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Obstructive sleep apnea in patients with type 2 diabetes mellitus in Egyptian population

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Abstract

Background Sleep disordered breathing (SDB) is a widespread disorder with a wide range of harmful outcomes including obstructive sleep apnea (OSA), central sleep apnea (CSA), or sleep-related hypoventilation.

Purpose The aim of the present study was to screen for the occurrence of sleep apnea syndrome in patients with type 2 diabetes mellitus (DM) and to evaluate the relation between the presence of sleep apnea and the level of glycemic control.

Methods This was a prospective clinical study that enrolled 59 patients who were previously diagnosed as type 2 DM. Sleep study level IV was done using overnight recording of oxygen saturation and pulse.

Results Among the studied patients, 42 were females and 17 were males, Their mean age was 59.76 ± 11.13 years. Obstructive sleep apnea was diagnosed in 46 patients (78%). Thirty three (86.8%) patients among those with uncontrolled glycemic level were diagnosed as OSA, whereas 13(61.9%) patients with controlled glycemic level were diagnosed as OSA showing statistically significant difference, $p = 0.047$. There was no correlation between either HbA1c, age, Mallampati score, or BMI and ODI but there was a correlation between STOP-BANG questionnaire and ODI ($P = 0.036$). The variables that were significantly related to presence of OSA, were comorbidities, ESS, Mallampati score, STOP-BANG, and sleep symptoms (nocturia and snoring) *P* value (0.029), (0.031), (0.022), (0.005), (0.049), and (0.012), respectively.

Conclusion Patients with type 2 diabetes showed a significant high prevalence of OSA. With significant higher prevalence among patients with uncontrolled DM versus controlled DM.

Keywords Sleep, Apnea, Obstructive, Screening, DM

Introduction

Sleep disordered breathing (SDB) is a widespread disorder with a wide range of harmful outcomes including obstructive sleep apnea (OSA), central sleep apnea (CSA) or sleep-related hypoventilation [1, 2]. The International Classification of Sleep Disorders, defined OSA as a chronic treatable disorder that has a clinical impact on lifespan. It is defined by repeated events of total (apnea) or partial (hypoapnea) blockage of the upper airway during sleep whereas respiratory efforts last, frequently causing arousals leading to intermittent hypoxemia,

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interrupted sleep, repeated arousals and sleep fragmentation [2]. The prevalence of OSA varies greatly between studies due to differences in the criteria used to define it as well as differences in the populations studied [3]. The estimated prevalence of OSA in the general adult public ranges from 9 to 38% [4–6]. Because chronic intermittent hypoxia (CIH) is a common component of OSA, it is a major cause of morbidity [7, 8].

Obesity, age, sex, race/ethnicity, and heritable factors are all well-documented risk factors in the pathology of sleep apnea [9]. Obese patients with OSA are more likely to develop type 2 diabetes [10–12]. Furthermore, Untreated OSA has been related to an increased risk of a number of illnesses and diseases over time, including hypertension, stroke, type 2 diabetes, obesity, dyslipidemia, metabolic syndrome, non-alcoholic fatty liver disease, cancer, and depression [13].

OSA is linked to glucose metabolism abnormalities such as insulin resistance and diabetes mellitus. Intermittent hypoxia, sleep fragmentation, aggravation of systemic inflammation, and elevation of sympathetic muscle activity are some of the pathophysiological mechanisms that relate OSA to DM [14].

Intermittent hypoxia, which can cause β cell malfunction and insulin resistance, is one proposed mechanism linking OSA to T2DM. An increase in adrenaline, norepinephrine, and cortisol secretion, in combination with oxyhemoglobin desaturation and hypercarbia, leads to increased gluconeogenesis. In many studies, continuous positive airway pressure (CPAP) was found to improve glycemic control, postprandial glucose levels, and HbA1c [15, 16].

OSA is also more common in overweight and obese people, and because excess body weight is also a key risk factor for T2DM, it is unclear whether the T2DM-OSA link is due to OSA-mediated changes in glucose metabolism or merely reflects a link with excess adiposity [17]. According to the previous findings, OSA is an independent risk factor for the development of type 2 diabetes, with 15–30% of OSA patients developing type 2 diabetes [18].

On the other hand, several studies have found a considerable increase in the prevalence of OSA among individuals with diabetes mellitus, with prevalence rates ranging between 73 and 86% [19]. The American Diabetes Association, the International Diabetes Taskforce on Epidemiology and Prevention, and the American Academy of Sleep Medicine (AASM) have announced clinical guidelines urging that patients with type 2 diabetes be screened for OSA on a regular basis [20, 21].

The aim of the present study was to screen for the occurrence of sleep apnea syndrome in patients with type 2 diabetes mellitus and to evaluate the relation between the presence of sleep apnea and the level of glycemic control.

Patients and methods

This was a prospective clinical study. The current study was conducted at the department of Diabetes and Metabolism, Alexandria Main University Hospital in the duration between May 2019 and May 2020.We enrolled 59 patients who were previously diagnosed as having type 2 DM. We enrolled Patients over 18 years of age diagnosed with type 2 DM. Exclusion criteria included patients known to have other sleep disorders, patients refusing to participate, type 1 diabetic patients, and critically ill patients. All patients enrolled in the study signed an informed consent before participation. The study was accepted by the local ethical committee of Alexandria Faculty of Medicine (available from www.med.alexu.edu.eg/wp-content/uploads/2012/04/ethics-guide.pdf). For every eligible patient the following data were collected: full history, smoking history, and history about any comorbid illness or drugs taken by the patients. Symptoms relevant to sleep disorders were reported as snoring, choking or gasping attacks at night, witnessed apneas, EDS, unrefreshing sleep, recurrent arousals, nocturia, morning headaches, memory and personality changes, morning dry mouth, morning laziness and fatigue. Anthropometric measurement were reported including BMI:(Quetelet's index) [22], neck circumference was measured at mid-neck, between the midcervical spine and the mid anterior neck, on subjects standing upright and facing forwards, with shoulders relaxed. In men with a laryngeal prominence (Adam's apple), it was measured just below the prominence [23] waist-hip ratio was measured according to WHO protocol [24]: waist circumference was measured at the end of several consecutive natural breaths, at a level parallel to the floor, midpoint between the top of the iliac crest and the lower margin of the last palpable rib in the mid axillary line. Hip circumference was measured at a level parallel to the floor, at the largest circumference of the buttocks. The subject was standing upright, with arms relaxed at the side, feet evenly spread apart [24]. Mallampati score [25] was assessed. The patient was instructed to open his or her mouth as wide as possible, while protruding the tongue as far as possible. Patients were instructed to not emit sounds during the assessment. A score (I–IV) was obtained by visual inspection of the soft palate, hard palate, and tongue. Assessment of excessive daytime sleepiness was done using Epworth sleepiness scale (ESS) [26]. STOP-BANG questionnaire was used to asses risk of having OSA [27]. Sleep study level IV was done using overnight recording of oxygen saturation and pulse by

the use of Heal Force Prince-100F Handheld Pulse Oximeter, Shanghai, China.

Based on the cutoff for "significant" oxygen desaturations 3% during sleep, we considered patients diagnosed as OSA if ODI > 5 plus symptoms or > 15 without symptoms [28]. Laboratory assessment included fasting plasma glucose level, fasting insulin level and glycated hemoglobin (HbA1c). The American diabetes association (ADA) has determined glycosylated hemoglobin (A1C) as the best measure of glycemic control, level less than 7% as a goal of optimal blood glucose control to prevent the complications and to reduce overall disease management costs [29].

Assessment of insulin resistance by using Homeostasis Model Assessment 2 (HOMA2) calculator [30]. Complete lipid profile was done [31] (total serum cholesterol, high-density lipoprotein cholesterol (HDL-cholesterol), low-density lipoprotein cholesterol (LDL-cholesterol), serum triglycerides) [32].

Statistical analysis of the data

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp.) [33]. Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution. Quantitative data were described using range (minimum and maximum), mean, standard deviation, median, and interquartile range (IQR). Significance of the obtained results was judged at the 5% level. The used tests were chi-square test: for categorical variables, to compare between different groups. Mann-Whitney test: for abnormally distributed quantitative variables to compare between two studied groups. Spearman coefficient: to correlate between two distributed abnormally quantitative variables. Student's t test: for normally distributed quantitative variables, to compare between two studied groups. Fisher's exact or Monte Carlo correction: correction for chi-square when more than 20% of the cells have expected count less than 5.

Results

Fifty-nine patients diagnosed as type 2 DM were enrolled in the current study in the period between May 2019 and May 2020. Among the studied patients, 42 (71.2%) were females and 17 (28.8%) were males, Their mean age was 59.76 ± 11.13 years (range 54–65.5 years). The mean BMI and neck circumference in the participants investigated was 34.56 ± 8.17 kg/m^2 (range 20.7–54.6 kg/m^2), and 40.49 ± 2.34 cm (range 36–45 cm) respectively. For waist/hip ratio, the mean value was 0.89 ± 0.09 ranging between 0.7 and 1.03. The distribution of the most common associated comorbidities other than DM was as follows: hypertension (HTN), ischemic heart diseases (IHD), asthma, atrial fibrillation (AF), hypothyroidism, chronic kidney diseases (CKD), and stroke in 46(78%), 16(27.1%), 8(13.6%), 4(6.8%), 2 (3.4%), 2 (3.4%), and 1 (1.7%) of the patients, respectively.

The most frequent presenting symptom was snoring which was reported in 44(74.6%) patients. This was followed by daytime sleepiness, nocturia, witnessed apnea and choking in 27 (45.8%), 24 (40.7%), 19(32.2%), and 7 (11.9%) patients, respectively. Their Epworth sleepiness scale ranged from 4 to 15 with a mean of 8.97 ± 2.74.

Patients were divided into two groups based on their OSA risk using STOP-BANG questionnaire: high risk (48(81.4%) patients) and low risk (11(18.6%) patients. STOP-BANG questionnaire score ranged from 1 to 7 with a mean of 4.48 ± 1.73. Mallampati score 4 was present in 32 (54.2%) patients, while Mallampati score 3 was in 4 (6.8%) patients, score 2 was in 14(23.7%) patients and score 1 was in 9 (15.3%) patients. The mean score was 3.0 ± 1.19 overnight pulse oximetry was used to screen for OSA and calculate ODI. Patients were diagnosed as OSA if ODI > 5 plus symptoms or > 15 without symptoms (Table 1).

Laboratory assessment of the studied patients was presented in Table 2. According to the results of the blood test, patients were classified as controlled or uncontrolled diabetes.

In our study, 33(86.8%) patients among those with uncontrolled glycemic level were diagnosed as OSA, whereas 13(61.9%) patients with controlled glycemic level were diagnosed as OSA showing statistically significant

Table 1 Distribution of the studied patients according to ODI ($n = 59$)

Pulse oximetry (ODI)	No	%
ODI		
< 5	11	18.6
5–15		
No symptoms	2	3.39
Symptoms	13	22
> 15		
> 15–30	12	20.33
> 30	21	35.59
Min.–max	1.0–90.75	
Mean ± SD	23.14 ± 19.49	
Median (IQR)	20.21(7.0–34.6)	
OSA		
No	13	22.0
Yes[a]	46	78.0

[a] Yes = ODI > 5 with symptoms or ≥ 15 without symptoms

ODI Oxygen desaturation index

Table 2 Laboratory investigations of the studied patients ($n=59$)

Laboratory assessment	Reference range	Min.–max	Mean ± SD	Median (IQR)
FBS (mg/dl)	70–110	75.0–371.0	164.0 ± 70.69	140.0(108.0–202.5)
HbA1c (%)	4.5–7	5.70–13.60	8.14 ± 1.76	7.70(6.9–9.1)
Insulin level (uIU/ml)	2.6–24.9	1.0–147.0	20.42 ± 19.46	18.0 (9.7–25.0)
HOMA	< 1	0.40–7.0	2.73 ± 1.53	2.51(1.3–3.7)
Total cholesterol (mg/dl)	< 200	82.0–321.0	182.2 ± 44.90	184.0(157.0–210.0)
HDL (mg/dl)	> 35	20.0–205.0	45.46 ± 25.33	42.0(33.0–48.5)
LDL (mg/dl)	Up to 140	38.0–226.0	112.4 ± 39.09	109.0(84.0–134.0)
TG (mg/dl)	< 200	56.0–359.0	143.2 ± 67.96	130.0(90.0–183.5)

difference, $p=0.047$ (Fig. 1). Thirty-three (71.7%) patients out of 46 patients were diagnosed as OSA had uncontrolled DM. Table 3 shows comparison between patients diagnosed as OSA and those not diagnosed as OSA regarding different variables.

In our study, there was no correlation between HbA1c, age, Mallampati score, and BMI and ODI but there was a correlation between STOP-BANG questionnaire and ODI ($P=0.036$), (Table 4).

By analyzing the effect of different variables on presence of OSA (Table 5). It was found that variables were significantly related to presence of OSA, which were comorbidities, ESS, Mallampati score, STOP-BANG, and symptoms of sleep (nocturia and snoring) P value was (0.029), (0.031), (0.022), (0.005), (0.049), and (0.012) respectively. Nevertheless, there was no variable taking the upper hand and affecting the other variables.

Discussion

Obstructive sleep apnea is one of the most major causes of sleep disruption (OSA) [34]. The purpose of this study was to assess presence of sleep apnea syndrome among patients with type 2 diabetes and if there was a link between sleep apnea and blood glucose levels.

We enrolled 59 persons with type 2 diabetes, with a mean age of 59.76 ± 11.13 years (more than 80% of the studied patient over 50 years). In the current study, 42 patients (71.2%) were females and 17 patients (28.8%) were males. This came in agreement with Megahed and Farag [35] who revealed that more than two thirds of their studied sample of diabetic patients were females. Similarly, two studies conducted in India by Dussa et al. [36] and Mufunda et al. [37] found that females represented more than two thirds of their studied diabetic

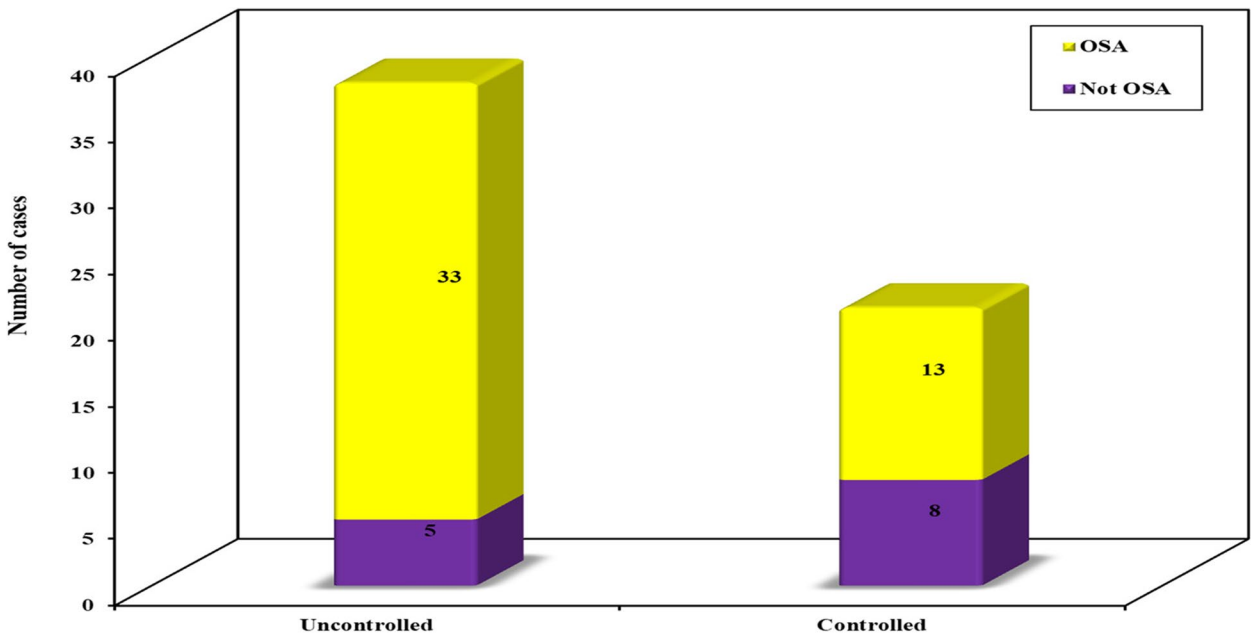

Fig. 1 The presence of OSA among patient with or without controlled DM ($n=59$)

Table 3 Comparison between patients with OSA and those without OSA regarding different variables

	OSA				Test of sig	*P*
	No (*n* = 13)		Yes (*n* = 46)			
	No	%	No	%		
Age (years)						
< 50	3	23.1	6	13	0.789	0.398
≥ 50	10	76.9	40	87		
Sex						
Male	4	30.8	13	28.3	0.031	1.000
Female	9	69.2	33	71.7		
Comorbidities						
No	4	30.8	3	6.5	5.699*	^{FE}p = 0.036*
Yes	9	69.2	43	93.5		
NC						
< 40	6	46.2	17	37.0	0.360	0.548
≥ 40	7	53.8	29	63.0		
Min.–max	37.0–45.0		36.0–45.0		*t* = 0.857	0.395
Mean ± SD	40.0 ± 2.16		40.63 ± 2.39			
Median (IQR)	40.0 (38–41)		40.0 (39–42)			
WHR						
Negative	9	69.2	15	32.6	5.633*	0.018*
Positive	4	30.8	31	67.4		
Min. – max	0.72–1.03		0.70–1.03		*t* = 1.745	0.086
Mean ± SD	0.85 ± 0.09		0.90 ± 0.09			
Median (IQR)	0.84 (0.8–0.9)		0.90 (0.9–0.9)			
Mallampati score						
1 and 2	9	69.2	14	30.4	6.414*	0.011*
3 and 4	4	30.8	32	69.6		
Min.–max	1.0–4.0		1.0–4.0		*U* = 179.0*	0.016*
Mean ± SD	2.31 ± 1.11		3.20 ± 1.15			
Median (IQR)	2.0 (2.0–3.0)		4.0 (2.0–4.0)			
According to STOP BANG questionnaire into						
Low risk (< 3)	6	46.2	5	10.9	8.319*	0.009*
High risk (≥ 3)	7	53.8	41	89.1		

χ^2 chi-square test, *FE* Fisher exact, *t* Student's *t* test, *U* Mann–Whitney test, *p p* value for comparing between no and yes, r_s Spearman coefficient

* Statistically significant at $p \leq 0.05$

Positive WHR: for males ≥ 0.9 and females ≥ 0.85

Table 4 Correlation between ODI with different parameters

	ODI	
	r_s	*P*
WHR	0.145	0.275
Mallampati score	0.157	0.234
Age (years)	0.066	0.619
BMI (kg/m^2)	-0.001	0.995
HbA1c	0.160	0.225
Stop bang (result)	0.273*	0.036*

r_s Spearman coefficient

* Statistically significant at $p \leq 0.05$

patients. This could be explained by a study done in Denmark by Juel et al. [38], which showed that men react later to severe symptoms than women.

Regarding the incidence of other comorbidities, the most common was hypertension (HTN) in 78% of the patients, followed by Ischemic heart diseases (IHD), asthma, atrial fibrillation (AF), hypothyroidism, chronic kidney diseases (CKD), and stroke that were present in 16 (27.1%), 8 (13.6%), 4(6.8%), 2 (3.4%), 2 (3.4%), and 1 (1.7%) patient, respectively. In accordance with Souliotis et al. [39] who found a significant prevalence of hypertension in 58.9% of diabetics evaluated.

Table 5 Univariate and multivariate analysis for the parameters affecting patients with OSA

OSA	Univariate		[a]Multivariate	
	P	OR (95%C.I)	*P*	OR (95%C.I)
Comorbidities (no[(R)] vs yes)	0.029*	6.370*(1.211–33.518)	0.072	7.028 (0.839–58.886)
ESS (numeric)	0.031*	1.348*(1.028–1.767)	0.983	0.995 (0.643–1.542)
WHR (numeric)	0.092	491.5 (0.361–668368)		
Mallampati score (numeric)	0.022*	1.873*(1.094–3.209)	0.124	1.786 (0.854–3.737)
Result of stop bang (numeric)	0.005*	1.833*(1.200–2.801)	0.676	1.165 (0.569–2.386)
Age (years)	0.094	1.050 (0.992–1.112)		
Sex (male[(R)] vs female)	0.860	1.128 (0.295–4.314)		
HbA1c	0.088	1.519 (0.940–2.454)		
Symptoms of sleep				
Nocturia	0.049*	5.042*(1.004–25.32)	0.487	2.088 (0.262–16.654)
Witnessed apnea	0.059	7.714 (0.922–64.53)		
Daytime sleepiness	0.074	3.636 (0.884–14.954)		
Snoring	0.012*	5.542*(1.465–20.96)	0.430	2.326 (0.286–18.931)
Choking	0.999	–		
Neck circumference	0.390	1.130 (0.856–1.491)		
BMI (kg/m^2)	0.264	1.047 (0.966–1.136)		

c Categories, *R* Reference, *OR* Odd's ratio, *CI* Confidence interval, χ^2 chi-square test, *FE* Fisher exact, *p p* value for comparing between no and yes

[a] All variables with $p < 0.05$ was included in the multivariate

* Statistically significant at $p \leq 0.05$

These findings are in line with earlier studies, which found a higher prevalence of these disorders in diabetics. In a cohort study conducted by Arnold et al. [40] hypertension was estimated to be present in 76.3% of the participants.

In this study of hospitalized diabetic patients, patients were considered uncontrolled using the result of HbA1c. The number of uncontrolled patients versus the number of controlled were 38 (64.4%) versus 21 (35.6%) patients, respectively. This result was also in line with findings from a large-scale outpatients multicenter survey of nearly 240,000 patients across China, which stated that patients with T2DM do not meet the American Diabetes Association (ADA) and the Chinese Medical Society's treatment guideline of a HbA1c of less than 7%. Glycemic control, as defined by HbA1c < 7.0%, was attained by less than a third of those with type 2 DM [41]. In a research done in India by Borgharkar et al. [42]. Nearly 76.6% of patients had uncontrolled glycated hemoglobin (HbA1c) ≥ 7%, according to a systematic analysis of cross-sectional data collected from urban healthcare facilities across 26 states. This could be explained by the fact that in a developing country already overwhelmed with a growing population, inadequate resources, and rising life expectancy, sub-optimal DM therapy is expected. Patient education is seen as a critical element in the management of diabetes. Effective diabetes education leads to better disease control [43].

In the current study, the most frequent presenting symptom related to sleep disorders was snoring which was reported by 44(74.6%) of the total studied patients. This was followed by daytime sleepiness, nocturia, witnessed apnea and choking in 27 (45.8%) patients, 24 (40.7%) patients, 19(32.2%) patients, and 7 (11.9%) patients, respectively. A retrospective cross-sectional study done by Monti et al. [44] in a sample of 102 geriatric inpatients, snoring was present in 46.9% of patients diagnosed as OSA. A study done in an Egyptian university hospital on 421 patients by Yousif et al. [45] found that snoring was also the most common presenting symptoms of sleep disorders present (84.6%). Regarding nocturia, it was represented by (40.7%) patients. Similar result was found in a research by Monti et al. [44] nocturia was in 39.1% in those diagnosed with OSA.

Obesity raises the potential for having both diabetes and OSA [46]. In this study, those who had been diagnosed with OSA (46 patients) were separated into two groups. Those having uncontrolled DM and controlled DM, comparing between both groups according to result of BMI. In patients having uncontrolled DM 10(30.3%) patients were found to have BMI < 35 and 23(69.7%) were found to have BMI ≥ 35.While in patients with controlled DM those with BMI < 35 were 11(84.6%) and 2(15.4%) patients with BMI ≥ 35.there was significant difference between both groups. This came in accordance with Nsr-Allah et al. [47]. When comparing uncontrolled diabetes

patients to controlled diabetic patients and healthy people, there were significant differences in BMI with increased obesity. These findings support those of Piniés et al. [48]. Who predicted that people with a BMI more than 40 kg/m^2 were seven times more likely than persons with a normal BMI to acquire diabetes. According to the findings of a meta-analysis, overweight, and obesity are strongly linked to OSA, and obesity is a significant risk factor for OSA [49].

In this study, a significant statistical difference was present when comparing between patients with OSA and those without OSA regarding WHR ($p=0.018$). Visceral obesity has been associated with increased risk of T2DM [50]. Obese adults with T2DM who had OSA had more visceral fat, WHR was significantly increased in OSA in a study by Lim et al. [51] ($p=0.003$, female $p=0.001$).

The comparison between the two groups diagnosed as OSA or not OSA regarding result of STOP-BANG questionnaire, showed that STOP-BANG questionnaire score was statistically significantly higher among patients with OSA versus those without ($p=0.009$). Moreover, a positive correlation between STOP-BANG questionnaire and ODI was found ($P=0.036$). Similarly, Chung et al. [52] found that the likelihood of severe OSA increases as the STOP-BANG score rises to 7 or 8.

High Mallampati score (3 and 4) was seen in 69.6% of patients with OSA. Our results agreed with Rodrigues et al. [53, 54] and Eldaboosy et al., who showed that about 65% of studied OSA patients were grouped in classes III and IV.

Patients with T2DM are more likely to develop OSA, yet many go undetected. In our study, among the 59 patients enrolled, OSA was detected in 46(77.9%) patients using the overnight pulse oximetry. We considered patients diagnosed as OSA if ODI > 5 plus symptoms or > 15 without symptoms. ODI from 5 to 15 with symptoms was found in 13(22%) patients, ODI from 15 to 30 in 12(20.33%) patients, and ODI > 30 in 21 patients (35.59%). Similar results were found in a study that enrolled 54 diabetic outpatients with symptoms of sleep disorders using full PSG to diagnose OSA by Buyukaydin et al. [55].

Thirty 8 patients (73%) were women, men made up 14 patients (27 percent). The mean age was 56 ± 7 years. The BMI mean was 32.4 ± 5.3 kg/m^2. OSAS was found in 35 patients (67.3%). Another study in Bangkok was done by Nimitphong et al. [56] enrolled 81 participants (33 men and 48 women) attending the outpatient clinic with mean age 54.7 years, and mean HbA1c of 7.6. The mean BMI was 28.3 kg/m^2. Sixty-five participants (80.2%) were diagnosed with OSA. A Japanese study done by Kashine et al. also reported similar results [57]. A total of 40 Japanese patients with T2DM who had been hospitalized were included in the study. An experienced polysomnographic technologist manually assessed all of the recordings. The main finding was that Japanese T2DM patients had a significant prevalence of SDB (77.5%). Another study done by Chen et al. [58] investigated sleep disorders and wound healing in diabetic foot ulcer patients. They discovered that the prevalence of SDB was alarmingly high, with 92% identified with SDB and 34% with severe SDB, using PSG. This study showed higher prevalence of SDB in diabetic patients than ours. This could be attributed to the use of PSG to diagnose sleep disorders which is more accurate than overnight pulse oximetry in addition to the presence of uncontrolled DM which could be linked to foot ulcers.

In an Egyptian study done by Shoukri et al. [59], there were 107 T2DM patients who were referred for sleep disorders evaluation, with 62 men (57.94%) and 45 women (42.05%), age ranged from 42 to 72 years old. Based on the results of nighttime pulse oximetry (OPO) and the PSG-detected apnea–hypopnea index, the patients were divided into two groups (AHI). Sixty-eight patients (63.55%) had moderate to severe OSA with considerable oxygen desaturation (≥ 15 desaturation events/hour), while 39 patients (36.44%) had a lower ODI (< 15 events/h) and minimal or mild OSA with AHI (< 15 events/h). Another population-based study done by Elmasry et al. involved 2668 men aged 40–79 years old, and the prevalence of severe OSA, defined as apnea–hypopnea index (AHI) ≥ 20, was significantly higher in diabetic patients than in normoglycemic subjects (36 vs. 14.5%, $P<0.05$) [60]. Lower prevalence rates were found in a study by Einhorn et al. [61]. There were 330 patients with T2DM who were sent to a diabetes clinic, and 279 of them finished the study. The presence of a sleep problem was determined using a single channel recording device that captures disturbed breathing events from a nasal cannula airflow signal. The prevalence rate was 36% overall. Because of differences in the population investigated, study designs, and the method and criteria used to diagnose OSA, the prevalence of OSA varies significantly between studies. Furthermore, because obesity and age are key risk factors for OSA, it is expected that the prevalence of OSA will rise as the obesity and elderly populations grow.

There is a bidirectional link between OSA and type 2DM: T2DM is a risk factor for OSA, and OSA is a also risk factor for T2DM [62]. In an Egyptian retrospective analysis of 244 patients with OSA by Sweed et al. [63], it was found that DM was present in 50% of the studied patients. DM was the second most common comorbidity after systemic HTN in this cohort of Egyptian patients with OSA. Furthermore, there were 332 incident cases of T2DM in a meta-analysis of 5953 patients with OSA who

were followed for 2–16 years [64]. Those with moderate to severe OSA were more likely to be affected [65]. In a study by Li et al. when compared to non SDB, SDB was linked to a 1.33 greater risk of developing diabetes (95% CI, 1.05–1.67) [66].

The Wisconsin Sleep Cohort supplied a completely unique possibility to inspect the connection among diabetes and SDB with both a cross-sectional and prospective analysis. In the cross-sectional study, discovered that patients with an AHI of 15 or more were three to four times more likely to have diabetes than patients with an AHI of less than 5. Same relation remained even after controlling risk elements which includes age, sex, and body habit. However, in their prospective analysis, they found no statistically significant causative connection between the chance of having type II diabetes and the severity of OSA (at the beginning of the study) [17].

Among our studied patients, comparing between controlled and uncontrolled diabetic patients regarding presence of OSA. Thirty-three (86.8%) patients having uncontrolled glycemic level were found to have OSA, while 13(61.9%) patients with controlled glycemic level were found to have OSA. There was a significant difference comparing between both groups ($p=0.047$). In a study by Aronsohn et al. [67], despite controlling obesity and a number of other possible confounders, there was a clear inverse relation between OSA severity and glucose control in adults with type 2 diabetes. The adjusted mean HbA1c was 1.49% higher in patients with mild OSA, 1.93% higher in patients with moderate OSA, and 3.69% higher in patients with severe OSA as compared to individuals without OSA. Several other studies have found that OSA and severity of OSA were linked to poor glycemic control (HbA1c) [68, 69]. Shoukri [59] et al. reported that patients in group 1 with a greater ODI and moderate to severe OSA had significantly higher HbA1c levels than patients in group 2 with minimal or mild OSA and an ODI of less than 15 desaturation events/h. In another Egyptian study by Agha et al. [70], 25 patients were enrolled with T2DM and OSA in the patient group, and 17 patients with T2DM but no OSA in the control group. The presence of OSA had an impact on glucose management in patients with treated T2DM, with HbA1c values significantly higher in the patients' group than in the control group. Most studies imply a link between OSA and glycemic measurements in those with type 2 diabetes. However, confounding factors as age, sex, obesity, DM duration, and early OSA diagnosis all influence this connection.

The impact of CPAP usage on glycemic control was studied in a few research. After two months of CPAP therapy, one study found that insulin sensitivity had improved [71]. The effect of 24 weeks of CPAP on glycemic control in patients with poorly controlled type 2 diabetes and OSA was studied in a randomized controlled trial, discovered that CPAP prescription results in improving glycemic control and/or insulin resistance significantly when compared to standard care [72]. In a meta-analysis study, researchers looked at RCTs that examined the impact of CPAP on glycemic management and insulin resistance in those with type 2 DM and OSA. Based on these findings, it was shown that CPAP treatment considerably improved glycemic management and insulin resistance, as seen by lower HbA1c, fasting glucose, and HOMA-IR values, as well as significantly lower blood pressure levels [73].

Regarding advantages of our study, we screened for the presence of sleep apnea in patients with type 2 DM using a simple affordable device (overnight pulse oximetry). we also used a previously proven effective questionnaire (STOP-BANG) to add more to our results. On the other hand, there were some limitations, such as small number of our study sample. A full PSG would have been more accurate to confirm the diagnosis of OSA.

- ❖ In conclusion, patients with type 2 diabetes showed a significant high prevalence of OSA (77.9%). There was statistical significant higher prevelance of OSA among patients with uncontrolled DM when compared to patients with controlled DM so there was an association between glycemic control and the risk of OSA. Despite increased prevelance of OSA among uncontrolled diabetic patients there was no correlation between Hb_{A1c} and severity of OSA. STOP-BANG questionnaire was the only factor that was correlated with the severity of OSA (ODI) among type 2 diabetic patients in our study. Using multiple regression analysis, we found that variables were significantly related to presence of OSA, which were comorbidities, ESS, Mallampati score, STOP-BANG, and symptoms of sleep (nocturia and snoring). On the other hand there was no variable taking the upper hand and affecting the other variables. Overnight pulse oximetry is an easy and affordable method for screening type 2 DM for presence of OSA. We recommend performing similar studies on larger scale of patients using full polysomnography if possible.

- ➢ Increase awareness as well as patients education of the harmful effect of undiagnosed and untreated OSA in diabetic patients and its effect on diabetic control.
- ➢ All diabetic patients (type 2) should undergo screening for OSA (using STOP-BANG questionnaire and overnight pulse oximetry).

Abbreviations

SDB	Sleep disordered breathing
OSA	Obstructive sleep apnea
PSG	Polysomnography
RDI	Respiratory disturbance index
AASM	American Academy of Sleep Medicine
PAP	Positive airway pressure
EDS	Excessive daytime sleepiness
BMI	Body mass index
REM	Rapid eye movement
CIH	Chronic intermittent hypoxia
AHI	Apnea hypopnea index
ESS	Epworth Sleepiness Scale
WHR	Waist hip ratio
T2DM	Type two diabetes mellitus
Hb_{A1c}	Glycated hemoglobin
CPAP	Continuous positive airway pressure
WHO	World health organization
DKA	Diabetes ketoacidosis
FBG	Fasting plasma glucose
OPO	Overnight pulse oximetry
ODI	Oxygen desaturation index
HTN	Hypertension
IHD	Ischemic heart diseases
AF	Atrial fibrillation
CKD	Chronic kidney diseases
FBS	Fasting blood sugar

Authors' contributions

Rania Ahmed Sweed directed the practical part of the research, presented the results, and wrote the manuscript. Nashwa Hassan Abd El Wahab decided the main idea of the research and the methodology, and revised the whole manuscript. Dina Mohsen Shetta performed the practical part, statistics, and data collection. Mona Saeed El Hooshy guided the practical part and revised the manuscript. Eman Youssef Morsy guided the practical part and revised the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The study was in accordance with the ethical standards of the institutional research committee (Alexandria Faculty of Medicine) and with the 1964 Helsinki declaration.

Consent for publication

Informed consent was obtained from all individual participants included in the study.

Competing interests

All authors declare that they have no conflict of interest.

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