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Research Article
Assessment of Lipid Profiles, Thyroxin and Uric Acid Levels in Patients with Type 2 Diabetes Mellitus in Taiz, Yemen

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Abstract

Background and Objective: The link between diabetes mellitus (DM) and thyroid dysfunction is well-known, but prevalence rates vary. Thyroid abnormalities in diabetic patients can impact metabolic control and clinical outcomes. This study assesses Thyroxin (T4) levels and their relationship with biochemical parameters among Yemeni patients with DM in Taiz. **Materials and Methods:** A total of 88 participants were enrolled, including 44 diabetics and 44 healthy controls, matched by age and sex. Data were collected via questionnaires and serum samples analyzed for T4, fasting blood glucose (FBG), cholesterol, triglycerides and HDL. Comparisons and correlations were statistically evaluated. Data were analyzed using SPSS v20, with results expressed as Mean±SD or percentages and associations tested by chi-square at $p<0.005$. **Results:** Diabetic patients showed significantly lower FT4 levels and higher FBG, with both increasing with disease duration. A positive correlation was observed between FT4 and FBG, as well as cholesterol. Males had higher cholesterol levels than females and triglycerides increased with age. The HDL was decreased in diabetics. BMI and weight gain were associated with age and disease duration. Notably, FT4 was lower in diabetics, correlating with higher glucose and BMI. Significant associations were also found between diabetes and hypertension, medication use, education and smoking. **Conclusion:** The study indicates a significant association between DM and reduced FT4 levels, suggesting a link with thyroid dysfunction such as goiter. These findings highlight the need for routine thyroid assessment in diabetics. Further research is necessary to explore long-term implications.

Key words: Diabetes mellitus, thyroxin (T4), biochemical parameters, Yemen, thyroid dysfunction, metabolic profile

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Thyroid dysfunction (TD) refers to disorders involving impaired thyroid activity, including both hypothyroidism and hyperthyroidism. These conditions arise from imbalances in the secretion of thyroid hormones, namely thyroxine (T4) and triiodothyronine (T3), which play essential roles in regulating metabolism, as well as supporting normal growth and physiological development. The global occurrence of TD differs widely across populations and is affected by several factors, including variations in iodine consumption, genetic susceptibility and environmental conditions[1].

Hypothyroidism affects approximately 1-2% of the general population, with higher rates observed among women and older adults, while hyperthyroidism impacts around 0.2-1%[2]. Although thyroid dysfunction is widely prevalent, it is frequently overlooked in clinical practice because its manifestations are often vague and not disease-specific. Common symptoms such as fatigue, changes in body weight, sensitivity to cold and alterations in mood can be easily attributed to other conditions, leading to delayed diagnosis. In contrast, Diabetes Mellitus (DM), especially Type 2 Diabetes Mellitus (T2DM), is a long-term metabolic condition marked by sustained elevation of blood glucose levels, primarily due to impaired insulin action, insufficient insulin production, or a combination of both[3]. The global burden of T2DM has escalated dramatically over recent decades, with estimates indicating over 460 mL affected adults and projections suggesting continued growth[4]. The coexistence of TD and T2DM has gained increasing attention due to the overlapping pathophysiological mechanisms and shared risk factors such as obesity, metabolic syndrome and sedentary lifestyles. Studies have reported that the prevalence of thyroid dysfunction among diabetic populations ranges from 10 to 32%, underscoring a significant association between these conditions[5].

The link between TD and T2DM is multifaceted and bidirectional. Thyroid hormones influence glucose metabolism by modulating hepatic gluconeogenesis, glucose absorption and insulin sensitivity[6]. Hypothyroidism can lead to dyslipidemia, weight gain and reduced metabolic rate, thereby increasing insulin resistance. Conversely, hyperthyroidism accelerates metabolic activity, which may result in increased hepatic glucose production and challenges in glycemic control. Additionally, thyroid autoimmunity, such as Hashimoto's thyroiditis and Graves' disease, often coexists with autoimmune processes affecting pancreatic β-cells, further complicating metabolic regulation[7]. In regions like Yemen, the prevalence of diabetes has risen sharply over the past two decades, driven by lifestyle changes, urbanization and nutritional factors. The prevalence of diabetes increased from 4.7% in 2000 to 6.57% in 2004, emphasizing the growing public health challenge. Despite this trend, limited data exist specifically examining the prevalence and impact of thyroid dysfunction among diabetic populations in Yemen, highlighting the need for localized research to inform targeted screening and intervention strategies[8] According to a study conducted in Sana'a, Yemen, by Saeedi *et al.*[9], the prevalence of diabetes mellitus among adults was found to be approximately 8.2%. The research identified several risk factors associated with the condition, including obesity, lack of physical activity and a family history of diabetes. The study highlights the increasing burden of diabetes in Yemen. It underscores the urgent need for effective screening and intervention strategies to address this growing public health challenge in the region. On the other hand, studies of Yemeni patients with diabetes have shown significant changes in thyroxine (T4) levels and other biochemical parameters. These abnormalities can complicate disease management, highlighting the importance of comprehensive screening for blood glucose, lipids and thyroid hormones to better understand their relationships and improve treatment outcomes in Yemen[10]. Understanding the interrelationship between TD and T2DM is critical for improving clinical outcomes. The coexistence of these disorders can exacerbate metabolic disturbances, increase the risk of cardiovascular complications and complicate disease management. Recognizing thyroid abnormalities in diabetic patients allows for tailored treatment approaches, potentially improving glycemic control and reducing morbidity. As both conditions continue to rise globally, especially in developing countries, elucidating their connection remains a priority for healthcare systems aiming to reduce the burden of endocrine and metabolic diseases[11].

This study aims to assess serum free thyroxine (FT4) levels and various biochemical parameters in Yemeni patients with diabetes mellitus in Taiz city, Yemen. It seeks to explore the associations between FT4 and factors such as fasting blood glucose, uric acid, BMI, height and weight, as well as evaluate the levels of glucose, lipids and uric acid in the participants. Additionally, the study aims to determine the prevalence of diabetes mellitus across genders and examine the relationships between thyroid function, metabolic parameters and lipid profiles in both males and females.

MATERIALS AND METHODS

Study area: The study was conducted from January 2 to March 2, 2023, in Taiz Al-Hawban, Yemen.

Study design: A matched case-control study design was employed; the specimens were analyzed at the University of Science and Technology. The sample size was determined to be 88 participants, with 44 individuals diagnosed with diabetes and 44 non-diabetic controls.

Ethical approval: This study was reviewed by the committee of the Medical Laboratory Department, Faculty of Medicine and Health Sciences, University of Science and Technology, Taiz, Yemen.

Source and study population: The source populations consisted of T2DM patients who had follow-up and treatment in selected private hospitals. Randomly selected T2DM patients with unknown TD and without T2DM (controls) comprised the study population.

Inclusion criteria: Patients without a diagnosis of any type of diabetes mellitus and not receiving treatment for thyroid dysfunction. T2DM patients who have not undergone FT4 assessment, are not receiving treatment for thyroid dysfunction, and have been on diabetes treatment for at least one year.

Exclusion criteria: Patients who are currently taking or have previously taken amiodarone or who have undergone contrast imaging. Additionally, patients whose FT4 levels have been tested and whose thyroid dysfunction status is known are excluded.

Questionnaire administration: Demographic characteristics and the effects of thyroid dysfunction, including associated symptoms and complications in individuals with Type 2 Diabetes Mellitus (T2DM), were obtained from each participant and documented using a structured questionnaire. The collected data encompassed personal information such as name, age, gender, contact number, smoking status, educational level, occupation and employment status. Additionally, clinical parameters, including blood pressure, family history of thyroid or diabetic conditions, presence of diabetic complications and treatment modalities, were recorded. Biochemical measurements and calculations included serum free thyroxine (FT4) levels, fasting blood glucose, cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), uric acid levels, as well as anthropometric data such as height (cm) and weight (kg).

Study variables

Dependent variable: Thyroid dysfunction among patients with type 2 diabetes mellitus.

Independent variables: Socio-demographic factors: age, gender, educational status, duration of diabetes, occupation. Lifestyle factors: Smoking status.

Knowledge and behavioral factors: Adherence to diabetes self-management practices and awareness of target blood glucose levels.

Clinical and treatment-related factors: Presence of chronic diabetic complications, clinical signs of thyroid dysfunction and laboratory parameters including blood glucose levels, lipid profile components (total cholesterol, LDL cholesterol, triglycerides, HDL cholesterol, non-HDL cholesterol) and serum uric acid levels.

Method of analysis: Quantitative determination of uric acid, glucose, triglycerides, cholesterol and HDL cholesterol was performed using a spectrophotometer (Hamburg, Germany). The TC96 ELISA MIROPLATE READER was employed for the measurement of free thyroxine (FT4). Low-Density Lipoprotein Cholesterol (LDL-C) levels were estimated using the Friedewald formula, a commonly applied calculation method in clinical practice that remains widely validated in contemporary studies[12]:

$$\text{LDL} - \text{C} = \text{Total cholesterol} - \text{HDL} - \text{C}\left(\frac{\text{Triglycerdes}}{5}\right)$$

Sample processing: A total of 88 blood samples were collected from patients with type 2 diabetes mellitus (T2DM) and non-diabetic controls. All participants fasted for at least 8-10 hrs overnight. A 5 mL venous blood sample was drawn in a disposable syringe in the morning, before breakfast, for serum lipid profile, fasting blood glucose, FT4 and uric acid analysis. The blood was then dispensed into a clot activator tube (without anticoagulant) and allowed to clot at room temperature (25°C). Serum was separated by centrifugation at 3000 rpm for 10 min using a Beckman Coulter centrifuge (USA) and an Allegra® X-12R centrifuge (China). The serum and plasma samples were immediately aliquoted into microtubes for the respective tests. All patients provided informed consent to participate in the study.

Biochemical test reagents: The use of specific clinical chemistry reagent kits from different systems includes Spin React for uric acid, SGM for glucose, HDL cholesterol and triglycerides and Lab Kit for total cholesterol.

Clinical assessments: Anthropometric data, including body weight (kg) and height (m), were recorded using a calibrated digital scale (Seca GmbH & Co. KG, Germany). The Body Mass Index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m^2). Based on standard international criteria, participants were classified into four distinct categories: underweight, normal weight, overweight, and obesity, according to the referenced guidelines[13].

Outcome variables: Subjects with uric acid (UA) levels >7.0 mg/dL for men and >5.7 mg/dL for women were classified based on WHO diagnostic criteria. Fasting Blood Glucose (FBG) was used to assess diabetes mellitus (DM), with a prevalence defined as FBG ≥126 mg/dL or a self-reported history of diabetes diagnosed by a healthcare professional. Impaired Fasting Glucose (IFG) was defined as FBG between 100-125 mg/dL.

Lipid profiles included measurements of i) Low-Density Lipoprotein Cholesterol (LDL-C): Normal range 50-100 mg/dL, ii) High-Density Lipoprotein Cholesterol (HDL-C): Normal range 40-100 mg/dL in males and 50-110 mg/dL in females, iii) Triglycerides (TG): Normal range 60-150 mg/dL iv) Total Cholesterol (TC): Normal range 140-200 mg/dL

Hypercholesterolemia was defined as TC ≥200 mg/dL. HDL-C was considered low if <40 mg/dL in males and <50 mg/dL in females. LDL-C was high if ≥100 mg/dL and triglycerides were elevated if ≥150 mg/dL. Dyslipidemia was identified when one or more of these lipid abnormalities were present, following the NCEP ATP III criteria. Atherogenic dyslipidemia was characterized by elevated triglycerides and low HDL-C, as per the International Diabetes Federation.

Thyroid function was assessed using FT4 levels measured by a kit, with normal adult ranges from 0.8 to 2.0 ng/dL and in pregnancy from 0.76 to 2.24 ng/dL. Hypothyroidism was defined as FT4 <0.8 ng/dL and hyperthyroidism as FT4 >2.0 ng/dL.

Biochemical analysis: Biochemical parameters, including glucose, FT4, triglycerides, uric acid, total cholesterol, HDL-cholesterol and LDL-cholesterol, were measured on the day of blood collection at the Division of Biochemistry, Faculty of Medicine and Health Sciences, University of Science and Technology, Taiz, Yemen.

Measurement of glucose: Fasting blood glucose (FBG) levels were determined enzymatically using the glucose oxidase-peroxidase method with a semi-automated spectrophotometer (Model RT-9200, Rayto, Hamburg, Germany). Patients with FBG ≥126 mg/dL were classified as diabetic, while those with FBG between 100-125 mg/dL were considered to have impaired fasting glucose (IFG)[14].

Measurement of triglycerides (TG): Serum triglyceride levels were measured enzymatically using a semi-automated spectrophotometer (Model RT-9200, Rayto, Hamburg, Germany). Hypertriglyceridemia was defined as TG levels exceeding 200 mg/dL[15].

Measurement of cholesterol: Total cholesterol was measured enzymatically using cholesterol esterase, cholesterol oxidase and peroxidase assays with a semi-automated spectrophotometer (Model RT-9200, Rayto, Hamburg, Germany). Hypercholesterolemia was defined as a total cholesterol level of ≥200 mg/dL, according to the American Diabetes Association[16].

The HDL-Cholesterol levels were measured using the PEG 6000 precipitating method with a semi-automated spectrophotometer (Model RT-9200, Rayto, Hamburg, Germany). The HDL-C was classified as low if levels were below 40 mg/dL in males and below 50 mg/dL in females, in accordance with the American Diabetes Association (2004) guidelines.

Measurement of uric acid: Serum uric acid levels were determined enzymatically using a semi-automated spectrophotometer (Model RT-9200, Rayto, Hamburg, Germany). Hyperuricemia was defined as serum uric acid levels exceeding 6.8 mg/dL in males and 7.7 mg/dL in females[17].

Measurement of free thyroxine (FT4): FT4 levels were quantified using the TC96 ELISA kit and read with the MIROPLATE READER (SGMA, UK/Italy). The manufacturer's reference ranges for FT4 were 0.8-2.0 ng/dL for non-pregnant adults and 0.76-2.24 ng/dL during pregnancy[18].

Statistical analysis: The study used statistical methods to analyze demographic and biochemical data, presenting numerical data as means and standard deviations and categorical data as counts and percentages. Chi-square tests evaluated associations between FT4 levels and other variables, with significance set at p<0.005. Analyses were performed using SPSS version 20.

RESULTS

Demographic characteristics of the sample: Table 1 presents the general demographic variables (gender, age, educational status - job) of the study sample, which comprised a total of 88 individuals. The distribution by gender revealed a higher proportion of females (n = 50, 56.8%) compared to males (n = 38, 43.2%). The age of participants ranged from 15 to 75 years, with a mean age of 44.33 years (SD = 16.60). The sample was stratified into three age groups, with the highest representation observed in the over-50 age group, accounting for 47.7% of the total sample. Regarding educational attainment, the majority of participants were unlettered, constituting 39.8% of the sample. Distribution by occupational status included categories such as traders, civil servants, students, unemployed individuals and others, with the "others" category representing the highest percentage at 58%. These findings provide a comprehensive overview of the demographic profile of the study population.

Associations between lipid profiles and demographic and clinical factors: This study examines the associations between lipid profile parameters namely total cholesterol, triglycerides, HDL and LDL and various demographic and clinical factors, including gender, incidence of diabetes, duration of infection, goiter presence and age. Table 2 presents the results of statistical analyses assessing these relationships. Specifically, it details the mean values, standard deviations and p-values derived from t-tests and ANOVA to evaluate the significance of observed differences. Regarding gender differences, the analysis reveals a statistically significant association (p<0.05), with females exhibiting higher mean HDL levels compared to males. Similarly, the presence of diabetes is significantly associated with decreased HDL levels (p<0.05). Furthermore, the duration of infection significantly influences lipid profiles; longer disease duration correlates with alterations in lipid levels, notably a decrease in HDL and triglycerides, as demonstrated by one-way ANOVA (p<0.05). Additionally, thyroid enlargement is significantly associated with increased triglyceride levels (p<0.05). Age stratification analysis indicates that older age groups exhibit a significant increase in triglyceride levels and a concomitant decrease in HDL levels (p<0.05), suggesting age-related alterations in lipid metabolism.

Associations between biochemical, demographic and clinical variables in patients: A statistical analysis: The statistical analysis explores the relationships between FBG levels, uric acid, BMI, height and weight in relation to demographic and clinical variables such as gender, age groups, diabetes status and duration of infection (Table 3). The results include mean values, standard deviations and p-values obtained through t-tests and ANOVA, with a significance threshold set at 0.05. Regarding gender differences, the analysis indicates a statistically significant association (p<0.05), with males exhibiting higher mean heights in relation to FBG and height levels. Concerning diabetes status, patients with diabetes show significant increases in mean levels of FBG, BMI, height and weight, alongside a significant decrease in serum FT4 levels compared to non-diabetic individuals (p<0.05). Age-related differences are also evident; one-way ANOVA results reveal a statistically significant effect (p<0.05), with older age groups demonstrating elevated mean levels of BMI and weight. Conversely, no significant association was found between thyroid enlargement and levels of FBG, uric acid, BMI, height, or weight (p>0.05). Furthermore, the analysis indicates that increasing age significantly correlates with higher mean BMI and weight levels (p<0.05), underscoring age-related variations in body composition parameters.

Associations of FT4 with lipid and glucose metabolism: The results from correlation analyses (Pearson and Spearman tests) examined the relationships between free thyroxine (FT4) levels and various lipid parameters, including total cholesterol, triglycerides, HDL and LDL, as well as other clinical and demographic variables, such as fasting blood glucose (FBG), uric acid, body mass index (BMI), height and weight. At a significance level of 0.05, the analyses revealed a statistically significant association between FT4 and total cholesterol (p<0.05), indicating that fluctuations in FT4 levels are significantly correlated with cholesterol concentrations. Additionally, significant correlations were

Table 1: General characteristics of demographic variables

Veritable	Frequency	Percent
Gender		
Male	38	43.2
Female	50	56.8
Total	88	100
Age		
18-33	30	34.1
34-49	16	18.2
More than 50	42	47.7
Total	88	100
Educational status		
Unlettered	35	39.8
Primary	17	19.3
Secondary	13	14.8
High	23	26.1
Total	88	100
Job's		
Trader	2	2.3
civil servants	9	10.2
Student	12	13.6
No employments	14	15.9
Other	51	58
Total	88	100
Age		
Minimum	18	
Maximum	75	
Mean±SD	44.33±16.60	

Data are presented as frequency (n) and percentage (%), Age is expressed as minimum, maximum and Mean±Standard Deviation (SD) and SD: Standard deviation

Table 2: Relationship between the level of lipids (cholesterol, triglyceride, HDL, LDL) and the gender, incidence of diabetes, duration of infection, goiter and age

	Level of lipids							
Parameter	Cholesterol	p value	Triglyceride	p value	HDL	p value	LDL	p value
Gender								
Male (N = 38)	157.66±48.10	0.583	152.76±111.05	0.735	3.37±21.32	0.043*	72.32±42.94	0.908
Female (N = 50)	164.48±63.5		159.78± 83.09		62.89±21.81		71.04±60.82	
Incidence of diabetes								
Yes (N = 44)	162.76±50,82	0.842	175.19±107.81	0.067	52.46±23.09	0.006*	75.26±44.107	0.524
No (N = 44)	160.31±63,53		136.40±87.31		65.10±19.08		67.93±61.89	
Duration of infection (Years)								
1-5	159.39±58.69	0.155	133.62±80.99	0.028*	65.37±19.162	0.001**	67.29±56.83	0.141
6-10	153.02±50.123		193.42±127.73		46.21±20.61		68.12±43.89	
More than 11	193.56±59.73		185.23±87.37		53.35±26.73		103.16±50.31	
Goiter		0.456		**0.000		0.078		
Yes (N = 4)	159.5±62.80		215.37±250.68		41.60±33.33		74.82±31.66	0.559
No (N = 84)	161.63±57.34		152.96±88.99		59.60±21.26		71.44±54.49	
Age (Years)								
18-33 (N = 30)	157.01± 42.68	0.406	116.48±53.58	0.006**	65.79±18.86	0.170	67.93±42.92	0.316
34-49 (N = 16)	148.76±33.76		140.5±63.68		63.74±23.68		56.92±30.46	
More than 50 (N = 42)	169.63±71.37		189.70±122.80		58.78±21.80		71.59±53.55	

Values are expressed as Mean±Standard Deviation (SD), LDL: Low-density lipoprotein (mg/dL), HDL: High-density lipoprotein (mg/dL), Triglycerides (mg/dL): Cholesterol (mg/dL), N: Number of participants, p value: Probability value used to determine statistical significance. : Statistically significant ($p<0.05$) and **: Highly statistically significant ($p<0.01$)

observed between FT4 and FBG ($p<0.05$), suggesting an association between thyroid function and glycemic regulation. These findings imply that FT4 may influence lipid metabolism and glucose homeostasis within the studied population (Table 4).

Evaluation of the association between thyroid gland enlargement and diabetes mellitus: A Cross-Sectional analysis: The prevalence of thyroid gland enlargement within the sample was 4.5%. This prevalence was evenly distributed, with 2.3% of participants exhibiting both thyroid

Table 3: Association between (FT4 - FBG - Uri. Acid – BMI – Height –Weight) and the gender, incidence of diabetes, duration of infection, goiter and age

	FT4	p value	FBG	p value	Uri. Acid	p value	BMI	p value	Height	p value	Weight	p value
Gender												
Male (N = 38)	0.89±0.679	0.389	134.44±89.14	0.016*	4.926±1.65	0.082	23.33±4.37	0.786	163.29±7.62	0.000**	61.68±13.26	0.096
Female (N = 50)	1.02±0.692		107.97±63.82		4.354±1.39		23.09±4.07		157.16±6.60		57.60±9.47	
Incidence of diabetes												
Yes (N = 44)	0.80±0.716	0.020*	158.76±90.99	0.000**	4.59±1.6755	0.983	24.44±4.41	0.004**	161.55±7.75	0.032*	63.48±12.81	0.001**
No (N = 44)	1.13±0.615		80.05±19.55		4.605±1.38		21.94±3.57		158.07±7.23		55.25±794	
Duration of infection (Years)												
1-5	1.03±0.623		91.13±37.55		4.530±1.47		22.64±4.16		158.89±7.69		57.43±11.167	
1-10	0.80±0.554	0.383	156.27±99.28	0.000**	4.754±1.72	0.839	24.04±3.90	0.299	161.04±8.03	0.358	62±10.68	
More than 11	1.169±0.37		183.64±100.1		4.620±1.46		24.15±4.86		161.80±6.30		63.50±12.88	0.124
Goiter												
Yes (N = 4)	0.88±0.854		102.27±20.88		4.50±1.14		25.42±3.73		162±6.78		65.25±7.54	
No (N = 84)	0.97±0.682	0.79	120.22±78.09	0.649	4.60±1.55	0.893	23.09±4.19	0.278	159.70±7.71	0.561	59.08±11.48	
Age (Years)												0.292
18-33 (N = 30)	1.08±0.824		108.40±78.20		4.153 ± 1.02		21.04 ± 2.80		160±6.983		53.30±6.041	
34-49 (N = 16)	1.12±0.506	0.181	128,313±83.6	0.618	4.394±1.845	0.056	23.57±4.40	0.001*	158.31 ±8.3	0.688	59.81±10.271	
More than 50 (N = 42)	0.82±0.619		123.87±73.38		5±1.62		24.59 ±4.36		160.24 ±8.0		63.52±12.875	0.001*

Values are presented as Mean±Standard Deviation (SD), FT4: Free thyroxine (ng/dL), FBG: Fasting blood glucose (mg/dL), Uri. Acid: Uric acid (mg/dL), BMI: Body mass Index (kg/m^2), Height (cm), Weight (kg), N : Number of participants, P value indicates statistical significance, •: Statistically significant (p<0.05) and **: Highly statistically significant (p<0.01)

Table 4: Association between thyroid hormone (FT4) and the variables such as lipid level (cholesterol- triglyceride- HDL- LDL) and (FBG – Uric Acid - BMI - Height -Weight

FT4	Cholesterol	Triglyceride	HDL	LDL	FBG	Uric Acid	BMI	Height	Weight
Pearson correlation (R)	-0.077	-0.171	0.0010	-0.019	-0.156	-0.008	-0.030	-0.062	-0.076
p-value	0.474	0.1100	0.996	0.859	0.147	0.940	0.782	0.565	0.483
Spearman correlation (R)	-0.233	-0.094	-0.093	-0.150	-0.287	0.046	-0.085	-0.043	-0.106
p-value	0.029*	0.383	0.389	0.164	0.007**	0.667	0.433	0.688	0.324

Pearson correlation (R) and Spearman correlation (R) coefficients are used to measure the strength and direction of association, FT4: Free thyroxine, FBG: Fasting blood glucose, BMI: Body mass index, HDL: High-density lipoprotein, LDL: Low-density lipoprotein, p value indicates statistical significance, : Statistically significant (p<0.05) and **: Highly statistically significant (p<0.01)

Table 5: Association between diabetes and the presence of an enlarged thyroid gland

			DM			
DM With the presence of goiter			Yes	No	Total	p value
The presence of goiter	Yes	Count %	2 (2.3)	2 (2.3)	4 (4.5)	0.692
	No	Count %	42 (47.7)	42 (47.7)	84 (95.5)	
Total		Count %	44 (50)	44 (50)	88 (100)	

Data are presented as count (n) and percentage (%), DM: Diabetes Mellitus and p value indicates the statistical association between diabetes and the presence of goiter

Table 6: Association between diabetes and high blood pressure:

			Blood pressure			
Blood pressure with DM			Yes	No	Total	p value
DM	Yes	Count %	20 (22.7)	24 (27.3)	44 (50)	0.000
	No	Count %	3 (3.4)	41 (46.6)	44 (50)	
Total		Count %	23 (26.1)	65 (73.9)	88 (100)	

Data are expressed as count (n) and percentage (%), DM: Diabetes Mellitus and p value indicates the statistical association between diabetes and blood pressure status

Table 7: Association between gender and qualification (educational status) with the use of a treatment for diabetes, type of treatment, multiple diabetes, middle obesity, genetic history of diabetes, duration of infection and blood pressure

	Using a treatment for diabetes			Type of treatment				Multiples of diabetes			
Gender	Yes	No	p value	Anti-diabetes tablet	Insulin use	No	p value	DM retinopathy	Peripheral neuropathy	No	p value
Male (N = 38)	28 (31.8)	10 (11.4)	0.001**	16 (18.2)	12 (13.6)	10 (11.4)	0.001**	10 (11.4)	1(1.1)	27 (30.7)	0.0063
Female (N = 50)	14 (15.9)	36 (40.9)		9 (10.2)	5 (5.7)	36 (40.9)		4 (4.5)	1(1.1)	45 (51.1)	
	Using a treatment for diabetes			Type of treatment				Middle obesity			
Educational status	Yes	No	p value	Anti-diabetes tablet	Insulin use	No	P value	Yes		No	p value
Unlettered	21 (23.9)	14 (15.9)	0.001**	12 (13.6)	9 (10.2)	24.444±4.41	0.003**	14 (15.9)		21 (23.9)	0.046*
Primary	13 (14.8)	4 (4.5)		9 (10.2)	4 (4.5)	21.94±3.5		6 (6.8)		11 (12.5)	
Secondary	4 (4.5)	9 (10.2)		1 (1.1)	3 (3.4)	21(23.9)		4 (4.5)		9 (10.2)	
High	4 (4.5)	19 (21.6)		3 (3.4)	1 (1.1)	9 (10.2)		2 (2.3)		12 (13.6)	
	Genetic history of b diabetes			Duration of infection				Blood pressure			
Gender	Yes	No	p value	1-5	6-10	More than 11	p value	Yes		No	p value
Male (N = 38)	21 (23.9)	17 (19.3)	0.500	14 (15.9)	15 (17)	9 (10.2)	0.1330	13 (14.8)		25 (28.4)	0.001*
Female (N = 50)	24 (27.3)	26 (29.5)		40 (45.5)	9 (10.2)	1 (1.1)		10 (11.4)		40 (45.5)	

Data are presented as count (n) and percentage (%) unless otherwise specified, DM: Diabetes mellitus, Peripheral neuropathy: Nerve damage associated with diabetes, Retinopathy: Eye disease related to diabetes, BMI: Body mass index (kg/m^2), p value indicates statistical significance, •: Statistically significant ($p<0.05$) and **: Highly statistically significant ($p<0.01$)

Table 8: The Association between smoking, diabetes and goiter

Smoking, with diabetes and an enlarged thyroid gland	Smoking	N	Percent	p-value
DM	Yes	17	18.18	0.000*
	No	71	80.68	
Total		88	100	
An enlarged thyroid gland	Yes	16	18.18	0.496
	No	71	80.68	
Total		88	100	

Data are expressed as frequency (n) and percentage (%), DM: Diabetes mellitus, p value indicates the statistical association between smoking, diabetes and goiter and •: Statistically significant ($p<0.05$)

enlargement and diabetes and another 2.3% exhibiting thyroid enlargement without diabetes. The Chi-square analysis indicated no statistically significant association between thyroid enlargement and diabetes ($p>0.05$), suggesting that the presence of an enlarged thyroid gland is not significantly correlated with diabetic status in this cohort (Table 5).

Significant association between diabetes mellitus and hypertension in the study population: Table 6 illustrates the association between diabetes mellitus and hypertension, where the prevalence of elevated blood pressure within the study population is 26.1%. Among males, the prevalence is higher in individuals with diabetes (22.7%) compared to those without diabetes (3.4%). The results of the Chi-square test yield a statistically significant p-value ($p<0.05$), indicating a significant association between diabetes mellitus and hypertension in this sample.

Associations between educational status and diabetes treatment modalities, obesity prevalence and related health factors: A cross-sectional analysis: As presented in Table 7, the overall prevalence of diabetes treatment utilization within the sample was 47.7%. Notably, the highest proportion of treatment users was observed among individuals with no formal education, accounting for 23.9%. This indicates that the uneducated subgroup exhibits a higher rate of diabetes treatment usage compared to other educational categories. The chi-square test yielded a statistically significant result ($p<0.05$), suggesting a significant association between educational status and the likelihood of receiving diabetes treatment. Regarding treatment modalities, 28.4% of the total sample reported using oral hypoglycemic agents (antidiabetic tablets), with a distribution of 42.2% among males and 57.8% among females. The use of insulin was reported by 19.3% of participants. Conversely, 52.3% of the sample reported not using any medication for diabetes management. The Chi-square analysis demonstrated a statistically significant association ($p<0.05$) between educational qualification and the type of diabetes treatment received. Concerning obesity, 29.5% of the total sample exhibited moderate obesity. The prevalence of moderate obesity was higher within the uneducated subgroup compared to other educational levels. The Chi-square test confirmed a significant association ($p<0.05$) between educational status and the presence of moderate obesity.

These findings underscore the significant influence of educational attainment on treatment patterns, obesity prevalence and associated health factors within the studied population.

Associations of smoking and diabetes mellitus with goiter prevalence: A cross-sectional study: In the study sample, the prevalence of smoking was 18.18%. The results, as presented in Table 8, indicate that the chi-square test yielded a statistically significant association ($p<0.05$) between smoking status and the incidence of diabetes. Specifically, the data suggest a significant relationship between smoking and the occurrence of diabetes. Conversely, no statistically significant association was observed between smoking and the presence of goiter ($p>0.05$). These findings underscore a potential link between smoking behavior and diabetes prevalence, while suggesting no apparent relationship between smoking and goiter in this population.

DISCUSSION

This study examined various demographic, biochemical and clinical parameters in relation to Type 2 Diabetes Mellitus (T2DM) and its associated conditions. The mean age of the sample was 44.33 ± 16.60 years, with a higher representation of females, consistent with previous findings indicating that the prevalence of T2DM is lower in individuals under 50 years of age[19]. This gender distribution aligns with prior research demonstrating a higher proportion of female participants among both diabetic and non-diabetic groups[20]. Notably, the study found a significant association between gender and diabetes prevalence, with males exhibiting a higher prevalence (63.6%) compared to females (36.4%). This finding contrasts with some previous studies that reported higher incidence rates among females[20-22]. The demographic profile outlined in this study aligns with previous research indicating varied participation across gender, age and educational levels. For instance, studies have reported similar distributions, particularly noting the higher representation of females and the prominence of older age groups in community-based samples[23].

Additionally, the prevalence of unlettered individuals is consistent with previous reports describing lower literacy rates among populations in low-resource and developing settings[24].These findings support the demographic characteristics observed in the present study and indicate consistency with population profiles reported in comparable communities.

This study found significant associations between lipid profiles and various factors. Females had higher HDL levels, while diabetics showed lower HDL ($p<0.05$). A longer infection duration was associated with decreased HDL and triglycerides and goiter was associated with increased triglycerides ($p<0.05$). Additionally, older age groups had higher triglycerides and lower HDL levels, indicating age-related metabolic changes ($p<0.05$). These findings suggest that demographic and clinical factors influence lipid levels, which may impact cardiovascular risk management[25]. Another study observed that males exhibited significantly higher levels of cholesterol and triglycerides, particularly with advancing age, while HDL levels were notably reduced in diabetic patients[26]. These findings reinforce the established link between dyslipidemia and T2DM, emphasizing the importance of lipid profile management in diabetic care[27,28]. Additionally, evidence suggests that age, female gender, obesity and thyroid peroxidase antibody positivity are risk factors for hypothyroidism, consistent with previous studies[29,30]. The prevalence of subclinical hypothyroidism was observed to increase with age[1] and gender differences in susceptibility to thyroid disorders were confirmed[31]. Interestingly, unlike some prior research[32], this study did not find a statistically significant association between obesity and goiter, suggesting that the relationship between obesity and thyroid disorders may be more complex and warrants further investigation. Several studies have examined uric acid levels in individuals with diabetes relative to healthy controls. Generally, findings indicate no significant difference in uric acid concentrations between the two groups. For instance, Dehghan *et al.*[33] observed comparable serum uric acid concentrations between diabetic and non-diabetic cohorts, suggesting that uric acid may not be directly correlated with diabetes status in certain populations. Similarly, Lv *et al.*[34] reported no statistically significant differences in uric acid levels when comparing elevated uric acid alone may lack specificity as a biomarker for diabetes. These findings imply that serum uric acid levels, in isolation, may be inadequate for reliably differentiating diabetic individuals from healthy subjects in clinical diagnostic contexts.

Elevated uric acid levels have been associated with increased Body Mass Index (BMI) and fasting blood glucose (FBG), aligning with prior studies indicating that serum uric acid (SUA) levels tend to be higher in healthy individuals but may decline in prediabetic states[35], importantly, higher SUA levels have been linked to an increased risk of developing Type 2 Diabetes Mellitus (T2DM), particularly among women, especially postmenopausal women, where BMI and dyslipidemia serve as significant mediators[36]. Regarding thyroid function, this study observed a significant decrease in free thyroxine (FT4) levels among diabetics (0.80 ± 0.72) compared to healthy controls (1.13 ± 0.62), supporting existing evidence that thyroid dysfunction, especially hypothyroidism, is common among diabetic patients[37]. Thyroid hormones play a crucial role in lipid and carbohydrate metabolism; alterations in FT4 levels have been associated with insulin resistance and metabolic syndrome[38]. Both hypothyroidism and hyperthyroidism can influence glucose homeostasis-hypothyroidism often predisposes individuals to insulin resistance, whereas hyperthyroidism may induce hyperglycemia through increased hepatic glucose production[39]. These findings underscore the complex bidirectional relationship between thyroid function and T2DM, highlighting the importance of routine thyroid assessment in diabetic patients.

CONCLUSION

This study highlights the complex interrelationship between lipid levels, thyroid function, and uric acid in individuals with type 2 diabetes. The findings confirm that men exhibit higher cholesterol and triglyceride levels, with these parameters worsening with age. Furthermore, hypothyroidismespecially subclinical hypothyroidismis more prevalent among older individuals and females. Overall, comprehensive metabolic and endocrine assessments are vital for early detection and effective management of related disorders in diabetic patients.

SIGNIFICANCE STATEMENT

This study highlights the clinical importance of monitoring thyroid function in diabetic patients, as reduced FT4 levels were significantly associated with altered metabolic parameters, including blood glucose and lipid profile. The findings emphasize the need for routine thyroid screening in diabetes management to improve metabolic control and reduce potential complications.

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