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ORIGINAL ARTICLE

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Relationship between metabolic syndrome and thyroid nodules and thyroid volume in an adult population

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Abstract

Purpose The effects of metabolic syndrome (MetS) on thyroid nodules (TN) and thyroid volume (TV), especially the related gender and age disparities, are controversial. In this study, we aimed to assess the relationships between MetS and TN and TV in an adult population.

Methods This cross-sectional study was performed in an adult population in Tianjin. A total of 2606 subjects were enrolled. TV and TN were measured by thyroid ultrasonography. Blood samples were collected to measure biochemical and metabolic parameters.

Results The prevalence of TN was significantly higher in the MetS (+) group than in the MetS (−) group ($P < 0.0001$). MetS was independently associated with increased TN risk (OR: 1.24, 95% CI: 1.01–1.51). When stratified by gender, MetS was associated with higher prevalence of TN in males (OR: 1.38, 95% CI: 1.05–1.81) compared with females (OR: 1.02, 95% CI: 0.75–1.39). However, the interaction effect of gender and MetS on TN was not statistically significant (P for interaction = 0.94). MetS was associated with the greater risks of TN in both the <60-year-old group (OR: 1.32, 95% CI: 1.05–1.68) and the ≥60-year-old group (OR: 1.84, 95% CI: 1.24–2.73), while the OR value was significantly higher in the elderly group (P for interaction = 0.03). Additionally, TV was significantly higher in subjects with TN ($\beta = 1.94$, $P < 0.0001$) and MetS ($\beta = 0.94$, $P = 0.0037$).

Conclusions This study suggested positive relationships between MetS and an increased risk of TN and enlarged TV. Elderly people (≥60 years old) with MetS were associated with a higher risk of TN than younger people (<60 years old). The effect of MetS on TN was not significantly affected by gender.

Keywords Metabolic syndrome · Thyroid nodules · Thyroid volume · Gender · Age

Introduction

Thyroid nodules (TN), one of the most common clinical thyroid diseases, have become increasingly prevalent worldwide. The prevalence of TN by palpation is 4–7%, while the prevalence by ultrasound is 13–67% [1]. It is estimated that 5% of clinically apparent thyroid nodules might become malignant. Furthermore, nontoxic nodules could develop into carcinomas [2]. Accordingly, the associated risk factors have received much attention in recent years.

The prevalence of TN could be affected by gender, age, iodine intake, blood lipid levels, smoking status, and alcohol consumption [3]. Previous studies have shown that obesity is an independent risk factor for TN, especially abdominal adiposity [4, 5]. Hypertension, fasting blood

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glucose (FBG), prediabetes, and diabetes have been associated with higher risks of TN [3]. Impaired glucose metabolism was also described as a risk factor for increased thyroid volume (TV) and TN prevalence [6]. Notably, all of the above risk factors are components of MetS. In addition, insulin resistance, which is the main pathogenesis of MetS [7], has been reported to explain an increase in thyroid cellular proliferation [8]. In recent years, a study found that the thyroid gland is one of the target organs of MetS [9]. Furthermore, thyroid nodularity and larger thyroid volume have also been reported in patients with MetS [10].

The associations between MetS and TN and TV remain controversial, especially the disparities by gender and age. Studies have described that the prevalence of TN is different in males and females and increases with age [11]. Additionally, some recent studies have shown that gender differences influence TN prevalence in people with MetS. One study found that the prevalence of TN in females was generally higher than that in males in a population with MetS aged over 45 years [4]. Another study indicated that there was no obvious gender difference in people aged 18 years or older [12]. Furthermore, MetS has been described as a risk factor for increased thyroid volume in earlier studies [7, 10]. Therefore, the aim of this study was to further investigate the relationship between MetS and TN and TV, as well as the age and gender disparities among urban and rural residents over 18 years of age.

Methods

Study population

This cross-sectional study was conducted in Tianjin, China, from March to October 2015. Random cluster sampling was used to select the study population. Adult residents who lived locally for at least 5 years were included, while participants taking iodine-containing drugs for the last three months and those missing TN or TV values were excluded. Pregnant women, breastfeeding women, and participants who had hepatic or renal dysfunction were excluded. A total of 2606 participants were recruited. Written informed consent was obtained from each participant. All research protocols were approved by the Medical Ethics Committee of Tianjin Medical University.

Data collection

Thyroid ultrasound examination was performed by a trained examiner using a 7.5 MHz transducer (Madison Portable B-SA-600) with the participants in the supine position fully exposing their necks. Thyroid volume was calculated using the following formula: volume of each lobe (mL) = 0.479 × depth × width × length(mm)/1000. Thyroid volume was recorded as the sum of the volumes of the left and right thyroid lobes.

A comprehensive questionnaire was used to obtain basic information, including medical history, family history of chronic diseases, current medication use, and smoking and drinking status. Height, weight, waist circumference, and blood pressure were measured based on standardized protocols and body mass index (BMI) was calculated according to the following formula: BMI = weight in kilograms/height in square meters. Waist circumference (WC), midway between the base of the costal arch and the top of the iliac crest, was measured in upright standing subjects. Fasting blood pressure was measured. Biochemical measurements, including FBG, triglycerides (TG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), and hemoglobin A1c (HbA1c), were conducted using a Roche automatic biochemistry analyzer (C8000).

Definition and diagnostic

Thyroid nodules were described as additional ultrasound structural focal abnormalities (circumscribed areas of greatly reduced or absent echogenicity). The location, number, echogenicity, boundary, diameter >1 cm or not, and calcification of thyroid nodules in each subject were recorded. The definition of a nodule included any area that had a different echogenicity compared to thyroid parenchyma. The criteria for the diagnosis of MetS in our study were provided by the International Diabetes Federation (IDF) [13]: abdominal adiposity (defined as WC ≥90 cm in Chinese men and WC ≥80 cm in Chinese women) plus at least two of the following components:

(1) Triglyceride concentration >150 mg/dl, (1.7 mmol/L) or previous lipid abnormalities, which were described as hypertriglyceridemia; (2) HDL concentrations <40 mg/dL (1.03 mmol/l) in men and <50 mg/dL (1.29 mmol/l) in women, which were described as low HDL; (3) blood pressure >130/85 mmHg or previous hypertension diagnosis, which were described as raised blood pressure; and (4) fasting glycemia >100 mg/L (5.6 mmol/l) or previous type 2 diabetes diagnosis, which were described as dysglycemia.

Statistical analysis

All statistical analyses were performed by SAS version 9.4 (SAS Institute Inc., Cary, NC, USA), Microsoft Excel (Win10, 2016) and R version 3.5.0 (http://www.r-project.org). Continuous variables were tested for normality according to the Kolmogorov–Smirnov test. Normally distributed variables were described as the mean ($x \pm SD$), including age, systolic blood pressure (SBP), diastolic

blood pressure (DBP), WC, FBG, LDL, HDL, TC, HbA1c, and thyroid volume. As BMI, TG and OGTT-2h were nonnormally distributed variables, values were expressed as medians (interquartile range, IQR). Categorical variables were described by using percentages such as the proportion of males and females and the prevalence of TN, MetS, abdominal adiposity, raised blood pressure, dysglycemia, low HDL, and hypertriglyceridemia. A *t*-test or Mann–Whitney U test was used to compare two continuous variables. The comparisons among the different groups were performed using the chi-square test. Multivariate binary logistic analysis was used to explore the associations between TN and MetS. Test for interaction was used to analyze interaction effect of gender and age and MetS on the prevalence of TN. Multiple linear regression analysis was conducted for the assessment of independent predictors of TV. All statistical tests were two-tailed, and a p value < 0.05 was considered statistically significant.

Results

Characteristics of participants

A total of 2606 subjects, including 1338 (51.34%) men and 1268 (48.65%) women, participated in the study, with a mean age of 43.08 ± 15.51 years old. The clinical characteristics of the subjects are presented in Table 1. The prevalence of TN was 26.13% in this study. The mean thyroid volumes in TN (+) and TN (−) were 11.54 ± 6.61 mL and 9.41 ± 3.65 mL, respectively ($P < 0.0001$).

The relationship between MetS and its components and TN

As presented in Table 2, the prevalence of TN was 23.54% in males and 28.86% in females. The prevalence of MetS was 29.43%, which was significantly higher in the TN (+) group than in the TN (−) group ($P < 0.0001$), for both males and females. There was a significant gender difference in the prevalence of MetS ($P < 0.0001$). According to the diagnostic criteria of MetS, further relationships between TN and metabolic components, including abdominal adiposity, raised blood pressure, dysglycemia, low HDL, and hypertriglyceridemia, were analyzed. The prevalence of abdominal adiposity, raised blood pressure, and dysglycemia was significantly higher in the TN (+) group than in the TN (−) group in both the male and female groups. However, a significantly higher prevalence of hypertriglyceridemia was found only in the female TN (+) group ($P < 0.0001$), while no significant differences in low HDL were found between TN (+) and TN (−) in either the male or female groups.

Table 1 Baseline characteristics of participants according to the presence of thyroid nodules

Variables	Total ($N = 2606$)	TN (+) ($n = 681$)	TN (−) ($n = 1925$)	P
Age (years)[a]	43.08 ± 15.51	50.14 ± 14.92	40.57 ± 14.92	<0.0001
Gender (n, %)[c]				0.0020
Male	1338 (51.34)	315 (46.36)	1023 (53.14)	
Female	1268 (48.66)	366 (53.74)	902 (46.86)	
BMI (kg/m^2)[b]	24.60 (22.09,27.24)	25.06 (22.85,27.45)	24.39 (21.83,27.11)	<0.0001
WC (cm)[a]	88.45 ± 11.84	89.95 ± 10.95	87.92 ± 12.10	<0.0001
FBG (mmol/L)[a]	5.31 ± 1.48	5.59 ± 2.11	5.21 ± 1.15	<0.0001
SBP (mmHg)[a]	124.46 ± 18.35	127.80 ± 18.70	123.3 ± 18.09	<0.0001
DBP (mmHg)[a]	79.60 ± 11.98	81.36 ± 11.59	78.98 ± 12.06	<0.0001
LDL (mmol/L)[a]	2.97 ± 0.81	3.11 ± 0.81	2.93 ± 0.80	<0.0001
HDL (mmol/L)[a]	1.44 ± 0.40	1.43 ± 0.38	1.44 ± 0.41	0.6684
TG (mmol/L)[b]	1.22 (0.80,1.84)	1.33 (0.93,1.95)	1.17 (0.76,1.79)	<0.0001
TC (mmol/L)[a]	4.89 ± 1.03	5.05 ± 1.04	4.84 ± 1.02	<0.0001
HbA1c (mmol/L)[a]	5.57 ± 0.88	5.76 ± 1.02	5.51 ± 0.83	<0.0001
OGTT-2h (mmol/L)[b]	6.57 (5.51,8.05)	6.97 (5.88,8.68)	6.46 (5.40,7.82)	<0.0001
Thyroid volume (mL)[a]	9.97 ± 4.70	11.54 ± 6.61	9.41 ± 3.65	<0.0001

BMI body mass index, *WC* waist circumference, *FBG* fasting blood glucose, *SBP* systolic blood pressure, *DBP* diastolic blood pressure, *LDL* low-density lipoprotein cholesterol, *HDL* high-density lipoprotein cholesterol, *TG* triglycerides, *TC* total cholesterol, *HbA1c* hemoglobin A1c, *OGTT-2h* 2h-oral glucose tolerance test

[a]A *t*-test was used to compare the groups

[b]The Mann–Whitney U test was used to compare the groups

[c]A χ^2 test was used to compare the groups

Table 2 The prevalence of MetS and its parameters in the TN (+) and TN (−) groups according to gender

Characteristics	Male ($n = 1338$)		P	Female ($n = 1268$)		P
	TN (+) ($n = 315$)	TN (−) ($n = 1023$)		TN (+) ($n = 366$)	TN (−) ($n = 902$)	
Age (years)[a]	50.86 ± 15.39	40.91 ± 15.09	<0.0001	49.52 ± 14.55	40.24 ± 14.76	<0.0001
BMI (kg/m^2)[b]	25.71 (23.66, 28.09)	25.29 (22.84, 27.77)	0.0327	24.56 (22.21, 26.77)	23.42 (20.96, 26.17)	<0.0001
MetS (n, %)[c]	139 (44.13)	324 (31.67)	<0.0001	115 (31.42)	189 (20.95)	<0.0001
Metabolic parameters						
Abdominal adiposity (n, %)[c]	224 (71.11)	602 (58.85)	<0.0001	265 (72.40)	574 (63.64)	0.0028
Raised blood pressure (n, %)[c]	200 (63.49)	530 (51.81)	0.0003	159 (43.44)	248 (27.49)	<0.0001
Dysglycemia (n, %)[c]	119 (37.78)	261 (25.51)	<0.0001	93 (25.41)	151 (16.74)	0.0004
Low HDL (n, %)[c]	64 (20.32)	169 (16.52)	0.1202	91 (24.86)	217 (24.06)	0.7618
Hypertriglyceridemia (n, %)[c]	120 (38.10)	374 (36.56)	0.6213	106 (28.96)	170 (18.85)	<0.0001

[a]A t-test was used to compare the groups

[b]The Mann–Whitney U test was used to compare the groups

[c]A χ^2 test was used to compare the groups

Table 3 Logistic regression analysis of MetS and its components predicting TN

	Model 1 odds radio (95% CI)			Model 2 odds radio (95% CI)			Model 3 odds radio (95% CI)			Model 4 odds radio (95% CI)		
	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI	P
MetS	1.64	(1.36,1.97)	<0.0001	1.24	(1.01,1.51)	0.0377	1.24	(1.01,1.51)	0.0382	1.23	(1.00,1.51)	0.0429
Metabolic components												
Abdominal adiposity	1.62	(1.34,1.96)	<0.0001	1.15	(0.94,1.41)	0.1871	1.18	(0.96,1.46)	0.1138	1.17	(0.95,1.45)	0.1255
Raised blood pressure	1.64	(1.38,1.96)	<0.0001	1.23	(1.01,1.49)	0.0398	1.30	(1.07,1.59)	0.0096	1.29	(1.06,1.58)	0.0130
Dysglycemia	1.66	(1.37,2.02)	<0.0001	1.11	(0.89,1.37)	0.3616	1.11	(0.89,1.37)	0.3640	1.10	(0.89,1.36)	0.3927
Low HDL	1.18	(0.95,1.45)	0.1344	1.09	(0.87,1.36)	0.4568	1.06	(0.85,1.32)	0.6321	1.06	(0.85,1.32)	0.6239
Hypertriglyceridemia	1.26	(1.05,1.52)	0.0156	1.18	(0.97,1.44)	0.0998	1.16	(0.95,1.42)	0.1543	1.16	(0.94,1.41)	0.1603

Model 1. Unadjusted model

Model 2. Adjusted for age and gender

Model 3. Adjusted for age, gender, education, income, and smoking status

Model 4. Adjusted for age, gender, education, income, smoking status, and salt intake

The risk factors of MetS for TN are shown in Table 3. MetS was associated with an increased risk of TN (OR: 1.64, 95% CI: 1.36–1.97) in the unadjusted model. In addition, abdominal adiposity (OR: 1.62, 95% CI: 1.34–1.96), raised blood pressure (OR: 1.64, 95% CI: 1.38–1.96), hypertriglyceridemia (OR: 1.26, 95% CI: 1.05–1.52) and dysglycemia (OR: 1.66, 95% CI: 1.37–2.02) were also positively associated with the prevalence of TN. However, after adjustment for confounding factors, the risk of TN was significantly higher only in subjects with raised blood pressure (OR: 1.29, 95% CI: 1.06–1.58) and MetS (OR: 1.23, 95% CI: 1.00–1.51). When stratified by gender, raised blood pressure showed risk trend in the prevalence of TN in males (OR: 1.26, 95% CI: 0.95–1.67) and females (OR: 1.25, 95% CI: 0.93-1.69), but P values both were not significant. Besides, the gender interaction effect was not statistically significant (P for interaction = 0.23).

The relationship between MetS and TN stratified by gender and age

As illustrated in Fig. 1, the prevalence of TN and MetS increased with age, while a significant difference was observed only in the ≥60-year-old group ($P = 0.0002$). The risk of MetS for TN stratified by gender and age (<60 years and ≥60 years) is presented in Fig. 2. MetS was significantly associated with increased TN risk in the male group (OR: 1.70, 95% CI: 1.32–2.21) and the female group (OR: 1.73, 95% CI: 1.32–2.27) in the unadjusted model. Besides, compared with female group, the risk tendency was considerably higher in the male group (OR: 1.38, 95% CI: 1.05–1.81 compared with OR: 1.02, 95% CI: 0.75–1.39) after adjusting for age, gender, education, income, smoking status, and salt intake. But the interactive effect of gender

and MetS on TN was not statistically significant (P for interaction = 0.94). Furthermore, MetS was significantly associated with risk of TN in both the <60-year-old group (OR: 1.32, 95% CI: 1.05–1.68) and the ≥60-year-old group (OR: 1.84, 95% CI: 1.24–2.73), while the OR values were higher in the elderly group (P for interaction = 0.0344).

The relationship between MetS and TV

In addition, TV was significantly higher in subjects with TN (Table 1). Gender, BMI, TN, MetS, abdominal adiposity, hypertriglyceridemia, and raised blood pressure were independently correlated with TV ($\beta = 1.99$, $P < 0.0001$; $\beta = 2.63$, $P < 0.0001$; $\beta = 1.94$, $P < 0.0001$; $\beta = 0.94$, $P = 0.0037$; $\beta = 1.00$, $P < 0.0001$; $\beta = -0.49$, $P = 0.0369$; $\beta = 0.50$, $P = 0.0162$; respectively). Figure 3 shows a significantly increasing trend of TV in the four groups ($P < 0.0001$) in part (a). There were significant differences in F MetS (+), M MetS (−) and M MetS (+) compared to F MetS (−) ($P < 0.0001$). Besides, the significant differences were observed in F MetS (+) compared to M MetS (+) and M MetS (−) compared to M MetS (+) ($P < 0.0001$), which indicated that TV varies by sex and enlarged TV is associated with MetS. In part (b), significant differences in A MetS (+) and B MetS (+) compared to A MetS (−) ($P < 0.0001$), A MetS (+) compared to B MetS (−) and B MetS (−) compared to A MetS (+) were observed ($P < 0.0001$), but no significant differences were found between B MetS (−) and A MetS (−) ($P = 0.1926$) as well as A MetS (+) and B MetS (+) ($P = 1.0000$), which showed that there were significant differences of TV between MetS (+) group and MetS (−) group, but not between <60-year-old group and ≥60-year-old group.

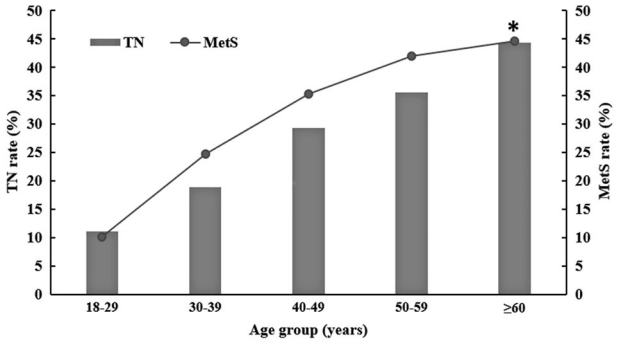

Fig. 1 The prevalence of MetS and TN according to age. A χ^2 test was used to compare the difference in the TN prevalence and MetS prevalence in the groups (18–29, 30–39, 40–49, 50–59, ≥60); * a significant correlation between TN and MetS was found only in the ≥60 group, $P = 0.0002$

Discussion

It is well known that the prevalence of TN is higher in women than in men and increased with age [3, 4, 11, 14], which is consistent with our studies. In addition, our data indicated that higher levels of WC, BMI, FBG, HbAlc, LDL, and TC were associated with the prevalence of TN. Recent studies showed that the prevalence of TN was positively associated with WC and BMI [15]. Furthermore,

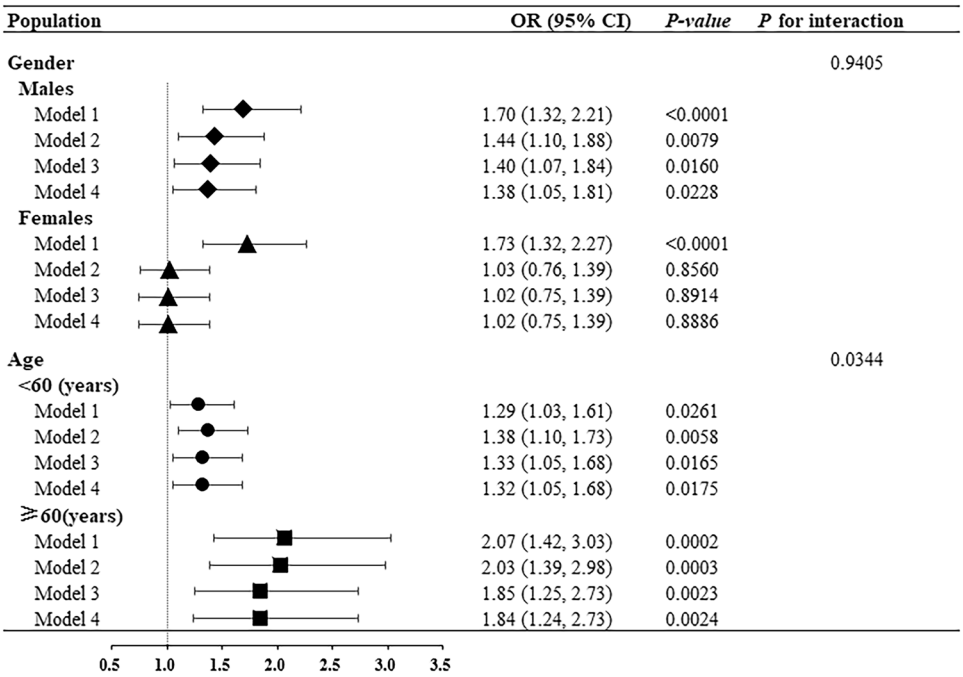

Fig. 2 The association between of MetS and TN stratified analysis by gender and age. Model 1. Unadjusted model. Model 2. Adjusted for age or gender. Model 3. Adjusted for age or gender, education, income, and smoking status. Model 4. Adjusted for age or gender, education, income, smoking status, and salt intake

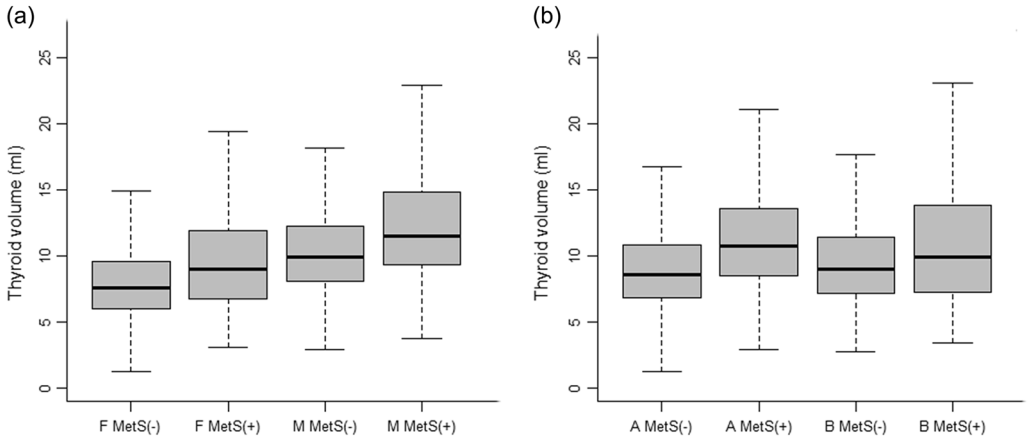

Fig. 3 Trends of thyroid volume level in different groups. The percentile values (2.5th and 97.5th percentiles with the median) of TV in different groups. The central box represents values from the lower to the upper quartile. The middle line represents the median, and the bars represent the 2.5th and 97.5th percentiles. The Bonferroni method was used for pairwise comparison between groups. F: female; M: male; A: <60 years old; B: ≥60 years old; MetS (−): without metabolic syndrome; MetS (+): with metabolic syndrome

a study by Shin et al. [16] suggested that the relationship between WC and TN was more significantly reflected in the male group. A study of 1,482 subjects performed in China also reported that WC is superior to BMI for assessing the risk of thyroid nodules [5]. Guo et al. [3] mentioned that possible explanations for the relationship between BMI and TN might lie in different ethnic groups.

Previous studies showed that the subjects with TN had significantly higher levels of FBG and HbAlc [4, 7, 17]. However, one Korean study found that the significant difference between TN and HbAlc was present only in women, and FBG levels did not show a significant association with TN either before or after adjustment for related factors [16]. Anil et al. [6] indicated that patients with impaired glucose metabolism have significantly increased TN prevalence. In the present study, SBP and DBP were significantly associated with TN. In addition, raised blood pressure showed a significant relationship with the presence of TN after adjusting for confounding factors. Although the mechanisms underlying the relationship between TN and raised blood pressure levels are unclear, the findings of previous studies [17–20] supported the results of our study. Both LDL and TC can reflect blood lipid levels in the body. A previous study indicated that the prevalence of dyslipidemia increased along with higher TSH concentrations [21]. Further, studies have demonstrated that TSH is a major regulator of the growth and differentiation of thyroid cells and could affect the formation of TN [22, 23].

In our study, risk tendency was significantly higher in the males group compared with females group in the logistic regression analysis. However, there was not a significant interaction effect of gender and MetS on the prevalence of TN. But another study showed that the prevalence of TN in MetS group was significantly increased only in females group [4], which yielded comparable results to those obtained in our study. Additionally, Chen et al. [12] found that both men and women with obesity, abdominal adiposity, hyperlipidemia, and MetS were significantly associated with higher risks of TN after full adjustment, while diabetes was associated with TN only in men [12]. It should be noted that those two studies did not further validate the gender interaction. Studies have shown that dietary habits play an important role in the onset of MetS [24]. Age, race, dietary habits, and a sedentary lifestyle were significantly associated with the prevalence of MetS [8]. Besides, previous studies have showed that gender differences in the prevalence of MetS do exist and while below 50 years it is slightly higher in men, it reverses after 50 years [25]. In addition, epidemiological studies have shown that the occurrence of TN was associated with genetic, autoimmune, and environmental factors [8]. However, in our study, we can't deduce gender disparity in the relationship between the prevalence of TN and MetS.

Moreover, one study found that in old age (>65 years old), patients with MetS were associated with an increased prevalence of TN [7]. Similarly, our results showed that ≥60-year-old subjects with MetS had a higher risk of TN. However, when we analyzed the associations between TN and the components of MetS, abdominal adiposity and hypertriglyceridemia were significant only in the <60-year-old group. Possible explanations for this finding might lie in complicated diseases increasing with age and weakening the influence of abdominal adiposity and hypertriglyceridemia on the relationship in the ≥60-year-old group. However, it was certain that MetS was associated with the higher risks of TN, and the risk increases with age, which was in agreement with earlier studies [10, 16]. Accordingly, better control of MetS should be a goal for elderly people.

In addition to the above, our data showed that MetS was associated with enlarged TV, especially in people with abdominal adiposity and raised blood pressure. A study conducted by Sari et al. [26] discovered that morphological alterations of the thyroid gland were associated with obesity. Another study explained that excessive adiposity leads to expansion of the interfollicular adipose depot or thyroid steatosis [27]. Strong correlations between TV and BMI, WC, body weight and body fat percentage were also demonstrated in previous studies [3, 4]. Studies have summarized that increased serum TSH could explain the correlation between increased TV and MetS [10]. Dauksiene et al. [28] showed that the risk of increased prevalence of TN and increased BMI was significantly associated with enlarged TV. Blanc et al. [7] found that elderly people with MetS were more inclined to be associated with greater TV. However, this study population was over 65 years old and could not be compared with populations younger than 65 years old with the same diseases. Our study showed that when people reach a certain age (60 years old), there is no significant change in TV if they stay in the same pathological and physiological state.

It is well known that people with MetS, especially those characterized by abdominal adiposity and dysglycemia, usually present with insulin resistance [4]. Insulin resistance forms the basis for the development of MetS [7, 8]. Because of the weakening of insulin sensitivity, the body must increase insulin secretion in order to ensure normal metabolism. Insulin is a growth factor that can stimulate the proliferation and hyperplasia process of thyroid cells [8]. Additionally, insulin growth factor receptor and insulin growth factor binding proteins have been found in thyroid tissue [14]. In addition, the association between components of MetS and morphological alterations of the thyroid gland was also mentioned [10, 15]. Therefore, it might be explained that MetS is associated with higher prevalence of TN and enlarged TV.

Conclusion

In summary, our study showed that MetS was associated with an increased risk of TN, especially in elderly people (≥60 years old). The effect of MetS on TN was not significantly affected by gender. The positive associations between the prevalence of MetS and TN with enlarged TV were found. Further, cohort studies of the gender disparity in the association between MetS and TN with larger sample size are required.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all participants included in the study.

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