



The Egyptian Society of Chest Diseases and Tuberculosis
Egyptian Journal of Chest Diseases and Tuberculosis

www.elsevier.com/locate/ejcd
www.sciencedirect.com



ORIGINAL ARTICLE

Pulmonary function changes in diabetic lung

I. Amal Abd El-Azeem ^{a,*}, Gehan Hamdy ^b, Mohamed Amin ^c, Alaa Rashad ^d

^a Chest Department, Faculty of Medicine, Zagazig University, Egypt

^b Internal Medicine Department, Faculty of Medicine, Cairo University, Egypt

^c Chest Department, Faculty of Medicine, Fayoum University, Egypt

^d Chest Department, Faculty of Medicine, Assuit University, Egypt

Received 25 May 2013; accepted 8 July 2013

Available online 20 August 2013

KEYWORDS

Pulmonary function test parameters;
 Diabetes mellitus

Abstract *Background:* Diabetes mellitus is a chronic and debilitating disease. Its complications give rise to micro and macrovascular diseases which affect eyes, kidneys, heart, blood vessels, nerves and also lungs. There may be a relationship between diabetes and reduced lung function, so this study was designed to evaluate the impairment of lung function on spirometry among diabetic patients.

Objectives: To study the effect of diabetes mellitus on the evolution of respiratory function parameters.

Patients and methods: Hundred subjects were enrolled in the study, 30 patients with type I, another 30 patients with type II and 40 subjects were controls. Mean age was 42.78 ± 3.14 years, 45 were males and 55 were females. Mean HbA1C was $8.9 \pm 1.1\%$. 22 patients with diabetes duration from 5 to 10 years, 38 patients with a duration of more than 10 years. Spirometric tests were done for all groups by computerized Spirometry with six parameters {Forced vital capacity (FVC), Forced expiratory volume in first second (FEV1), Peak expiratory flow rate (PEFR), Forced expiratory volume in first second to forced vital capacity (FEV1/FVC), Peak expiratory flow rate (FEFR 25–75) and Diffusing capacity for carbon monoxide (DLCO)}.

Result: There was a predominant reduction in all the Spirometric parameters of diabetic patients toward the restrictive pattern as there was significant deterioration in DLCO in comparison with healthy controls. FVC ($p < 0.01$), and FEV1/FVC% ($p < 0.001$) were significantly lower in type I diabetic patients in comparison to those of type II. Impairment of lung functions was obvious with a longer duration of diabetes.

* Corresponding author. Tel.: +20 01000089246.

E-mail address: amalsadon@yahoo.com (I. Amal Abd El-Azeem).

Peer review under responsibility of The Egyptian Society of Chest Diseases and Tuberculosis.



Conclusion: Diabetes is associated with a significant impaired pulmonary function in a restrictive pattern as compared to non diabetics. The pulmonary function impairment was found to be more marked with diabetic duration especially after 10 years. Subjects with type I diabetes had lower FVC and FEV1/FVC% than predicted; it could be related to poor glycemic control.

© 2013 Production and hosting by Elsevier B.V. on behalf of The Egyptian Society of Chest Diseases and Tuberculosis. Open access under [CC BY-NC-ND license](#).

Introduction

Diabetes Mellitus (DM) is considered as a metabolic disorder of multiple aetiologies (genetic and environmental). It is characterized by chronic hyperglycemia due to absolute or relative insulin deficiency (defects in either insulin secretion or insulin action or both). This results in disturbances of carbohydrate, protein and fat metabolism [1]. The major side effects of diabetes mellitus are due to its microangiopathic and macroangiopathic complications, which affect eyes, kidneys, nerves, heart, major vessels and the lungs [2].

Type I or IDDM is due to insulin deficiency caused by autoimmune destruction of B cells in the islets of pancreas. The second form of diabetes mellitus is Type 2 or NIDDM, is characterized by insulin resistance and impaired insulin receptors. It is a common type of diabetes and usually develops after the age of 40 years. It is associated with normal B cell morphology [3].

The lung was targeted in diabetic microangiopathy, histopathology showed basal lamina thickening and fibrosis [4]. The lung is rich in micro-vascular circulation and abundant connective tissue that raises the possibility of lung affection by microangiopathic process and non-enzymatic glycosylation of tissue proteins, induced by chronic hyperglycemia, rendering the lung a "target organ" in diabetic patients [5]. The normal lung mechanics and gas exchange are influenced by the integrity of pulmonary connective tissue and microvasculatures, so any abnormalities in either of the two structural components lead to abnormal pulmonary function tests (PFT) [6].

The association between diabetes and impaired lung function was noticed and necessitated attention. Diabetes mellitus is associated with increased levels of systemic inflammatory mediators and inflammatory markers which together with microangiopathy are accused in alterations of lung matrix proteins and hence the impairment of pulmonary functions [7].

It is likely that persistent inadequate blood glucose control over time may alter the regulation of inflammatory pathways that are involved in pulmonary function impairment; this impairment is mainly restrictive with obvious reduction in diffusing capacity to carbon monoxide [8].

Aim of the work

We aimed in this study to assess the status of pulmonary function in diabetics.

Subjects and methods

A total number of 100 subjects were referred from outpatient clinics of the internal medicine department of the Sabah hospitals, from January 2012 to November 2012. 30 patients had

type 1 DM and 30 patients had type 2 DM. 40 normal individuals were included as the control group who had no history of DM as confirmed by normal fasting, postprandial blood sugar and urine for sugar. These persons had identical characters for those of DM regarding age, sex and body mass index with similar exclusion criteria as the study group. Consent was taken from all the subjects.

Inclusion criteria

Previously diagnosed diabetic patients which are uncontrolled or poorly controlled for more than 5 years duration of the illness.

Exclusion criteria

Patients with a history of smoking, acute or chronic respiratory disease, history of occupational exposure, neuromuscular or cardiovascular diseases or any physical disability that may affect lung function as kyphoscoliosis, pectus excavatum and pectus carinatum. Obese persons were excluded (BMI more than 30 kg/m²).

Method

1. Detailed history and physical examination were carried out for all groups regarding the respiratory, cardiac and neuromuscular systems to be sure that these systems are clinically free.

2. X-ray chest, ECG and ECHO were done to all groups to exclude any hidden pulmonary or cardiac problems.

3. Pulmonary function tests were performed by using a computerized system (Jaeger) model. Pulmonary function parameters which include forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and the ratio of the forced expiratory volume in 1 s to the forced vital capacity in percentage (FEV1/FVC%) Peak expiratory flow rate (PEFR), forced expiratory flow in 25–75% of vital capacity (FEF25–75) and DLCO was measured by the single-breath method using gas chromatographic equipment.

4. Biochemical investigations: Blood samples were obtained after a 12 h overnight fast for the estimation of levels of blood glucose and repeated two hours postprandially. The oral glucose tolerance test (OGTT) was done for the control group only to exclude diabetes in addition to impaired fasting glycemia (IFG) and impaired glucose tolerance (IGT). Fasting blood glucose of ≥ 126 mg/dL was used to define diabetes while the fasting blood glucose of ≥ 110 mg/dL and < 126 mg/dL was used to define IFG. IGT was defined as a 2 h blood glucose post 75 g of glucose of ≥ 140 mg/dL and < 200 mg/dL [9]. Only control subjects with a normal fasting blood glucose of < 110 mg/dL and 2 h post oral glucose of < 140 mg/dL were recruited into the study. HbA1c was used

Table 1 Subjects with diabetes mellitus: characteristic at the start.

Number	100
Age (years)	42.78 ± 3.14
Sex	55 F & 45 M
Types of subjects	30 type I DM & 30 type II DM & 40 as controls
DM duration (years)	5–10 years: 22 patients > 10 years: 38 patients
Hb A1c	8.9 ± 1.1

as an index of diabetic control over the last 3 months. Values over 7.5% were considered as poor glycemic control and lower than this level was considered as good glycemic control. [10].

5. Anthropometric measurements: Height and weight of all subjects were recorded and BMI was calculated by the formula of weight/height².

The pulmonary function parameters were compared between the diabetics and control groups then between the diabetics according to the type and duration of diabetes.

Result

Hundred patients were included in this study with a mean age of 42.78 ± 3.14. Of these 55 were females and 45 were males. 30 patients had type I diabetes mellitus (DM) and 30 patients had type II DM while 40 subjects were controls. Regarding the duration of diabetes, 22 patients had DM from 5 to 10 years while 38 patients had DM for more than 10 years. For the diabetic subjects, the mean HbA1c was 8.9 ± 1.1 indicating poor glycemic control (Table 1). The main finding is that the ventilatory functions were significantly reduced in diabetic subjects compared with controls. The ventilatory dysfunction was predominantly restrictive as shown by the preserved ratio of FEV1/FVC% and the reduced DLCO as compared with the controls (Table 2).

Our study showed no significant difference in pulmonary function parameters between diabetic groups regarding the duration of diabetes but reduction in the ventilatory function was observed as the duration of diabetes increased (Table 3).

Regarding the type of diabetes, there was a significant reduction in FVC and FEV1/FVC in type I DM while other ventilatory function parameters revealed no significance but more reduction in the ventilatory function was observed between type I and type II DM (Table 4).

Table 3 PFT parameters between diabetic patients according to the duration of diabetes.

PFT parameters	5–10 years	> 10 years	P value
	Mean ± SD	Mean ± SD	
FEV1 (L)	1.90 ± 0.7	1.80 ± 0.91	0.64NS
FVC (L)	2.3 ± 0.9	2.1 ± 0.7	0.35NS
FEV1/FVC%	82.6 ± 0.14	85.19 ± 0.48	0.15NS
PEFR (l/S)	3.51 ± 0.3	3.29 ± 0.71	0.53NS
FEF 25–75% (l/S)	1.59 ± 0.71	1.48 ± 0.49	0.45NS
DLCO (ml/min/mmHg)	14.10 ± 2.7	13.32 ± 2.1	0.84NS

Table 4 PFT parameters according to the type of diabetes.

PFT parameters	Type I DM	Type II DM	P value
	Mean ± SD	Mean ± SD	
FEV1(L)	1.5 ± 0.5	1.70 ± 0.1	0.52NS
FVC (L)	1.6 ± 0.3	2.0 ± 0.2	0.05S
FEV1/FVC%	93.8 ± 0.2	85.1 ± 0.1	0.05S
PEFR (l/S)	3.12 ± 0.2	3.25 ± 0.6	0.12NS
FEF 25–75% (l/S)	1.21 ± 0.3	1.40 ± 0.5	0.31NS
DLCO (ml/min/mmHg)	13.11 ± 1.2	13.97 ± 1.9	0.24NS

Statistical analysis

The results were analyzed using mean and standard deviation for all variables and comparison was done using the Student's *t*-test. Frequencies were generated for categorical variables and compared with the chi square test. $p < 0.05$ was accepted as significant.

Discussion

Diabetic patients are susceptible to a series of complications including microvascular complications like diabetic retinopathy, diabetic nephropathy and diabetic neuropathy. The lungs are affected by diabetic microangiopathy [11]. The effect of diabetes on the ventilatory function is the focus of this study. The main finding is that the ventilatory function is significantly reduced in diabetic patients compared with the controls. Ventilatory dysfunction in diabetics was predominantly restrictive as shown by the preserved ratio of FEV1/FVC% and decreased carbon monoxide diffusing capacity (DLCO) compared with controls. The histopathological finding seen in the diabetic lung revealed microangiopathic changes such as fibrosis and basal lamina thickening that will lead to a

Table 2 PFT parameters in comparison between diabetes and control groups.

PFT parameters	Diabetes mellitus (n = 60)	Controls (n = 40)	P value
	Mean ± SD	Mean ± SD	
FEV1 (L)	1.7 ± 0.47	2.89 ± 0.35	0.01S
FVC (L)	2.02 ± 0.41	3.11 ± 0.52	0.01S
FEV1/FVC%	84.15 ± 0.53	92.91 ± 0.61	0.001S
PEFR (l/S)	3.34 ± 1.05	5.89 ± 0.8	0.001S
FEF 25–75% (l/S)	1.28 ± 0.6	2.61 ± 0.34	0.001S
DLCO (ml/min/mmHg)	13.71 ± 2.5	22.51 ± 2.7	0.001S

restrictive lung defect [12]. Another study in the Asian population in Saudi Arabia also had similar findings [13]. Several previous studies have found a significant correlation between uncontrolled DM and pulmonary function impairment which support the concept that, the lung is a target organ for diabetic microangiopathy [8]. Our findings were consistent with those met by Irfan et al. [14] and Ljubic et al. [15] as they observed a significant reduction in DLCO in patients with diabetic microangiopathy. The possible pathophysiological mechanisms are that, the lung has an extensive capillary bed, so it is expected to be affected by diabetic microangiopathy [16]. Also, postmortem examination revealed thickened alveolar epithelial and pulmonary capillary basal laminae in diabetic patients which explained the deteriorated pulmonary gas exchange and a decrease in DLCO [17].

Many post-mortem studies on diabetic patients explained the relationship between microangiopathy and the impairment of DLCO as they show that the thickening of alveolar epithelial and pulmonary capillary basal laminae is considered to be the initial lesion in the development of diabetic microangiopathy [18]. Keerthi et al. postulated that the observed decrease in TLC might be due to an altered collagen matrix in the lung. A significant decrease in lung volumes was found and this was thought to be due to decreased lung compliance due to restriction of chest wall expansion as a result of altered collagen metabolism or altered collagen/elastic ratio [1].

Many explanations were given to explain the restrictive ventilatory dysfunction in diabetic patients but these explanations were not investigated in our study. These explanations include the involvement of the neuromuscular respiratory muscles due to diabetic neuropathy of the thoracic nerves that contributes to the respiratory dysfunction [19]. Other investigators found that hyperglycemia was associated with poor skeletal muscle strength due to increased protein catabolism, for this reason respiratory muscle endurance also decreased in diabetes mellitus [20]. Ozmen et al. [21] investigated lung function in diabetics and age-matched control subjects and they found that, the lung elastic recoil was decreased in these patients and because the elastic structure of the lung supports the intrathoracic airways and helps to maintain their patency, the patients with diabetes were at risk for developing chronic airflow obstruction. Others found both decreased lung elasticity and CO transfer capacity and also decreased pulmonary capillary blood volume [3]. Meo et al. [22] and Davis et al. [23] found that there was a combined obstructive and restrictive pattern of pulmonary function in diabetics but it was predominately restrictive.

Regarding the duration of diabetes, the current study showed a reduction in the pulmonary function parameters with increasing duration of the disease but there was no significance. Davis et al. [24] supported this concept as he found that there was a clear decline in PFT with an increase in the duration of DM, but there was no significance. The same findings were consistent with the results met by Sinhs et al. [25] as they found a reduced ventilatory function in diabetics and they related this observation to the inflammatory process associated with diabetes and as this disease is progressive, progressive decrease in lung function may be mediated via progression of inflammation, the severity of which would increase with a longer duration of diabetes. Shravya et al. [26] showed that DLCO% decreased significantly as the duration of DM increased and the reduction was greater in patients with diabetic microangiopathy and in type I DM. Also Van den Borst et al.

[27] showed a negative correlation between DLCO% and the duration of the disease. Hsia and Raskin [28] concluded that 60% of the diabetic population had abnormal pulmonary function, mild reduction of lung elastic recoil and/or a reduction in pulmonary capillary blood volume. The degree of pulmonary dysfunction was correlated with the duration of DM, which was consistent with our study. Regarding the type of diabetes, we observed a reduction in pulmonary function parameters including a decrease in DLCO in both types of diabetes, but the reduction was more in type I than type II. Several pathological conditions may affect the lungs of type-1 diabetic patients, as chronic hyperglycemia causes microvascular changes as the thickening of basal laminae in the smaller vessels of the lungs and this causes a reduction of vascular diffusing capacity [24]. It was also observed that hyperglycemia affects the lung by nonenzymatic glycosylation of the chest wall and bronchial tree proteins which prevent lung expansion so, the volume and elastic recoil of the lung were reduced in type-1 diabetic patients [28]. Our observations are in agreement with Khan et al. [20] who reported that both IDDM and NIDDM were associated with a slight reduction in FVC. This reduction was more pronounced in diabetic subjects treated with insulin (type I). Similar observations were met by Sreeja et al. [29]. Fimognari et al. [30] and Nakagima et al. [31] who reported reduced FVC and normal FEV1/FVC and concluded that restrictive pulmonary function but not the obstructive pattern might be associated with metabolic disorders and the metabolic syndrome. The possible explanation of restrictive ventilatory dysfunction is non-enzymatic glycosylation of pulmonary collagen leading to the accumulation of advanced glycosylation end products and resulting in increased cross-link formation [31]. Another explanation was given by Pinar et al. [18]. who said that the long duration of DM and the presence of high grade pulmonary microangiopathy and the decrease in DLCO with diabetes mellitus type 1 were thought to be due to the fact that the patients using insulin usually had a longer duration of disease. Similar observations were met by Sina et al. [32], Sanjeev et al. [33], Falah [3], Benbassat et al. [34], Khan et al. [20] and Nandhini et al. [35].

Conclusion

- The present study showed significant restrictive ventilatory dysfunction in uncontrolled diabetic patients with microangiopathy as compared to control subjects.
- The PFT parameters were affected more with longer duration of DM.
- DM type I affects lung function more than DM type II.

References

- [1] G. Keerthi, B. Sharan, B. Hari Krishna, M. Suresh, Deterioration of pulmonary functions in type 2 diabetes mellitus, *J. Pharm. Biol. Sci.* 1 (2012) 39–43.
- [2] M.O. Ali, S. Begum, T. Ali, S. Ferdousi, FVC, FEV1, and FEV1/FVC% in type 2 diabetes and their relationships with duration of the disease, *J. Bangladesh Soc. Physiol.* 4 (2) (2009) 81–87.
- [3] F.G. Wiliam, Endocrine function of pancreas and regulation of carbohydrate metabolisms, in: *Review of Medical Physiology*,

- second ed., Mc Graw-Hill Company, India, pp. 340–354 (Chapter 19).
- [4] A.D. Falah, Spirometric changes in patients with diabetes mellitus, *Med. J. Babylon* 8 (2) (2011) 1–10.
 - [5] M. Marvisi, L. Bartolini, P. Del Borello, Pulmonary function in non-insulin-dependent diabetes mellitus, *Respiration* 68 (2001) 268–272.
 - [6] D.H. Kanya Kumari, S.M. Nataraj, H.S. Devaraj, Correlation of duration of diabetes and pulmonary function tests in type 2 diabetes mellitus patients, *Int. J. Biol. Med. Res.* 2 (4) (2011) 1168–1170.
 - [7] J. Dennis, Dario. Maldonado, Maria X. Rojas, Pablo Aschner, Martin Rondón, Laura. Charry, Alejandro Casas, Inadequate glucose control in type 2 diabetes is associated with impaired lung function and systemic inflammation: a cross-sectional study, *BMC Pulm. Med.* 10 (2010) 38.
 - [8] P. Zimmet, K.G. Alberti, J. Shan, S. Tiwari, Global and societal implications of the diabetes epidemic, *Nature* 414 (2001) 782–787.
 - [9] O.B. Ozoh, N.U. Okubabejo, E.O. Bandeje, C.C. Chukwu, Ventilatory function in Nigerians with type 2 diabetes, *African J. Resp. Med.* (2010) 18–22.
 - [10] P.J. Watkins, P.L. Drury, S.L. Howell, *Diabetes and its Management*, Blackwell Science Ltd, London, 1996, pp. 143–218.
 - [11] A. Kaparianos, E. Argyropoulou, F. Sampsonas, Pulmonary complications in diabetes mellitus, *Chron. Resp. Dis.* 5 (2008) 101–108.
 - [12] Y. Hsin-Chieh, M.P. Naresh, W. Nae-Yuh, et al, Cross sectional and prospective study of lung function in adults with type 2 diabetes, *Diabetes Care* 31 (2008) 741–746.
 - [13] S.A. Meo, A.M. Al-Drees, M. Arif, K. Al-Rubean, Lung function in type 2 Saudi diabetic patients, *Saudi Med. J.* 27 (2006) 338–343.
 - [14] M. Irfan, Abdul Jabbar, Ahmed Suleman Haque, Safia Awan, Syed Fayyaz Hussain, Pulmonary functions in patients with diabetes mellitus, *Lung India* 28 (2011) 89–92.
 - [15] S. Ljubic, Z. Metelko, N. Car, G. Roglic, Z. Drazic, Reduction of diffusion capacity for carbon monoxide in diabetic patients, *Chest* 114 (1998) 1033–1035.
 - [16] M.D. Goldman, Lung dysfunction in diabetes, *Diabetes Care* 26 (2003) 1915–1918.
 - [17] David.G. Michael, Lung dysfunction in diabetes, *Diabetes Care* 26 (6) (2003) 1915–1918.
 - [18] C. Pinar, O. Bilgin, Y. Arzu, O. Dilek, C. Gursel, Pulmonary function parameters in patients with diabetes mellitus, *Turkish J. Endocrinol. Metab.* 1 (1999) 5–10.
 - [19] Sanjeev Sinha, R. Guleria, A. Misra, R.M. Pandey, R. Yadav, Tiwari Sumit, Pulmonary functions in patients with type 2 diabetes mellitus & correlation with anthropometry & microvascular complications, *Indian J. Med. Res.* 119 (2004) 66–71.
 - [20] A. Mohammad Khan, Nasim Jahan, Nayma Sultana, A. Rezina, FVC, FEV1 and FEV1/FVC% in type-1 diabetic male and their relationships with HbA1c, *J. Bangladesh Soc. Physiol.* 7 (1) (2012) 23–28.
 - [21] B. Ozmen, P. Celic, A. Yorgancigolo, Pulmonary function parameters in patients with diabetes mellitus, *Diabetes Res. Clin. Pract.* 57 (2002) 209–211.
 - [22] S.A. Meo, A.M. Al-Drees, M. Arif, S.F.A. Shah, K. Al-Rubean, Assessment of respiratory muscle endurance in diabetic patients, *Saudi Med. J.* 27 (2) (2006) 223–226.
 - [23] W.A. Davis, M. Knuiman, P. Kendall, V. Grange, T.M.E. Davis, Glycemic exposure is associated with reduced pulmonary function in type 2 diabetes, *The Fremantle diabetes study*, *Diabetes Care* 27 (3) (2004) 752–757.
 - [24] T. Davis, M. Knuiman, P. Kendall, H. Vu, W.A. Davis, Reduced pulmonary function and its associations in type 2 diabetes, the Fremantle diabetes study, *Diabetes Res. Clin. Pract.* 50 (2000) 153–159.
 - [25] S. Sinhs, R. Guleria, R.M. Pandey, S. Tiwari, Pulmonary functions in patients with type 2 diabetes mellitus and correlation with anthropometry and microvascular complications, *Indian J. Med. Res.* 119 (2004) 66–71.
 - [26] G. Shravya Keerthi, Bandi Hari Krishna, M. Suresh, J.K. Preetham, N. Mallikarjuna Reddy, M. Sharan B Singh, Role of duration of diabetes on ventilatory capacities and expiratory flow rates in type 2 diabetes mellitus, in: *J. Biol. Agric. Healthcare* 2 (6) (2012).
 - [27] B. Van den Borst, H.R. Gosker, M.P. Zeegers, A.M. Schols, Pulmonary function in diabetes: a metaanalysis, *Chest* 138 (2) (2010) 393–406.
 - [28] C.C.W. Hsia, P. Raskin, Lung function changes related to diabetes mellitus, *Diabetes Technol. Ther.* 9 (2007) 73–82.
 - [29] C.K. Sreeja, E. Samuel, C. Kesavachandran, S. Shashidhar, Pulmonary function in patients with diabetes mellitus, *Indian J. Physiol. Pharmacol.* 47 (1) (2003) 87–93.
 - [30] F.L. Fimognari, P. Pasqualetti, L. Moro, et al, The association between metabolic syndrome and restrictive ventilatory dysfunction in older persons, *J. Gerontol. A Biol. Sci. Med.* 62 (7) (2007) 760–765.
 - [31] K. Nakagima, Y. Kubouchi, T. Muneyuki, et al, A possible association between suspected restrictive pattern as assessed by ordinary pulmonary function test and the metabolic syndrome, *Chest* 134 (4) (2008) 712–718.
 - [32] S. Sina, R. Guleria, A. Misra, et al, Pulmonary functions in patients with Type 2 DM and correlation with anthropometry and microvascular complications, *Indian J. Med. Res.* 119 (2) (2004) 66–71.
 - [33] Sanjeev. Verma, Mumtaz Goni, P. Rattan Kudiyar, Assessment of pulmonary functions in patients with diabetes mellitus, *Jammu J&K-India* 11 (2) (2009) 71–74.
 - [34] C.A. Benbassat, E. Stern, M. Kramer, J. Lebzelter, I. Blum, G. Fink, Pulmonary function in patients with diabetes mellitus, *Am. J. Med. Sci.* 322 (2001) 127–132.
 - [35] R. Nandhini, S.S. Syed Safina, P. Saikumar, Respiratory myopathy in type II diabetes mellitus, *J. Clin. Diagn. Res.* 6 (2012) 354–357.