folia medica

Folia Medica 67(5)
DOI: 10.3897/folmed.67.e159172

Research Article

Thyroid dysfunction and metabolic syndrome: age- and sex-related associations in hospitalized patients

Stefanka Z. Kisova[1,2], Maria M. Orbetzova[1,2], Kristian R. Argirov[3]

1 *Clinic of Endocrinology and Metabolic Diseases, St George University Hospital, Plovdiv, Bulgaria*

2 *Department of Endocrinology, Faculty of Medicine, Medical University of Plovdiv, Plovdiv, Bulgaria*

3 *Department of Human Anatomy, Histology and Embryology, Faculty of Medicine, Medical University of Plovdiv, Plovdiv, Bulgaria*

Corresponding author: Stefanka Z. Kisova, Clinic of Endocrinology and Metabolic Diseases, St George University Hospital, Plovdiv, Bulgaria; Email: Stefanka.Kisova@phd.mu-plovdiv.bg

Received: 16 May 2024 ♦ **Accepted:** 19 June 2025 ♦ **Published:** 30 October 2025

Citation: Kisova SZ, Orbetzova MM, Argirov KR. Thyroid dysfunction and metabolic syndrome: age- and sex-related associations in hospitalized patients. Folia Med (Plovdiv) 2025;67(5):e159172. doi: 10.3897/folmed.67.e159172.

Abstract

Introduction: Thyroid hormones exert pleiotropic effects on lipid and glucose metabolism, blood pressure regulation, and energy expenditure. Thyroid dysfunction is a known risk factor for cardiovascular disease. The association between thyroid pathology and the components of metabolic syndrome (MetS) has emerged as a significant clinical focus, as both conditions contribute to increased morbidity and mortality. Studies indicate that patients with overt and subclinical hypothyroidism have a higher risk of developing MetS. Even in euthyroid individuals, TSH levels in the upper normal range (>2.5 mIU/L) are significantly associated with increased MetS prevalence.

Aim: To investigate the correlations between thyroid dysfunction and metabolic syndrome, with a specific focus on age and sex differences.

Materials and methods: This naturally randomized observational study included 726 patients with thyroid pathology hospitalized at the Clinic of Endocrinology, St George University Hospital in Plovdiv between October 2019 and December 2021. Data were extracted from the electronic system GammaCodeMaster and medical records, including clinical, anthropometric, and biochemical parameter.

Results: The study revealed a trend of increasing MetS prevalence with advancing age. The highest proportions of patients with MetS were observed in the 51–61 and 62–72 age groups, accounting for 39.1% and 29.7%, respectively. A statistically significant positive correlation between TSH levels and age was also established ($p<0.05$).

Conclusion: Given these findings, it is essential to assess the presence of MetS components in patients with thyroid pathology, as the combination of these factors considerably increases cardiovascular risk.

Keywords

age, metabolic syndrome, thyroid disorders, TSH

Introduction

Thyroid diseases are a major medical and biological concern because of the wide range of systemic effects they have on the human body. They are associated with an increased risk of cardiovascular diseases and accelerated atherogenesis, leading to rising mortality rates. Thyroid hormones play a key role in the regulation of metabolism, with the cardiovascular system being particularly sensitive to their fluctuations.

The relationship between thyroid function and the components of metabolic syndrome (MS) is still not fully understood, although it is believed to be mediated by genomic and non-genomic mechanisms.[1] Several hypotheses have been proposed regarding this connection: thyroid hormones are involved in the pathogenesis of insulin resistance[2], which in turn is considered a major etiological factor in the development of MS.[3,4] Furthermore, there are closely related interactions between the individual components of metabolic syndrome and thyroid function, suggesting the possibility that MS may arise as an end phenotype in the context of thyroid dysfunction.

For example, hypothyroidism contributes to increased body weight, and thyroid-stimulating hormone (TSH) has been shown to positively correlate with body mass index (BMI) and the presence of obesity, even within reference ranges.[5] Both overt and subclinical hypothyroidism are associated with unfavorable lipid profiles, including hypercholesterolemia, reduced HDL-cholesterol levels, and elevated blood pressure.[6]

Aim

To investigate the correlations between thyroid dysfunction and metabolic syndrome, with a specific focus on age- and sex-specific patterns, and to evaluate whether elevated TSH levels—even within the reference range—are associated with increased metabolic risk.

Materials and methods

This study is a retrospective cross-sectional analysis involving 726 patients with thyroid pathology who were hospitalized in the Clinic of Endocrinology at St. George University Hospital in Plovdiv between October 2019 and December 2021. All procedures were conducted in accordance with the ethical standards of the Declaration of Helsinki and the established Good Clinical Practice guidelines. The study was approved by the Ethics Committee of the Medical University of Plovdiv (protocol No. 5/24.04.2025). Among the patients, 499 were diagnosed with Hashimoto's thyroiditis (HT). The remaining 227 patients were distributed according to the following diagnoses: non-toxic thyroid nodule (n=24), multinodular goiter (MNG) (n=59), diffuse toxic goiter (n=79), toxic multinodular goiter (n=11), malignant thyroid diseases (n=19), and postoperative hypothyroidism(n=35). All participants met the established inclusion criteria. The diagnosis of Hashimoto's thyroiditis was based on a combination of clinical features, supported by the presence of thyroid autoantibodies (anti-Tg, anti-TPO), elevated or altered TSH levels, characteristic ultrasound findings, and, in rare cases when required, fine-needle aspiration biopsy (FNAB). Hyperthyroidism was diagnosed through typical clinical presentation and confirmed by thyroid hormone tests (TSH, T3, and T4). Graves' disease was identified by diffuse goiter, positive family history, ophthalmopathy, and elevated TRAb or TSI levels. High-resolution thyroid ultrasound was used to evaluate nodules with suspicious features, including hypoechogenicity, irregular margins, microcalcifications, a taller-than-wide shape, and abnormal cervical lymph nodes. FNAB was performed for definitive diagnosis of malignancy. Thyroid scintigraphy was applied in nodules >1 cm with suppressed TSH. Patients included both newly diagnosed and previously diagnosed individuals, with or without ongoing treatment.

During their hospitalization, all patients had their anthropometric, instrumental, and biochemical parameters measured. Body height (cm) and weight (kg) were measured, and BMI was calculated using the standard formula: weight (kg)/[height (m)]^2.

Fasting blood samples were collected between 07:00 and 09:00 AM, in accordance with all standard patient preparation requirements. Serum levels of thyroid-stimulating hormone (TSH), free triiodothyronine (FT3), and free thyroxine (FT4) were measured using chemiluminescent immunoassay on the fully automated Access 2 Immunoassay System (Beckman Coulter Inc., USA). Metabolic parameters—total cholesterol (TC), triglycerides (TG), low-density (LDL) and high-density lipoproteins (HDL), as well as fasting plasma glucose (FPG)—were analyzed enzymatically using the AU 480 clinical chemistry analyzer (Beckman Coulter, USA) with validated standard methods. Reference ranges for the laboratory parameters used were as follows: TSH: 0.34–5.60 mIU/L; FT3: 3.8–6.0 pmol/L; FT4: 7.86–14.41 pmol/L; TC: 3.0–5.2 mmol/L; TG: 0.4–1.70 mmol/L; LDL: 2.6–4.1 mmol/L; HDL: 1.03–1.60 mmol/L; and FPG: 2.8–6.1 mmol/L.

A statistical analysis of the data was conducted using univariate and bivariate distributions and descriptive statistics methods. The Student's t-test was employed to compare two independent groups with normal distribution. The results were graphically represented using Microsoft PowerPoint, and statistical analyses were performed using SPSS software, version 19.0 (Chicago, IL, USA). A p-value of less than 0.05 was considered to be statistically significant.

Results

Given the well-documented differences in the prevalence of

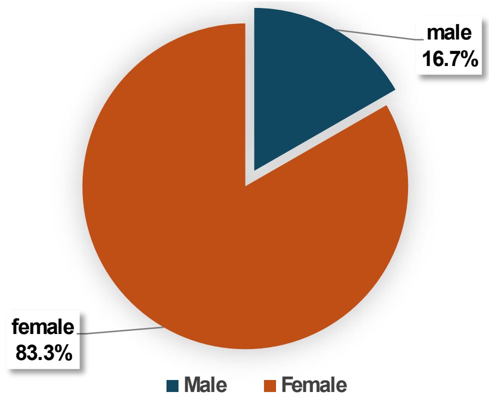

Figure 1. Distribution of the studied patients by sex.

thyroid gland disorders between sexes, a percentage-based distribution of patients by sex was performed **(Fig. 1)**.

Analysis of the overall sample showed that thyroid pathology was significantly more common in women—83.3%, whereas men represented only 16.7% of the studied cases. This approximately 5:1 female-to-male ratio corresponds with established epidemiological trends and may partly be explained by the higher frequency of healthcare-seeking behavior and preventive checkups among women. In addition to behavioral factors, biological mechanisms also contribute to the observed female predominance in thyroid disorders. Women generally exhibit a more active immune response, which predisposes them to autoimmune conditions, including Hashimoto's thyroiditis and Graves' disease. Furthermore, hormonal fluctuations—particularly during pregnancy, the postpartum period, and menopause—can influence thyroid function and autoimmunity, thereby increasing the risk of thyroid dysfunction in females.

A clear predominance of female patients was observed across all forms of thyroid pathology, with prevalence increasing progressively with age. Thyroid hormones exert pleiotropic effects on lipid and glucose metabolism, blood pressure regulation, and energy expenditure, which is why thyroid dysfunction is regarded as an independent risk factor for cardiovascular disease.

The growing interest in the interaction between thyroid dysfunction and the components of metabolic syndrome (MetS) is justified by the fact that both conditions are associated with considerable morbidity and mortality. Recent studies suggest that elevated levels of thyroid-stimulating hormone (TSH), even within the reference range, may be linked to an unfavorable lipid profile. It has been demonstrated that both clinical and subclinical hypothyroidism are associated with an increased risk of developing MetS.[7] Particularly relevant are findings indicating that even within the euthyroid range, TSH levels >2.5 mIU/L may be linked to adverse metabolic outcomes. Ruhla et al.[8] observed that TSH levels below 2.5 mIU/L correlated with a more favorable metabolic profile, while Oh et al.[9] recommended screening for MetS in apparently healthy women with TSH levels exceeding 2.5 mIU/L. Nonetheless, some studies report conflicting evidence and do not support a statistically significant association between TSH and MetS prevalence[10,11], which may reflect differences in study design, population characteristics, or MetS diagnostic criteria. These inconsistencies underscore the need for further investigation, and future analyses could benefit from sensitivity assessments using different TSH thresholds.

Metabolic syndrome

Metabolic syndrome (also known as syndrome X or insulin resistance syndrome) is a multifactorial clinical continuum with a variety of negative health consequences. The condition arises on the basis of insulin resistance[12,13] and includes a combination of risk factors for the development of type 2 diabetes, coronary artery disease, metabolic dysfunction-associated steatotic liver disease (MASLD), and certain types of malignancies.

The most commonly used diagnostic criteria for metabolic syndrome include a combination of the following parameters[14]: waist circumference ≥102 cm in men and ≥88 cm in women; triglycerides ≥1.70 mmol/L; HDL-cholesterol <1.03 mmol/L in men and <1.29 mmol/L in women; blood pressure ≥130/85 mmHg or use of antihypertensive therapy; and fasting plasma glucose ≥5.6 mmol/L.

The diagnosis of metabolic syndrome is established when at least three of the above criteria are present. It should be noted that the diagnostic cut-off values may vary across different international organizations, and additional factors such as age, ethnicity, and family history also influence the risk of developing metabolic syndrome.

In our study, patients were divided into the following clinical groups: Hashimoto's thyroiditis, Graves' disease (GD), multinodular goiter (MNG), and thyroid adenoma, as well as postoperative hypothyroidism—including patients with previous surgery due to thyroid carcinoma, MNG, or GD.

A total of 499 patients were diagnosed with Hashimoto's thyroiditis, of whom 417 were women (83.6%) and 82 were men (16.4%). The remaining thyroid disorders encompassed 227 cases and are summarized in **Table 1**.

Table 1. Percentage distribution of patients by admission diagnosis

Diagnosis	Number	% of 227
Thyroid adenoma (non-toxic nodule)	24	10.6%
Multinodular goiter (MNG)	59	26.0%
Graves' disease (thyrotoxicosis with diffuse goiter)	79	34.8%
Toxic multinodular goiter / solitary toxic nodule	11	4.8%
Thyroid malignancy	19	8.4%
Postoperative hypothyroidism	35	15.4%

The sex distribution among patients with autoimmune thyroid diseases (HT and GD) was 477 women (82.5%) and 101 men (17.5%). The total number of patients with autoimmune thyroid disorders (HT and GD) amounted to 578, representing 79.6% of all 726 cases.

Notable trends in the diagnostic structure include:

- Thyroid adenomas: accounted for approximately 10.6% of the reviewed patients and were evenly distributed across all age groups, with no clear sex predominance.
- Multinodular goiter: increased with age. The highest frequency was observed in the 62–72 years age group (35.6% of the cases in this category).
- Graves' disease was the most common form of thyrotoxicosis, comprising 34.8% of the remaining 227 non-HT cases. The disease predominated among women aged between 29 and 50 years.

Age and sex distribution of the study population

The studied patients were categorized into six age subgroups, defined by decades: 18–28 years, 29–39 years, 40–50 years, 51–61 years, 62–72 years, and over 73 years. **Table 2** presents the data on distribution by sex and age.

Table 2. Distribution of the studied group by sex and age (n=726)

Age group (years)	18–28	29–39	40–50	51–61	62–72	73+	Total
Men	20	32	19	20	20	10	121
Women	70	117	140	136	92	50	605
Total	90	149	159	156	112	60	726

There are significant differences in age distribution by sex. Men in the sample are, on average, younger, with the highest frequency observed in the 29–39 age group. Women are significantly more numerous—approximately six times more than men—with a peak in frequency between 40 and 61 years of age.

Age and TSH Values

The average TSH value in the study population was 4.05 mIU/L. While age showed a normal distribution, TSH levels exhibited slight right skewness, with deviations at the extreme values. **Fig. 2** illustrates the relationship between age and serum TSH levels.

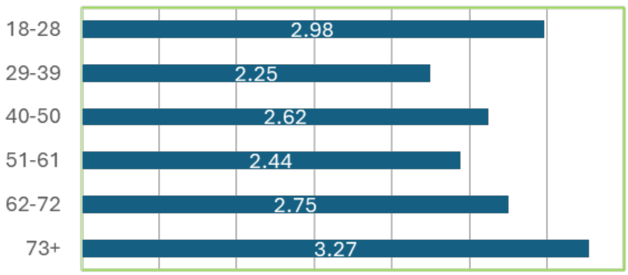

Figure 2. Mean TSH value by age group.

To evaluate the effect of age on TSH, patients were divided into two groups based on the median age of 56 years. An independent samples t-test was conducted, which showed that patients over the age of 56 had higher mean TSH levels (4.44 mIU/L) compared to patients under 56, who had a mean TSH of 3.67 mIU/L. The difference was statistically significant ($p<0.05$).

These findings are consistent with studies that report a trend of increasing TSH values with advancing age.[15] One possible hypothesis is reduced pituitary sensitivity to thyroid hormones in older individuals, leading to compensatory TSH elevation. Additional explanations include changes in thyroid hormone homeostasis and metabolism with aging.[16] In this view, it might be possible that the observed increase in TSH with advancing age reflects a progressive decline in the thyroid gland's ability to synthesize and secrete thyroid hormones. This reduced functional reserve may represent a physiological adaptation or early subclinical dysfunction, even in the absence of overt disease. Age-related changes in the hypothalamic-pituitary-thyroid axis and altered tissue sensitivity to thyroid hormones may further contribute to this trend.[17]

A study from the American Cardiovascular Research Survey, which included 843 participants with a mean age of 72 years, showed a 13% increase in TSH (an average of 0.34 mIU/L) over a nearly 13-year follow-up period.[18] Another study found that centenarians had significantly higher TSH levels compared to younger control groups (average age 72), which was interpreted as a possible protective mechanism that slows catabolism in advanced age.[19]

However, there is no universal consensus regarding the upper reference limit for TSH in older adults. Some authors suggest using age-adjusted reference ranges when interpreting results.[20] Globally, there is ongoing debate over whether mildly elevated TSH levels in the elderly warrant therapeutic intervention or represent a physiological feature of aging. In the context of metabolic risk, however, even "borderline" values may have clinical significance and warrant closer monitoring.

Out of the 499 patients diagnosed with Hashimoto's thyroiditis, 64 (12.8%) met at least three of the criteria for metabolic syndrome. Among them, 46 (71.9%) were women and 18 (28.1%) were men. Women represented a significantly larger proportion of patients with MetS, which aligns with the general trend of a higher prevalence of thyroid disorders among females. The data suggest that women with HT are more than twice as likely to have MetS compared to men.

As shown in **Fig. 3**, the highest prevalence of MetS was observed in the 51–61 age group (39.1%) and the 62–72 age group (29.7%). This age-related pattern was more pronounced among women, particularly those in the post-menopausal period, where decreased estrogen activity is believed to contribute to a worsening of the metabolic profile. Among women with MetS—defined by the presence of three key criteria: elevated triglycerides, low HDL-cholesterol, and arterial hypertension—the highest prevalence

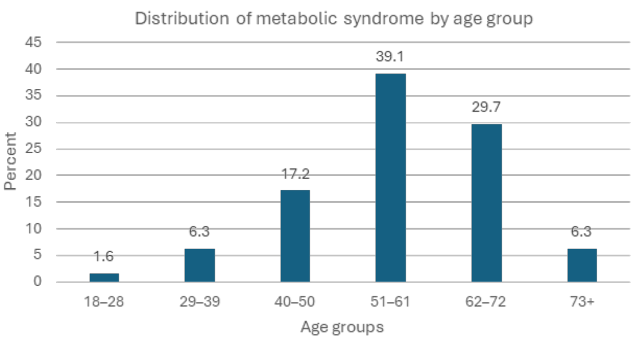

Figure 3. Percentage distribution of MetS cases by age group.

was recorded in the 51–61 age group (38.2%) and the 62–72 age group (35.3%). These findings support the hypothesis that the postmenopausal period is associated with an increased risk of metabolic disturbances, including the development of MetS, particularly in the context of coexisting thyroid dysfunction.[21]

Elevated TSH levels—even when within the euthyroid reference range—are associated with an unfavorable lipid and glucose profile, as well as elevated blood pressure. In our study, patients with TSH >2.5 mIU/L demonstrated a trend toward higher prevalence of metabolic syndrome (MetS).

It should be noted that some studies[22] have not found a statistically significant association between TSH levels and MetS prevalence, which is likely due to heterogeneity in the studied populations, differences in diagnostic criteria, or variation in participant selection.

Our findings indicate an increased prevalence of MetS in patients with autoimmune thyroid disorders, especially among women in middle and older age groups. The observed positive correlation between age and TSH, as well as the association between elevated TSH and specific MetS components, highlights the need for early metabolic screening in patients with thyroid disease. This emphasizes the importance of using age-adjusted reference ranges for TSH and ensuring timely identification and management of associated metabolic disturbances.

Discussion

Over the past decades, global lifestyle patterns have undergone a profound transformation, characterized by increasing consumption of high-calorie foods and reduced physical activity. As a result, there has been a sharp rise in the prevalence of obesity, hyperglycemia, and arterial hypertension—trends that have reached pandemic proportions worldwide.[23] According to data from the World Health Organization, over 1 billion adults globally are overweight, and more than 300 million suffer from obesity.

As early as 2008, Misra and Khurana[24] reported high prevalence rates of MetS in various regions: Sub-Saharan Africa (33.5%), India (28.8%), Turkey (33.4%), Iran (33.7%), Venezuela (31.2%), and Brazil (25.4%). MetS is associated with an increased risk of developing type 2 diabetes and serious cardiovascular events, including myocardial infarction, stroke, and heart failure. According to Huang et al.[25], obesity and smoking are leading risk factors for chronic non-communicable diseases. Obesity alone accounts for more than 363,000 deaths and 12.3 million years lived with disability.

Metabolic regulation demonstrates a marked sex dimorphism, which determines the differing cardiovascular risk profiles in men and women. Premenopausal women are in a more favorable metabolic position due to lower visceral adiposity, mediated by estrogenic activity.[26] After menopause, the decline in circulating estrogens leads to changes in the lipid profile and fat distribution, shifting toward a central (android) pattern similar to that in men.[27]

The results of the present study confirm a positive correlation between advancing age and the prevalence of metabolic syndrome, as well as a linear relationship between age and thyroid-stimulating hormone levels. The physiological decline in ovarian function leads to estrogen deficiency, while androgen production by the adrenal cortex remains relatively preserved. This hormonal imbalance contributes to adverse changes in the metabolic profile. Menopause is associated with increased frequency of all components of MetS—central obesity, arterial hypertension, atherogenic lipid profile, and insulin resistance.[28]

Available data indicate that the overall prognostic value of MetS for cardiovascular events and all-cause mortality is higher in women compared to men.[29] In addition, there are distinct sex differences in the prevalence of thyroid diseases, particularly autoimmune disorders, which are significantly more common in women and increase with age in both sexes. It should be emphasized that even subclinical forms of thyroid dysfunction are associated with an increased risk of coronary artery disease and all-cause mortality, supporting the need for screening, especially in patients with MetS.

Aging is a complex process involving morphological and functional changes that lead to a progressive decline in biological functions. In women, this process is marked by a sharp decline in sex hormones accompanying the cessation of reproductive function, whereas in men, androgen reduction is more gradual and progressive.[30] Age is a significant moderating factor in the relationship between thyroid function and MetS. Lao et al.[31] identify population aging as a key factor in the rising prevalence of MetS. Sex differences in the distribution, age of onset, and severity of MetS, as well as its cardiovascular consequences, are likely due to the differing pace of hormonal decline between the sexes. Our findings confirm the progressive increase in both the prevalence of MetS and thyroid dysfunction with advancing age.

Recent guidelines from the American Thyroid Association (ATA) and other expert consensus panels emphasize the importance of considering age-related changes in thyroid physiology when interpreting thyroid-stimulating hormone (TSH) levels. While the standard reference range for TSH in adults is generally 0.4–4.0 mIU/L, several studies and expert groups suggest that TSH values tend to increase with age, even in the absence of overt thyroid disease. Consequently, applying a uniform reference interval across all age groups may lead to overdiagnosis of subclinical hypothyroidism in the elderly. The ATA recommends individualized interpretation of TSH results, particularly in adults over 65 years of age, and supports higher upper reference limits in this population to avoid unnecessary treatment. These age-adjusted thresholds are increasingly being recognized in clinical practice to ensure more accurate diagnosis and management decisions.

In addition to screening considerations, the American Thyroid Association (ATA) provides guidance on the treatment of subclinical hypothyroidism, emphasizing a personalized approach based on age, TSH levels, and symptomatology. Treatment is generally recommended for patients under 65 years with a TSH level ≥10 mIU/L, even if asymptomatic, due to the increased risk of cardiovascular events and progression to overt hypothyroidism. For patients with TSH levels between 4.5 mIU/L and 9.9 mIU/L, treatment may be considered in younger individuals, especially in the presence of symptoms, positive anti-thyroid antibodies, or risk factors such as dyslipidemia, infertility, or goiter. However, in older adults (≥65 years), the ATA advises a more conservative approach. In this population, treatment is typically reserved for those with TSH ≥10 mIU/L, and individualized decisions should be made for those with lower elevations due to the lack of clear evidence of benefit and potential risk of overtreatment, including atrial fibrillation and bone loss.[32,33]

Study limitations

This study has several limitations that should be acknowledged. First, it was conducted in a single tertiary care university hospital and included only hospitalized patients. This hospital-based design may introduce selection bias, limiting the generalizability of the findings to the broader population, especially to individuals with milder or asymptomatic thyroid dysfunction who are managed in outpatient settings. Second, the retrospective cross-sectional nature of the study prevents the establishment of causal relationships between thyroid dysfunction and components of metabolic syndrome; thus, temporal associations cannot be inferred, and reverse causation remains a possibility.

Furthermore, the absence of multivariable analysis limits the ability to control for potential confounding factors such as age, body mass index (BMI), and medication use, which may have influenced the observed associations. Additionally, important lifestyle and treatment-related variables—including physical activity, dietary habits, smoking, alcohol consumption, socioeconomic status, and the use of medications such as statins, antihypertensives, or thyroid hormone replacement therapy—were not collected or analyzed, which may have affected both metabolic and thyroid function outcomes.

The diagnosis of metabolic syndrome was based on standard criteria; however, data for all diagnostic components, such as waist circumference and medication use, were not consistently available across patient subgroups. This may have led to underestimation or misclassification of MetS prevalence. Moreover, while the study highlights an increased risk of MetS in postmenopausal women, it did not include a direct assessment of menopausal status or hormone replacement therapy, both of which are relevant factors influencing metabolic risk.

Finally, although the relationship between thyroid-stimulating hormone (TSH) levels and age was explored, the study applied uniform reference intervals for TSH rather than using age-specific thresholds. This could result in misclassification of thyroid status, particularly in older adults.

Despite these limitations, the findings provide meaningful insights into the interplay between thyroid dysfunction and metabolic syndrome, particularly in the context of age- and sex-specific differences. These results may inform future prospective studies and guide targeted preventive strategies in clinical practice.

Conclusion

The results of this study highlight a significant association between metabolic syndrome (MetS) and thyroid dysfunction, with age and sex playing a substantial moderating role. It was found that older women, particularly those in the postmenopausal period, were at an increased risk of developing MetS in the presence of elevated thyroid-stimulating hormone levels. This likely reflects the combined influence of estrogen deficiency and the higher prevalence of thyroid disorders in women.

The findings underscore the need for targeted screening for thyroid dysfunction in patients with MetS, with particular attention to vulnerable age and sex subgroups. These insights may contribute to a deeper understanding of the pathophysiological mechanisms underlying cardiometabolic risk and support early identification and appropriate management of high-risk individuals. Early identification of thyroid dysfunction through routine screening in primary care is essential for timely intervention, especially in high-risk groups such as older adults and women. Preventive strategies, including regular monitoring and patient education, can help reduce the burden of metabolic and cardiovascular complications associated with undiagnosed or subclinical thyroid disorders.

Recommendations for Future Research

- Prospective and interventional studies are needed to better understand the causal mechanisms between thyroid function and metabolic syndrome.
- A detailed analysis of the impact of various hormonal states (e.g., menopause, hypogonadism) would help more precisely identify at-risk groups.
- Future research could also incorporate genetic and inflammatory markers to better elucidate the pathogenic link between the two conditions.

Ethics approval and consent to participate

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the institutional Ethics Committee of St George University Hospital in Plovdiv, Bulgaria. All data were obtained through retrospective analysis of medical records, ensuring full anonymity and confidentiality of patient information. The requirement for written informed consent was waived due to the retrospective nature of the study and the use of de-identified data, in line with local regulations and institutional guidelines.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. Davis PJ, Davis FB. Nongenomic actions of thyroid hormone on the heart. Thyroid 2002; 12:459–66.
2. Maratou E, Hadjidakis DJ, Peppa M, et al. Studies of insulin resistance in patients with clinical and subclinical hyperthyroidism. Eur J Endocrinol 2010; 163:625–30.
3. Cornier MA, Dabelea D, Hernandez TL, et al. The metabolic syndrome. Endocr Rev 2008; 29:777–822.
4. Zhao W, Zhang J, Mu Y, et al. Age- and sex-specific associations between subclinical hypothyroidism and metabolic syndrome in a Chinese population. Endocrine 2022; 75(2):417–26. doi: 10.1007/s12020-021-02884-1
5. De Moura Souza A, Sichieri R. Association between serum TSH concentration within the normal range and adiposity. Eur J Endocrinol 2011; 165:11–5.
6. Waring AC, Rodondi N, Harrison S, et al. Thyroid function and prevalent and incident metabolic syndrome in older adults: the health, ageing and body composition study. Clin Endocrinol 2012; 76:911–8.
7. Erdogan M, Canataroglu A, Ganidagli S, et al. Metabolic syndrome prevalence in subclinic and overt hypothyroid patients and the relation among metabolic syndrome parameters. J Endocrinol Invest 2011; 34:488–92.
8. Ruhla S, Weickert MO, Arafat AM, et al. A high normal TSH is associated with the metabolic syndrome. Clin Endocrinol 2010; 72:696–701.
9. Oh JY, Sung YA, Lee HJ. Elevated thyroid stimulating hormone levels are associated with metabolic syndrome in euthyroid young women. Korean J Inter Med 2013; 28:180–6.
10. Garduno-Garcia Jde J, Alvirde-Garcia U, Lopez-Carrasco G, et al. TSH and free thyroxine concentrations are associated with differing metabolic markers in euthyroid subjects. Eur J Endocrinol 2010; 163:273–8.
11. Bakiner O, Bozkirli E, Cavlak G, et al. Are plasma thyroid-stimulating hormone levels associated with degree of obesity and metabolic syndrome in euthyroid obese patients? A Turkish cohort study. ISRN Endocrinol 2014; 2014:803028.
12. Olufadi R, Byrne CD. Clinical and laboratory diagnosis of the metabolic syndrome. J Clin Pathol 2008; 61(6):697-706.
13. Hernandez-Baixauli J, Quesada-Vázquez S, Mariné-Casadó R, et al. Detection of early disease risk factors associated with metabolic syndrome: a new era with the NMR metabolomics assessment. Nutrients 2020; 12(3):806.
14. Grundy SM, Cleeman JI, Daniels SR, et al. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. Circulation 2005; 112:2735–52.
15. Alzahrani SH, Albattat YM, Alghamdi MF, et al. Prevalence of subclinical hypothyroidism and its association with metabolic parameters in Saudi Arabia: A retrospective cohort study. J Clin Med Res 2023; 15(3):97–104. doi: 10.14740/jocmr4912
16. Alberti KG, Eckel RH, Grundy SM, et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation 2009; 120:1640–5.
17. Dayan CM, Onyekachukwu OK. Age-related variation in thyroid function-a narrative review. Thyrioid Res 2023; 16:7.
18. Surks MI, Hollowell JG; Cardiovascular Health Study All-Stars Investigators. Longitudinal changes in thyroid function in the oldest old and survival: the Cardiovascular Health Study All-Stars Study. J Clin Endocrinol Metab 2012; 97(10):3945–52. doi: 10.1210/jc.2012-2569
19. Atzmon G, Barzilai N, Hollowell JG, et al. Extreme longevity is associated with increased serum thyrotropin. J Clin Endocrinol Metab 2009; 94(2):1251–4.
20. Gu D, Reynolds K, Wu X, et al. Prevalence of the metabolic syndrome and overweight among adults in China. Lancet 2005; 365:1398–1405.
21. Huang J, Fang Y, Zhao Y, et al. Association between thyroid function and metabolic syndrome in women before and after menopause. Front Endocrinol (Lausanne) 2021; 12:634092. doi: 10.3389/fendo.2021.634092
22. Tognini S, Polini A, Pasqualetti G, et al. Age and gender substantially influence the relationship between thyroid status and the lipoprotein profile: results from a large cross-sectional study. Thyroid 2012; 22:1096–103.
23. Eftekharzadeh A, Khamseh ME, Farshchi A, et al. The association between subclinical hypothyroidism and metabolic syndrome as defined by the ATP III criteria: a metaanalysis. Metab Syndr Relat Disord 2016; 14(3):137–44.
24. Misra A, Khurana L. Obesity and the metabolic syndrome in developing countries. J Clin Endocrinol Metab 2008; 93:S9–S30.
25. Huang C, Yu H, Koplan JP. Can China diminish its burden of non-communicable diseases and injuries by promoting health in its policies, practices, and incentives? Lancet 2014; 384:783–92.
26. Van Pelt RE, Jankowski CM, Gozansky WS, et al. Sex differences in the association of thigh fat and metabolic risk in older adults. Obesity 2011; 19:422–8.
27. Pellegrini M, Pallottini V, Marin R, et al. Role of the sex hormone estrogen in the prevention of lipid disorder. Curr Med Chem 2014; 21:2734–42.
28. Regitz-Zagrosek V, Lehmkuhl E, Mahmoodzadeh S. Gender aspects of the role of the metabolic syndrome as a risk factor for cardiovascu-

lar disease. Gender Med 2007; 4(Suppl B):S162–S77.
29. Ford ES. Risks for all-cause mortality, cardiovascular disease, and diabetes associated with the metabolic syndrome: a summary of the evidence. Diabetes Care 2005; 28:1769–78.
30. Guarner-Lans V, Rubio-Ruiz ME, Perez-Torres I, et al. Relation of aging and sex hormones to metabolic syndrome and cardiovascular disease. Exp Gerontol 2011; 46:517–23.
31. Lao XQ, Ma WJ, Sobko T, et al. Dramatic escalation in metabolic syndrome and cardiovascular risk in a Chinese population experiencing rapid economic development. BMC Pub Health 2014; 14:983.
32. Garber JR, Cobin RH, Gharib H, et al. Clinical practice guidelines for hypothyroidism in adults: cosponsored by the American Association of Clinical Endocrinologists and the American Thyroid Association. Endocr Pract 2012; 18(6):988–1028. doi: 10.4158/EP12280.GL
33. Biondi B, Cappola AR, Cooper DS. Subclinical hypothyroidism: a review. JAMA 2019; 322(2):153–60. doi: 10.1001/jama.2019.9052 .