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Iodine nutritional status, the prevalence of thyroid goiter and nodules in rural and urban residents: a cross-sectional study from Guangzhou, China

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Abstract

Objectives: A variety of factors differed between rural and urban areas may further influence iodine status and thyroid structure. Hence, this study compared iodine nutrition, the prevalence of thyroid goiter, and nodules between rural and urban residents in Guangzhou, a southern coastal city of China.
Methods: A total of 1211 rural residents and 1305 urban residents were enrolled in this cross-sectional study. A questionnaire regarding personal characteristics was administered. Urinary iodine concentration (UIC) was examined. Ultrasonography of the thyroid was performed to evaluate thyroid goiter and nodules. Multiple logistic analysis was used to identify the potential associated factors.
Results: The median UIC was significantly lower in rural residents than in urban residents (120.80 μg/L vs 136.00 μg/L, $P < 0.001$). Although the coverage rate of iodized salt was much higher in rural residents than in urban residents (99.59% vs 97.29%, $P < 0.001$), the percentages of seafood intake (8.60% vs 29.29%, $P < 0.001$), iodine-containing drug consumption (0.33% vs 1.24%, $P = 0.011$), and iodine contrast medium injection (0.58% vs 1.87%, $P = 0.004$) were lower in rural residents than in urban residents. Both the prevalence of thyroid goiters and nodules was significantly higher in rural residents than in urban residents (goiter: 8.06% vs 1.20%, $P < 0.001$; nodules: 61.89% vs 55.04%, $P = 0.023$). Living in rural areas was associated with thyroid goiter (OR 5.114, 95% CI 2.893–9.040, $P < 0.001$).
Conclusions: There were differences in iodine nutrition and the prevalence of thyroid goiter and nodules in rural and urban residents in Guangzhou. Differentiated and specialized monitoring is recommended in our area.

Key Words

- iodine status
- thyroid goiter
- thyroid nodules
- rural resident
- urban resident

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Introduction

Iodine is an essential micronutrient required by the thyroid gland to synthesize and secrete thyroid hormones (1). Iodized salt is the main supplement to iodine, and China has implemented universal salt iodization (USI) policy since 1996. In addition to iodized salt, other dietary products, including seafood, are important sources of

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iodine (2, 3). Similarly, medical interventions, such as the use of iodine-containing drugs, are related to urinary iodine concentration (UIC) (4, 5). During the past 20 years, along with the rapid and great economic progress in China, the dietary habits, lifestyles, and medical practices of residents have changed greatly. Hence, it is necessary to evaluate iodine nutrition once again. Moreover, Michael B Zimmermann observed that the geographic region of residence influences iodine intake (6). Although a previous study reported that rural residents had lower median urinary iodine concentrations (7), another survey found contradictory results (5). The factors associated with iodine nutrition mentioned above also remain largely different between rural and urban residents, and thus, iodine nutrition may be different among subjects living in rural vs urban areas.

Adequate iodine levels are also very important for maintaining a normal thyroid structure. Thyroid goiter is the most visible sequela and a common problem associated with iodine deficiency (8). In 1999, the coastal area of Guangdong Province had a prevalence of thyroid goiter of 12.45% (9), which was much higher than the national prevalence of 5.02% (10). After 20 years under the Chinese USI policy, the national prevalence of thyroid goiter decreased to 2.9% in 2011 (10) and to 1.17% in 2015 (11). However, in contrast to the large decline in thyroid goiter, thyroid nodules have become increasingly common in mainland China, increasing from 2.73% in 1999 to 12.8% in 2011 and then to 20.43% in 2015 (10, 11). The marked increase in thyroid nodules may be largely due to the widespread use of thyroid ultrasound. Other factors, including economic conditions, nutritional status, and medical care, have also been found to correlate with thyroid nodules (12, 13). Likewise, these factors are also associated with thyroid goiter. In addition to iodine nutrition, these other factors also differed between residents living in rural and urban areas, which may further affect the prevalence of thyroid goiters and nodules in residents living in rural/urban areas. However, the latest prevalence data on both thyroid goiter and nodules have not been reevaluated in Guangzhou, the coastal southern provincial city of Guangdong Province.

Thus, in this study, we first assessed the urinary iodine concentration and the prevalence of thyroid goiter and nodules in Guangzhou. Furthermore, we evaluated and compared residents living in rural areas with those living in urban areas. This study aimed to provide a specific reference and guidance for the management of iodine nutrition, thyroid goiter, and nodules among rural and urban residents in Guangzhou.

Materials and methods

Subjects

A cross-sectional study was conducted in Guangzhou from 2015 to 2016. A rural sampling unit (county-level city) located in a suburban area and an urban sampling unit (county) located in a central area was selected. The study population was from the Epidemiological Evidence from 31 Provinces of Mainland China (11). In total, 2720 residents who met the following inclusion and exclusion criteria were screened in the survey. Voluntary residents with the following characteristics were included in this study: (i) age older than 18 years and (ii) residing in the area for over 5 years. Residents who were pregnant or lactating, those with previous thyroid diseases, and those taking thyroid drugs, glucocorticoids, or dopamine during the past 3 months were excluded. Residents with previous thyroid diseases (n= 189) and residents who failed to provide information on the history of thyroid diseases (n=10) were excluded in the final analyses. In addition, another three residents with incomplete data of age and two residents with incomplete data of urinary iodine concentration were also excluded in the final analyses. Hence a total of 2516 eligible residents were included in the final analyses. This study was approved by the Medical Ethics Committee of Sun Yat-sen Memorial Hospital, Sun Yat-sen University (AF-SOP-07-1.0-01). All residents provided written informed consent to participate before any data or samples were collected.

Methods

A questionnaire was designed and administered to obtain information regarding date of birth, sex, type of salt used, seafood intake within the last 3 days, iodine-containing drug consumption within the 3 days, i.v. injection of iodine contrast medium within the last 3 months, smoking status, and history of thyroid disease.

Urine samples were collected between 08:00 and 10:00 h. All urine samples were stored at –20°C and underwent centralized examination within 1 month of collection. The urinary iodine concentration was analyzed by an As-Ce Catalytic Chromatographer (Agilent 7700x; Agilent Technologies).

Thyroid ultrasonography was performed by two trained technicians using a 7.5 MHz ultrasound imager (GE, LOGIQ@100). The volume of each thyroid lobe was calculated using the formula V (mL) = 0.479 × width × length × thickness, and the thyroid volume consisted of the sum of the volumes of the two lobes.

Diagnostic criteria

According to the WHO guidelines, insufficient iodine was defined as a urinary iodine concentration of <100 µg/L, adequate iodine was defined as a urinary iodine concentration of 100–199 µg/L, above adequate iodine was defined as a urinary iodine concentration of 200–299 µg/L, and excessive iodine was defined as a urinary iodine concentration of >300 µg/L (1).

Thyroid goiter was defined as a thyroid volume > 14.4 mL for females and >18.8 mL for males, as described in a previous study (14). A thyroid nodule was defined as a nodule >1 mm in diameter detected using thyroid ultrasonography. Multiple thyroid nodules were defined as the total number of thyroid nodules > 1.

Statistical analyses

Data processing was performed by SPSS version 21.0. Normally distributed continuous variables and non-normally distributed continuous variables are reported as the mean ± s.d. and median (25th and 75th centile), respectively. *t*-Tests and Mann–Whitney *U*-tests were used when appropriate. Categorical variables are presented as percentages, and the chi-square test was used. Univariate and multiple logistic regression analyses were used to identify the risk factors associated with thyroid goiter, thyroid nodules, and multiple thyroid nodules. In addition, we performed the following sensitivity analysis: excluding residents ≥ 65 years old and repeating the univariate and multiple logistic analysis.The odds ratio (OR) and 95% CI were calculated by the logistic regression model. $P < 0.05$ was considered significant.

Results

Iodine nutritional status in residents of rural and urban areas

Among the 2516 residents in the final analyses, the mean age was 45.75 ± 15.72 years (18–88), and 55.96% (1408/2516) were female. The coverage rate of iodized salt was 96.00%. The median (25th and 75th centiles) urinary iodine concentration was 129.15 µg/L (88.00 and 183.00).

A number of 1211 (48.13%) residents lived in rural areas, and 1305 (51.87%) lived in urban areas. The personal characteristics and iodine nutrition of rural residents and urban residents are presented in Table 1.

Thyroid goiter in residents of rural and urban areas

A total of 2449 residents who had complete thyroid volume data were included in this part of the analysis (Table 2). The prevalence of thyroid goiter was 4.57% (112/2449) in this population. Females had a higher prevalence of thyroid goiter than males (6.86% (94/1370) vs 1.67% (18/1079), P < 0.001, χ^2 test). The residents with thyroid goiter were older than those without goiter (51.91 ± 1.26 years vs 45.46 ± 0.33 years, $P < 0.001$, *t*-test). The median (25th and 75th centile) UIC of residents with and without goiter was found to be 131.25 µg/L (80.75 and 167.08) and 130.00 µg/L (89.00 and 184.90), respectively ($P=0.279$, Mann–Whitney *U*-test).

Among residents living in rural areas, the prevalence of thyroid goiter was 8.06% (97/1204), which was higher than that in residents living in urban areas (8.06% (97/1204) vs 1.20% (15/1245), $P < 0.001$, χ^2 test). Furthermore, when we adjusted for potential risk factors by multiple logistic regression analysis, the results illustrated that living in rural areas (OR 5.114, 95% CI 2.893–9.040) was significantly associated with thyroid goiter (Table 3).

Thyroid nodules in residents of rural and urban areas

A total of 2508 residents completed thyroid ultrasonography examination, 44.22% of whom had thyroid nodules (Table 4). Females had a higher prevalence of thyroid nodules than males (50.39% (708/1405) vs 36.36% (401/1103), $P < 0.001$, χ^2 test). The residents with nodules were older than those without nodules (52.54 ± 0.44 years vs 40.30 ± 0.38 years, $P < 0.001$, *t*-test). The median UIC (25th and 75th centiles) of residents with nodules was 123.60 µg/L (84.00 and 173.00), which was significantly lower than that of residents without nodules (133.90 µg/L (92.00 and 189.00), $P < 0.001$, Mann–Whitney *U*-test).

Among residents living in rural areas, the prevalence of thyroid nodules was 49.21% (593/1205), which was significantly higher than that among residents living in urban areas (49.21% (593/1205) vs 39.60% (516/1303), $P < 0.001$, χ^2 test). Similarly, the prevalence of multiple nodules was much higher in residents living in rural areas than in those living in urban areas (61.89% (367/593) vs 55.04% (284/516), $P=0.023$, χ^2 test). Further multiple logistic regression analysis showed that both female sex and increasing age were significantly associated with

Table 1 Clinical characteristics and iodine nutritional status of residents living in rural and urban areas. Age was expressed as the mean ± s.d.; urinary iodine concentration was expressed as median with interquartile range; the other variables were presented as *n* (%). The *t*-test was adopted for age; the Mann–Whitney *U*-test was adopted for urinary iodine concentration; and the χ^2 test was used for the other variables. $P < 0.05$ was considered significant.

	Rural resident	Urban resident	*p*
Age (years)	49.74 ± 0.42	42.04 ± 0.44	<0.001
Sex (%)			<0.001
Male	33.44 (406/1211)	53.86 (703/1305)	
Female	66.56 (806/1211)	46.13 (602/1305)	
Smoking status (%)			0.016
Non-smoker	80.92 (980/1211)	77.01 (1005/1305)	
Smoker	19.08 (231/1211)	22.99 (300/1305)	
Iodized salt intake (%)			<0.001
Yes	99.59 (1204/1209)	97.29 (1257/1292)	
No	0.41 (5/1209)	2.71 (35/1292)	
Seafood intake within the last 3 days (%)			<0.001
Yes	8.60 (104/1209)	29.29 (381/1301)	
No	91.4 (1105/1209)	70.71 (920/1301)	
Iodine-containing drug consumption within the last 3 days (%)			0.011
Yes	0.33 (4/1207)	1.24 (16/1292)	
No	99.67 (1203/1207)	98.76 (1276/1292)	
Intravenous injection of iodine contrast medium within the last 3 months (%)			0.004
Yes	0.58 (7/1208)	1.87 (24/1283)	
No	99.42 (1201/1208)	98.13 (1259/1283)	
Urinary iodine concentration (µg/L)	120.80 (83.10, 170.20)	136.0 (93.00, 192.00)	<0.001
Iodine status (%)			<0.001
Insufficient	36.91 (447/1211)	28.20 (368/1305)	
Adequate	45.91 (556/1211)	48.81 (637/1305)	
Above adequate	13.29 (161/1211)	16.17 (211/1305)	
Excessive	3.88 (47/1211)	6.82 (89/1305)	
TPOAb(+) (%)			0.081
Yes	12.14 (147/1211)	9.96 (130/1305)	
No	87.86 (1064/1211)	90.04 (1175/1305)	
TgAb(+) (%)			0.269
Yes	14.95 (181/1211)	13.41 (175/1305)	
No	85.05 (1030/1211)	86.59 (1130/1305)	

TgAb, thyroglobulin antibody; TPOAb, thyroid peroxidase antibody.

thyroid nodules and multiple thyroid nodules, as presented in Table 4.

Sensitivity analysis

When we excluded residents ≥ 65 years old, the multipe logistic regression analysis demonstrated that living in rural areas was significantly associated with thyroid goiter after adjusting for potential risk factors ($P < 0.05$, Supplemental Table, see section on supplementary materials given at the end of this article). Similarly, both female sex and increasing age were significantly associated with thyroid nodules and multiple thyroid nodules for residents < 65 years old (all $P < 0.05$), as shown in the Supplemental Table.

Discussion

In this study, we found that the median UIC of rural residents in Guangzhou was 120.80 µg/L, which was significantly lower than that of urban residents (136.0 µg/L). The coverage rate of iodized salt was higher in rural residents than in urban residents, whereas the percentage of seafood intake, iodine-containing drug consumption, and iodine contrast medium injection was lower in rural residents than in urban residents. Both the prevalence of thyroid goiter and thyroid nodules was significantly higher in rural residents in Guangzhou. Thus, residents living in rural areas were found to be more likely to have thyroid goiter.

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Table 2 Thyroid goiter of residents living in rural and urban areas. Age is expressed as the mean ± S.D.; urinary iodine concentration is expressed as the median with interquartile range; the other variables are presented as *n* (%). The *t*-test was adopted for age; the Mann–Whitney *U*-test was adopted for urinary iodine concentration; and the χ^2 test was used for the other variables. $P < 0.05$ was considered significant.

	With thyroid goiter			**Without thyroid goiter**				
	Rural resident	Urban resident	*P1*	Rural resident	Urban resident	*P2*	***P3***	***P4***
Age (years)	51.39 ± 1.32	55.27 ± 3.92	0.297	49.54 ± 0.44	41.79 ± 0.45	<0.001	0.230	0.001
Age category (years) (%)			0.379			<0.001	0.323	0.001
>45	65.98 (64/97)	80.00 (12/15)		60.89 (674/1107)	38.78 (477/1230)			
≤45	34.02 (33/97)	20.00 (3/15)		39.11 (433/1107)	61.22 (753/1230)			
Sex (%)			0.064			<0.001	<0.001	0.098
Male	13.40 (13/97)	33.33 (5/15)		35.05 (388/1107)	54.72 (653/1230)			
Female	86.60 (84/97)	66.67 (10/15)		64.95 (719/1107)	45.28 (557/1230)			
Iodized salt intake (%)			0.017			<0.001	>0.999	0.052
Yes	100.00 (97/97)	86.67 (13/15)		99.55 (1100/1105)	97.62 (1188/1217)			
No	0.00 (0/97)	13.33 (2/15)		0.45 (5/1105)	2.38 (29/1217)			
Seafood intake within the last 3 days (%)			>0.999			<0.001	0.930	0.137
Yes	8.25 (8/97)	6.67 (1/15)		8.51 (94/1105)	24.31 (298/1226)			
No	91.75 (91/97)	93.33 (14/15)		91.49 (1011/1105)	75.69 (928/1226)			
Urinary iodine concentration (μg/L)	129.70 (79.15, 166.55)	135.00 (116.00, 212.00)	0.270	120.80 (83.50, 170.60)	138.00 (94.00, 196.00)	<0.001	0.715	0.731
Iodine status (%)			0.036			<0.001	0.526	0.291
Insufficient	39.18 (38/97)	20.00 (3/15)		36.68 (406/1107)	27.48 (338/1230)			
Adequate	44.33 (43/97)	53.33 (8/15)		45.98 (509/1107)	48.62 (598/1230)			
Above adequate	14.43 (14/97)	6.67 (1/15)		13.28 (147/1107)	16.99 (209/1230)			
Excessive	2.06 (2/97)	20.00 (3/15)		4.07 (45/1107)	6.91 (85/1230)			
TPOAb(+) (%)			0.334			0.154	0.003	0.011
Yes	21.65 (21/97)	33.33 (5/15)		11.38 (126/1107)	9.51 (117/1230)			
No	78.35 (76/97)	66.67 (10/15)		88.62 (981/1107)	90.49 (1113/1230)			
TgAb(+) (%)			0.230			0.001	<0.001	0.001
Yes	28.87 (28/97)	46.67 (7/15)		13.82 (153/1107)	9.35 (115/1230)			
No	71.13 (69/97)	53.33 (8/15)		86.18 (954/1107)	90.65 (1115/1230)			

TgAb, thyroglobulin antibody; TPOAb, thyroid peroxidase antibody; P3, rural resident with thyroid goiter vs rural resident without thyroid goiter; P4, urban resident with thyroid goiter vs urban resident without thyroid goiter.

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Table 3 The associated risk factors for thyroid goiter, thyroid nodule and multiple thyroid nodules. Univariate logistic regression, when adjusted for residential area (urban area and rural area), sex (male and female), age (continuous variable), smoking status (non-smoker and smoker), iodine status (adequate, insufficient, above adequate, and excessive), iodized salt intake (no and yes), seafood intake within the last 3 days (no and yes), iodine-containing drug consumption within the last 3 days (no and yes), i.v. injection of iodine contrast medium within the last 3 months (no and yes), TPOAb (negativity and positivity), and TgAb (negativity and positivity), was used to identify the associated risk factors for thyroid goiter, thyroid nodule and multiple thyroid nodules, respectively. Moreover, factors with a *P* value <0.05 in the univariate logistic analysis were further adjusted by using multiple logistic regression. *P* < 0.05 was considered significant.

	Thyroid goiter		**Thyroid nodule**		**Multiple thyroid nodules**	
	OR (95% CI)	*P*1	OR (95% CI)	*P*2	OR (95% CI)	*P*3
Univariate logistic analysis						
Residential area	7.185 (4.146, 12.451)	<0.001	1.478 (1.261, 1.731)	<0.001	1.315 (1.035, 1.672)	0.025
Sex	4.342 (2.605, 7.237)	<0.001	1.778 (1.513, 2.089)	<0.001	1.282 (1.001, 1.644)	0.049
Age	1.026 (1.014, 1.038)	<0.001	1.057 (1.051, 1.064)	<0.001	1.036 (1.027, 1.045)	<0.001
Smoking status	0.562 (0.324, 0.977)	0.041	0.867 (0.713, 1.053)	0.150	1.010 (0.748, 1.366)	0.946
Iodine status						
Insufficient	1.198 (0.470, 3.055)	0.706	1.347 (0.932, 1.948)	0.113	1.515 (0.842, 2.726)	0.165
Above adequate	1.433 (0.556, 3.693)	0.457	1.703 (1.169, 2.480)	0.006	1.626 (0.897, 2.949)	0.109
Excessive	1.096 (0.390, 3.074)	0.862	1.200 (0.799, 1.802)	0.380	1.326 (0.695, 2.530)	0.392
Iodized salt intake	1.224 (0.290, 5.158)	0.783	1.143 (0.611, 2.136)	0.676	0.950 (0.379, 2.381)	0.913
Seafood intake within the last 3 days	0.432 (0.217, 0.862)	0.017	0.689 (0.553, 0.857)	0.001	0.767 (0.543, 1.084)	0.133
Iodine-containing drug consumption within the last 3 days	0.000 (0.000, -)	>0.998	0.581 (0.220, 1.534)	0.273	1.387 (0.253, 7.605)	0.706
Intravenous injection of iodine contrast medium within the last 3 months	0.710 (0.096, 5.256)	0.737	0.911 (0.445, 1.868)	0.800	0.803 (0.268, 2.406)	0.695
TPOAb	2.605 (1.647, 4.120)	<0.001	1.009 (0.784, 1.297)	0.947	1.141 (0.777, 1.678)	0.501
TgAb	2.994 (1.973, 4.544)	<0.001	0.943 (0.752, 1.182)	0.611	0.933 (0.660, 1.318)	0.693
Multiple logistic analysis						
Residential area	5.114 (2.893, 9.040)	<0.001	0.890 (0.741, 1.070)	0.215	1.064 (0.823, 1.376)	0.634
Sex	4.281 (2.006, 9.139)	<0.001	1.904 (1.591, 2.279)	<0.001	1.319 (1.013, 1.717)	0.040
Age	1.016 (1.002, 1.029)	0.023	1.059 (1.052, 1.065)	<0.001	1.036 (1.026, 1.045)	<0.001
Smoking	2.087 (0.917, 4.751)	0.080	–	–	–	–
Seafood intake within the last 3 days	0.815 (0.395, 1.678)	0.578	0.968 (0.757, 1.239)	0.798	–	–
TPOAb	1.289 (0.717, 2.318)	0.397	–	–	–	–
TgAb	2.057 (1.203, 3.518)	0.008	–	–	–	–

TgAb, thyroglobulin antibody; TPOAb, thyroid peroxidase antibody.

The results of the current study showed that the median UIC of the total population was 129.15 µg/L in Guangzhou, indicating adequate iodine status on the basis of the 2007 WHO/ICCIDD criteria (1). However, 32.39% of residents had a UIC of <100 µg/L. Moreover, rural residents had a significantly higher prevalence of a UIC < 100 µg/L than did urban residents. This result was consistent with that obtained from a survey of urban and rural Mexican schoolchildren (15). Likewise, we also found that the median UIC of rural residents was much lower than that of urban residents. This finding was similar to the results reported by the Korea National Health and Nutrition Examination Survey (7), which revealed that UIC was highest in urban and coastal regions and lowest in rural and inland regions. However, a study conducted in Italy failed to show a significant difference in UIC between schoolchildren in rural/mountainous regions and those in urban regions (16). Although another study including two cross-sectional surveys was carried out in China in 2011 and 2013 and found significant differences in the median UIC between rural children and urban children, the direction of the difference was found to differ between the survey carried out in 2011 and that carried out in 2013 (17). Hence, the variations in UIC between rural and urban areas could not be generalized. There have been a variety of associated factors reported to affect the urinary iodine concentration and iodine nutritional status.

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Table 4 Thyroid nodules in residents living in rural and urban areas. Age is expressed as the mean ± S.D.; urinary iodine concentration is expressed as the median with interquartile range; the other variables are presented as *n* (%). The *t*-test was adopted for age; the Mann–Whitney *U*-test was adopted for urinary iodine concentration;and the χ^2 test was used for the other variables. $P < 0.05$ was considered significant.

	With thyroid nodule			**Without thyroid nodule**				
	Rural resident	Urban resident	*P1*	Rural resident	Urban resident	*P2*	***P3***	***P4***
Age (years)	54.71 ± 0.55	50.04 ± 0.69	<0.001	44.85 ± 0.57	36.76 ± 0.49	<0.001	<0.001	<0.001
Age category (years) (%)			<0.001			<0.001	<0.001	<0.001
>45	75.55 (448/593)	62.40 (322/516)		47.55 (291/612)	24.40 (192/787)			
≤45	24.45 (145/593)	37.60 (194/516)		52.45 (321/612)	75.60 (595/787)			
Sex (%)			<0.001			<0.001	<0.001	<0.001
Male	25.97 (154/593)	47.87 (247/516)		40.36 (247/612)	57.81 (455/787)			
Female	74.03 (439/593)	52.13 (269/516)		59.64 (365/612)	42.19 (332/787)			
Iodized salt intake (%)			<0.001			0.076	0.062	0.072
Yes	100.00 (592/592)	96.28 (492/511)		99.18 (606/611)	97.95 (763/779)			
No	0.00 (0/592)	3.72 (19/511)		0.82 (5/611)	2.05 (16/779)			
Seafood intake within the last 3 days (%)			<0.001			<0.001	0.006	0.258
Yes	6.25 (37/592)	21.98 (113/514)		11.90 (65/546)	24.71 (194/785)			
No	93.75 (555/592)	78.02 (401/415)		88.10 (481/546)	75.29 (591/785)			
Urinary iodine concentration (μg/L)	120.10 (79.95, 167.05)	128.50 (89.00, 185.75)	0.015	121.40 (85.55, 177.25)	142.00 (100.00, 199.00)	<0.001	0.185	0.004
Iodine status (%)			0.005			<0.001	0.089	0.006
Insufficient	38.28 (227/593)	32.95 (170/516)		35.62 (218/612)	24.90 (196/787)			
Adequate	46.21 (274/593)	46.32 (239/516)		45.42 (278/612)	50.57 (398/787)			
Above adequate	12.48 (74/593)	14.73 (76/516)		14.22 (87/612)	17.15 (135/787)			
Excessive	3.04 (18/593)	6.01 (31/516)		4.74 (29/612)	7.37 (58/787)			
TPOAb(+) (%)			0.734			0.008	0.142	0.155
Yes	10.79 (64/593)	11.43 (59/516)		13.56 (83/612)	9.02 (71/787)			
No	89.21 (529/593)	88.57 (457/516)		86.44 (529/612)	90.98 (716/787)			
TgAb(+) (%)			0.280			0.541	0.863	0.475
Yes	14.84 (88/593)	12.60 (65/516)		15.20 (93/612)	13.98 (110/787)			
No	85.16 (505/593)	87.40 (451/516)		84.80 (519/612)	86.02 (677/787)			

TgAb, thyroglobulin antibody; TPOAb, thyroid peroxidase antibody; P3, rural resident with thyroid nodule vs rural resident without thyroid nodule; P4, urban resident with thyroid nodule vs urban resident without thyroid nodule.

Iodized salt has been widely accepted as the main and effective supplement to iodine (2). In Guangzhou, the coverage rate of iodized salt was 96.00% of the total population. This result was similar to that obtained in Fujian Province (95.1%), a coastal area near Guangzhou in China (18). Interestingly, we found that the coverage rate of iodized salt was significantly higher in rural residents, although they had a much lower median UIC than urban residents. This result suggested that in the Guangzhou area there might be other factors affecting UIC among residents living in rural and urban areas. In addition to iodized salt, seafood is one of the most common dietary sources of iodine. Our results suggest that urban residents have a significantly higher seafood intake than rural residents. Similar findings have also been reported previously: the frequency of laver seaweed, fish, and kelp was found to be higher in coastal areas than in inland areas, and the household coverage rate of iodized salt was found to be lower in coastal areas (19). Compared to urban residents, rural residents living in suburban and mountainous areas may have less access to seafood. Moreover, several medical practices can influence urinary iodine concentrations (20, 21). Hence, we further compared the percentage of iodine-containing drug consumption within the last 3 days and the proportion of iodine contrast medium i.v. injection within the last 3 months between rural and urban residents. The results showed both the percentage of iodine-containing drug consumption and the proportion of iodine contrast medium injection were much higher in residents living in urban areas than in those living in rural areas. These results partially explain the difference in UIC between rural residents and urban residents. In addition to iodized salt consumption, it is important and necessary to consider other dietary factors and relevant medical practices when evaluating iodine nutritional status in residents living in rural and urban areas.

Based on the current iodine status in this population, the prevalence of goiter was found to be 4.57% of the total population, similar to the results obtained from other iodine adequate areas in China, ranging from 4.3% to 4.7% (10, 11). In 1999, the prevalence of thyroid goiter was 12.45% in the Guangdong coastal area (9), which was much higher than our present results. The prevalence in our study was also lower than that in India (13.98%) (22), Pakistan (25.5%) (23), and Ethiopia (36.6%) (24). The implementation of universal salt iodization programs has markedly decreased the prevalence of thyroid goiter in Guangzhou. However, when we compared the prevalence of thyroid goiter between residents of rural areas and urban areas, our results indicated that the prevalence was significantly higher in rural areas. However, a cross-sectional study of 2178 schoolchildren in Italy found no significant difference in goiter prevalence between urban and rural/mountain areas (16). This discrepancy may be explained by the differences in iodine status across different countries. Although the Italian study found no significant difference in UIC between urban and rural/mountain areas, our study showed a significantly lower UIC among rural residents than among urban residents. We failed to show an association between iodine status and thyroid goiter in the univariate logistic analysis, but we did find that residents living in rural areas were more likely to have goiter after adjusting for multiple associated factors. This result was in line with the findings of a previous study conducted in Ethiopia, which indicated that high school girls living in rural areas had an increased odds of thyroid goiter than those living in urban settings (25). The higher prevalence of thyroid goiter in rural residents may be related to a lack of education. Another previous study also reported a correlation between low education and an increased frequency of thyroid goiter (23). In addition, repeat pregnancies can increase the occurrence of thyroid goiter (16, 24). Although the total fertility rate of females was higher in rural areas than urban areas, we did not investigate and compare these factors in our study. This speculation warrants further investigation for confirmation.

The prevalence of thyroid nodules was 44.22% in our survey. However, Lai *et al.* found that in Guangdong Province, the detection rate of thyroid nodules was 6.02 and 10.30% among subjects receiving health examinations in 2009 and 2016, respectively (26), which was much lower than our result. In addition to the widespread use of ultrasonic examination in recent years, this inconsistency may be partially explained by the older age of our subjects, as it has been widely accepted that the incidence and prevalence of thyroid nodules increase with age. In addition, our residents had an adequate iodine status, and thyroid nodules were defined as nodules > 1 mm in size. A study by LAI X and his colleagues did not evaluate iodine nutrition status or provide a definition of thyroid nodules (26). Differences in the iodine nutrition status and definition of thyroid nodules between these two studies may also partially explain the discrepancy in the results. The SPECT-China study found a 41.4% prevalence of thyroid nodules, similar to our result (27). The prevalence in Shanghai in 2009 was 27.76% (28), and in Heilongjiang Province in 2018, it was 36.88% (29). The definition of thyroid nodules differs across these studies: thyroid nodules were defined as nodules> 2 mm in size in the SPECT-China study, >5 mm in size in the Chinese study from 2011, and >3 mm in size in Shanghai and Heilongjiang. Moreover, we found that rural residents had a higher prevalence of thyroid nodules than urban residents. The prevalence of multiple thyroid nodules was also higher in rural residents. This result was inconsistent with the findings of other studies, which indicated that residents in urban areas have an increased prevalence of nodules compared with rural areas in Shanghai (28), while no significant difference was found in the prevalence of thyroid nodules among communities between coastal and inland areas in Zhejiang Province in China (19). The population selected, iodine status, and dietary and lifestyle factors were very different across these populations, which may explain this difference (10, 11, 12, 13). Notably, an increased risk of thyroid nodules and multiple thyroid nodules associated with female sex and increasing age has been consistently observed (28).

One limitation of this cross-sectional survey was that it failed to include changes in the urinary iodine concentration and the prevalence of thyroid goiter and nodules over time. Hence, causal relationships could not be fully elucidated. Further longitudinal studies are needed to clarify this point. In addition, the amount of iodized salt intake and other dietary products such as eggs, milk, and pickled food and the association with UIC was not evaluated in this study (30).

Conclusions

In summary, the results of this study showed that rural residents had a lower UIC than urban residents in Guangzhou. Although the coverage rate of iodized salt was higher in rural residents, the percentage of seafood intake, iodine-containing drug consumption, and iodine contrast medium injection was significantly higher in urban residents. The prevalence of thyroid goiters and nodules was higher in residents living in rural areas, and residents living in rural areas were more likely to have goiters. Hence, it is necessary to consider both dietary habits and medical factors when evaluating iodine nutritional status in Guangzhou. Monitoring thyroid goiters and nodules should be differentiated and specialized for residents living in rural and urban areas in Guangzhou.

Supplementary materials
This is linked to the online version of the paper at https://doi.org/10.1530/EC-21-0418.

Declaration of interest
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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Author contribution statement
Yuerong Yan and Lili You contributed equally to this work. Yuerong Yan wrote the final version of the manuscript. Lili You performed the statistical analyses. Mingtong Xu and Li Yan both conceived of the project and helped to modify the manuscript together. Xiaoyi Wang, Muchao Wu, Jin Zhang, and Biwen Xia assisted with the data interpretation. Feng Li, Hongshi Wu, Zhuo Zhang, Jiayun Wu, Caixia Chen, and Xiaohui Li participated in the data collection. All authors approved of the final version of the manuscript.

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