BMC Endocrine Disorders

RESEARCH

Open Access

Prevalence and predictors of thyroid nodules among adults: analyzing the association with metabolic syndrome in a cross-sectional study

Golbarg Abrishami[1], Maryam Emadzadeh[2], Aida Bakhshi[2,3], Yasamin Moeinipour[4], Ghazaleh Taghavi[3] and Solmaz Hasani[5*]

Abstract

Background Thyroid nodules are prevalent clinical findings with potential for malignancy, particularly in aging populations. Metabolic syndrome, characterized by interrelated metabolic abnormalities, has been implicated as a potential risk factor. This study explores the prevalence of thyroid nodules and their association with metabolic syndrome, leveraging data from a large cohort.

Methods A cross-sectional study was conducted within the Persian Organizational Cohort in Mashhad, comprising 4,121 participants aged 35–70 years. Thyroid nodules were identified via ultrasonography, and metabolic syndrome was assessed using the NCEP ATP III criteria. Demographic, clinical, and laboratory data were analyzed using descriptive statistics, chi-square tests, and logistic regression models to identify predictors of thyroid nodules.

Results Thyroid nodules were detected in 27.4% of participants, with a higher prevalence in females (60%) than males (40%, $p < 0.001$). The average age of individuals with nodules was significantly higher than those without (47.9 vs. 43.5 years, $p < 0.001$). Metabolic syndrome prevalence was notably higher among those with thyroid nodules (5.3% vs. 3.8%, $p = 0.028$). Logistic regression analysis identified metabolic syndrome (OR = 1.43, $p = 0.03$), age (OR = 1.05 per year increase, $p < 0.001$), and gender as significant predictors of thyroid nodules.

Conclusion Metabolic syndrome significantly predicts the presence of thyroid nodules, suggesting shared pathophysiological mechanisms, including chronic inflammation and hormonal dysregulation. These findings underscore the importance of integrating metabolic health management into thyroid nodule evaluation and highlight the need for multidisciplinary approaches to optimize care and prevention strategies.

Keywords Thyroid nodules, Metabolic syndrome, Aging Population, Risk factors

*Correspondence:
Solmaz Hasani
hasanis@mums.ac.ir
[1]Department of Internal Medicine, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
[2]Clinical Research Development Unit, Ghaem Hospital, Mashhad University of Medical Sciences, Mashhad, Iran
[3]Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
[4]Cardiovascular Surgery, Cardiothoracic Surgery Division, Cardiothoracic Surgery Department, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran
[5]Endocrine Research Center, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

Introduction

Thyroid nodules have received significant attention in medical research because of their potential to become malignancies and their association with various metabolic and demographic factors. While thyroid nodule prevalence increases with age, the observed higher frequency of metabolic syndrome among older populations has also been linked to an increased prevalence of thyroid nodules [1]. This potential connection warrants further exploration, as both conditions share age-related biological pathways that may contribute to their coexistence [2].

Thyroid nodules, which are often found during routine clinical examinations or when imaging for non-thyroid-related conditions, can pose a challenge in the clinic because of their high prevalence and potential for thyroid cancer. The risk of thyroid cancer can be influenced by factors such as age, gender, and the presence of specific metabolic disorders [3, 4].

Several risk factors have been identified for the development of thyroid nodules. Age, gender, family history of thyroid nodules or thyroid cancer, radiation exposure, iodine deficiency or excess, and autoimmune thyroid disease are all factors that may be considered. Other factors that have been associated with thyroid nodules include metabolic syndrome, irregular meal times, smoking, stop drinking, heavy manual labor, hypertension, diabetes, dyslipidemia, and centripetal obesity [5–9].

The complex relationship between thyroid nodules and metabolic health necessitates a deeper explore. To manage and prevent disease, it is crucial to identify the prevalence of thyroid nodules in the context of metabolic syndrome components and understand the demographic characteristics and clinical profiles of those affected [10–12].

Metabolic syndrome, characterized by a cluster of interrelated metabolic abnormalities, is prevalent among aging individuals and has been identified as a potential risk factor for thyroid nodules [13]. The shared pathophysiological mechanisms, such as chronic low-grade inflammation and hormonal dysregulation, provide a rationale for investigating the interplay between these two conditions [14, 15]. Understanding this relationship is crucial for identifying at-risk populations and optimizing preventive and therapeutic strategies.

This study was conducted based on the hypothesis that individuals with metabolic syndrome, particularly in the aging population, have a higher prevalence of thyroid nodules due to overlapping pathophysiological processes. We aim to evaluate this hypothesis by determining the prevalence of thyroid nodules and assessing their association with metabolic syndrome in a large cohort. By addressing this hypothesis, our research seeks to elucidate potential pathways linking metabolic health and thyroid pathology, offering valuable insights for clinical practice.

This study aimed to evaluate the prevalence and predictors of thyroid nodules in a large cohort while analyzing the relationship between thyroid nodules and metabolic syndrome, particularly in the context of aging. By integrating these findings, the study seeks to provide insights into the potential links between metabolic health and thyroid pathology, thereby informing future research and clinical practices.

Methods

Study design and participants

We conducted a cross-sectional observational study within the framework of the Persian organizational cohort study in Mashhad (POCM). While the broader cohort is prospective in nature, the present analysis represents a retrospective evaluation of existing data within the cohort.

The POCM is a branch of the larger Persian Cohort Study, a nationwide initiative aimed at investigating the epidemiology of non-communicable diseases in Iran. Specifically, the POCM targets employed individuals in Mashhad, focusing on identifying risk factors for cardiovascular diseases, metabolic disorders, and other chronic conditions. This sub-cohort encompasses a diverse group of over 12,000 participants aged 30 to 70 years, all of whom are employees of various organizations, representing a broad cross-section of working-age adults in northeastern Iran. Participants in the POCM are enrolled through workplace health initiatives and undergo periodic evaluations, including detailed health questionnaires, physical examinations, and laboratory assessments. These evaluations are designed to gather comprehensive data on demographic factors, lifestyle behaviors, medical history, and clinical parameters. The standardized data collection process ensures consistency and quality, making the POCM a robust resource for studying non-communicable disease patterns in the region [16].

For this specific study, we analyzed data from 4,121 individuals aged 35 to 70 years who had complete medical records and met the inclusion criteria. This subset of the POCM population provided a well-characterized cohort for investigating the association between metabolic syndrome and thyroid nodules.

Our exclusion criteria were specifically designed to ensure the integrity and relevance of our data. We excluded women currently using contraceptives or estrogen supplements and those who were pregnant. Additionally, individuals suffering from severe and chronic diseases such as chronic renal failure (CRF), liver failure, cirrhosis, and heart failure were not considered for this study. Participants were excluded if they were using

medications known to affect thyroid function. This included amiodarone, iodine supplements, lithium, glucocorticosteroids, opioids, non-steroidal anti-inflammatory drugs (NSAIDs), or any other medications with documented effects on thyroid hormone metabolism or function. This comprehensive exclusion aimed to eliminate potential confounders related to drug-induced thyroid dysfunction. Finally, individuals with incomplete or insufficient medical records were also excluded from the study.

Study measurements and clinical assessments

Metabolic Syndrome related variables were assessed based on National Cholesterol Education Program's Adult Treatment Panel III (NCEP ATP III) guidelines criteria [17]. These were subcategorized in two ways: first, by examining the distribution of each risk factor individually; and second, by evaluating the number of risk factors present in each participant. Although newer criteria, such as IDF 2005 and IDF 2009, are available, we adopted the NCEP ATP III criteria as they are more aligned with the national population characteristics. Metabolic Syndrome-related variables were assessed based on the National Cholesterol Education Program's Adult Treatment Panel III (NCEP ATP III) criteria. A diagnosis of metabolic syndrome required the presence of three or more of the following criteria:

1. Abdominal obesity: Waist circumference ≥ 102 cm (40 inches) in men or ≥ 88 cm (35 inches) in women.
2. Hypertriglyceridemia: Triglyceride levels ≥ 150 mg/dL (1.7 mmol/L).
3. Reduced HDL cholesterol: <40 mg/dL (1.03 mmol/L) in men or < 50 mg/dL (1.29 mmol/L) in women.
4. High blood pressure: ≥130/85 mmHg or use of antihypertensive medication.
5. High fasting glucose: ≥100 mg/dL (5.6 mmol/L) or use of medication for hyperglycemia."

Thyroid nodules were identified and evaluated using ultrasonography, which was performed by experienced radiologists. The nodules were classified according to the Thyroid Imaging Reporting and Data System (TIRADS).

The clinical variables under investigation encompassed a broad array of health markers, highlighting comorbidities associated with Metabolic Syndrome, such as Diabetes Mellitus, Hypertension, Thyroid Disease, and conditions related to pregnancy, including Hypertension and Diabetes, alongside a history of cardiovascular disease (CVD). Chronic renal failure was defined and excluded based on estimated glomerular filtration rate (eGFR) levels below 60 mL/min/1.73 m^2, as calculated using the CKD-EPI formula. Patients with long-term type 2 diabetes or early renal complications (e.g., microalbuminuria) but preserved normal eGFR were not excluded from the study.

Laboratory measurements included Fasting Blood Glucose (FBG), Triglycerides (TG), Cholesterol (CHOL), High-Density Lipoprotein Cholesterol (HDLC), and Thyroid Stimulating Hormone (TSH).

Thyroid-related variables such as family history of thyroid disease, personal history of thyroid disease, Hypothyroidism, Hyperthyroidism, Goiter, and Hashimoto's thyroiditis were also evaluated.

Behavioral variables included current smoking and alcohol consumption status, providing a comprehensive overview of each participant's health profile.

To minimize potential confounding factors, we employed stringent exclusion criteria targeting conditions and medications that could independently influence thyroid function. Nevertheless, we acknowledge that certain residual confounders, such as unmeasured environmental factors or dietary habits, might persist.

Statistical analysis

Statistical analyses were performed using the R studio (version 3.5.3, R Core Team, 2019) and SPSS version 26 (SPSS Inc., Chicago, Illinois, USA). Data analysis involved descriptive statistics to summarize demographic and clinical variables. The prevalence of thyroid nodules was calculated as the percentage of participants with detected nodules. Chi-square tests and Wilcoxon rank sum tests were used to compare categorical and continuous variables, respectively. Logistic regression analysis was performed to identify predictors of thyroid nodule development, adjusting for potential confounders like age and gender. The adjusted model assessed the impact of metabolic syndrome, diabetes, hypertension, and other relevant factors. All statistical tests were two-sided, and a p-value of less than 0.05 was considered statistically significant.

Ethical considerations

The study was approved by the Ethics Committee for Research at Mashhad University of Medical Sciences (Ref: IR.MUMS.MEDICAL.REC.1402.209). Also, written informed consent was obtained from all participants. The study adhered to the principles of the Declaration of Helsinki.

Results

Prevalence of thyroid nodules

In our study cohort comprising 4121 participants, thyroid nodules were detected in 1129 individuals (27.4%). A gender-based disparity was evident, with females demonstrating a notably higher prevalence (60%, $n = 677$) in contrast to males (40%, $n = 452$; $p < 0.001$). The average age of participants diagnosed with thyroid nodules was 47.9

years, significantly exceeding that of participants without nodules, who averaged 43.5 years ($p < 0.001$). Additionally, a marginally elevated mean BMI was observed in the thyroid nodule cohort (27.2 kg/m²) compared to those without nodules (26.9 kg/m²; $p = 0.017$) (Table 1).

Comorbidities and metabolic parameters

The incidence of metabolic syndrome was more pronounced in participants with thyroid nodules (5.3%) than in those without (3.8%; $p = 0.028$). Participants with nodules also exhibited an elevated Mean Arterial Pressure (MAP) of 96.1 mmHg, in comparison to 94.2 mmHg in the non-nodule group ($p < 0.001$). Notably, the presence of diabetes (8.3% vs. 5.1%; $p < 0.001$), hypertension (16% vs. 9.1%; $p < 0.001$), and existing thyroid diseases (12% vs. 4.8%; $p < 0.001$) was significantly higher among individuals with thyroid nodules (Table 1).

Table 1 Association between thyroid Nodule Presence and various demographic and clinical variables

Variable	Overall, *N* = 4,121[1]	Thyroid nodule		*p*-value[2]
		No,*N* = 2,992[1]	Yes,*N* = 1,129[1]	
Demographic Variables				
Gender				< 0.001
Female	2,127 (52%)	1,450 (48%)	677 (60%)	
Male	1,994 (48%)	1,542 (52%)	452 (40%)	
Age (years)	44.7 (9.36)	43.5 (8.84)	47.9 (9.93)	< 0.001
BMI (kg/m²)	27.0 (4.32)	26.9 (4.43)	27.2 (4.02)	0.017
Clinical Variables				
Metabolic Syndrome	173 (4.2%)	113 (3.8%)	60 (5.3%)	0.028
MAP (mmHg)	94.7 (12.96)	94.2 (12.69)	96.1 (13.56)	< 0.001
Systolic blood pressure (mmHg)	107.3 (14.79)	106.6 (14.31)	109.1 (15.83)	< 0.001
diastolic blood pressure (mmHg)	69.3 (9.18)	69.2 (8.97)	69.5 (9.72)	0.7
Diabetes	246 (6.0%)	152 (5.1%)	94 (8.3%)	< 0.001
Hypertension	452 (11%)	273 (9.1%)	179 (16%)	< 0.001
Cardiac Disease	0 (0%)	0 (0%)	0 (0%)	
Myocardial Infarction	15 (0.4%)	10 (0.3%)	5 (0.4%)	0.6
Thyroid Disease	279 (6.8%)	145 (4.8%)	134 (12%)	< 0.001
Pregnancy Hypertension	95 (2.3%)	63 (2.1%)	32 (2.8%)	0.2
Pregnancy Diabetes	64 (1.6%)	43 (1.4%)	21 (1.9%)	0.3
CVD History	26 (0.6%)	18 (0.6%)	8 (0.7%)	0.7
WHR Category				< 0.001
High Risk	3,357 (81%)	2,398 (80%)	959 (85%)	
Moderate Risk	757 (18%)	587 (20%)	170 (15%)	
Low Risk	7 (0.2%)	7 (0.2%)	0 (0%)	
Laboratory Measurements				
FBG (mg/dL)	99.9 (25.97)	99.1 (24.98)	102.2 (28.30)	< 0.001
TG (mg/dL)	126.7 (78.11)	127.2 (79.02)	125.4 (75.69)	0.7
CHOL (mg/dL)	178.9 (35.67)	178.3 (35.47)	180.3 (36.17)	0.10
HDLC (mg/dL)	55.5 (12.10)	55.3 (11.99)	56.0 (12.38)	0.11
Thyroid Stimulating Hormone	1.9 (1.86)	1.8 (1.90)	2.0 (1.74)	< 0.001
Thyroid-Related Variables				
Thyroid Family History	1,073 (26%)	754 (25%)	319 (28%)	0.046
Thyroid disease History	274 (6.7%)	183 (6.2%)	91 (8.1%)	0.039
Hypothyroidism	158 (3.9%)	119 (4.1%)	39 (3.5%)	0.4
Hyperthyroidism	64 (1.6%)	37 (1.3%)	27 (2.4%)	0.010
Goiter	27 (0.7%)	7 (0.2%)	20 (1.8%)	< 0.001
Hashimoto	10 (0.2%)	6 (0.2%)	4 (0.4%)	0.5
Behavioral Variables				
Current Smoking	217 (65%)	157 (67%)	60 (62%)	0.4
Alcohol consumption	64 (1.6%)	44 (1.5%)	20 (1.8%)	0.5

MAP: Mean Artery Pressure, BMI: Body Mass Index, FBG: Fasting Blood Glucose , TG: Triglycerides, HTN: hypertension, CHOL: Total Cholesterol, HDLC: High-Density Lipoprotein Cholesterol,, WHR: Waist to Hip Ratio, CVD: Cardiovascular Disease; [1]Median (IQR) or Frequency (%), [2]Wilcoxon rank sum test; Pearson's Chi-squared test; Fisher's exact test.

Table 2 Univariate Logistic Regression Analysis of predictors for thyroid nodules

variable	Crude logistic regression	
	***P* value**	**OR (Lower - Upper)**
Metabolic Syndrome	0.03	1.43 (1.04–1.97)
Gender (1)	< 0.01	0.63 (0.55–0.72)
Age (years)	< 0.01	1.05 (1.04–1.06)
Systolic blood pressure	< 0.01	1.01 (1.01–1.02)
Thyroid Family History	0.05	1.17 (1.00–1.36)
Thyroid disease History	0.04	1.32 (1.01–1.71)
Hyperthyroidism	0.01	1.92 (1.16–3.16)
Goiter	< 0.01	7.53 (3.18–17.86)
Diabetes	< 0.01	1.70 (1.30–2.22)
Hypertension	< 0.01	1.88 (1.53–2.30)
Thyroid Disease	< 0.01	2.64 (2.07–3.38)
BMI (kg/m^2)	0.04	1.02 (1.00–1.03)
Thyroid Stimulating Hormone	0.01	1.05 (1.01–1.10)

FBG: Fasting Blood Glucose , TG: Triglycerides, HTN: hypertension, HDLC: High-Density Lipoprotein Cholesterol.

Laboratory measurements

Distinct differences were observed in several laboratory parameters. The FBG levels were higher in the thyroid nodule group (102.2 mg/dL) compared to those without nodules (99.1 mg/dL; $p < 0.001$). Additionally higher average TSH values were noted in the thyroid nodule group (2.0 µIU/mL) compared to the non-nodule group (1.8 µIU/mL; $p < 0.001$) (Table 1).

Family and personal history

The study revealed a higher prevalence of both family (28% vs. 25%; $p = 0.046$) and personal history (8.1% vs. 6.2%; $p = 0.039$) of thyroid diseases in participants with thyroid nodules. Additionally, conditions like hyperthyroidism and goiter were significantly more frequent in the thyroid nodule group (Table 1).

Behavioral factors

No significant correlation was found between thyroid nodule presence and behavioral factors such as smoking and alcohol consumption (Table 1).

Logistic regression analysis

The logistic regression analysis, aimed at identifying predictors for the development of thyroid nodules, delineated several significant variables. In the regression analysis, Metabolic Syndrome was identified as a notable predictor of thyroid nodule presence (OR 1.43, $p = 0.03$).Also, gender differences were evident, with males showing a lower likelihood of having nodules (OR 0.63, $p < 0.001$). Age also significantly influenced the risk (OR 1.05 per year, $p < 0.001$). systolic blood pressure (OR 1.01, $p < 0.001$), a history of hyperthyroidism (OR 1.92, $p = 0.01$), the presence of goiter (OR 7.53, $p < 0.001$), diabetes (OR 1.70, $p < 0.001$), hypertension (OR 1.88, $p < 0.001$), existing thyroid disease (OR 2.64, $p < 0.001$), Body Mass Index (BMI) (OR 1.02 per kg/m^2, $p = 0.04$), and TSH levels (OR 1.05, $p = 0.01$) emerged as additional significant predictors (Table 2).

Discussion

In this observational study involving 4121 participants, we explored the prevalence, demographic characteristics, and predictors of thyroid nodules. Our findings contribute significantly to the understanding of thyroid nodule epidemiology.

We observed a thyroid nodule prevalence of 27.4%, with a notable gender disparity (60% in females vs. 40% in males; $p < 0.001$). The average age of participants with nodules was 47.9 years, highlighting age as a potential risk factor. These results are consistent with previous studies, such as those by Panagiotou et al. [18] and Wang et al. [19], which identified age, female gender, menopausal age, and reproductive history as significant factors. Further, Chen et al. [20] noted a correlation between lower levels of sex hormone-binding globulin and increased thyroid nodule risk in men.

The presence of metabolic syndrome has emerged as a significant predictor of thyroid nodules (OR = 1.43, $p = 0.03$), suggesting a complex interplay between systemic metabolic dysfunction and thyroid health. This association may be underpinned by shared pathophysiological mechanisms, including chronic inflammation, insulin resistance, and hormonal imbalances, which are central to metabolic syndrome and potentially contribute to thyroid nodule formation.

Chronic low-grade inflammation, a hallmark of metabolic syndrome, plays a pivotal role in its pathogenesis. Adipose tissue dysfunction drives this inflammatory state by secreting pro-inflammatory cytokines, such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α), which contribute to insulin resistance and metabolic dysregulation [21]. These inflammatory processes are also implicated in thyroid dysfunctions, where oxidative stress and systemic inflammation influence thyroid hormone conversion, particularly T4 to T3, potentially leading to hormonal imbalances that promote nodule formation [22, 23].

Although metabolic syndrome emerged as a significant predictor, the interplay between metabolic health and thyroid nodule development may involve additional factors such as dietary patterns, genetic predispositions, and environmental exposures. These factors, while not fully accounted for in this study, may influence the systemic inflammation and hormonal dysregulation underlying nodule formation.

Adipose tissue acts not only as an energy storage site but also as an endocrine organ, producing adipokines that enhance inflammatory responses. These adipokines

contribute to insulin resistance in metabolic syndrome and may also influence thyroid hormone metabolism, thereby linking metabolic syndrome to thyroid health [24, 25]. Furthermore, systemic hormonal dysregulation, including insulin and sex hormone imbalances, exacerbates inflammatory pathways, creating a feedback loop that affects both metabolic and thyroid function [26, 27].

Both metabolic syndrome and thyroid nodules share underlying mechanisms such as systemic low-grade inflammation, elevated C-reactive protein levels, and dysregulated glucose and lipid metabolism [14, 15]. These shared pathways suggest that thyroid nodule formation in the context of metabolic syndrome may result from the cumulative effects of inflammation, insulin resistance, and hormonal imbalances on thyroid tissue remodeling.

Participants with nodules showed a higher prevalence of metabolic syndrome, diabetes, hypertension, and elevated MAP. This finding corroborates previous research by Mayers [28], Zhang [29], Blanc [13], and Liu [30], which linked metabolic syndrome components such as low HDL, impaired fasting glucose, poor metabolic control, and waist circumference to an increased risk of thyroid nodules.

Additionally, our data showed altered laboratory parameters, including elevated FBG, and TSH levels, in the nodule group. Particularly, the elevated TSH levels could suggest a response to thyroid tissue changes or an effect of metabolic imbalances. This is in line with studies examining thyroid function and metabolic health, such as those exploring the impact of diabetes on thyroid hormone signaling and the mediating role of TSH in the association between metabolic syndrome and lead exposure [31, 32]. The prognostic value of serum TSH levels, as highlighted by Golbert [33] and Mondal [34], further underscores its importance in assessing the risk of thyroid cancer in nodules.

The higher prevalence of family and personal history of thyroid diseases in participants with nodules suggests a genetic or familial predisposition, aligning with the current understanding of the hereditary nature of thyroid disorders.

Research has consistently shown a strong association between family history of thyroid diseases and the development of thyroid nodules. Byun (2020) found a significant increase in the incidence of thyroid cancer in individuals with a family history of the disease. This is further supported by O'Brien (1981), who reported a case of familial thyroid nodulation, suggesting a genetic predisposition to thyroid diseases. Hwangbo (2018) also highlighted the role of genetics in the development of thyroid diseases, including thyroid cancer.

Our study observed a higher prevalence of family and personal history of thyroid diseases among participants with thyroid nodules, suggesting a potential genetic or familial predisposition. This observation is consistent with research that highlights the hereditary nature of thyroid disorders. For instance, Byun [35] demonstrated an increased incidence of thyroid cancer in individuals with a family history of the disease. Similarly, Hwangbo [36] provided evidence supporting a genetic predisposition to thyroid diseases.

Additionally, our findings align with studies indicating an increased risk of thyroid cancer in hyperthyroid patients, especially those with Graves' disease and thyroid nodules, as reported by Haraj [37] and Pazaitou-Panayiotou [38]. While the exact relationship between hyperthyroidism and thyroid cancer risk remains a topic of debate, these findings underscore the need for careful evaluation of thyroid nodules in hyperthyroid patients to effectively manage potential malignancies.

The correlations observed in this study have important clinical implications. First, they suggest that metabolic syndrome should be considered risk factors for thyroid nodules, particularly in aging populations. Screening for metabolic syndrome in patients presenting with thyroid nodules could facilitate early identification of individuals at risk for metabolic and cardiovascular complications. Second, the findings emphasize the need for a multidisciplinary approach in managing thyroid nodules, integrating endocrinology, cardiology, and metabolic health specialists. Finally, the observed associations may inform preventive strategies, such as lifestyle interventions targeting weight management and metabolic health, to reduce thyroid nodule risk.

This study has several limitations that should be considered when interpreting the findings. First, the sample size, although reflective of the available cohort data, may limit the generalizability of the results to broader populations. While the cohort provided a robust dataset, a larger sample size could enhance statistical power and enable more detailed subgroup analyses.

Second, the study's cross-sectional design precludes the establishment of causality between metabolic syndrome and thyroid nodules. Longitudinal studies are needed to confirm these associations and explore potential causal mechanisms.

Third, despite comprehensive exclusion criteria, the possibility of residual confounding due to unmeasured variables, such as undiagnosed comorbidities or other lifestyle factors, cannot be entirely ruled out.

Lastly, the study was conducted in a specific geographical and demographic setting, which may limit the applicability of the findings to other populations with different genetic, dietary, or environmental characteristics. Future studies incorporating more diverse populations are warranted to validate these findings.

Our findings underscore the importance of identifying at-risk individuals for thyroid ultrasonography,

particularly older adults with metabolic syndrome, elevated TSH levels, or a family history of thyroid disease. Early detection in these populations may allow for timely interventions, reducing the risk of malignancy and other complications.

Conclusion

The observed correlation between metabolic syndrome and thyroid nodules underscores a shared pathophysiological basis, primarily involving chronic inflammation and hormonal dysregulation. These interconnected mechanisms not only provide deeper insight into the etiology of thyroid nodules but also emphasize the importance of addressing systemic metabolic health in mitigating thyroid-related complications.

Our study highlights the intricate relationship between thyroid nodules and metabolic health, advocating for a comprehensive and multidisciplinary approach to the evaluation and management of thyroid nodules. From a clinical perspective, individuals with metabolic syndrome should be prioritized for thyroid evaluation, particularly those with additional risk factors. Integrating metabolic health management and targeted screening protocols could enhance the detection and management of thyroid nodules. These findings serve as a foundation for future research aimed at exploring the metabolic underpinnings of thyroid nodule development and their clinical implications, paving the way for integrated therapeutic strategies.

Acknowledgements
This article is the result of the support of the Research Vice-Chancellor of Mashhad University of Medical Sciences from the Internal medicine resident Thesis, which is now appreciated.

Author contributions
G.A. conceived and designed the experiments, supervised the project, and contributed to manuscript revision and editing. M.E. conducted the experiments, analyzed the data, and contributed to manuscript drafting and critical revision. A.B. contributed to data acquisition and analysis, and participated in drafting the initial manuscript. Y.M. contributed to data acquisition and analysis, and participated in drafting the revised manuscript. G.T. contributed to data acquisition and analysis, and participated in drafting the initial manuscript. S.H. contributed to the experimental design, performed statistical analysis, and assisted in manuscript preparation and editing. All authors have read and agreed to the published version of the manuscript.

Funding
This study was supported by Mashhad University of Medical Sciences Research Council, Mashhad, Iran (Ref: 4020423).

Data availability
Data will be available upon reasonable request from the corresponding author.

Declarations

Ethics approval and consent to participate
This study was conducted in full accordance with ethical principles, including the World Medical Association Declaration of Helsinki (version 2008). The research protocol was reviewed and approved by the Ethics Committee of Mashhad University of Medical Sciences under the ethical approval code: IR.MUMS.MEDICAL.REC.1402.209.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

Clinical trial number
Not applicable.

Patient consent statement
All patients provided their written, informed consent for their neonates anonymized information to be published in this article. They understood that their children names and initials will not be published, and due efforts will be made to conceal their identity.

Received: 25 June 2024 / Accepted: 5 February 2025
Published online: 13 February 2025

References

1. Moon JH, Hyun MK, Lee JY, Shim JI, Kim TH, Choi HS, et al. Prevalence of thyroid nodules and their associated clinical parameters: a large-scale, multi-center-based health checkup study. Korean J Intern Med. 2018;33(4):753–62.
2. Arora N, Scognamiglio T, Zhu B, Fahey Iii TJ. Do benign thyroid nodules have malignant potential? An evidence-based review. World J Surg. 2008;32:1237–46.
3. Dong X, Li Y, Xie J, Li L, Wan Z, Kang Y, et al. The prevalence of thyroid nodules and its factors among Chinese adult women: a cross-sectional study. Front Endocrinol (Lausanne). 2022;13:967380.
4. Ameer ANA, Alsadi H, Alghamdi AAS, Alshahrani HS, Alshehri MS, Hamuman AA et al. Non-surgical treatment of Benign thyroid nodules Worldwide and Saudi Arabia. Int J Med Developing Ctries. 2023.
5. Zhao ZL, Wei Y, Peng LL, Li Y, Lu NC, Yu MA. Recurrent laryngeal nerve Injury in Thermal ablation of thyroid nodules-risk factors and cause analysis. J Clin Endocrinol Metab. 2022;107(7):e2930–7.
6. Liu LH, Yang BB, Liu Y, Wang JL, Wang DD, Ding HY, et al. Factors related to the absorption rate of benign thyroid nodules after image-guided microwave ablation: a 3-year follow-up. Int J Hyperth. 2022;39(1):8–14.
7. Soares MN, Borges-Canha M, Neves C, Neves JS, Carvalho D. The role of Graves' disease in the development of thyroid nodules and thyroid cancer. Eur Thyroid J. 2023;12(4).
8. Wan Z, Li Y, Dong X, Kang Y, Luo J, Wang J et al. Influence of metabolic syndrome and lifestyle factors on thyroid nodules in Chinese adult men: a cross-sectional study. Eur Thyroid J. 2023;12(6).
9. Vakili V, Vakili K, Bidari MZ, Azarshab A, Vakilzadeh MM, Kazempour K. Effect of social beliefs on consumption of dairy products and its predicting factors based on the Transtheoretical model: a population-based study. Journal of Environmental and Public Health. 2023;2023.
10. Liu J, Wang C, Tang X, Fu S, Jing G, Ma L, et al. Correlation analysis of metabolic syndrome and its components with thyroid nodules. Diabetes Metab Syndr Obes. 2019;12:1617–23.
11. Zhang F, Li Y, Yu X, Wang X, Lin Z, Song B, et al. The relationship and gender disparity between thyroid nodules and metabolic Syndrome Components based on a recent Nationwide Cross-sectional Study and Meta-Analysis. Front Endocrinol (Lausanne). 2021;12:736972.
12. Ding X, Xu Y, Wang Y, Li X, Lu C, Su J, et al. Gender disparity in the relationship between prevalence of thyroid nodules and metabolic Syndrome Components: the SHDC-CDPC Community-based study. Mediators Inflamm. 2017;2017:8481049.
13. Blanc E, Ponce C, Brodschi D, Nepote A, Barreto A, Schnitman M, et al. Association between worse metabolic control and increased thyroid volume and nodular disease in elderly adults with metabolic syndrome. Metab Syndr Relat Disord. 2015;13(5):221–6.
14. Gerges M. The Effect of Low-Grade Chronic Inflammation on the Pathogenesis of Metabolic Syndrome. 2020.
15. Saltiel A, Olefsky J. Inflammatory mechanisms linking obesity and metabolic disease. J Clin Invest. 2017;127:1.

16. Poustchi H, Eghtesad S, Kamangar F, Etemadi A, Keshtkar A-A, Hekmatdoost A, et al. Prospective epidemiological research studies in Iran (the PERSIAN Cohort Study): rationale, objectives, and design. Am J Epidemiol. 2018;187(4):647–55.
17. Lipsy RJ. The National Cholesterol Education Program Adult Treatment Panel III guidelines. J Manag Care Pharm. 2003;9(1 Suppl):2–5.
18. Panagiotou G, Komninou D, Anagnostis P, Linardos G, Karoglou E, Somali M, et al. Association between lifestyle and anthropometric parameters and thyroid nodule features. Endocrine. 2017;56:560–7.
19. Wang K, Yang Y, Wu Y, Chen J, Zhang D, Liu C. The association of menstrual and reproductive factors with thyroid nodules in Chinese women older than 40 years of age. Endocrine. 2015;48:603–14.
20. Chen Y, Chen Y, Wang N, Chen C, Nie X, Li Q, et al. Are thyroid nodules associated with sex-related hormones? A cross-sectional SPECT-China study. BMJ open. 2017;7(8):e015812.
21. Esposito K, Giugliano D. The metabolic syndrome and inflammation: association or causation? Nutrition, metabolism, and cardiovascular diseases. NMCD. 2004;14 5:228–32.
22. Mancini A, Di Segni C, Raimondo S, Olivieri G, Silvestrini A, Meucci E et al. Thyroid Hormones, Oxidative Stress, and Inflammation. Mediators of Inflammation. 2016;2016.
23. Neto M, Parisi M, Tambascia M, Alegre S, Pavin E, Zantut-Wittmann D. The influence of body mass index and low-grade systemic inflammation on thyroid hormone abnormalities in patients with type 2 diabetes. Endocr J. 2013;60 7:877–84.
24. Lee YH, Pratley R. The evolving role of inflammation in obesity and the metabolic syndrome. Curr Diab Rep. 2005;5:70–5.
25. Wisse B. The inflammatory syndrome: the role of adipose tissue cytokines in metabolic disorders linked to obesity. J Am Soc Nephrology: JASN. 2004;15 11:2792–800.
26. Petersen L, Brixi G, Li J, Hu J, Wang Z, Han X et al. Understanding and Predicting Polycystic Ovary Syndrome through Shared Genetics with Testosterone, SHBG, and Chronic Inflammation. 2023.
27. Ahonen T, Ahonen T, Kosma V. Low-Grade Inflammation in Relation to Preceding Factors and the Course of the Metabolic Syndrome. 2012.
28. Mayers RA, Soria Montoya A, Piscoya Rivera A, Silva Caso WG. Association between metabolic syndrome and euthyroid nodular goiter: a case-control study. Colombia Médica. 2019;50(4):239–51.
29. Zhang F, Teng D, Tong N, Wang G, Li Y, Yu X, et al. Gender-specific associations between metabolic disorders and thyroid nodules: a cross-sectional population-based study from China. Thyroid. 2022;32(5):571–80.
30. Liu J, Wang C, Tang X, Fu S, Jing G, Ma L et al. Correlation analysis of metabolic syndrome and its components with thyroid nodules. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy. 2019:1617-23.
31. Choi JY, Huh DA, Moon KW. Association between blood lead levels and metabolic syndrome considering the effect of the thyroid-stimulating hormone based on the 2013 Korea National health and nutrition examination survey. PLoS ONE. 2020;15(12):e0244821.
32. Cokkinos DV, Pantos C. [Type 1 diabetes impairs compensatory response after myocardial infarction; role of tissue hypothyroidism and effects of thyroid hormone administration]. Bull Acad Natl Med. 2011;195(1):151–64. discussion 64– 5.
33. Golbert L, de Cristo AP, Faccin CS, Farenzena M, Folgierini H, Graudenz MS, et al. Serum TSH levels as a predictor of malignancy in thyroid nodules: a prospective study. PLoS ONE. 2017;12(11):e0188123.
34. Mondal HP, Sen S, Sasmal S, Ghosal PK, Mukhopadhyay SK, Mukhopadhyay M. Clinicopathological correlation of serum TSH in patients with thyroid nodule. J Indian Med Assoc. 2011;109(5:330):5, 8.
35. Byun S-H, Min C, Choi H-G, Hong S-J. Association between family histories of thyroid cancer and thyroid cancer incidence: a cross-sectional study using the Korean genome and epidemiology study data. Genes. 2020;11(9):1039.
36. Hwangbo Y, Park YJ. Genome-wide association studies of autoimmune thyroid diseases, thyroid function, and thyroid cancer. Endocrinol Metabolism. 2018;33(2):175–84.
37. Haraj NE, Ahandar H, El Aziz S, Chadli A. Association hyperthyroïdie Et cancers différenciés de la thyroïde. Pan Afr Med J. 2016;24(1).
38. Pazaitou-Panayiotou K, Michalakis K, Paschke R. Thyroid cancer in patients with hyperthyroidism. Hormone and metabolic research. 2012:255– 62.

Publisher's note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.