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Thyroid Dysfunction In Type 2 Diabetes: An Epidemiological Assessment Of Prevalence And Association In An Algiers Center Cohort

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ABSTRACT

OBJECTIVES: The aim of this study was to estimate the prevalence of thyroid dysfunction, to investigate the association between the two pathologies, and to identify associated risk factors in patients with type 2 diabetes.

METHODS: A cross-sectional study conducted in the diabetology department of the Central Hospital of Algeria in Algiers, between 2024 and 2025. Out of a total of 380 patients with Type 2 Diabetes (T2D) identified within the department, 100 patients were included in this epidemiological study, as they satisfied all selection criteria, notably the availability of thyroid function tests. The final included sample thus represents 26.3% of the identified T2D population. The remaining 280 patients were excluded from this specific analysis and will be considered for a subsequent study. Demographic, clinical, biological, and hormonal data (Glycemia, HBA1c, TSH and total hemoglobin) were collected, and the risk factors associated with thyroid disorders were assessed by comparing diabetic patients according to their thyroid status. The statistical analysis was performed using SPSS version 26 software, with the level of significance set at $p < 0.05$.

RESULTS: The mean age of the patients was 56 .13 ± 13,65 years, with 56 % of the cohort being male. The overall prevalence of thyroid disorders among patients with Type 2 Diabetes (T2D) was 26.31%. The majority of the cohort (75%) was euthyroid, while the remaining 25% presented with hypothyroidism. It is noteworthy that no cases of hyperthyroidism were observed. Regarding metabolic control, the mean fasting blood glucose (FBG) level was marginally higher in hypothyroid patients (1.72 ± 0.86 g/L) compared to euthyroid patients (1.55 ± 0.67 g/L); however, this difference did not reach statistical significance ($p = 0.461$).

In contrast, hypothyroidism was significantly more prevalent in patients with uncontrolled diabetes (36.7%) than in those with controlled HbA1c (13.7%), establishing a highly significant association between the two variables ($\chi^2 = 7.05$; $p = 0.008$).

Further analysis showed that hypothyroid patients exhibited a significantly longer duration of diabetes (17.0 ± 10.42 years) compared to euthyroid patients (9.85 ± 6.07 years). This difference was highly significant ($p = 0.002$), underscoring a strong association between the duration of diabetes and hypothyroidism. Furthermore, hypothyroidism was significantly associated with diet: it was observed in 35.3% of patients reporting an unbalanced diet, compared to only 14.3% in those with a balanced diet ($\chi^2 = 5.88$; $p = 0.015$).

Conversely, no statistically significant association was found between thyroid status and the presence of either hypertension or dyslipidemia, nor with the presence of microvascular or macrovascular complications.

Finally, while univariate analysis revealed a marked female predominance and an increased frequency of thyroid disorders in older individuals, those with a sedentary lifestyle, and those using certain types of treatment, only a sedentary lifestyle proved to be an independent risk factor in our population. This suggests a potential primary role of lifestyle in the occurrence of these disorders.

CONCLUSIONS: Hypothyroidism exhibits a significant prevalence in T2DM patients and is strongly

associated with poor glycemic control and a long duration of diabetes. Crucially, no significant association was found between thyroid status and the presence of micro- or macrovascular complications. Sedentary lifestyle was identified as the sole independent risk factor for thyroid dysfunction. These findings underscore the need for targeted screening (especially among women and sedentary individuals) and the crucial importance of lifestyle modifications for the prevention of this comorbidity.

Keywords: Type 2 diabetes, Thyroid disorders, Hypothyroidism, Prevalence, Comorbidity, Complications; Lifestyle.

INTRODUCTION

Thyroid disorders (TD) and Type 2 Diabetes (T2D) are among the most prevalent endocrine diseases globally. Both conditions contribute significantly to worldwide morbidity and the economic burden on healthcare systems.

T2D is currently in the midst of a major epidemiological expansion. In 2021, an estimated 537 million people were living with diabetes. This figure is projected to reach 643 million by 2030 and 783 million by 2045 [1]. Furthermore, an estimated 541 million individuals were suffering from impaired glucose tolerance in 2021[1], and its global cost, linked to disease management and its consequences, is substantial and continuously increasing [2].

T2D and thyroid dysfunctions are particularly linked in clinical practice, and their coexistence is frequently observed [3]. Furthermore, recent data suggest a complex pathophysiological interrelation stemming from their shared endocrine origins [4;5].

On one hand, the central and peripheral control of thyroid hormones (TH) directly impacts glucose homeostasis [6;7], and, on the other hand, insulin sensitivity can, in turn, modulate the TH feedback loop (4; 8). Evidence suggests a significant correlation between glycosylated hemoglobin (HbA1c) levels and TH [9]. For instance, subclinical hypothyroidism can induce insulin resistance (IR) via altered GLUT2 gene expression [4;8]. Conversely, IR (a hallmark of diabetes) can lead to changes in the thyroid gland, including goiter formation.

TH significantly influence the expression and function of glucose transporters (GLUT2, GLUT3, and GLUT4) across various tissues [10;11;12]. Hypothyroidism is specifically associated with IR predominantly in peripheral tissues (skeletal muscle and adipose tissue), resulting in decreased glucose uptake and utilization [10]. The totality of these mechanisms (including altered GLUT4 translocation [11] and TH-mediated hepatic GLUT2 upregulation [12] collectively underscores the central role of TH in maintaining metabolic homeostasis.

While the prevalence of thyroid disorders is high in diabetic patients and vice-versa [4;5;8;9;13], research findings in this area sometimes remain inconsistent [14]. Moreover, despite the recognition of this comorbidity, comprehensive data describing the specific types, demographic characteristics, genetic, and clinical profiles of thyroid disorders within the T2D subgroup remain limited.

Consequently, understanding the prevalence and precise characteristics of thyroid dysfunction in T2D patients is crucial for optimizing screening strategies, personalized therapeutic approaches, and improving patient prognosis.

This cross-sectional study aims to determine the prevalence and characteristics of thyroid disorders in T2D patients, to analyze the association between the two pathologies, and to identify associated risk factors in this population. By doing so, it seeks to inform clinical practice and guide future research on the management of these interdependent endocrine and metabolic disorders.

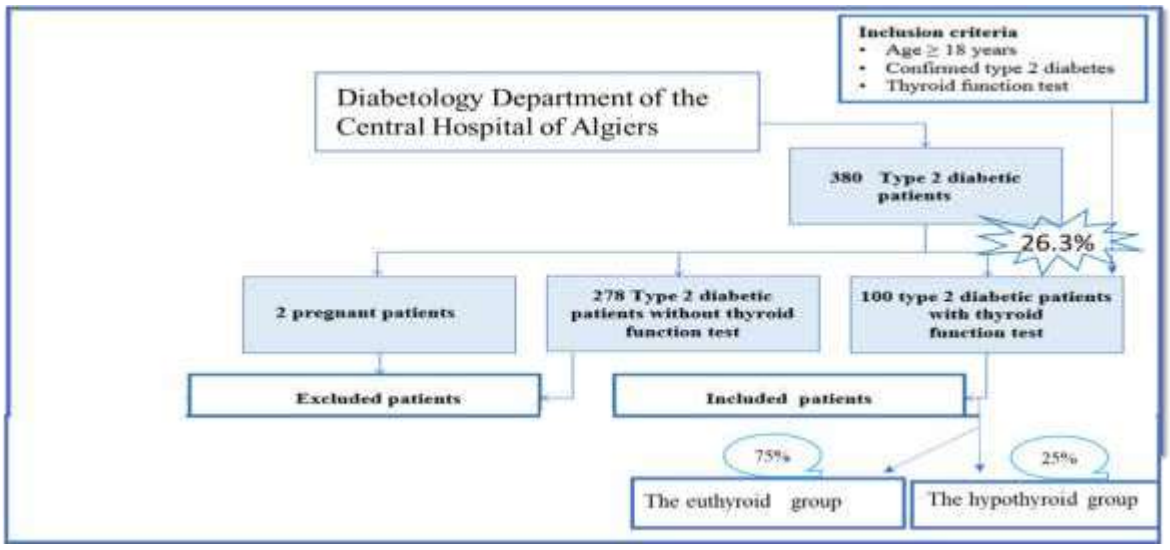
Materials and methods

This cross-sectional study was conducted over a one-year period, between 2024 and 2025, within the Diabetology Department of a central hospital located in the North and Central region of Algeria. The study was performed in compliance with the ethical principles of the Declaration of Helsinki, and formal authorization from the hospital administration and head of department was obtained. Patient participation was strictly voluntary, and their informed consent was collected after they were informed

of the study objectives, data confidentiality, and their right to withdraw. During the study period, a total of 380 patients diagnosed with Type 2 Diabetes (T2D) consulted the department for medical follow-up. The final sample was constituted by the rigorous application of selection criteria: being 18 years of age or older (≥18 years) and having complete thyroid function test (TSH, FT4) results available. Following this selection process, 100 eligible patients were included in the final analysis, while the remaining 280 patients were excluded due to non-compliance with the mentioned criteria, primarily the lack of thyroid function data. The detailed sampling and participant selection process is illustrated by the flow diagram presented in Figure 1.

The data collection followed a dual approach: firstly, through direct observation during medical consultations, involving the completion of pre-established clinical and biological information forms; and secondly, through consultation of computerized records via the hospital system to complete or verify missing information. For each included patient, data were rigorously documented using pre-established questionnaires. The parameters studied notably covered sociodemographic variables (age, sex), lifestyle factors (smoking status, dietary habits, and physical activity level), and treatment history (oral and mixed anti-diabetic medications). Thyroid dysfunction was diagnosed by the endocrinology specialist within the diabetology department, based on clinical evaluation and biochemical findings. Thyroid status was classified into three subgroups: Euthyroidism (TSH between 0.4 and 4.0 mIU/L), Hypothyroidism (TSH > 4.0 mIU/L or on treatment), and Hyperthyroidism (TSH < 0.4 mIU/L or on treatment). Key biological parameters measured included Glycemia, HbA1c, and Total Hemoglobin (Hb). An HbA1c level ≤ 7% defined satisfactory glycemic control, while a level > 7% indicated poorly controlled diabetes. Anemia was defined by an Hb level below 12 g/dL for women and 13 g/dL for men. Clinical parameters included the duration of diabetes, history of hypertension (HTN), and dyslipidemia. Finally, diabetic complications were thoroughly documented, covering microvascular complications (retinopathy, neuropathy, nephropathy) and macrovascular complications (Myocardial Infarction (MI), Cerebrovascular Accident (CVA), Peripheral Artery Occlusive Disease (PAOD).

Figure1: Flow diagram of patient selection for type 2 diabetes study



Statistical analysis

Data analysis was performed using IBM SPSS Statistics version 26. Qualitative variables (such as sex, dietary habits, and physical activity level) were described using frequencies (n) and percentages (%). Quantitative variables (such as age, diabetes duration, HbA1c, and TSH) were expressed as mean ± standard deviation (SD) or median (IQR), depending on their distribution. The Shapiro-Wilk test, the most appropriate for this sample size, was used to assess the normality of distributions. For comparing means between two groups, the student's t-test was used when the distribution was normal; otherwise, the Mann–Whitney U test was applied. Associations between qualitative variables were analyzed using the Chi-squared test ($\chi 2$).

To identify factors independently associated with the occurrence of hypothyroidism, a Binary Logistic Regression model was employed, using thyroid status (hypothyroid vs. euthyroid) as the dependent variable. The model included independent variables that had shown a significant association in preliminary correlation tests: sex, age, smoking status, physical activity level, dietary habits, duration of diabetes, HbA1c, and type of diabetes treatment. Results are reported as Odds Ratios (OR) with 95% Confidence Intervals (CI). Graphs and visualizations were generated using SPSS.

The level of statistical significance was set at $P < 0.05$. Significance levels were interpreted as follows: $P < 0.05$ (significant *), $P < 0.01$ (very significant **), and $P < 0.001$ (highly significant ***).

Results

1. Subject characteristics

A total of 380 participants, all diagnosed with Type 2 Diabetes (T2D), were included in the thyroid pathology screening. Among these patients, 100 were diagnosed with a concomitant thyroid disorder, representing 26.3 % of the total T2D sample.

The mean age of the patients was 56 .13 ± 13,65 years, and 56 % of the sample was male. The complete details regarding age, sex, and sociodemographic characteristics of this population are presented in Table 1.

The assessment of behavioral and lifestyle factors was conducted to contextualize the clinical data of the cohort. Regarding smoking status, the majority of participants (66%) reported being never-smokers. Nevertheless, a combined proportion of 34 % was classified as either active smokers (19 %) or former smokers (15%). Alcohol consumption was reported as null within the entire sample (100 % non-drinkers).

The distribution of physical activity level was found to be heterogeneous: 36 % of patients were classified as sedentary, while 29 % exhibited moderate activity, and 35 % were considered physically active. Finally, the analysis of dietary habits revealed a near-equal distribution, with 51 % of patients reporting an unbalanced diet versus 49 % reporting a balanced diet **(Table 2).**

Table 1: Sociodemographic profile of patients with type 2 diabetes (n=100)

Sociodemographic profile of patients with type 2 diabetes (n=100)	
Characteristics	**Mean ±SD/n (%)**
Sex	
Female	44 (44)
Male	56 (56)
Average age	56 .13 ± 13,65
Marital status	
Single	8 (8)
Married	88 (88)
Divorced	0 (00)
Widowed	4 (4)
Socioeconomic Level	
Low	15 (15)
Middle	70 (70)
High	15 (15)
Educational Level	
Illiterate	10,0(10)
Primary	7,0 (7)
Middle School	21,0 (21)
High School	25,0 (25)

Higher Education	37,0 (37)

SD: standard deviation

Table 2: Lifestyle profile of patients with type 2 diabetes (n=100)

Lifestyle profile of patients with type 2 diabetes (n=100) n (%)	
Smoking	
Smoker	19 (19)
Former smoker	15 (15)
Non-smoker	66 (66)
Alcohol consumption	
Non-drinker	100 (100)
Drinker	0 (0)
Level of physical activity	
Sedentary	36 (36)
Moderately active	29 (29)
Active	35 (35)
Dietary habits	
Unbalanced diet	51 (51)
Balanced diet	49 (49)

2. Prevalence, Comorbidities and Diabetic Complications

Table 3 summarizes the results of the clinical and biological assessments of the sample. The mean duration of diabetes within the cohort was 11.59 ± 7.93 years.

Regarding metabolic control, the average fasting blood glucose (FBG) was 1,59 ± 0,72g/L. The mean HbAc1, at 7.70 ± 1.99 %, indicated an overall moderately controlled glycemic level. The distribution of patients according to glycemic status was nearly balanced: 51% exhibited satisfactory control, compared to 48 % showing glycemic imbalance (uncontrolled HbAc1). The mean TSH level was 2,61 ± 2,32 µIU/ml.

Analysis of comorbidities revealed a high prevalence of arterial hypertension (HTN) in 57 % of patients and dyslipidemia in 40 %.

Concerning micro- and macroangiopathic complications, retinopathy was the most frequent, affecting 18 % of the sample. It was followed by cardiopathy (14 %), stroke (CVA) (5%), and nephropathy (5%). Notably, no cases of neuropathy, diabetic foot, or heart failure were recorded (0% for these three complications).

Table 3: Clinical and Biological profile of patients with type2 diabetes (n=100)

Clinical and Biological profile of patients with type 2 diabetes (n=100)	
Characteristics	Mean ±SD/n (%)
Duration of Diabetes	11.59± 7.93
Diabetes Comorbidities	
HTN	57 (57)
Dyslipidemia	40 (40)
Diabetes Complications	
Macrovascular complications	
AVC	5 (5)
Heart failure	0 (0)
Cardiopathy	14 (14)
Microvascular complications	

Retinopathy	18(18)
Nephropathy	5 (5)
Neuropathy	0 (0)
Diabetic Foot	0 (0)
Biological characteristics	
HbA1c %	7,70±1,99
Total Hb (g/dl)	13,74±2,01
Fasting blood glucose (g/L)	1,59 ±0,72
TSH (µIU/ml)	2,61 ± 2,32
Diabetes treatment	
Oral	48(48)
Mixed	52(52)

SD: standard deviation; HTN: Arterial hypertension; AVC: Cerebrovascular Accident; Hb: hemoglobin; HbA1c: hemoglobin A1c; TSH: thyroid-stimulating hormone

3. Association and Risk factors

Thyroid assessment revealed that 75% of the participants maintained a normal thyroid function (euthyroidism). Hypothyroidism was significantly prevalent in 25% of the diabetic patients, with hyperthyroidism being entirely absent from the cohort.

Subsequently, a comparative analysis of the two groups defined by their thyroid status 'the euthyroid) group (n = 75) and the hypothyroid group (n = 25)' revealed a highly significant difference in gender distribution ($\chi^2 = 13.85$; $p < 0.001$). Specifically, the majority of hypothyroid patients were women (43.2%), whereas euthyroid patients were predominantly men (89.3%) Table 4. The comparative analysis also showed a significant difference in average age between the two groups ($p = 0.049$). The mean age of hypothyroid patients was significantly higher (60.88 ± 11.90) years compared to euthyroid patients (54.57 ± 13.90) years Figure 2.

- **Association Between Hypothyroidism, Diabetes Duration, and Glycemic Control**

Patients with hypothyroidism exhibited a significantly longer duration of diabetes (17.0 ± 10.42) years compared to euthyroid patients (9.85 ± 6.07) years. This difference was highly statistically significant ($p = 0.002$), underscoring a strong association between the duration of diabetes and hypothyroidism Figure 3.

Regarding indicators of glycemic control, although the mean Fasting Plasma Glucose (FPG) was slightly higher in hypothyroid patients (1.72 ± 0.86 g/L) compared to euthyroid patients (1.55 ± 0.67 g/L), this difference was not statistically significant ($p = 0.461$) Figure 4.

Nevertheless, hypothyroidism was observed significantly more frequently in patients with uncontrolled diabetes (36.7%) than in those with controlled HbA1c (13.7%). This outcome indicates a highly significant association between uncontrolled HbA1c status and the presence of hypothyroidism ($\chi^2 = 7.05$; $p = 0.008$) Table 5. Finally, an increased prevalence of hypothyroidism was noted in patients receiving mixed treatment (insulin and oral antidiabetic drugs) (34.6%) compared to those treated solely with oral antidiabetic drugs (14.6%) Table 6.

Figure 2: Age profile based on thyroid status in type 2 diabetes patients (* P < 0,05)

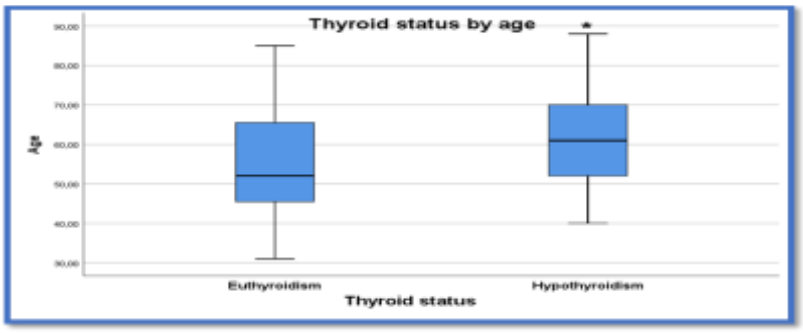


Figure 3: Diabetes duration by thyroid status in type 2 diabetes patients (P < 0,01)**

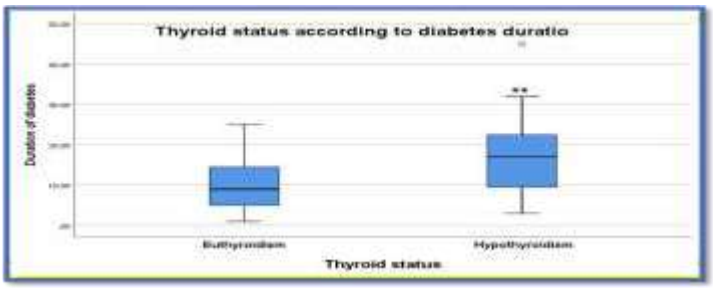


Figure 4: Fasting blood glucose by thyroid status in type 2 diabetes patients

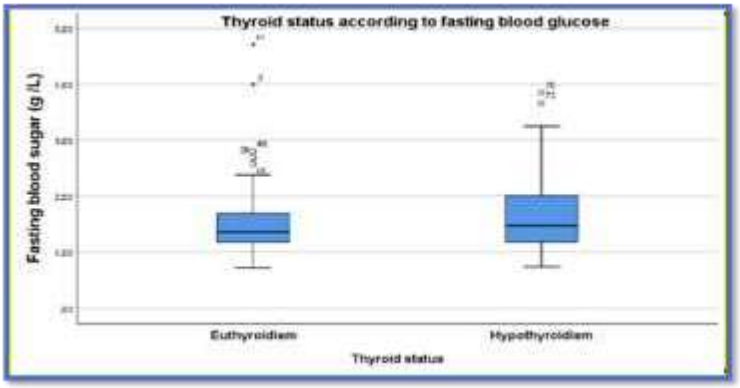


Table 4: Gender and thyroid status association in type 2 diabetes patients

Sex, n (%)	Euthyroid (n = 75)	Hypothyroid (n = 25)	X^2	P-value
Male sex	50 (89.3 %)	6 (10.7%)	13,85	< 0,001 ***
Female sex	25 (56.8 %)	19 (43.2%)		

Table 5: Glycemic control (HbA1c) and thyroid status association in type 2 diabetes patients

HbA1c, n (%)	Euthyroid (n = 75)	Hypothyroid (n = 25)	X^2	P-value
Uncontrolled	31(63.3%)	18(36.7%)	7,05	0.008 **
Controlled	44(86.3%)	7(13.7%)		

Table 6: Diabetes treatment modality and thyroid status in type 2 diabetes patients

Diabetes Treatment, n (%)	Euthyroid (n = 75)	Hypothyroid (n = 25)	**X^2**	P-value
Oral	41(85.4%)	7(14.6%)		

Mixed	34(65.4%)	18(34.6%)	5,34	0.021*

- **Lifestyle Habits and Hypothyroidism**

Comparative analysis of lifestyle habits revealed a strong association between thyroid status and several modifiable factors. Physical activity showed a highly significant difference ($\chi^2 = 14.94$; $p = 0.001$), with hypothyroidism being markedly more frequent among sedentary patients (47.2%) compared to those who were either moderately active (10.3%) or active (14.3%). Conversely, euthyroid patients were predominantly categorized as active or moderately active Table 7.

Similarly, dietary imbalance was significantly associated with hypothyroid status ($\chi^2 = 5.88$; $p = 0.015$); hypothyroid patients were found significantly more often among those reporting an unbalanced diet (35.3%) compared to those with a balanced diet (14.3%) Table 8.

Finally, the analysis of smoking status also demonstrated a significant difference ($\chi^2 = 7.25$; $p = 0.027$). Interestingly, hypothyroidism was most prevalent among non-smokers (33.3%), whereas it was less common in both former smokers (6.7%) and active smokers (10.5%). These findings, illustrated in Figure 5, suggest that, within this specific cohort, hypothyroidism is significantly more common in patients who have never smoked.

Figure 5: Smoking status and thyroid status in type 2 diabetes patients (* P < 0,05)

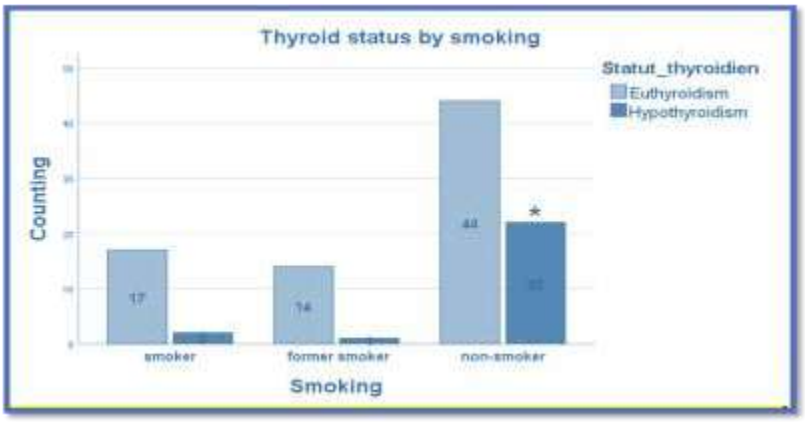


Table 7: Physical activity level and thyroid status in type 2 diabetes patients

Physical Activity Level, n (%)	Euthyroid (n = 75)	Hypothyroid (n = 25)	**X²**	P-value
Sedentary	19(52.8%)	17(47.2%)	14,94	0.01**
Moderately active	26(89.7%)	3(10.3%)		
Active	30(85.7%)	5(14.3%)		

Table 8: dietary habits and thyroid status in type 2 diabetes patients

Dietary Habits, n (%)	Euthyroid (n = 75)	Hypothyroid (n = 25)	X²	P-value
Unbalanced diet	33(64.7%)	18(35.3%)		

Balanced diet	42(85.4%)	7(14.3%)	5,88	0.015*

- **Complications and Comorbidities**

Vascular Complications and Thyroid Status

The analysis revealed no significant association between thyroid status (hypothyroidism versus euthyroidism) and the presence of either microvascular or macrovascular complications ($p > 0.05$), as detailed in Table 9.

Similarly, common cardiovascular risk factors, hypertension and dyslipidemia, were also independent of thyroid status (Table 10). Hypothyroidism was observed in 26.3% of hypertensive patients versus 23.3% of non-hypertensive patients ($p = 0.726$). For dyslipidemia, the prevalence of hypothyroidism was 22.5% in affected patients compared to 26.7% in non-affected patients ($p = 0.637$).

Multivariate Analysis of Factors Influencing Hypothyroidism

The multivariate analysis demonstrated that a low level of physical activity was significantly associated with hypothyroidism (OR = 0.35; $p = 0.022$), indicating that physical activity acts as a protective factor against hypothyroidism in this cohort.

A trend towards an increased risk for females was also noted, where female sex was associated with a 3.7 -fold higher probability of being hypothyroid, although this finding did not achieve statistical significance at the 5% threshold ($p = 0.066$). The remaining variables, despite their significant associations in univariate analysis, did not remain significant independent predictors in the final multivariate logistic regression model. The complete results, including the Odds Ratios (OR) and p-values, are presented in Table 11.

Table 9: Vascular complications and thyroid status in type 2 diabetes patients

Complications of Diabetes	Euthyroid (n = 75)	Hypothyroid (n = 25)	**X^2**	P-value
Macrovascular Complications				
AVC				
No	72(75.8%)	23(24.2%)	0,63	0.427
Yes	3(60%)	2(40%)		
Cardiopathy				
No	65(75.6%)	21(24.4%)	0,11	0.739
Yes	10(71.4%)	4(28.6%)		
Microvascular Complications				
Retinopathy				
No	61(74.4%)	21(25.6%)	0,09	0.764
Yes	14(77.8%)	4(22.2%)		
Nephropathy				
No	71(74.7%)	24(25.3%)	0,07	0.791
Yes	4(80%)	1(20%)		

Table 10: Comorbidities and thyroid status in type 2 diabetes patients

Variables	Euthyroid (n = 75)	Hypothyroid (n = 25)	X^2	P-value
HTA, n (%)				
No	33(76.7%)	10(23.3%)		

Yes	42(73.7%)	15(26.3%)	0,12	0.726
Dyslipidemia, n (%)				
No	44(73.3%)	16(26.7%)	0,22	0.637
Yes	31(77.5%)	9(22.5%)		

Table 11: Predictors of hypothyroidism in type 2 diabetes patients (Logistic Regression Analysis

Variable	OR (Exp(B))	P-value
Sex (female)	3,74	0,066
Age	0,99	0,716
Smoking status	1,29	0,632
Low physical activity	0,35	0,022
Unbalanced dietary habits	1,41	0,726
Duration of diabetes (years)	1,45	0,312
High HbA1c	1,25	0,827
Diabetes treatment	2,50	0,177

Discussion

The complex interplay between thyroid function and Type 2 Diabetes (T2D), particularly hypothyroidism, which can potentially exacerbate metabolic derangements and glucose homeostasis [15, 16], highlights the clinical significance of this comorbidity. Our results reveal a significant prevalence of thyroid disorders (TD) within this cohort, thus confirming the status of TD as a major comorbidity of diabetes mellitus. Specifically, the observed prevalence of hypothyroidism (25%) is not only high but also fully aligns with the findings of several similar studies that reported comparable high rates, such as 22.04% [17] and 20% [18]. Furthermore, our observations concerning the total absence of hyperthyroidism (0%) in our sample are also supported by other studies [19; 20], suggesting that hypothyroidism constitutes the dominant form of thyroid dysfunction in patients with T2D. Furthermore, the descriptive analysis revealed a significantly higher prevalence of TD among women 43.2% compared to men 10.7 % (χ^2 = 13.85; $p < 0.001$), a classic finding in endocrinology which is frequently observed in studies on T2D and thyroid function [17;18;19;20]

Our analysis further demonstrated highly significant associations between thyroid status and both diabetes duration and long-term glycemic control (HbA1c). Hypothyroid patients exhibited a significantly longer duration of diabetes (17.0 ± 10.42 years vs 9.85 ± 8.43 years, p = 0.002), corroborating literature that suggests cumulative exposure to the chronic diabetic state may be an aggravating factor [18]. Consistent with these findings, we determined that hypothyroidism was four times more frequent in patients with uncontrolled HbA1c compared to those with controlled levels (p = 0.008). Thyroid hormones (THs) are integral to glucose metabolism and insulin sensitivity, and their dysregulation contributes to Insulin Resistance (IR) [21]. This result points to the existence of a potential bidirectional interaction [18]: on one hand, poor glycemic control may exacerbate thyroid dysfunction, while on the other hand, hypothyroidism (even subclinical) directly impairs glucose homeostasis by inducing peripheral insulin resistance and affecting GLUT transporters [8, 12, 22]. Hypothyroidism is indeed associated with IR primarily in peripheral tissues, leading to decreased glucose uptake and utilization [21], impairing insulin sensitivity and reducing insulin clearance [18]. This distinction is crucial, as the lack of difference in Fasting Blood Glucose (FBG) (p = 0.461) implies that chronic metabolic status (reflected by HbA1c) is a more potent and relevant factor of association than a single point-in-time glycemic measurement (FBG) in this endocrine comorbidity. These alterations in insulin sensitivity underscore the critical role

of thyroid function in maintaining metabolic homeostasis, emphasizing the importance of monitoring and managing IR in these patients to prevent the progression of metabolic complications.

Regarding the analysis of factors influencing the comorbidity, our study demonstrated a strong association between thyroid status and several modifiable lifestyle factors. Physical activity showed a highly significant difference ($\chi^2 = 14.94$; $p = 0.001$), with hypothyroidism being markedly more frequent among sedentary patients (47.2%) compared to those moderately active or active (10.3% and 14.3%, respectively). This protective role was confirmed by multivariate analysis, demonstrating that a low level of activity was an independent risk factor for hypothyroidism (OR = 0.35; $p = 0.022$). It is crucial to note that this association is poorly documented in existing literature on T2D and TD, which gives our result an original character and warrants further research.

The protective effect of physical activity is primarily mediated by two central mechanisms. First, through the improvement of insulin sensitivity in peripheral tissues, notably skeletal muscle and adipose tissue. Hypothyroidism, even subclinical, is known to exacerbate IR and dyslipidemia, thereby contributing to poor glycemic control in T2D [23, 24, 25]. Physical activity corrects this dysfunction by increasing the expression and translocation of the glucose transporter GLUT4 to the cell membrane, allowing for better glucose uptake [26]. By reducing IR and HbA1c [26], exercise decreases overall metabolic stress, lessening the burden on the thyroid and potentially slowing the progression of thyroid dysfunction. Second, both hypothyroidism (often autoimmune due to Hashimoto's thyroiditis) and T2D are characterized by a state of low-grade chronic inflammation. Regular physical activity is a potent natural anti-inflammatory agent. It leads to increased release of anti-inflammatory cytokines (such as IL-6 and IL-10) from muscle (myokines) and reduces pro-inflammatory cytokines (such as TNF-alpha and IL-1beta). This reduction in systemic inflammation may decrease Oxidative Stress on the thyroid gland, thus protecting thyrocytes [27].

Similarly, dietary imbalance ($\chi^2 = 5.88$; $p = 0.015$) and smoking status ($\chi^2 = 7.25$; $p = 0.027$) showed significance in univariate analysis, but these factors did not retain their predictive power in the final logistic regression model, underscoring the primacy of physical inactivity in this comorbidity. Multivariate analysis also confirmed a trend toward an increased risk for females (OR} = 3.7; $p = 0.066$).

Addressing the clinical impact, our analysis revealed no significant association between thyroid status and the presence of microvascular or macrovascular complications ($p > 0.05$), nor with hypertension ($p = 0.726$) or dyslipidemia ($p = 0.637$). This lack of association contrasts with numerous studies that highlight a significant worsening of vascular complications in T2D patients with thyroid dysfunction [23;24;25]. The absence of a link in our study may be attributable to the cross-sectional nature of the study or to selection bias. Nevertheless, these alterations emphasize the importance of monitoring and managing IR in diabetic patients with TD. In conclusion, this study confirms the high prevalence of hypothyroidism in T2D patients and clearly identifies a low level of physical activity as a major independent risk factor. The results reinforce the clinical imperative for systematic TD screening in T2D patients, emphasizing the importance of promoting physical activity, particularly in women and those with long-duration diabetes or poor glycemic control.

CONFLICT OF INTERESTS

All authors declare that they have no any conflict of interests.

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