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ORIGINAL ARTICLE

Prevalence and risk factors of poor glycemic control and diabetic nephropathy among patients with type 2 diabetes mellitus in Dhamar, Yemen

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Abstract

Background Glycemic control is a significant step in reducing diabetic complications. The purpose of this study was to determine the prevalence and risk factors for poor glycemic control and diabetic nephropathy in patients with type 2 diabetes mellitus (T2DM) in Dhamar, Yemen.

Methods A study was carried out in which 200 patients with type 2 diabetes were recruited from the outpatient departments of Dhamar General Hospital. Information on their sociodemographic and clinical factors were collected. Blood and urine samples were taken following an overnight fast. Automated instruments were utilized to evaluate HbA1c, microalbuminuria, creatinine, and fasting blood sugar (FBS) using standardized procedures.

Results This study revealed that 58% of people with diabetes have poor glycemic control, while 14% have fair glycemic control. Multivariate logistic analysis showed that combined antihyperglycaemic drugs (oral tablet + insulin) [adjusted odds ratio (AOR) = 3.77; %CI = 1.36- 10.44], poor diet adherence (AOR = 1.97; %CI = 1.03–3.77) and lack of education (2.34; %CI = 0.93–5.90) were potential risk factors for poor glycemic control. The prevalence of diabetic nephropathy was 32%. It was found that age over 50 years (AOR = 2.37; %CI = 1.15–4.90), hypertension (AOR = 3.22; %CI = 1.39–7.47), uncontrolled blood glucose (AOR = 2.67; %CI = 1.16–6.16), the duration of diabetes of 5 years or more (AOR = 1.78; %CI = 1.05–3.00), and a lack of education (AOR = 1.90; %CI = 1.16–3.11) were risk factors for diabetic nephropathy.

Conclusion The prevalence of uncontrolled glycemic status and diabetic nephropathy is significantly high among Yemeni T2DM patients in Dhamar, which may contribute to an increasing prevalence of complications and thus pose extra challenges to the poor health care services in Yemen.

Keywords Type 2 diabetes mellitus · Glycemic control · Nephropathy · Yemen

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Introduction

The prevalence of type 2 diabetes mellitus (T2DM) has been steadily increasing over time. People with diabetes comprise 10.5 percent (536.6 million people) of the world's population in 2021, and it is predicted that the number of cases of diabetes will rise to 783.2 million (12.2%) by 2045. In the United States, the age-adjusted comparative prevalence of diabetes, has progressively climbed from 9.4% in 2011 to 10.7% in 2021 and expected to reach 12.9% in 2045 [1]. With regard to the Middle East, it has the highest prevalence of diabetes in the world, with Kuwait scoring the highest (24.95), followed by Egypt (20.9%), Qatar (19.5%), Saudi Arabia (18.7%), the United Arab Emirates (16.4%), Jordan (15.4%), Syria (14.9%), Bahrain (11.3%), Iraq (10.7%), Iran (9.1%) and Yemen (5.4%) [1].

Diabetes is reported to be responsible for 6.7 million deaths in 2021 [1]. Diabetes is associated with complications such as cardiovascular diseases (CVD), nephropathy, retinopathy, and neuropathy, which can lead to chronic morbidities and mortality [2]. CVD is reported to be the leading cause of mortality, resulting in 2/3 of deaths in people with T2DM, and this rate is primarily driven by growth in renal complications [3]. On the other hand, a previous study reported that diabetic kidney disease (DKD) occurs in approximately 20–40% of patients with T2DM, and those patients have a higher risk of cardiovascular and all-cause mortality [4].

Glycemic control is based on how well your blood sugar levels are controlled. There are three levels: good, fair, and poor. Patients with good glycemic control have HbA1c levels that are below 7%. Patients with fair glycemic control have HbA1c levels that are between 7 and 8%. HbA1c levels in patients with poor glycemic control exceed 8% [5]. Glycemic control is important in preventing complications from diabetes, such as retinopathy, nephropathy, neuropathy, and CVD [6, 7]. Studies have found that between 40 and 60% of people with diabetes have poorly controlled blood sugar levels [8–11]. In many Middle Eastern countries, a high percentage of people have diabetes that is not well controlled. This is especially common in Kuwait (78.8%), Saudi Arabia (74.9%), the United Arab Emirates (69%), Jordan (65.1%), and Oman (65.0%) [12–15].

Both modifiable and non-modifiable factors shape glycemic control's aetiology and affect the extent of poor glycemic control in T2DM patients. Previous studies revealed that a low education level, a longer duration of diabetes, the use of a combination of oral antihyperglycaemic drugs with insulin or insulin alone, the patient's family history, exercise levels, and weight status were significantly associated with poor glycemic control [12, 16].

Despite the fact that glycemic control is the primary therapeutic goal for the prevention of chronic complications in T2DM patients, there are many issues that make it difficult for people with diabetes to manage their disease in some parts of the world, such as Yemen. These issues include economic issues and a lack of adequate health care. Furthermore, studies on the extent of poor glycemic control and the relationship between glycemic status and diabetic nephropathy in Yemeni T2DM patients are lacking. The current study's goal is to estimate the prevalence and risk factors for poor glycemic control and diabetic nephropathy among T2DM patients in Dahmer, Yemen.

Materials and Methods

Study design

The current study was carried out on T2DM patients who visited an outpatient clinic in the Dhamar General Hospital Commission between August 2019 and January 2020. It used a cross-sectional design. 200 diabetic patients were chosen at random from the diagnosed patients undergoing routine investigation at an outpatient clinic. The sample size was calculated using the following assumptions: a power of study of 84%, a sample percentage of 50%, and a confidence level of 95%. All T2DM patients who are receptive to the study's invitation are eligible for inclusion. Patients with severe haematuria or pyuria, anemia, non-type 2 diabetic patients, patients with overt renal failure, patients with cardiac failure, patients with mental illness, and patients with psychological problems are among the patients who are excluded.

Data collection

Face-to-face interviews with each patient were conducted using a pre-tested questionnaire. Socio-demographic (age, gender, education, profession, diet adherence, smoking status, Qat chewing, and physical activity) and clinical data (duration of diabetes, family history of diabetes, mode of treatment of diabetes, and hypertension) were obtained.

Anthropometric measurements

Each subject's height was measured in centimeters while the participant stood still without shoes, and weight was measured to the nearest 0.1 kg with an electronic weight scale in kilograms with the participant lightly clothed. BMI was calculated as weight divided by the square of height (kg/m2).

Estimation of biochemical parameters

The blood and urine samples were collected from all participants after an overnight fast. HbA1c was determined using the HbA1c Tina Quant assay (Roche Diagnostics GmbH, Mannheim, Germany). Urine albumin was determined by Tina-quant Albumin Gen 2 [17]. FBS was estimated by the hexokinase enzymatic reference method, and urinary creatinine was estimated by a modified Jaffe's method [17, 18]. All estimations were carried out using an automated analyzer. The albumin/creatinine ratio was calculated in mg/g.

Definition of data

Glycemic status was defined based on the level of HbA1c as; good glycemic control (HbA1c $<$ 7%), fair glycemic control (HbA1c 7–8%), and poor glycemic control (HbA1c $>$ 8%) [5]. The average blood glucose was calculated using the patient's results throughout the previous three months with the last examination performed during the trial. Regarding diet adherence, patients were scored based on their responses to particular questions, including: i. follow the instructions of the physician (if the answer is yes, it gets 1 point); ii. the frequency of consumption of fruit, plant-based proteins, vegetables, and fish per week (if the answer is > 3 times, each gets 1 point); iii. If less than three times a week is answered for meat consumption, the answer receives 1 point. Those patients who scored 4 or more out of 6 are considered to have a good level of diet adherence. According to WHO guidelines, subjects were divided into three categories based on their BMI: normal weight (BMI < 25 kg/m2), overweight (BMI 25–29.9 kg/m2), and obese (BMI > 29.9 kg/m2) [19]. Microalbuminuria is defined as albumin levels ranging from 30 to 300 mg/g of creatinine and overt macroalbuminuria, or proteinuria is defined as a urinary albumin excretion of > 300 mg/g of creatine [20]. Hypertension was defined by either a documented diagnosis of hypertension, the patient taking antihypertension medications, or the latest blood pressure readings (systolic ≥ 140 or diastolic ≥ 90 [21]. Physical activity was defined as 150–300 min per week of regular exercise or an equivalent occupational physical activity [22].

Data analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) Version 23. Data were expressed as frequency counts (n) and percentages (%). A univariate logistic regression was performed to identify the factors associated with poor glycemic control and diabetic nephropathy in the study sample. To determine relationships between potential risk factors and poor diabetes control as well as diabetic nephropathy, the variables identified by the univariate logistic regression were later included in a multivariate logistic regression. The relationship of glycemic control status with diabetic nephropathy was evaluated using Pearson correlation. Statistical significance was set at a *p*-value of < 0.05.

Table 1 Characteristics of the study population

Variable		Frequencies	Percent
Age	> 50	95	47.5%
	≤ 50	105	52.5%
Sex	Male	108	54%
	Female	92	46%
Address	Urban	99	49.5%
	Rural	101	50.5%
Occupation	Employed	59	29.5%
	Unemployed	149	70.5%
Education	Uneducated	103	51.5%
	Primary	41	20.5%
	University	56	28%
Diet adherence	Poor	129	64.5%
	Good	71	35.5%
Qat chewing	No	65	32.5%
	Yes	135	67.5%
Smoking	Yes	41	20.5%
	No	159	79.5%
Diabetic duration	≥ 5 years	134	67%
	< 5 years	66	33%
Hypertension	Yes	80	40%
	No	120	60%
Types of antihyperglycaemic drugs	Oral	168	84%
	Insulin + Oral	32	16%
Physical activity	Inactive	105	52.5%
	Active	95	47.5%
Family history of T2DM	No	77	38.5
	Yes	123	61.5%
BMI kg/m^2	Obese	46	23%
	Overweight	82	41%
	Normal	72	36%

BMI Body mass index, *T2DM* Type 2 Diabetes Mellitus

Results

Characteristics of the study population

Approximately half of the 200 patients who participated in this study were male (54%), over 50 (47.5%), uneducated (51.5%), and lived in rural areas (50.5%). The majority of the T2DM patients were unemployed (70.5%), had a habit of chewing Qat (67.5%), had poor diet adherence (64.5%), and were treated with oral antihyperglycaemic drugs (84%). Diabetes duration of ≥ 5 years, diabetes family history, and hypertension were determined in 67%, 61.5%, and 40% of the participants, respectively. The distribution of obesity and overweight was found in 23% and 41% of the participants, respectively. (Table 1).

Prevalence and patterns of poor glycemic control among study population

Glycemic control status of diabetic patients is shown in Fig. 1. The study's findings indicated that among patients with T2DM in Dhamar Governorate, Yemen, poor glycemic control (HbA1c > 8.0%) was at 58%, fair glycemic control (HbA1c 7–8%) was at 14%, and good glycaemic control (HbA1c 7%) was at 28%.

Correlation of average levels of FBS with HbA1c

Average levels of FBS were calculated as a mean of FBS in the past three months along with the last estimation during this study. Figure 2 showed that there was no correlation between HbA1c and FBS average in the study population.

Risk factors associated with prevalence of poor glycemic control status in T2DM

Univariate and multivariate analysis (Table 2) showed that patients who are treated with combined antihyperglycaemic

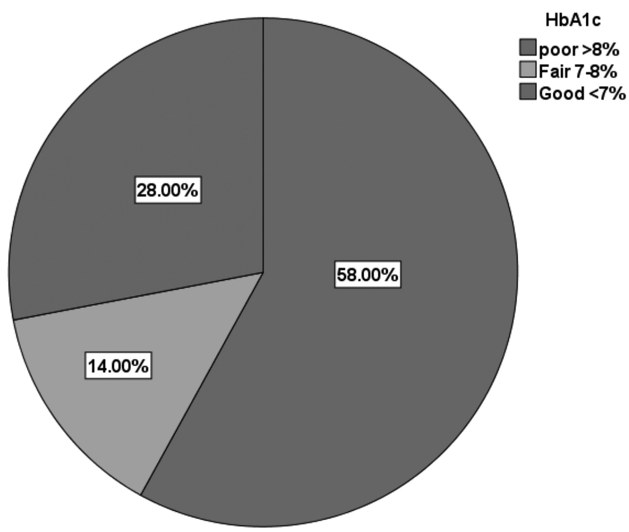

Fig. 1 Prevalence and patterns of poor glycemic control among study population

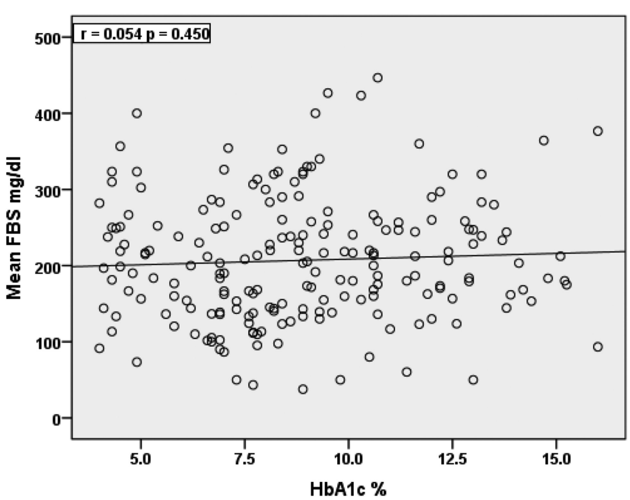

Fig. 2 Correlation of average levels of FBS with HbA1c

agents (insulin and oral medication), had poor diet adherence and uneducated diabetic patients are more likely to have poor glycemic control. Multivariate analysis with the adjusted odd ratio (AOR) showed that there is a greater chance of poor glycemic control among patients who are treated with combined antihyperglycaemic agents (AOR = 3.77; %CI = 1.36–10.44; $p = 0.011$), patients had poor diet adherence (AOR = 1.97; %CI = 1.03–3.77; $p = 0.041$), and patients with lack of education (AOR = 2.34; %CI = 0.93–5.90; $p = 0.051$). Diabetic patients with habit of Qat chewing showed a high probability of poor glycemic state (AOD = 1.97; %CI = 0.92–4.24; $p = 0.081$). Patients with a family history of diabetes or who smoke, on the other hand, are less likely to have poor glycemic control.

Prevalence and patterns of diabetic nephropathy among type 2 diabetes mellitus patients

Diabetic nephropathy is defined in terms of albuminuria in this study. The results estimate that among T2DM patients who participated in this study, 28% had microalbuminuria, 4% had macroalbuminuria, and 68% had normoalbuminuria (Fig. 3).

Factors associated with microalbuminuria among patients with T2DM

Univariate analysis indicated that variables that were associated with microalbuminuria were age > 50 years (OR = 3.31; %CI = 1.77–6.19; $p = 0.000$), hypertension (OR = 2.69; %CI = 1.46–4.95; $p = 0.002$), and uneducated patients (OR = 2.33; %CI = 1.10–4.94; $p = 0.027$). Multivariate analysis revealed that T2DM patients were more likely to have microalbuminuria if they had poor glycemic control (AOR = 2.67; %CI = 1.16–6.16; $p = 0.022$), had a diabetic duration of ≥ 5 years (AOR = 1.78; %CI = 1.05–3.00, $p = 0.031$), and had hypertension (AOR = 3.22; %CI = 1.39–7.47; $p = 0.006$). In patients of advanced age > 50 years (AOR = 2.37; %CI = 1.154.90; $p = 0.020$) and uneducated diabetics (AOR = 1.90; %CI = 1.16–3.11; $p = 0.010$), the probability of developing microalbuminuria is higher (Table 3).

Correlation of albumin/creatinine ratio with FBS, age, HbA1c and diabetic duration

The result of the present study indicates a positive correlation of age ($r = 0.300$; $p = 0.000$), HbA1c ($r = 0.160$; p 0.024), and diabetic duration ($r = 0.202$; $p = 0.004$) with albumin/creatine ratio (Table 4).

Discussion

Glycemic control is critical in preventing diabetes complications. The present study revealed for the first time the prevalence of poor glycemic control among Yemeni T2DM patients in Dhamar and determined the associated risk factors. The study also identified patterns of diabetic nephropathy as well as the relationship between glycemic control status and diabetic nephropathies. In this study, 200 type 2 diabetic patients were enrolled, of whom 108 (54%) were males.

Our study found that 58% of diabetic patients had poor glycemic control, which is similar to a study from Bangladesh that found that 54.7% of diabetic patients had poor glycemic control [23]. About 72% of the diabetic patients in this study did not achieve the recommended HbA1c target of less than 7%. This is in line with studies from Oman (65.0%), Jordan (65.1%), the

Table 2 Risk factors associated with prevalence of poor glycemic control status in T2DM

Variable		HbA1c > 8% Frequency %	OR; 95% CI; *p* value	AOR; 95% CI; *p* value
Age	≤ 50	58 (55.2%)	1	1
	> 50	58 (61.1%)	1.27; .072–2.23; 0.406	0.94; 0.47- 1.89; 0.858
Sex	Female	56 (60.9%)	1	1
	Male	60 (55.6%)	0.804; 0.46–1.41; 0.448	1.21; 0.516–2.84; 0.661
Diabetic duration	< 5 years	38 (57.6%)	1	1
	≥ 5 years	78 (58.2%)	1.03; 0.57–1.86; 0.932	0.83; 0.40–1.70; 0.608
Types of antihyperglycaemic drugs*¥	Oral	90 (53.6%)	1	1
	Oral + Insulin	26 (81.3%)	3.77; 1.47–9.59; 0.006	3.77; 1.36- 10.44; 0.011
Diet adherence*¥	Good	46(35.7%	1	1
	Poor	83 (64.3%)	2.08; 1.15–3.75; 0.015	1.97; 1.03–3.77; 0.041
Physical activity	Active	57 (60.0%)	1	I
	Inactive	59 (56.2%)	0.86; 0.49–1.50; 0.586	0.90; 0.46–1.73; 0.744
Hypertension	No	64 (53.3%)	1	1
	Yes	52 (65.0%)	1.63; 0.91–2.91; 0.103	1.54; 0.76–3.10; 0.231
Education*¥	University	25 (44.6%)	1	1
	Uneducated	67 (65.0%)	2.31; 1.19–4.49; 0.014	2.34; 0.93–5.90; 0.051
	Primary	24 (58.5%)	1.75; 0.78–3.95;0.178	1.65; 0.66–4.12; 0.282
Family history of diabetes*¥	No	52 (67.5%)	1	1
	Yes	64 (52.0%)	0.52; 0.29–0.94; 0.032	0.48; 0.24–0.95; 0.036
BMI	Normal	44 (61.1%)	1	1
	Overweight	45 (54.9%)	0.77;0.41–1.47; 0.435	0.57; 0.28–1.18; 0.131
	Obese	27 (58.7%)	0.90; 0.43–1.92; .794	0.71;0. 30–1.72; 0.450
Qat chewing	No	34 (52.3%)	1	1
	Yes	82 (60.7%)	1.41;0.78–2.56; .259	1.97; 0.92–4.24; 0.081
Smoking ¥	No	96 (60.4%)	1	1
	Yes	20 (48.8%)	0.625; 0.31–1.25; 0.182	0.42; 0.18–0.99; 0.049

BMI Body mass index, *OR* Odd ratio, *AOR* Adjusted odd ratio, *CI* Confidence interval, *HbA1c* Haemoglobin A1c

*: Significance in univariate analysis

¥: significance in multivariate analysis

Fig. 3 Prevalence and patterns of diabetic nephropathy among type 2 diabetes mellitus patients

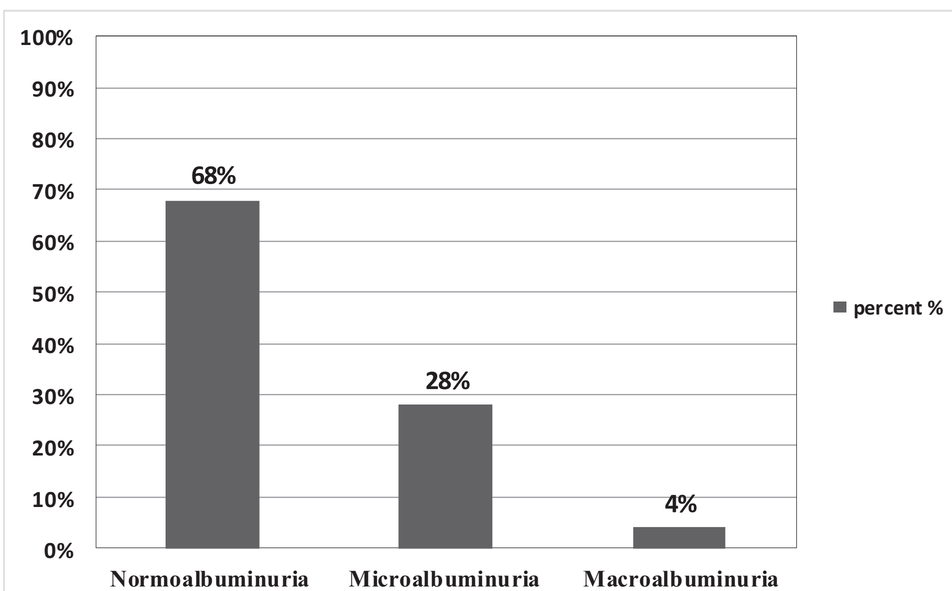

Table 3 Factors associated with microalbuminuria in patients with T2DM

Variable		Microalbuminuria	OR; 95% CI; *p* value	AOR; 95% CI; *p* value
Age[*¥]	≤50	21 (20%)	1	1
	>50	43 (45.3%)	3.31; 1.77- 6.19; 0.000	2.37; 1.15–4.90; 0.020
Sex	Female	26 (28.3%)	1	1
	Male	38 (35.2%)	1.38; 0.76- 2.52; 0.296	1.70; 0.69–4.17; 0.250
Diabetic duration[¥]	<5 years	18 (27.3%)	1	1
	≥5 years	46 (34.3%)	1.39; 0.73–2.67; 0.316	1.78;1.05–3.00, 0.031
Types of antihyperglycaemic drugs[¥]	Oral	50 (29.8%)	1	1
	Oral + Insulin	14 (43.8%)	1.84; 0.85–3.98; 0.123	2.05; 1.25–3.38; 0.031
Diabetic control status[¥]	Good	14 (25%)	1	1
	Fair	10(35.7%)	1.67; 0.63–4.45; 0.308	2.00; 0.75–5.33; 0.166
	Poor	40(34.5%)	1.58; 0.77–3.23; 0.211	2.67; 1.16–6.16; 0.022
Physical activity	Active	30 (31.6%)	1	1
	Inactive	34 (32.4	1.04; 0.57–1.88; 0.903	0.80; 0.39–1.65; 0.548
Hypertension[*¥]	No	28 (23.3%)	1	1
	Yes	36 (45%)	2.69; 1.46–4.95; 0.002	3.22; 1.39–7.47; 0.006
Education*¥	University	12(21.4%)	1	1
	Primary	12(29.3%)	1.52; 0.60–3.84; 0.378	0.54; 0.30–0.99; 0.045
	Uneducated	40 (38.8%)	2.33; 1.10–4.94; 0.027	1.90; 1.16–3.11; 0.010
Family history of diabetes	No	30 (39%)	1	1
	Yes	34 (27.6%)	0.60; 0.33–1.10; 0.096	0.78; 0.50–1.22; 0.276
BMI	Normal	26(36.1%)	1	1
	Overweight	26(31.7%)	0.82; 0.42–1.60; 0.564	0.70; 0.32–1.51; 0.361
	Obese	12(26.1%)	0.62; 0.28–1.41; 0. 257	0.39; 0.15–1.02; 0.055
Qat chewing	No	23(35.4%)	1	1
	Yes	41(30.4%)	0.80; 0.43–1.50; 0.477	0.67; 0.30–1.52; 0.341
Smoking	No	47 (29.6%)	1	1
	Yes	17(41.5%)	1.69; 0.83–3.43; 0.148	1.80; 1.71–4.52; 0.219

BMI Body mass index, *AOR* Adjusted odd ratio, *OR* Odd ratio, *CI* Confidence intervals

[*]: Significance in univariate analysis

¥: significance in multivariate analysis

Table 4 Correlation of albumin/creatinine ratio with FBS, age, HbA1c and diabetic duration

Correlation analysis	
Variable	Albumin/creatinine ratio
Age/ year*	$r = 0.230$ $p = 0.001$
FBS mg/dl	$r = 0.081$ $p = 0.256$
HbA1c %*	$r = 0.160$ $p = 0.024$
Duration of diabetes*	$r = 0.202$ $p = 0.004$

r Pearson Correlation, *HbA1c*: Haemoglobin A1c

[*]Significant $p < 0.05$

United Arab Emirates (69%), and Kuwait (78.8%) [13–15]. Additionally, several studies carried out in Saudi Arabia reported that 67.7%, 67.9%, and 74% of diabetic patients in Riyadh, Al Hasa, and Jazan, respectively, had poor glycemic control [12].

The current study found no correlation between FBS and HbA1c ($r = 0.054$; $p = 0.450$) (Fig. 2). Determination of HbA1c is the recommended method for determining glycemic status [5]. The estimation of HbA1c is the recommended procedure to determine the glycemic status [5]. In some countries, such as Yemen, it is often replaced by FBS. The blood glucose level reflects the glucose level at the time of measurement, while HbA1c reflects the average blood glucose level over the last 2 to 3 months. Therefore, HbA1c is suitable for monitoring long-term glycemic control and predicting the risk of developing diabetic complications in diabetic patients. Although many research studies have demonstrated a correlation between blood sugar and HbA1c, most of these studies evaluated the effectiveness of the HbA1c test in diagnosing diabetics. This relationship may seem acceptable, regardless of some of these studies have not found a perfect correlation between the measurement of FBS and HbA1c in the diagnosis of diabetes [24].

On the other hand, the acute daily blood glucose fluctuations that can be caused by diet, treatment types and stress seem to have little influence on the HbA1c result [25]. Furthermore, poor health education is regarded as a significant challenge among patients. Some patients regulate the quality of their meals and use discipline in applying therapies prior to the examination day in order to achieve good fasting blood sugar levels, which is not a common daily practice. All of these factors can have a significant impact on the correlation of FBS and HbA1c.

Univariate and multivariate logistic regression were used to study the risk factors for poor glycemic control (Table 2). According to multivariate logistic analysis results, combined antihyperglycaemic medications (oral + insulin), lack of education, and poor diet adherence were independently associated with poor glycemic control in T2DM patients. Hypertension and Qat chewing, on the other hand, were associated with a higher risk of poor glycemic control. A feasible explanation for why diabetic patients treated with combined antihyperglycaemic agents had a higher risk of poor glycemic control is that the patients who attempted this process of treatment struggled to maintain adequate glycemic control. A healthy diet is very important for people with diabetes. Each individual's diet should be tailored to their needs. Achieving good dietary adherence is a complex process that requires health education, family support, diet recommendations, and financial support. This is particularly difficult in Yemen due to economic problems and lack of health services. Therefore, it is not surprising to find in this study a high percentage of patients with poor dietary state (64.5%) who are approximately twice as likely to have poor glycemic control (AOR = 1.97). Education is the most fundamental and important way to promote a healthy lifestyle and blood sugar control. Diabetic patients in this study with a lack of education had a 2.34 times greater risk of having poor glycemic control. These results were consistent with previous studies [12, 13, 16, 26]. Although duration of diabetes and physical activity have been reported to be factors determining the degree of glycemic control [12, 16, 26], we did not find a significant association in this study. In addition, it was found that diabetics with a family history of diabetes mellitus were less likely to have poor glycemic control (AOR = 0.48; %CI = 0.240.95; $p = 0.036$). This may be attributed to the fact that individuals with a family history of diabetes mellitus were more knowledgeable about the illness than others. Qat is a type of plant (Catha edulis) that is chewed for its stimulant effect. In Yemen, chewing Qat is a common habit among adults. Unfortunately, there is a misconception among diabetics that chewing Qat lowers blood sugar levels, although many studies have shown an adverse effect [27].

The current study has also evaluated the prevalence and risk factors of diabetic nephropathy. Microalbuminuria was found in 28% of the cases in this investigation, while macroalbuminuria was found in 4%. (Fig. 3). The prevalence of microalbuminuria in this study was in line with other studies conducted in Bahrain, Kuwait, and Egypt [28–30]. Further, macroalbuminuria in this study was found lower than that reported in Kuwait, Egypt, Taiwan, and Thailand [29–32]. In Yemen, the prevalence of microalbuminuria and macroalbuminuria was reported to be 21.2% and 12.4% [33]. The possible reasons for the variations in the prevalence of albuminuria could be attributed to diagnostic criteria, population selection, and the laboratory methodology used in the estimation of urine albumin.

Multivariate analysis with AOD revealed that age > 50 years, hypertension, poor glycemic control, diabetic duration ≥ 5 years, and poor education were potential risk factors associated with developing microalbuminuria in T2DM patients (Table 3). It has been reported in several studies that age, duration of diabetes, high blood pressure, and persistent hyperglycaemia play a significant role in the development of diabetic nephropathy [34, 35]. In addition, the mechanism of albuminuria associated with hypertension is due to hemodynamic changes in the kidneys that compromised the permeability of the glomeruli and caused structural damage to the glomeruli and arterioles. There is strong evidence that prolonged exposure to hyperglycaemia results in non-enzymatic glycosylation of proteins and lipids and increased production of advanced glycosylation end products (AGEs), activation of the polyol pathway, activation of protein kinase C, and increased production of reactive oxygen species. All these metabolic changes are believed to play an important role in the pathogenesis of nephropathy. Furthermore, our study found a positive correlation between age ($r = 0.300$; $p = 0.000$), HbA1c ($r = 0.160$; $p = 0.024$) and diabetes duration ($r = 0.202$; $p = 0.004$) with the albumin/creatinine ratio.

The current study has the advantage of accurately reflecting the glycemic control status of T2DM patients. Unlike most previous studies, this study utilized standard biomarkers for the determination of glycemic control and diabetic nephropathy. Despite the fact that the study's results were similar to those in many of its neighboring countries, the findings in a nation like Yemen, which is plagued by serious economic problems, political unrest, and a dearth of studies on conditions related to glycemic control, will be of great importance to many international organizations and health offices throughout the country. This might motivate the appropriate authorities to take the required actions to minimize this condition and try to address the risk factors in the relevant ways. In contrast, the findings of this study have to be seen in light of some limitations. First, through a cross-sectional study, we could not establish a cause-and-effect relationship between the risk factors and poor glycemic control as well as diabetic nephropathy, however, the result of this study still triggers a warning to the health authority that there is an urgent need for glycemic management. Second, since the present study was only conducted in the city of Dhamar and included a small sample size, the results may not be generalizable to the general diabetic population in Yemen. Third, as the study was concerned with glycemic control status and diabetic nephropathy, other diabetes-related complications, such as retinopathy or neuropathy, were not investigated. Finally, some self-reported data, such as diet adherence, physical activity, and Qat chewing, may be subject to recall and social desirability bias.

Conclusion

Based on this study, it is clear that a significant number of diabetic patients in Dhamar, Yemen have uncontrolled blood glucose levels and diabetic nephropathy, which can lead to more complications and greatly complicate the healthcare of the patients. Health care professionals need to focus on the modified risk factors for diabetes and diabetic nephropathy in order to help improve glycemic control and reduce the impact of complications on these patients. Long-term follow-up studies are recommended to evaluate the effect of antihyperglycaemic medications on glycemic control status and the impact of poor glycemic control on the development of diabetic complications.

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Author Contributions Abdulqawi A Al- Shammakh, Abdul Haleem S Al-Tamimi and Qaid T Qaid designed the study and planned the experiments. Abdulqawi A Al- Shammakh analysed the data, explained the results and wrote the manuscript. Abdul Haleem S Al-Tamimi contributed in the discussion of the results. Qaid T Qaid, Faheem Q Al-Mojahid performed the laboratory tests. All authors reviewed the results and approved the final version of the manuscript.

Declarations

Ethical clearance All eligible patients were given a written informed consent form to sign. The study was approved by the ethical committee of Thamar University.

Conflict of interest The authors report no conflicts of interest in this work.

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