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# *Association of Metabolic Disorders with Thyroid Nodules among Teachers in Puyang County*

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***Abstract:*** Teachers may carry a substantial burden of thyroid nodules (TN), but the contribution of metabolic diseases and related indicators remains unclear. We analyzed health check-up data from 3,029 in-service teachers to quantify the associations between metabolic diseases/indicators and TN and to characterize dose–response relationships. Multivariable binary logistic regression assessed the associations, and restricted cubic spline (RCS) models characterized nonlinearity. Overall, 1,575 teachers had TN, yielding an age-standardized prevalence of 35.7%. Compared with those without TN, the TN group included higher proportions of women, older individuals, and those with overweight/obesity and hypertension (all $P<0.05$), and showed higher BMI and systolic blood pressure but lower serum uric acid (SUA) levels (all $P<0.05$); the prevalence of hyperuricemia (HUA) was lower in the TN group. In multivariable analyses, hypertension, overweight/obesity, female sex, and older age were positively associated with TN. RCS analysis demonstrated a nonlinear dose–response between SUA and TN, with an inverse association at SUA ≤356.16 μmol/L and a positive association at SUA >356.16 μmol/L. TN appears relatively common among teachers; female sex and advancing age are independent risk factors, overweight/obesity and hypertension are positively associated with TN, and SUA shows a threshold-like nonlinear relationship.

## 1. Introduction

Thyroid nodules (TN) are masses formed within thyroid tissue as a result of abnormal proliferation of thyroid cells [1]. In clinical practice, the diagnosis of TN primarily relies on thyroid ultrasonography. The detection rate of TN using high-resolution ultrasonography ranges from 20% to 76% [2]. In China, the prevalence of TN is approximately 10% to 47%, and the detection rate among individuals aged 18 to 65 years is 33% [3]. Without timely intervention, about 7% to 15% of TN may progress to thyroid carcinoma [4]. The development of TN is influenced by multiple factors, including sex [5], age [6], hypertension [7], disorders of glucose metabolism [8], and lipid metabolism abnormalities [9]. Teachers, as a distinct occupational group, often exhibit unhealthy lifestyle and dietary habits, which increase the incidence of metabolic diseases [10, 11]. With the accumulation of disease risk factors, the detection rate of TN among teachers has also shown an upward trend [12]. Based on physical examination data of teachers in Puyang County in 2023, this study analyzes the association between metabolic diseases and TN among teachers, explores the dose–response relationship between metabolic indicators and TN, identifies the influencing factors of TN, and aims to provide a scientific basis for reducing the incidence of TN in teachers and the general population.

## 2. Methods

### 2.1. Data Source

The data were derived from the 2023 health examination program organized by the Puyang County Education Bureau for all in-service teachers. The participants completed their examinations at designated hospitals within the specified period. The collected information included: (1) demographic and anthropometric parameters such as sex, age, height, weight, and blood pressure; (2) biochemical indicators, including fasting plasma glucose (FPG), total cholesterol (TC), triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and serum uric acid (SUA); (3) ultrasonographic examinations of the thyroid gland and liver.

### 2.2. Examination Methods

Participants were instructed to maintain a light diet for three days prior to the examination, abstaining from tobacco, alcohol, greasy and high-protein foods, as well as strenuous exercise. On the day before the examination, they consumed a light dinner and were required to fast after 10:00 p.m. While ensuring adequate sleep. On the day of the examination, morning exercise and beverage consumption were prohibited, and participants were advised to wear loose-fitting clothing. A 5 mL sample of fasting venous blood was collected from the cubital vein for biochemical analysis. Subsequently, each participant underwent ultrasonographic examinations of the thyroid and liver, as well as measurements of blood pressure, height, and body weight.

### 2.3. Diagnostic Criteria for Thyroid Nodules

Thyroid ultrasound findings served as the diagnostic standard [2]. Based on the diagnostic reports, participants were categorized into the TN group and the non-thyroid nodule group. Individuals with suspected TN were re-examined one week later, and final grouping was determined according to the follow-up results.

### 2.4. Criteria for Independent Variables

(1) Hypertension: Defined as systolic blood pressure (SBP) ≥ 140 mmhg and/or diastolic blood pressure (DBP) ≥ 90 mmhg [13].

(2) Dyslipidemia: Hypercholesterolemia (HCH): Total cholesterol (TC) ≥ 5.2 mmol/L; High LDL-C: Low-density lipoprotein cholesterol (LDL-C) ≥ 3.4 mmol/L; Hypertriglyceridemia (HTG): Triglycerides (TG) ≥ 1.7 mmol/L; Low HDL-C: High-density lipoprotein cholesterol (HDL-C) < 1.0 mmol/L [14].

(3) Abnormal Glucose Metabolism: Fasting plasma glucose (FPG) ≥ 6.1 mmol/L [15].

(4) Body Mass Index (BMI) Classification [16], Overweight: 24.0–27.9 kg/m$^2$; Obesity: ≥ 28.0 kg/m$^2$

(5) Hyperuricemia (HUA): Defined as elevated serum uric acid (SUA) levels on two separate fasting measurements (non-consecutive days), with thresholds of > 420 μmol/L in men and > 357 μmol/L in women [17].

(6) Fatty liver disease: Diagnosed based on ultrasonographic findings of the liver.

### 2.5. Statistical Methods

Continuous variables were expressed as medians with interquartile ranges (IQRs), and comparisons between groups were performed using the Mann–Whitney U test. Categorical variables were presented as frequencies and percentages, with group comparisons conducted using the chi-square test. Binary logistic regression analysis was employed to assess the associations between metabolic diseases/parameters and the presence of TN. Restricted cubic spline (RCS) models were applied to explore the dose–response relationships between metabolic parameters and TN.

All statistical analyses were conducted using SPSS version 27.0 and R software, with a two-tailed $P < 0.05$ considered statistically significant.

## 3. Results

### 3.1. General Characteristics of the Study Population

Table 1: The general characteristics of the study population [n (%)] or M ($P_{25}$, $P_{75}$)].

| characteristic | Total | TN | Non-TN | $\chi^2$/z | *P*-value |
|---|---|---|---|---|---|
| Gender | | | | 39.317 | < 0.001 |
| male | 1349(44.6) | 616(39.1) | 733(50.4) | | |
| female | 1679(55.4) | 959(60.9) | 720(49.6) | | |
| Age, (years) | 45(39,52) | 46(41,54) | 44(37,50) | -8.091 | < 0.001 |
| Age group | | | | 63.245 | < 0.001 |
| ≤ 40 years | 879(29.0) | 369(23.4) | 510(35.1) | | |
| 41-50 years | 1252(41.3) | 661(42.0) | 591(40.7) | | |
| ≥ 50 years | 897(29.6) | 545(34.6) | 352(24.2) | | |
| BMI ($kg/m^2$) | 25.15 (22.83,27.46) | 25.22 (23.01,27.67) | 25.04 (22.70,27.19) | -2.398 | 0.016 |
| overweight/fat, yes, n (%) | 623(20.6) | 347(22.0) | 276(19.0) | 4.264 | 0.039 |
| SBP (mmHg) | 123(112,136) | 124(113,138) | 122(110,134) | -3.825 | < 0.001 |
| DBP (mmHg) | 77(69,85) | 77(69,86) | 77(69,85) | -0.789 | 0.430 |
| hypertension , yes, n (%) | 770(25.4) | 447(28.4) | 323(22.2) | 15.080 | < 0.001 |
| TC (mmol/L) | 4.91(4.29,5.63) | 4.92(4.28,5.63) | 4.91(4.29,5.62) | -0.101 | 0.957 |
| HCH, yes, n(%) | 1168(38.6) | 607(38.5) | 561(38.6) | 0.002 | 0.968 |
| LDL-C(mmol/L) | 2.55(2.08,3.08) | 2.55(2.05,3.10) | 2.57(2.09,3.10) | -0.491 | 0.641 |
| High LDL-C, yes, n (%) | 418(13.8) | 225(14.3) | 193(13.3) | 0.639 | 0.424 |
| TG (mmol/L) | 1.19(0.79,1.86) | 1.20(0.80,1.85) | 1.18(0.78,1.88) | -0.624 | 0.509 |
| HTG, yes, n(%) | 890(29.4) | 457(29.0) | 433(29.8) | 0.224 | 0.636 |
| HDL-C(mmol/L) | 1.37(1.17,1.60) | 1.37(1.17,1.60) | 1.36(1.17,1.60) | -0.541 | 0.556 |
| Low HDL-C, yes, n (%) | 202(6.7) | 105(6.7) | 97(6.7) | 0.001 | 0.992 |
| FPG (mmol/L) | 5.30(4.99,5.74) | 5.30(4.99,5.78) | 5.29(5.00,5.69) | -0.885 | 0.381 |
| Dysglycemia, yes, n (%) | 480(15.9) | 261(16.6) | 219(15.1) | 1.273 | 0.259 |
| SUA (μmol/L) | 309.20 (258.80,370.88) | 299.90 (249.90,364.20) | 317.10 (269.60,377.90) | -5.604 | < 0.001 |
| HUA, yes, n (%) | 544(18.0) | 260(16.5) | 284(19.5) | 4.732 | 0.030 |
| Fatty Liver Disease, yes, n (%) | 1353(54.7) | 853(54.2) | 803(55.3) | 0.373 | 0.541 |

SBP: systolic blood pressure, DBP: diastolic blood pressure, TC: total cholesterol, HCH: hypercholesterolemia, HTG: hypertriglyceridemia, FPG: fasting plasma glucose, SUA: serum uric acid, HUA: hyperuricemia.

As shown in Table 1, a total of 3,029 teachers were included in the study, among whom 1,575 were diagnosed with TN, yielding a detection rate of 52.0%. Participants' ages ranged from 21 to 65 years, and the age-standardized prevalence rate was 35.7%. The TN group had higher proportions of women, older age groups, individuals with overweight or obesity, and those with hypertension than the non-

TN group (all $p<0.05$). Conversely, the prevalence of hyperuricemia was lower in the TN group. In addition, the TN group exhibited higher BMI and systolic blood pressure, but lower serum uric acid levels than the non-TN group ($P < 0.05$).

## 3.2. Metabolic Diseases and TN

In the multivariable models, men without metabolic disease served as the reference group (Table 2). Hypertension (OR: 1.23, 95% CI: 1.03 - 1.47), overweight or obesity (OR: 1.34, 95% CI: 1.11 - 1.62), female sex (OR: 2.20, 95% CI: 1.87 - 2.58), and older age (OR: 1.04, 95% CI: 1.03 - 1.05) were positively associated with TN. In contrast, the negative association between hyperuricemia and TN appeared to be influenced by other confounding factors.

Table 2: Associations between Metabolic Diseases and TN.

| Variables | Reference group | OR (95%CI)① | OR (95%CI)② | OR (95%CI)③ | OR (95%CI)④ |
|---|---|---|---|---|---|
| Gender | Male | 1.59(1.37,1.83)** | -- | 2.14(1.81,2.54)** | 2.20(1.87,2.58)** |
| Age | | 1.03(1.02,1.04)** | -- | 1.04(1.03,1.05)** | 1.04(1.03,1.05)** |
| hypertension | No | 1.39(1.18,1.64)** | 1.28(1.07,1.53)* | 1.26(1.05,1.51)* | 1.23(1.03,1.47)* |
| HCH | No | 1.00(0.86,1.15) | 0.93(0.80,1.08) | 0.90(0.75,1.08) | -- |
| High LDL-C | No | 1.09(0.89,1.34) | 1.00(0.81,1.24) | 1.08(0.85,1.39) | -- |
| HTG | No | 0.96(0.83,1.13) | 1.02(0.86,1.20) | 0.99(0.82,1.18) | -- |
| Low HDL-C | No | 1.00(0.75,1.33) | 1.22(0.91,1.64) | 1.17(0.86,1.59) | -- |
| Dysglycemia | No | 1.12(0.92,1.36) | 1.06(0.86,1.31) | 1.02(0.82,1.26) | -- |
| Overweight | No | 1.21(1.01,1.44)* | 1.38(1.14,1.66)** | 1.39(1.14,1.71)** | 1.34(1.11,1.62)* |
| HUA | No | 0.81(0.68,0.98)* | 0.97(0.80,1.18) | 0.92(0.75,1.13) | -- |
| FL | No | 0.96(0.83,1.10) | 1.00(0.85,1.18) | 0.90(0.75,1.08) | -- |

TN: thyroid nodules, OR: odds ratio; CI: confidence interval; HCH: hypercholesterolemia, HTG: hypertriglyceridemia, HUA: Hyperuricemia, FL: fatty liver disease; ① crude model; ② adjusted for sex and age; ③ full model including all variables; ④ backward stepwise model; * $P < 0.05$; ** $P < 0.001$.

## 3.3. Metabolic Indicators and TN

Table 3: Associations between Metabolic Indicators and TN.

| Variables | OR(95%CI)① | OR(95%CI)② | OR(95%CI)③ | OR(95%CI)④ |
|---|---|---|---|---|
| BMI | 1.024(1.004,1.045)* | 1.036(1.014,1.059) ** | 1.048(1.020,1.076) ** | 1.048(1.022,1.075) ** |
| SBP | 1.008(1.004,1.012)** | 1.004(1.000,1.009) | 1.005(0.998,1.013) | -- |
| DBP | 1.003(0.997,1.009) | 1.003(0.997,1.010) | 0.995(0.985,1.006) | -- |
| TC | 0.994(0.926,1.066) | 0.953(0.886,1.026) | 1.003(0.721,1.395) | -- |
| LDL-C | 0.979(0.890,1.078) | 0.935(0.846,1.033) | 0.927(0.623,1.380) | -- |
| TG | 0.996(0.950,1.044) | 1.023(0.974,1.074) | 1.008(0.912,1.114) | -- |
| HDL-C | 1.079(0.864,1.348) | 0.841(0.664,1.066) | 0.919(0.598,1.413) | -- |
| FPG | 1.044(0.987,1.105) | 1.029(0.969,1.093) | 1.014(0.952,1.080) | -- |
| SUA | 0.998(0.997,0.999) ** | 1.000(0.999,1.001) | 0.999(0.998,1.000) | -- |
| FL | 0.959(0.831,1.107) | 1.002(0.853,1.178) | 0.846(0.697,1.026) | 0.841(0.698,1.013) |

TN: thyroid nodules, OR: odds ratio; CI: confidence interval; SBP: systolic blood pressure, DBP: diastolic blood pressure, TC: total cholesterol, TG: triglycerides, FPG: fasting plasma glucose, SUA: serum uric acid, FL: fatty liver disease ; ① crude model; ② adjusted for sex and age; ③ full model including all variables; ④ backward stepwise model; * $P < 0.05$; ** $P < 0.001$.

As shown in Table 3, BMI was positively associated with TN, while the relationships between other metabolic indicators and TN remained unclear. As illustrated in Figure 1, a nonlinear dose–response relationship was observed between serum uric acid and TN ($P_{\text{-total}} < 0.0001$, $P_{\text{-nonlinear}} = 0.0008$). When SUA was below 356.16 μmol/L, SUA was negatively associated with TN, whereas above this threshold, the association became positive. BMI, systolic blood pressure, and triglycerides all exhibited positive dose–response relationships with TN ($P_{\text{-total}} < 0.0001$, $P_{\text{-nonlinear}} > 0.05$).

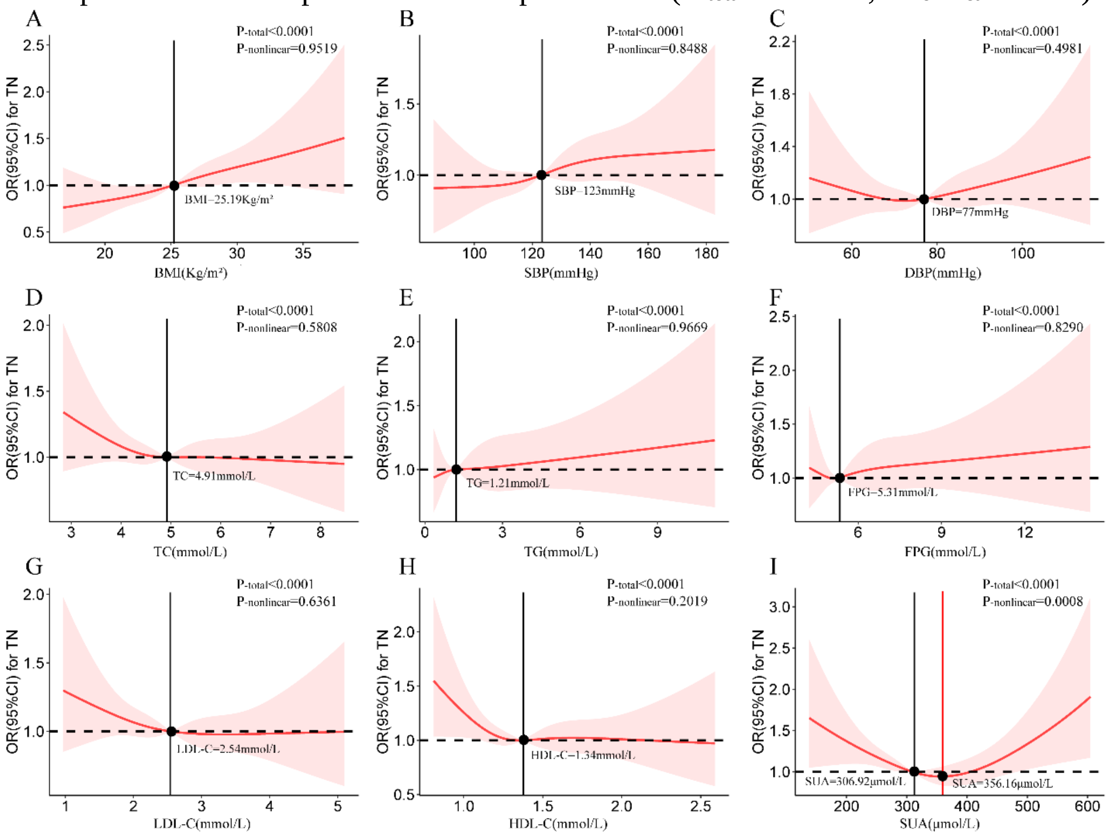


Figure 1 Dose–response relationships between metabolic indicators and TN.

## 4. Discussion

This study, based on the 2023 physical examination data of teachers in Puyang County, included a total of 3,029 participants. The crude detection rate of TN was 52.0%, slightly lower than the 57.0% reported among university faculty members in a previous study [12]. The age-standardized prevalence was 35.7%, marginally higher than the national prevalence of 33% among adults aged 18-65 years in China [3]. These findings suggest that teachers have become a population with a notably high prevalence of TN.

In multivariable analyses, women had higher odds of TN than men, and the odds increased with age. This trend is consistent with previous reports on TN prevalence among healthy adults in China [18]. Binary logistic regression analysis showed that both hypertension and overweight/obesity were positively associated with TN, consistent with findings from a study in Beijing, which reported a positive association between hypertension (OR: 1.361, 95% CI: 1.139–1.625, $P < 0.05$) and TN [19]. Another health examination–based study also identified overweight or obesity as an independent risk factor for TN (OR: 3.679, 95% CI: 1.257–10.279, $P = 0.006$) [20].

Analysis of metabolic indicators revealed positive dose–response relationships between systolic blood pressure, body mass index, and TN ($P$-total < 0.001, $P$-nonlinear > 0.05), consistent with previous research [21]. Evidence has shown that SBP is positively correlated with thyroid-stimulating hormone (TSH) levels ($\beta = 0.045$, $P = 0.001$) [22], and elevated TSH may indicate worsening TN [23], suggesting that hypertension could contribute to the development of TN. Moreover, obesity may influence thyroid hormone metabolism by regulating deiodinase activity [24], leading to reduced thyroid function and promoting TN formation.

Although previous studies have suggested that diabetes, fatty liver disease, and dyslipidemia may also facilitate TN development, no significant associations were observed in the present study. Further cohort studies with stronger causal inference and mechanistic experiments are needed to clarify the potential relationships between these metabolic abnormalities and TN.

Serum uric acid is an important biomarker for assessing hyperuricemia [25]. A decrease in SUA levels may weaken the body's antioxidant capacity, leading to oxidative damage to thyroid cells by free radicals [13]. Conversely, SUA levels exceeding 4 mg/dl are considered an early warning signal for cardiovascular diseases [26]. HUA can induce oxidative stress in adipocytes and promote obesity [27], while obesity in turn increases the risk of TN; thus, HUA may indirectly contribute to TN development.

Binary logistic regression analysis in this study indicated that both SUA and HUA were negatively associated with TN. However, restricted cubic spline analysis revealed a nonlinear dose–response relationship between SUA and TN ($P_{\text{-total}} < 0.0001$, $P_{\text{-nonlinear}} = 0.0008$): SUA exceeded this threshold. SUA was negatively associated with TN when below 356.16 μmol/L; however, the association became positive when SUA exceeded this threshold.

In summary, the relationship between HUA and TN appears to be complex. Current research on this association remains limited and inconclusive. Therefore, large-scale randomized controlled trials and mechanistic studies are warranted to further elucidate the nature of this relationship and to determine potential threshold levels and underlying biological mechanisms.

## 5. Conclusion

The prevalence of TN among teachers in this county was relatively high. In multivariable models, female sex and older age were independently associated with TN, and overweight or obesity and hypertension were also positively associated. A nonlinear dose–response relationship with an inflection point was observed between serum uric acid and TN. No significant associations were found between TN and diabetes, fatty liver disease, or dyslipidemia.

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