IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 19, Issue 12 Ser.3 (December. 2020), PP 35-42
www.iosrjournals.org

Effect of Type 2 Diabetes mellitus duration on Pulmonary functions in rural population

Dr. Sudhir G.K[1].Mr. Adnan Nayazi[2], Dr. Malini M[3].
[1](Professor & Head, Department of Physiology, Adichunchanagiri Institute of Medical Sciences B.G. Nagara-571448, Nagamangala, Karnataka, India). [2](Undergraduatestudent,Department of Physiology, Adichunchanagiri Institute of Medical Sciences B.G.Nagara-571448, Nagamangala, Karnataka, India)[3](Assistant Professor,Department of Physiology,Adichunchanagiri Institute of Medical Sciences, B.G.Nagara-571448, Nagamangala, Karnataka, India)

Abstract:
Background & Objectives: *Like other organs, lung is also affected in diabetes mellitus due to the presence of extensive microvasculature and abundant connective tissue. (6,7) Early detection of pulmonary changes in diabetic patients through routine Pulmonary function testing(PFT) check-up may help in planning strategies to delay the progression of cardio-respiratory complications. The objective of this study was to compare the PFT parameters FVC, FEV_1& PEFR recorded in the study participants with the duration of diabetes mellitus, as early as the time of its diagnosis and observe the pattern of its change with increase in its duration.*
Methods: *60 male patients with Type-2 diabetes mellitus with duration of illness ranging from less than 5 years to more than 10 years, visiting the outpatient department in a tertiary care hospital were recruited for the study. PFT parameters FVC, FEV_1& PEFR and blood glucose parameters FBG & PPBG were recorded in these subjects. One way ANOVA and Pearson's correlation was used to compare the means & standard deviations of FBG, PPBG, PFT with the duration of illness.*
Results: *FVC and FEV_1 showed a significant decrease ($P<0.05$) with increasing duration of diabetes mellitus. FEV_1/FVC showed no significant difference between the three groups. FBG & PPBG showed no significant relation with FEV_1& FVC.*
Conclusion: *The decreasing trend in FEV_1& FVC and unaltered FEV_1/FVC & PEFR with increase in duration of illness, indicates a predominantly restrictive pattern of pulmonary function among patients with diabetes mellitus. The study concludes that pulmonary complications of type 2 diabetes mellitus sets in as early as the time of its diagnosis and is of the restrictive type.*
Key words: *Pulmonary function testing, FEV1, FVC, PEFR, diabetes mellitus duration,*

Date of Submission: 25-11-2020 Date of Acceptance: 09-12-2020

I. Introduction

The term diabetes mellitus describes a metabolic disorder of multiple etiology, characterized by chronic hyperglycemia with disturbances of carbohydrate, fat and protein metabolism resulting from defects in insulin secretion, insulin action or both. [(1)]Diabetes mellitus (DM), a chronic non-communicable disease has reached epidemic proportions worldwide. In the year 2000, India topped the world (31.7 million) with highest number of people with diabetes mellitus. Currently it is gaining a potential epidemic status with more than 62 million individuals diagnosed with the disease. [(2,3).] The prevalence of Type 2 diabetes in Asian Indians is the highest prevalence in the world and Type 2 diabetes comprises 90% of people with diabetes in the world.[(4)]

Damage, dysfunction and failure of various organs have been implicated as the long-term effects and complications of Type 2 diabetes mellitus. Microangiopathic and macroangiopathic changesare implicated in causing the major morbidities in Type 2 diabetes mellitus which include retinopathy, nephropathy, cardiomyopathy and peripheral neuropathy. [(5)]Like other organs, lung is also affected in diabetes mellitus due to the presence of extensive microvasculature and abundant connective tissue. Chronic hyperglycemia results in thickening of basal lamina in pulmonary capillaries and also non-enzymatic glycosylation of skeletal muscle and connective tissue leading to decrease in the diffusion capacity and lung compliance. [(6,7)]Though diabetes is strongly associated with systemic cardiovascular disease, the relationship with pulmonary vascular disease has often been disregarded owing to the subclinical nature of its effects. However, such changes may become clinically important as the patients subsequently develop chronic restrictive and obstructive pulmonary functional pathologies. [(8 - 11)]

Little is known about the implications of diabetes on pulmonary function. The prevalence of defective pulmonary function in asymptomatic diabetic patients is more than generally thought, involving 60% of adult cases. [12 - 14]In spite of sufficient evidence supporting the concept of lung as a target organ for diabetic microangiopathy, results of studies on lung mechanical abnormalities in diabetes (FVC, FEV1, PEFR) have been less convincing.Further diabetes mellitus has been inconsistently associated with spirometric abnormalities in a number of earlier retrospective cross-sectional studies and involving a very small sample size of less than 50 subjects. [15]The results of earlier studies on pulmonary functions in diabetes mellitus are varied, showing both restrictive and obstructive patterns[16]and most of the earlier studies done to observe the effect of duration of diabetes on pulmonary functions have considered the duration of the disease above 5 years.Despite the unclear nature, the relationship between diabetes mellitus and pulmonary function test remains important because of potential epidemiological and clinical implications.

Early detection of pulmonary changes in diabetic patients through routine PFT checkup may help in planning strategies to delay the progression of cardio-respiratory complications.Also, this could help in deciding on the need for a PFT as part of pre-anesthetic checkup in Type 2 DM patients to know the baseline pulmonary function for better cardio-respiratory monitoring during surgery. Hence this study is done with the hypothesis that significant changes in pulmonary function test parameters exists as early as the time of diagnosis of diabetes mellitus and would further worsen with increase in its duration.

II. Aim And Objectives

Aim: To observe for the change in pattern of pulmonary function tests with increasing duration of Type 2 diabetes mellitus.

Objectives:

1. To record the pulmonary function test parameters in patients with Type 2 diabetes mellitus.
2. To compare thepulmonary function test parameters with the duration of diabetes mellitus.

III. Material And Methods

Study setting: This study was undertaken in the teaching hospital of a rural medical college in South India.
Type of study: Clinical / Epidemiological investigation
Study design: Cross sectional study.
Study population: The study subjects were selected from among the patients visiting the General Medicineoutpatient and also those admitted in the General Medicine wards of the teaching hospital.
Sample size: Study group consisted of 60 male subjects with Type 2 diabetes mellitus who were further sub-divided into 3 sub-groups based on the duration of diabetes. Group A – patients with diabetes duration ≤5 years, Group B – patients with diabetes duration between >5 – ≤10 years & Group C – patients with diabetes duration for > 10 years.

Inclusion criteria:

1. Male patients above 30 years of age with Type 2 diabetes mellitus.
2. Patients providing voluntary written consent for participation in the study.

Exclusion criteria:

1. Patients with existing pulmonary diseases like COPD, Asthma etc. & past history of tuberculosis.
2. Patients with musculoskeletal disorders such as scoliosis, kyphosis, myopathies etc.
3. Patients with cardiovascular diseases like hypertension, ischemic heart disease, peripheral vascular disease, endocrine disorders of the thyroid, adrenal gland etc.
4. Patients with systemic illness (acute / chronic) at the time of study.
5. Smokers & alcoholics.

Data collection: This study was conducted for a period of 2 months (August to September 2019)after obtaining approval from Institutional Ethics Committee. Following the selection of subjects, their general information, duration of diabetes mellitus and its treatment and other related information were recorded. A general physical examination was performed and the anthropometric measurements of – Height (in cms) using a stadiometer, Weight (in Kgs) using a digital weighing scale (precision of 100 grams) were obtained and Body mass index (BMI) calculated and documented on a bi-lingual questionnaire.
Following this, the selected subjects were tested for fasting(FBG) &2 hours post-prandial blood glucose (PPBG) and a pulmonary function test was done after the blood sample for PPBG was obtained, to record the followingparameters - FVC, FEV_1, FEV1/FVC, FEF_{25-75}, PEFR.

Blood glucose measurement: Fasting and post-prandial blood glucose measurements were done by Glucose-oxidase method. FBG ≥ 110 mg/dL and PPBG ≥ 180 mg/dL were used as cut-off values for diagnosis of DM. However, values greater than the above in spite of treatment for DM in the subjects was considered to be poorly controlled.

Pulmonary function testing (PFT): PFT was done by using 'BPL ARPEMIS' PC based hand--eld Spirometer from BPL Healthcare. Following explaining and demonstrating the Spirometry procedure to the subject, a trial run of the procedure was done for each subject. Once the procedure was satisfactorily performed, the final recording of PFT parameters was done on each subject. Three recordings were obtained at a time gap of 2 minutes between the recordings and the best of the three was selected for analysis. Forced Vital Capacity (FVC) in liters, Forced Expiratory Volume in 1st second (FEV1) in liters, FEV1/FVC ratio expressed as % of FVC, Forced Expiratory Flow 25-75 (FEF 25-75) in liters per second & Peak Expiratory Flow Rate (PEFR) in liters per second were recorded. The necessary ethnic correction for the population is selected, the predicted value for each parameter is calculated by the software automatically using the in-built normative database for the population under consideration. The pattern of pulmonary function was evaluated by the software by comparing with predicted value for each parameter and expressed as % of the predicted value. The same was also confirmed by manually working out using the data. FEV1, FVC and FEV1/FVC values ≥80 % of predicted value was considered normal for this population.[31]

Characteristics of spirometric parameters in different patterns of pulmonary function:[32]

	FVC (L)	FEV1 (L)	FEV1/FVC %
Normal	≥ 80 %	≥ 80%	≥ 80%
Restrictive	< 80 %	< 80 %	≥ 80%
Obstructive	≥ 80 %	< 80 %	< 80 %
Mixed	< 80 %	< 80 %	< 80 %

Statistical analysis: Data entry was made in Excel spread sheet and statistical analysis was performed using SPSS software. Comparison of the means and standard deviations of anthropometric parameters, fasting, post-prandial blood glucose and PFT parameters between the three groups was done by one way ANOVA and expressed as f – value. The association between duration of Type 2 DM and PFT was done by Pearson's correlation test and expressed as its co-efficient r – value. Statistical significance was considered at 5% error i.e., $P < 0.05$.

IV. Results

This study included 60 male patients with Type-2 diabetes mellitus,segregated into three groups of 20 each based on the duration of illness. Group - A (0 -5 years), Group - B (> 5 - ≤ 10 years) and Group - C (> 10 years). Pulmonary function testing (PFT) was done in all the three groups to observe the effect of duration of diabetes mellitus on lung functions.

A. Physical parameters:

Table – 1: **Anthropometric characteristics of all the groups**

	Group	N	Mean	SD	F-value	P-value
Age (Years)	A	20	49.9	9.60	3.99	**0.02**
	B	20	52.25	8.92		
	C	20	57.1*	5.53		
Height (cms)	A	20	165.85	6.35	0.80	0.45
	B	20	164.3	5.48		
	C	20	163.55	5.62		
Weight (Kg)	A	20	65.8	6.42	1.032	0.36
	B	20	62.9	10.21		
	C	20	62.15	8.38		
BMI (Kg/m^2)	A	20	23.92	2.34	0.32	0.72
	B	20	23.32	3.42		
	C	20	23.25	2.82		

*Significant from Group A at $P < 0.05$

Table 1 shows anthropometric characteristics ofthe three groups with respect to their age, height, weight and body mass index, expressed as Mean ± SD of the values. There was no significant difference between the three groups in any of the parameters except age which was significantly more in Group C in comparison with Group A at $P<0.05$.

B. Biochemical parameters:

Table – 2: Fasting (FBG) and Post-prandial blood glucose (PPBG) levels in all the groups

	Group	N	Mean	SD	F-value	P-value
FBG (mg/dL)	A	20	124.2	23.09	4.27	**0.01**
	B	20	139.4*	28.64		
	C	20	120.05	10.10		
PPBG (mg/dL)	A	20	166.6	40.52	2.16	0.12
	B	20	188.75	47.64		
	C	20	167.85	19.49		

*Significant from Group C at P < 0.05

Table 2 shows the fasting and post-prandial blood glucose levels in mg/dL, compared between the three groups and expressed as Mean ± SD of the values. FBG showed no significant difference between the three groups except for Group B which had a significantly higher FBG compared to Group C (P<0.05). However, PPBG showed no significant difference between any of the three groups.

C. Pulmonary function test parameters:

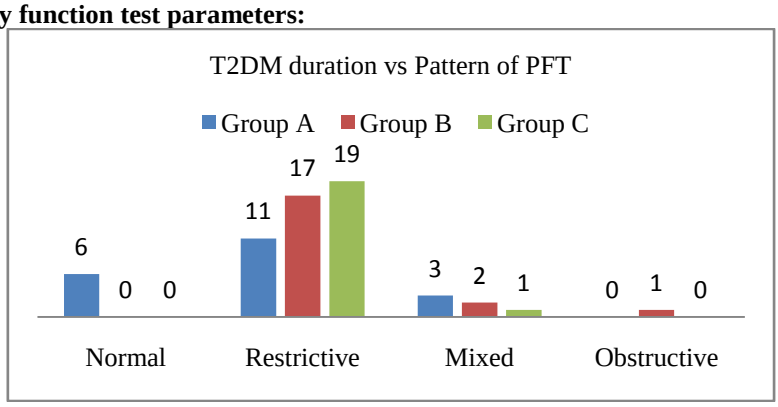

Figure – 1: Pattern of pulmonary function in all the three groups

Figure 1 shows the pattern of pulmonary function in all the three groups based on FVC, FEV1 & FEV1/FVC % as normal, restrictive, mixed and obstructive patterns. Restrictive pattern was predominantly seen in all three groups. However this restrictive pattern showed a linear increase with increase in the duration of T2DM. The next common pattern seen was the mixed pattern, which showed a paradoxical decrease in the number with increased duration of illness. Normal pattern was seen only in Group A with short duration (≤ 5 years) of T2DM. However pure obstructive pattern was almost not seen any of the groups.

Table – 3: Characteristics of PFT parametersin all the three groups

	Group	N	Mean	SD	F-value	P-value
FVC (L)	A	20	1.93	0.65	6.05	**0.00**
	B	20	1.65	0.36		
	C	20	1.41*	0.33		
FEV_1 (L/sec)	A	20	1.84	0.50	14.23	**0.00**
	B	20	1.50#	0.33		
	C	20	1.30*	0.25		
FEV_1/FVC (%)	A	20	91.9	14.68	0.38	0.68
	B	20	93.36	13.28		
	C	20	95.12	12.20		
FEF 25-75 (L/sec)	A	20	2.97	1.30	1.64	0.20
	B	20	2.32	1.25		
	C	20	2.45	1.00		
PEFR (L/sec)	A	20	4.17	1.30	3.57	**0.03**
	B	20	3.13#	1.36		
	C	0	3.44	1.10		

Significant from Group A at P<0.05 * Significant from Group A at P<0.01

Table 3 shows the comparison of Means and SD of PFT parameters (FVC, FEV1, FEV1/FVC, FEF 25-75 and PEFR) between the three groups.

FVC showed a significant decrease only in Group C as compared to Group A (P<0.05). However the FVC showed a decreasing trend with increase in duration of diabetes mellitus, indicating increase in lung restriction with increased duration of the illness.

FEV1 showed a significant decrease in Group B & C against Group A (P<0.05). However a decreasing trend of FEV1 was also seen with increased duration of diabetes mellitus, matching with decreased FVC.
FEV_1/FVC (%) showed no significant difference between the three groups in spite of a decrease in FVC & FEV1 in the three groups, indicating a maintained ratio between FEV1 and FVC in all the three groups, which is characteristic of restrictive lung pathology.
FEF 25-75 which provides information on patency of medium and small airways showed no significant difference between the three groups, which is also characteristic of restrictive lung pathology.
PEFR also showed no significant difference between the three groups except for Group B which had a significantly lower PEFR (P<0.05) as against Group A, which could indicate either increased degree of restrictive lung pathology or co-existence of obstructive pathology. However there is a decreasing trend in PEFR seen with increase in duration of diabetes mellitus which is in match with decrease in FVC.

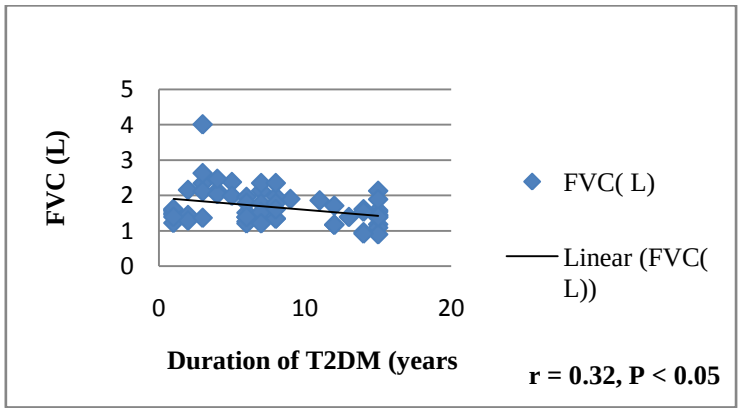

Figure 2: Correlation between FVC and duration of T_2DM in the study population (N = 60) (Pearson's correlation test)

Figure 2 shows a correlation between duration of diabetes mellitus and FVC in the study group as a whole (N = 60). The Pearson's testshows a negative correlation (r = - 0.32) between duration of diabetes mellitus and FVC which is significant (P<0.05).

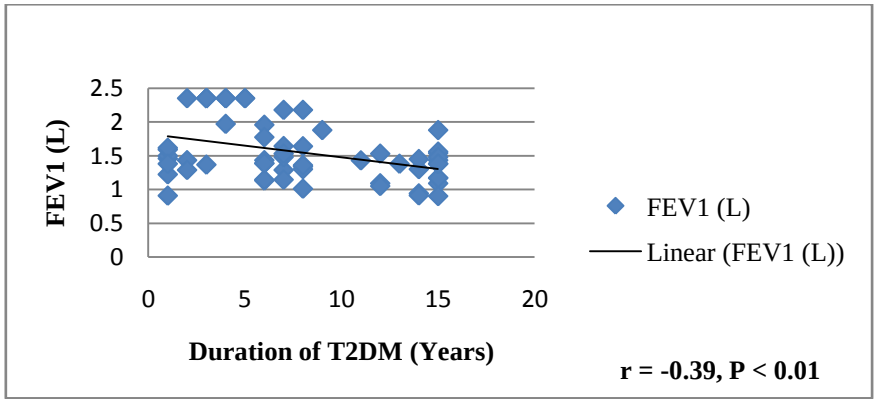

Figure 3: Correlation between FEV1 and duration of T_2DM in the study population (N = 60)

Figure 3 shows a correlation between duration of diabetes mellitus and FEV1 in the study group as a whole (N = 60). The Pearson's test shows a negative correlation (r = - 0.39) between duration of diabetes mellitus and FEV1 which is significant (P<0.01).

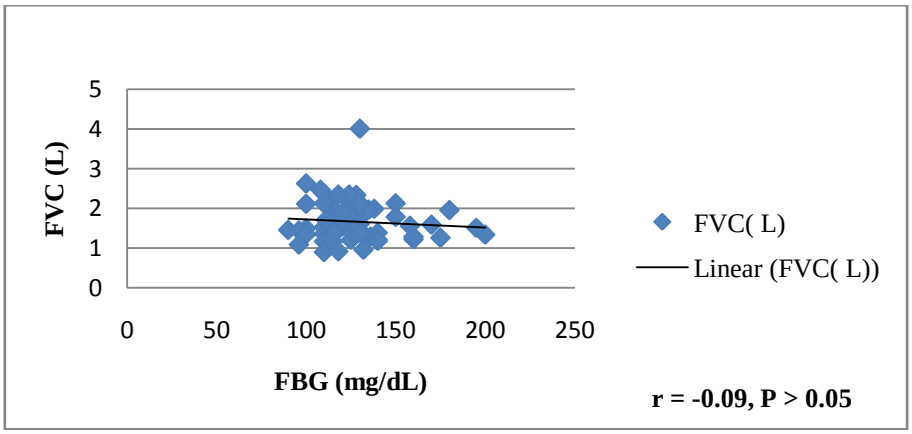

Figure 4: Correlation between FBG and FVC in the study population (N = 60)

Figure 4 shows a correlation between fasting blood glucose (FBG) and FVC for the study group as a whole (N = 60). The Pearson's test shows a negative correlation (r = - 0.09) between FBG and FVC which is not significant (P > 0.05).

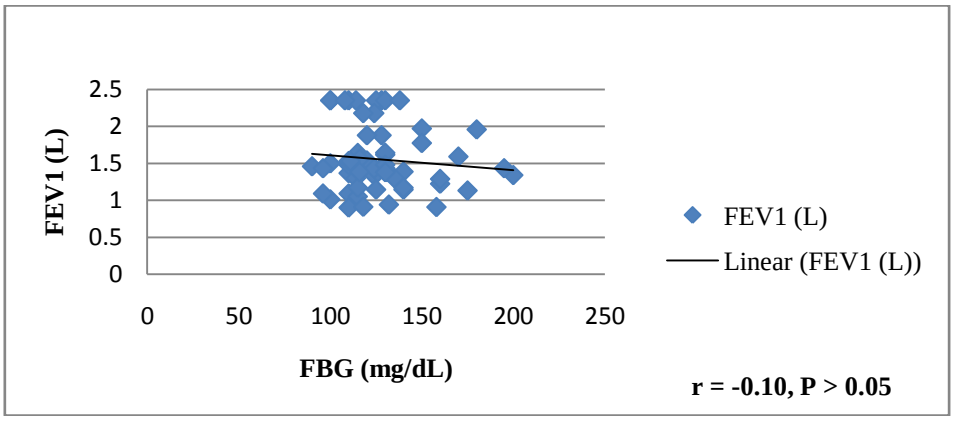

Figure 5: Correlation between FBG and FEV1 in the study population (N = 60)

Figure 5 shows a correlation between fasting blood glucose (FBG) and FEV1 for the study group as a whole (N = 60). The Pearson's test shows a negative correlation (r = - 0.10) between FBG and FEV1 which is not significant (P > 0.05).

V. Discussion

The present study was done in a rural medical college of South India to observe the changes in lung functions in patients with Type 2 diabetes mellitus in relation to the duration of the illness. 60 male Type 2 diabetes mellitus patients > 30 years of age were included in the study. Participants were grouped based on their duration of diabetes mellitus into Group A (≤5 years), Group B (>5 – ≤10 years) & Group C (> 10 years), with 20 patients in each group.

The anthropometric parameters, biochemical and pulmonary function test parameters were recorded in the participants. Aim of this study was to observe for changes in pulmonary function tests parameters with increasing duration of Type 2 diabetes mellitus.

Physical parameters: (Table 1 – Mean & SD of anthropometric parameters**)**

The mean age of the three groups of patients was comparable except for the age of Group C individuals which was significantly more in comparison with Group A (P < 0.05). The mean height of the three groups of patients showed no statistically significant difference (P = 0.45). The mean weight of the three groups of patients showed no statistically significant difference (P = 0.36). The mean BMI of the three groups of patients showed no statistically significant difference (P = 0.72). This indicates that the study population was perfectly matched with respect to their anthropometric parameters, which would thereby eliminate the bias of anthropometric parameters influencing the pulmonary function test parameters measured.

Biochemical parameters: Table 2 (Mean & SD of FBG & PPBG)
The means of fasting blood glucose (FBG) showed no difference between the three groups except for Group B which had higher FBG compared to Group C which was statistically significant ($P < 0.05$). The means of post-prandial blood glucose (PPBG) also showed no statistically significant difference between the three groups ($P > 0.05$). This indicates that the study population was grossly comparable with respect to the blood glucose levels, which could have independently affected the pulmonary function parameters if a significant difference would have existed between the three groups as observed by the Framingham heart study, which found a linear association of increased fasting blood glucose with decrements in FEV1, FVC & FEV1/FVC. [27]
Pulmonary function test parameters: Figure 1 (Pattern of pulmonary function in the three groups)
The pattern of pulmonary functions in the three groups determined based on the normative data for FVC, FEV1, FEV1/FVC[31,32] showed predominantly restrictive type of pulmonary function. This restrictive pattern showed a gradual increase with increase in the duration of T2DM. Similar observations were made by Dr. Garima Charak et.al. in their study on "Effect of duration of T2DM on lung function test" also observed a similar pattern of change in pulmonary function with increased duration of T2DM [33] and the Framingham heart study which found a predominantly restrictive lung pathology in patients with T2DM on treatment.[27]and Lange et.al. in their study, which found the existence of mild forms of ventilatory dysfunctions before the diagnosis of diabetes mellitus, which further aggravates with prolonged hyperglycemia. The predominance of restrictive lung pathology is explained on the basis of non-enzymatic glycosylation of tissue proteins, collagen fibers particularly in the lung parenchyma, which reduces its elasticity and hence the distensibility of the lung above a certain volume. [24]

The comparison of means of the pulmonary function test parameters between the groups – FVC, FEV1, FEV1/FVC, FEF 25-75 & PEFR showed a significant decrease of FVC in Group C (> 10 years of DM) against Group A (≤ 5 years) at $P < 0.01$. FEV1 also showed a significant decrease in Group B and Group C against Group A at $P < 0.05$ & $P < 0.01$ respectively. However FEV1/FVC %, FEF 25-75 & PEFR did not show significant changes between the groups. These changes are similar to the observations made by Lange et.al.[22] in their study on "Diabetes mellitus and ventilator capacity: a five year follow up study" and Meo SA et.al.[23]in their study on "Lung function in type 2 Saudi diabetic patients". The changes in FVC are attributed to the decrease in elasticity of the lung parenchyma which results due to the glycosylation of collagen and other proteins in the lung, limiting its expansion. Since FEV1 depends on the FVC and degree of elastic recoil of the lung along with the patency of the airways, there is a simultaneous decrease in FEV1 in diabetes. However the ratio of FEV1/FVC is maintained or is increased as both the parameters are decreased or a predominance of FVC decrease is seen in diabetes mellitus. Similarly FEF 25 – 75 and PEFR remain unaltered as there is no significant obstructive lung pathology.

The duration of T2DM when correlated with FVC for the entire group **(Figure 2)** showed a linear decline of FVC with increase in the duration of diabetes mellitus which was statistically significant ($P < 0.05$). Similar decline in FEV1 was observed with increase in duration of T2DM which was also statistically significant ($P < 0.01$). These observations are in line with the observations made by Lange et.al[22] indicating the decrease in ventilatory function parameters with prolonged hyperglycemia. However there was no significant association between FBG and FVC or FEV1, indicating the importance of long term control of blood glucose in determining the effects on pulmonary functions.

Conflict of interest: Nil
Source of funding: Self funded
Ethical clearance: Ethical clearance was obtained from Institutional Ethical Committee.

References

[1]. Albert KGMM, Zimmet PZ for the WHO Consultation. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus. Provisional report of a WHO consultation. Diabetic Medicine 1998; 15:539-553.
[2]. Joshi SR, Parikh RM. India - diabetes capital of the world: now heading towards hypertension. J Assoc Physicians India. 2007;55: 323–4
[3]. Kumar A, Goel MK, Jain RB, Khanna P, Chaudhary V. India towards diabetes control: Key issues. Australas Med J. 2013; 6(10):524-31.
[4]. King H, Aubert RE, Herman WH. Global burden of diabetes, 1995-2025: prevalence, numerical estimates and projections. Diabetes Care. 1998 Sep;21(9): 1414-31.
[5]. Sandler M, Bunn AE, Stewart RI. Cross-section study of pulmonary function in patients with insulin dependant diabetes mellitus. Am Rev Respir Dis 1987; 135: 223-9.
[6]. Boulbou MS, Gourgoulianis KI, Klisiaris VK, Tsikrikas TS, Stathakis NE, Molyvdas PA.
[7]. Diabetes mellitus and lung function. Med Princ Pract.2003; 12(2): 87-91.
[8]. Ali MO, Begum S, Ali.T and Ferdousi.S.FVC,FEV1, and FEV1/FVC% in type 2 diabetes
[9]. and their relationships with duration of the disease. J. Bangladesh Soc Physiol.2009;4(2):81-87.
[10]. Zhang J., Cheng Y., Gu J., Wang S., Zhou S., Wang Y., Tan Y., Feng W., Fu Y., MellenN., et al. Fenofibrate increases cardiac autophagy via FGF21/SIRT1 and prevents fibrosis and inflammation in the hearts of Type 1 diabetic mice. Clin. Sci. 2016;130:625–641.

[11]. Fouty B. Diabetes and the pulmonary circulation. Am. J. Physiol. Lung Cell Mol. Physiol. 2008;295:L725–26.
[12]. Goldman M.D. Lung dysfunction in diabetes. Diabetes Care. 2003;26:1915–1918.
[13]. Mirrakhimov A.E. Chronic Obstructive pulmonary disease and glucose metabolism: A bitter sweet symphony. Cardiovasc. Diabetol. 2012;11:132–158.
[14]. Bell, D, Collier, A, Mathews, DM, Cooksey, EJ, Mettardy, GJR, Clarke, BF. Are reduced lung volumes in IDDM due to defect in connective tissue? Diabetes 1988; 37: 829– 831.
[15]. Cooper, BG, Taylor, R, Alberti, KGMM, Gibson, GJ. Lung func-tion in patients with diabetes mellitus. Respir Med 1990; 84: 235–39.
[16]. Guazzi, M, Brambilla, R, Pontone, G, Agostoni, P, Guazzi, MD. Effects of non-insulin dependent diabetes mellitus on pulmonary function and exercise tolerance in chronic congestive heart failure.Am J Cardiol 2002; 89: 191 – 197.
[17]. A Kaparianos et.al., Pulmonary complications in diabetes mellitus.Chronic Respiratory Disease 2008; 5: 101 –108.
[18]. Shilpa Karande, Sangeeta J. Pednekar, S. T. Nabar, Arunab Mehta, Vasanti Iyengar Pulmonary functions in type 2 diabetes mellitus patients: an observational study at a tertiary level hospital in Mumbai, Maharashtra, India. IJRMS.2016;4(5): 1574-77.
[19]. Kanyakumari DH, Natraj S M. Correlation of duration of diabetes and pulmonary function tests in type 2 diabetes mellitus patients. Int J Biol Med Res. 2011;2(4):1168-70.
[20]. Engelgau, MM, Geiss, LS. The burden of diabetes mellitus. In:Leahy, JL, Clark, NG, Cefalu, WT. Medical management of diabetes mellitus. New York: Marcel Dekker; 2000.
[21]. Schuyler M R, Niewoehner D E, Inkley S R, Kohn R. Abnormal lung elasticity in juvenile diabetes mellitus. Am Respir Dis. 1976;113:37-41.
[22]. Kida K, Utsuyama M, Takizawa T, Thurlbeck W M. Changes in lungg morphologic features and elasticity caused by streptozocin-induced diabetes mellitus in growing rats. Am Rev Respir Dis.1983;128: 125-131.
[23]. Sandler M.Is the lung a "target organ" in diabetes mellitus? Arch Int Med. 1990;150: 1385-88.
[24]. Lange P, Groth S, Mortensen J, Appleyard M, Nyboe J, Schnohr P, Jensen G. Diabetes mellitus and ventilator capacity: a five year follow up study. Eur Respir J.1990;3: 288-92.
[25]. Meo S A, AL-Dress A M, Arif M, Al-Rubean K. Lung function in type 2 Saudi diabetic patients. Saudi Med J. 2006;27(3):338-343.
[26]. Swati S H, Sonawane P, Nahar P, Vaidya S, Salvi S. Pulmonary function tests in type 2 diabetes mellitus and their association with glycemic control and duration of the disease. Lung India. 2013;30(2):108-112.
[27]. Schnack, C, Festa, A, Schwarzmaier-D 'Assie, A, Haber, P, Schernthaner, G. Pulmonary dysfunction in type 1 diabetes in rela-tion to metabolic long-term control and to incipient diabeticnephropathy. Nephron 1996; 74: 395– 400.
[28]. Innocenti, F, Fabbri, A, Anichini, R, Tuci, S, Pettina, G, Vannucci, F, et al . Indications of reduced pulmonary function in type 1 (insulin-dependent) diabetes mellitus. Diabetes Res Clin Pract 1994; 25: 161 –168.
[29]. Walter, RE, Beiser, A, Givelber, RJ, O 'Connor, GT, Gottlieb, DJ. Association between glycemic state and lung function: the Framingham Heart Study. Am J Respir Crit Care Med 2003; 167 :911– 916.
[30]. Litonjua, AA, Lazarus, R, Sparrow, W, DeMolles, D, Weiss, S. Lung function in type 2 diabetes: the Normative Aging Study. Respir Med 2005; 99: 1583– 1590.
[31]. Engstrom, G, Hedblad, B, Nilsson, P, Wollmer, P, Berglund, G, Janzon, L. Risk of developing diabetes is inversely related to lung function: a population-based cohort study. Diabet Med 2002; 19:167– 170.
[32]. Engstrom, G, Hedblad, B, Nilsson, P, Wollmer, P, Berglund, G, Janzon, L. Lung function, insulin resistance and the incidence of cardiovascular disease. A longitudinal cohort study. J Intern Med 2003; 253 : 574 –581.
[33]. John B West. Tests of Pulmonary Function. Respiratory Physiology – The Essentials. Wolter Kluwer/Lippinctt Williams and Wilkins: 2012; 9th Ed: 160-61.
[34]. Jeremy D. Johnson, Wesley M Theurer. A stepwise approach to the interpretation of Pulmonary function tests.Am Fam Physician. 2014; 89(5): 359-66.
[35]. Dr, Garima Charak, Dr. Anupama Kaur, Dr. Surinder Kaur, Dr. Sonia Kocchar. Effect of duration of Type 2 Diabetes Mellitus on Lung Function Tests. IOSR-JDMS. 2016; 15(10):8-14.

Dr. Sudhir G.K, et. al. "Effect of Type 2 Diabetes mellitus duration on Pulmonary functions in rural population." *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*, 19(12), 2020, pp. 35-42.