both parameters when comparing control with diabetic 6-10 year and >10 year ($p<0.05$). This shows the pulmonary functions were more deranged in patients with diabetes of longer duration.

FVC, FEV1were having a mean decrease in diabetic group compared to the control group which was statistically proven by getting a P value of <0.05. The % prediction of the spirometric parameters also showed a decrease in diabetic group compared to the controls.

Pulmonary dysfunction in diabetes includes reduced lung volumes in younger patients, decreased elastic recoil across age groups, and impaired diffusion in adults due to reduced capillary blood volume. These changes are likely related to nonenzymatic glycation of connective tissue and pulmonary microangiopathy, supporting the concept of the lung as a target organ in diabetes mellitus (Sandler M,1990).[8]

Insulin-treated diabetic animals demonstrated increased collagen and DNA synthesis, indicating altered lung connective tissue metabolism. The

accumulation of collagen and elastin is partly due to reduced degradation, supporting structural changes seen in diabetes (Ofulue AF & Thurlbeck WM, 1988).[9]

The study by Karintholil AR et al., 2021, suggests a trend toward increasing restrictive lung impairment with longer diabetes duration, though without clear clinical symptoms.[10]

In patients with a diabetes duration of 1–5 years, FVC, FEV_1 , and FEV_1 /FVC were comparable to controls, while PEFR was significantly reduced (Taha EH et al., 2018).[11]

The study by Mittal S et al., 2023, showed significantly lower FVC, FEV_1 , FEF_{25-75} %, and MVV in diabetic subjects compared to controls ($p < 0.05$). These findings suggest that reduced lung function may be a chronic complication of type 2 diabetes mellitus.[12]

Ashwarya roy et al., in 2021 studied Correlation of Pulmonary Function Tests with Anthropometry and Glycemic Control in Type 2 Diabetes Mellitus. In this study FVC was 2.21±0.74, FEV1 – 1.76±0.63, PEFR – 4.57±1.86, FEV1/FVC - 80±8.0.[13]

The average age of participants in the control group was 50.96 ± 6.85 years, while in the type 2 diabetes group it was 51.47 ± 8.43 years. The study findings demonstrated that individuals with diabetes had significantly reduced values of FVC, FEV_1 , FEF25–75%, and MVV compared to the control group ($p < 0.05$) (Mittal S et al., 2023).[14]

In a study of 22 nonsmoking individuals by Maccioni FJ & Colebatch HJ, 1991, with insulin-dependent diabetes, pulmonary function and lung distensibility were comparable to predicted and healthy control values. Apart from a normal age-related decline, no significant abnormalities were observed, suggesting that insulin-dependent diabetes does not impair lung function and routine testing may not be necessary in otherwise healthy patients.[15]

FVC reduction was more marked in patients with diabetes duration over five years and was not attributable to age alone. Poor glycemic control was associated with worse spirometric outcomes, likely due to non-enzymatic glycation of connective tissue, particularly collagen. Larger, multicentric studies are needed to further explore these associations across diverse populations (Jagadesha CG & Raju SD, 2019).[16]

Pulmonary function is diminished in individuals with type 2 diabetes. The duration of the disease appears to have a stronger impact than glycemic control, although factors such as obesity and vascular complications may also play a role (Davis TM et al., 2000).[17]

Spirometric values were reduced by over 10% at baseline and continued to decline annually in patients with type 2 diabetes. Poor glycemic control was consistently associated with worsening lung function, and reduced FEV_1 independently predicted all-cause mortality. These findings suggest that impaired lung function is a chronic complication of diabetes, with severity linked to glycemic exposure (Davis WA et al., 2004).[18]

In a cohort of 55 subjects, individuals with diabetes showed reduced %PEF compared to prediabetic and euglycaemic groups, while $\%FEV_1$, %FVC, and FEV_1 /FVC remained similar. Fasting glucose was associated with declines in multiple spirometric measures, whereas HbA1c correlated only with %PEF, suggesting acute glycemic status has a greater impact on lung function than chronic control (Ledesma Velázquez A et al., 2019).[19]

Adults with diabetes generally exhibit reduced FVC, FEV_1 , and diffusion capacity, with FVC more consistently affected. Lung function decline is linked to higher glucose levels, longer disease duration, and severity, independent of smoking or obesity. Proposed mechanisms include microangiopathy, inflammation, autonomic neuropathy, and collagen glycation. However, the exact relationship and causality remain unclear and require further study (Klein OL et al., 2010).[20]

In a study of 131 participants, individuals with diabetes had reduced exercise capacity, walking 109 m less on the Six-Minute Walk Test (6MWT), along with lower FEV_1 , Total Lung Capacity (TLC), and diffusion capacity compared to healthy controls ($P < 0.001$). These findings indicate impaired pulmonary function and physical performance in diabetes, with the 6MWT serving as a useful tool for functional assessment (Kuziemski K et al., 2019).[21]

Across nine cohort studies, lower FVC %pred and FEV_1 %pred were significantly associated with a higher risk of developing type 2 diabetes, while the FEV_1 /FVC ratio showed no association. These findings suggest that restrictive, rather than obstructive, lung impairment is linked to incident T2DM, warranting further investigation into underlying mechanisms (Zhou Y et al.,2022).[22]

A study by Charak G et al., 2016 and Shravya KG et al., 2012, shows a reduction in FVC in diabetes >10 years compared to diabetes <10 years.[23,24]

Diabetes is linked to a modest but significant reduction in lung function with a restrictive pattern, even in the absence of overt pulmonary disease. Further research is needed to assess its impact in diabetic patients with conditions such as COPD or asthma (Van den Borst B et al., 2010).[25]

Poor glycemic control, reflected by elevated HbA1c, is associated with impaired lung function in type 2 diabetes and appears more detrimental than disease duration. Regular pulmonary screening may help detect early dysfunction, and maintaining good glycemic control could improve respiratory and overall health outcomes (Maan HB et al., 2021).[26]

CONCLUSION

Pulmonary function parameters (FVC and FEV_1) were significantly reduced in type 2 diabetes mellitus patients compared to healthy controls ($p < 0.001$), with a further decline observed with increasing

duration of diabetes. Percentage predicted values also showed a similar decreasing trend. Statistical analysis demonstrated significant differences across groups, with a negative correlation between disease duration and pulmonary function. These findings indicate a progressive deterioration of lung function in T2DM, suggesting a restrictive pattern and supporting the role of the lung as a target organ in diabetes. However, large-scale, multicentric prospective studies are needed to further validate these findings and to better understand the underlying mechanisms and clinical implications.

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