Iodine Nutritional Status and Thyroid volume of School-Aged Children in Wuhan, central of China

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Abstract

Background/Aims:

Iodine deficiency is a public health problem over the world. China has achieved the iodine deficiency disorders (IDD) elimination goal through a mandatory universal salt iodization (USI) program. The aim of this study is to assess the current iodine nutritional status and thyroid volume of school-aged children in Wuhan, central of China.

Methods

The cross-sectional study was conducted among 8–10 years old children from 5 districts in Wuhan. A total of 1000 students were investigated. Salt iodine concentrations, urine iodine concentrations were determined using the standardized methods recommended by WHO/ICCIDD. An ultrasonography of thyroid and anthropometric measurements were performed in all subjects.

Results

The median urinary iodine concentration(MUI) of students was 247.50 μg/L with interquartile range of 147.00 to 384.00 μg/L. Two districts were classified as regions with adequate iodine nutrition, two districts as regions above the requirement, and one district as a region excessive according to the MUI. The prevalence of goiter was 3.0% and 7.8% according to Chinese national and WHO reference values, respectively, and the difference was not observed among different iodine nutrition groups($P > 0.05$). The median thyroid volume(Tvol) of all students was 2.56 ml and the P97 of thyroid volume of both male and female in our study was generally higher than that reported by WHO/ICCIDD in 2007 as a function of age and BSA. The Tvol was in significant association with age, height, weight and BSA by Spearman's correlation analysis($P < 0.001$),and the result of multivariate linear regression analysis showed that only BSA were found to have a significant effect on thyroid volume after log conversion ($t = 13.437$, $P < 0.001$).

Conclusion

The present study indicated that the iodine nutrition among school-aged children in Wuhan was generally adequate with a relatively low goiter rate, while some of them have excess iodine nutrition. Thyroid volume in our study was higher than the reference of WHO and showed a significant correlation with BSA. So further researches were needed to evaluate the thyroid function in children with iodine excessive and the applicability of WHO reference in goiter diagnose. It was also highly recommended to establish the local reference values for thyroid volume that might be applicable to precisely define goiter prevalence in Wuhan.

Background

Iodine is an important micronutrient element for the formation of the thyroid hormones, which are essential for physical and intellectual development [1]. According to the WHO, more than two billion people were suffering from iodine deficiency globally, most of them children and infants [2]. In some developing countries, iodine deficiency was still the main cause of growth retardation and mental deficiency [3]. In China, iodine deficiency disorders(IDD) have long been a significant public health problem with over 700 million people being iodine deficient in the 1990s [4].Although iodine deficiency is widespread and harmful, it can be prevented by appropriate iodine intervention. Salt iodization is one of the most cost-effective nutrition interventions for controlling and eliminating IDD recommended by international organizations such as the WHO, UNICEF and IGN[5]. Conversely however, the harm of excess iodine cannot be ignored either, it can also goiter, thyroiditis, hyper- and hypo-thyroidism, thyroid cancer and so on[6].

WHO and the Iodine Global Network recommend using the urinary iodine concentration (UIC, expressed in μg/L) to express the recent iodine intake of a population, which is a well-accepted, cost-effective, and easily obtainable indicator[7][8]. On account of urinary iodine may fluctuate in a short time due to the influence of urine volume, perspiration volume, dietary iodine intake and other intra-individual variation factors, the median of urinary iodine (MUI) is often used to evaluate the iodine nutritional status of the population. While the thyroid volume is relatively stable in a short time, so thyroid volume can be used as an indicator to evaluate the iodine nutritional status of individuals. Moreover, the goiter rate of 8–10 year-old children can represent the local residents' status of IDD.

Wuhan is a region lies in the central of China with severe iodine deficiency in history, and has achieved the target of IDD elimination program in 2010 after implementing the salt iodization policy for 26 years. According to the survey results of the iodine content in drinking water of residents in 2017[9], the iodine concentration in drinking water was 2.9 μg/L, indicating that Wuhan was still an iodine-deficient area in the external environment, which cannot be changed for a long time. The aim of the present study was to assess the current iodine nutritional status and thyroid volume of school-age children in Wuhan after 26 years of universal salt iodization.

Methods

Investigation method

This cross-sectional study was embedded into the 2016 China's National IDD Surveillance Program led by National Health Commission of the People's Republic of China[10],which was conducted in 5 of 13 districts/counties of Wuhan from May through October in 2019,non-boarding students aged 8–10 years old were selected from each of the five sample areas in the east, west, south, north and middle. Students were asked to provide a random mid-stream spot urine sample and a household salt sample taking from their home. Salt and urine samples were collected in two days to prevent urine samples from being contaminated by salt and causing false test results. All students were measured for height and weight, thyroid ultrasonography was performed for the determination of Tvol. Written informed consent was received from the parents or legal guardians of participants before the study.

Testing methods and evaluation standards

Iodine content in table salt was measured using a titration method with sodium thiosulphate (GB/T 13025.7–2012) and was expressed as mg/kg[11]. According to the legislation all salt must be iodized with potassium iodate; the amount of iodine in table salt should be18-33 mg/kg. Salt with iodine levels of less than 5 mg/kg was considered non-iodized salt. Inadequately iodized when between 5 and 18 mg/kg, adequately iodized when between 18 and 33 mg/kg, excessively iodized when > 33 mg/kg[12].

Each urine sample was kept in a properly labelled sterile plastic tube with a tight-fitting stopper that was further sealed with special plastic band. UIC was determined using arsenic-cerium catalytic spectrophotometry (WS/T 107.1–2016) and was expressed as μg/L. The criteria for classifying the iodine nutrition of a population proposed by the WHO/UNICEF/IGN criteria are < 20 μg/L as severe iodine deficiency;20–49 μg/L as moderate iodine deficiency; 50–99 μg/L as mild iodine deficiency; 100–199 μg/L as adequate iodine nutrition; 200–299 μg/L as above the requirement; and ≥300 μg/L as excessive[13].

Thyroid volume was determined by ultrasonography performed by experienced examiners working in the municipal centers for disease control, using a 7.5-MHz transducer. The volume of each lobe was calculated from the measurements of the length, width, and thickness by the following formula: V (mL) = length (cm) × width (cm) × thickness (cm) × correction factor

0.479. Tvol was calculated as the sum of the volume of both lobes. Goiter prevalence was calculated based on both Chinese standard and WHO standard. According to Chinese domestic diagnostic criteria for endemic goiter (WS 276–2007), the normal reference range for thyroid volume for children aged 8, 9 and 10 years are less than 4.5 mL, 5.0 mL and 6.0 mL, respectively[14]. The criteria of WHO is defined by a gender-specific P97 as a function of age and BSA, which in the age of 8–10, P97 was 3.71, 4.19, 4.73 mL separately for boys, and 3.76, 4.32, 4.98 mL separately for girls [5].Body surface area (BSA, in m^2) was calculated using the formula BSA = weight (kg)$^{0.425}$ × height (cm)$^{0.725}$ × 71.84 × 10^{-4}[15]

Statistical Analysis

Descriptive statistics and hypothesis testing were analyzed by the Statistical Package for the Social Sciences (SPSS) software, version 20.0. Kolmogorov–Smirnov (KS) test was used for normality test. The significance of variation among the various statuses was evaluated by Kruskal–Wallis test, and pairwise comparisons were performed using the Mann-Whitney rank sum test. Comparisons of Iodine nutrition classification among subgroups were done using chi-squared test. Spearman correlation analysis was used to determine the relationship between thyroid volume and UIC with age, height, weight, BSA and salt iodine content. The values of thyroid volume, iodine content of table salt and UIC were natural log transformed to assure normality of data and then constructed through multiple linear regression to estimate the relationship between thyroid volume and age, UIC and iodine content of table salt. $P < 0.05$ was considered statistically significant.

Results

General Survey

A total of 1000 school-aged children from 5 districts of Wuhan were investigated and examined. The sample included 499 boys and 501 girls, of which 269 were 8-year-olds, 321 were 9-year-olds, and 410 were 10-year-olds. The Shapiro-Wilks test for normality indicated that the frequency distribution curve of the height(cm),weight(kg),BSA(m^2),BMI, Tvol(ml),UIC(μg/L) for all involved children was not normally distributed($Z = 1.754,3.476,1.765,3.189,3.637,4.481$,and all $p < 0.05$), so the median and interquartile range (IQR) were employed to describe their central tendency.

Table 1 showed that the median height of all involved school-aged children was 140.00 cm, median weight was 31.00 kg, median BSA was 1.10 m^2, and median BMI was 16.22. Meanwhile, height, weight, BSA, and BMI increased with an increase of age($\chi^2 = 243.194,123.158,196.241,8.802$, and all $p < 0.05$). Boys had higher height, weight, BSA and BMI than girls ($Z=-3.149,-5.429,-5.092,-4.682$ and all $p < 0.05$). There were statistically significant difference in height, weight, BSA, and BMI among children in different districts of Wuhan ($\chi^2 = 31.648,33.210,31.434,15.467, 23.86$,and all $p < 0.05$).

Table 1
Descriptive statistics of children in the study[M(IQR)]

Variable		N	Height(cm)	Weight(kg)	BSA(m^2)	BMI
Gender	boy	499	140.00(135.00,146.00)	32.50(28.00,39.00)	1.12(1.04,1.23)	16.56(14.88,19.17)
	girl	501	140.00(132.00,145.00)	30.00(26.00,35.75)	1.09(1.00,1.18)	15.85(14.49,17.59)
Age	8	269	132.00(128.00,138.00)	28.00(25.00,32.00)	1.02(0.95,1.06)	15.90(14.61,17.73)
	9	321	140.00(134.00,145.00)	31.00(27.00,36.55)	1.10(1.03,1.19)	16.04(14.55,18.18)
	10	410	144.00(140.00,148.00)	34.00(30.00,40.00)	1.16(1.09,1.25)	16.56(14.92,18.54)
District	Hongshan	200	140.00(132.00,145.00)	32.00(27.13,40.00)	1.12(1.02,1.24)	16.71(14.83,19.37)
	Hanyang	200	142.50(138.00,147.00)	32.00(28.00,38.50)	1.12(1.05,1.23)	16.15(14.54,18.33)
	Hannan	200	140.00(134.00,148.00)	32.35(28.00,38.00)	1.12(1.04,1.23)	15.75(14.03,17.63)
	Jiangxia	200	139.00(132.25,143.00)	30.45(27.00,35.00)	1.09(1.01,1.16)	16.00(14.88,17.60)
	Dongxihu	200	138.00(130.13,146.00)	30.00(25.00,35.00)	1.07(1.00,1.17)	16.38(14.96,18.53)
Total		1000	140.00(133.00,146.00)	31.00(27.00,37.00)	1.10(1.02,1.20)	16.22(14.70,18.21)

Urinary Iodine and Salt Iodine Concentration

The MUI for the selected students was 247.50 μg/L with interquartile range of 147.00 to 384.00 μg/L. The percentage of samples less than 100 μg/L as 14.00% and more than 300 μg/L as 36.70%. Boys had higher levels of UICs than girls (Z = -2.592, p =0.01),and difference in age for UICs were also observed(χ^2 = 8.621,p = 0.013). The MUIs of 5 districts were within the range of 159.50 μg/L to 337.00 μg/L. There were statistically significant difference in UIC among the 5 districts(χ^2 = 157.610,p < 0.001). Among them, the iodine nutritional status of children in Hanyang and Dongxihu district fell in an appropriate level, while the iodine nutrition status in Hannan district was excessive. Furthermore, there was no significant correlation in UICs with height, BSA, and thyroid volume(r=-0.039,0.041,0.034, and all p > 0.05),but the UIC was in weak correlation with weitht(r = 0.076,p = 0.016) by spearman correlation analysis(Table 2).

A total of 1000 table salt samples were collected and detected, the median iodine content of the table salt was 23.20 mg/kg(IQR:20.83–25.32 mg/kg) with a coverage rate of 98.60% and an adequately iodized salt coverage rate of 95.20% referring iodized table salt. There were 1.4% and 0.6% of iodized table salts specimens detected to be inadequately and excessively iodized, respectively. Children who were provided inadequately iodized salt had the lowest median UIC, but also had more than adequate iodine nutrition. Iodine nutritional status were not statistically different among different salt-consuming subgroups(χ^2 = 13.398,P = 0.34).

Table 2
The Urinary Iodine Concentration of school-aged children

Variable		**N**	**classification of UIC(μg/L)**					**The ratio below 100(%)**	**The ratio above 300(%)**	**MUI(μg/L)**
			<50	**50~**	**100~**	**200~**	**300~**			
Gender	boy	499	19	45	103	129	203	12.83	40.68	259.00
	girl	501	22	54	122	138	165	15.17	32.93	233.00
Age	8	269	6	25	58	75	105	11.52	39.03	256.00
	9	321	16	44	80	77	104	18.69	32.40	223.00
	10	410	19	30	87	115	159	11.95	38.78	257.08
District	Hongshan	200	0	11	37	65	87	5.50	43.50	281.44
	Hanyang	200	19	34	62	46	39	26.50	19.50	159.50
	Hannan	200	4	8	29	51	108	6.00	54.00	337.00
	Jiangxia	200	5	9	37	55	94	7.00	47.00	293.61
	Dongxihu	200	13	37	61	50	39	25.00	19.50	179.00
Table salt	Non-iodized	14	3	1	3	3	4	28.57	28.57	223.60
	Inadequately Iodized	28	0	2	8	8	10	7.14	35.71	218.56
	Adequately Iodized	952	38	95	214	254	351	13.97	36.87	248.15
	Excessively iodized	6	0	1	1	2	2	16.67	33.33	232.78
Total		1000	41	99	226	267	367	14.00	36.70	247.50

Influencing factors of thyroid volume

The median thyroid volume of all participating students was 2.56 ml with IQR of 2.13 to 3.21 ml. The median and IQR of thyroid volume of different subgroups were list in Table 3.The difference in thyroid volume among children of different age, district, height, weight, and BMI groups was statistically significant($P < 0.05$).However, there were no significant differences among children of different genders, UIC and table salt groups($P > 0.05$).

The Tvol was in significant association with age($r = 0.206$, $P < 0.001$), height($r = 0.373$, $P < 0.001$), weight($r = 0.406$, $P < 0.001$),BSA ($r = 0.425$, $P < 0.001$),but not associated with gender($r=-0.031$, $P = 0.327$), UIC ($r = 0.034$, $P = 0.284$) and district($r=-0.054$, $P = 0.086$) by Spearman correlation analysis.

Table 3
Influencing factors of thyroid volume

Variable		**N**	**Median of Tvol(IQR)**	***Z/χ2***	***P***
Gender	boy	499	2.57(2.16,3.28)	-0.981	0.327
	girl	501	2.56(2.10,3.16)		
Age	8	269	2.31(1.98,2.81)	47.585	< 0.001
	9	321	2.68(2.13,3.30)		
	10	410	2.74(2.28,3.35)		
District	Hongshan	200	2.47(2.04,3.24)	15.467	0.004
	Hanyang	200	2.76(2.27,3.51)		
	Hannan	200	2.61(2.16,3.36)		
	Jiangxia	200	2.59(2.13,3.11)		
	Dongxihu	200	2.47(2.02,3.03)		
Height(cm)	<130	118	2.11(1.84,2.54)	82.269	< 0.001
	130~	347	2.39(2.05,2.98)		
	140~	398	2.77(2.28,3.41)		
	150~	137	3.05(2.54,4.04)		
Weight(kg)	<30	388	2.30(1,93,2,72)	130.466	< 0.001
	30~	426	2.72(2.25,3.30)		
	40~	141	3.10(2.44,3.95)		
	50~	45	3.16(2.49,4.22)		
BMI	normal	778	2.50(2.08,3.09)	31.166	< 0.001
	overweight	116	2.96(2.34,3.61)		
	obesity	106	2.83(2.31,3.92)		
UIC(μg/L)	<100	140	2.65(2.13,3.24)	4.220	0.239
	100 ~ 200	226	2.62(2.12,3.32)		
	200 ~ 300	267	2.48(2.12,3.00)		
	≥300	367	2.61(2.13,3.30)		
Table salt	Non-iodized	14	2.23(1.90,3.81)	3.813	0.282
	Inadequately Iodized	28	2.34(1.98,3.00)		
	Adequately Iodized	952	2.58(2.13,3.21)		
	Excessively iodized	6	2.65(2.24,3.59)		
Total		1000	2.56(2.13,3.21)		

Due to the BSA was a composite indicator calculated by height and weight, strong correlations were found in BSA with height and weight(r = 0.818 and 0.947, all P < 0.001). Considering the collinearity, height and weight were excluded from multivariate analysis. The result of multivariate linear regression analysis showed that only BSA were detected to have a significant effect on thyroid volume after log conversion ($t = 13.437$, $P < 0.001$) (Table 4).

Table 4
Multivariate regression for thyroid volume in log scale

Variable	B	Beta	Std.Error	t	p
BSA	1.179(0.182,0.422)	0.435	0.088	13.437	< 0.001
Age	0.002(-0.009,0.013)	0.012	0.006	0.370	0.712
Gender	0.016(-0.001,0.013)	0.054	0.008	1.859	0.063
District	0.001(-0.016,0.018)	0.003	0.009	0.099	0.921
UIC	0.011(-0.013,0.034)	0.025	0.012	0.885	0.377

Comparison of two reference values

Results of ultrasonography from a study population should be compared with reference data [16]. According to the Chinese national standard, among the 1000 children examined by ultrasound, 30 were found to have goiter, accounting for 3.00% of the group. Of which 13 were boys,17 were girls and 11 were in the 8 year-old group,10 were in the 9-year-old group,9 were in the 10-year-old group .The difference in the ratio of goiter was not observed among different genders, ages and iodine nutrition groups ($\chi2 = 0.533$,$p = 0.465$, $\chi2 = 2.024$,$p = 0.363$, $\chi2 = 4.071$,$p = 0.396$).The MUI of children with goiter and without goiter were 338.00 μg/L and 244.50 μg/L respectively, and no statistically significant difference was found between them($Z=-1.898$,$P = 0.058$).

When compared to the WHO recommended reference (2007), the goiter rate identified to be 7.8% and indicated a status of mild IDD endemic. And with WHO reference, goiter rates were statistically different among age groups with the highest value of 8.18%(22/269) in 8-year group, consistent with the result of Chongqing Province[17].Comparing with WHO/IGN recommended references ,the thyroid volume in the present study of school age children was averaged 26.46% (20.08%~30.19%) higher for boys and 25.49%(16.67%~36.70%) for girls when defined by age,and averaged 4.53% (-30.61%~47.45%) higher for boys and 7.21%(-42.11%~35.88%) for girls when defined by BSA. The gender-specific P97 of thyroid volume by age and BSA of present study and reference of WHO was showing in Figs. 1 and 2.

Discussion

Universal salt iodization (USI) is the recommended strategy for controlling iodine deficiency[18]. The iodization level has been changed three times in order to fine-tune the National IDD Elimination Programme since it was initialized in 1994[19].Wuhan has chosen 25 mg/kg(18–33 mg/kg) in the last change of iodization level in 2012 in order to avoid not only iodine deficiency but also iodine excess taking into account the actual iodine nutritional status of local population. In the present study, Wuhan has a high level of iodized salt coverage rate, which has guaranteed adequate iodine nutrition of population in Wuhan. Significant difference was not observed between UIC and different iodine content of table salt, in spite of the lowest UIC was in the inadequately iodized salt group.

The MUI value was the most commonly assessed indicator of iodine nutrition for the sampled population. The MUI of the present study was 247.50 ug/L, fell in the level of more than adequate recommended by international organizations [13], which had met the national iodine deficiency elimination standard. Compared with iodine nutrition of other parts of China, the iodine nutrition of Wuhan which located in central of China was relatively adequate. The MUI of Zhejiang Province which located in the eastern coastal area of China was 178ug/L[20].Similar to the results of this study, the MUI of Chongqing, which located in western China was found to be 222.00ug/L[17].The present result indicated that the situation of iodine deficiency in Wuhan have been corrected, and the comprehensive prevention and control measures based on salt iodization for 26 years have achieved remarkable achievements. However, excessive iodine nutrition (≥ 300 μg/L) was observed among 36.70% of the children, especially in Hannan district ,and 14.00% of the children had UIC below requirement(< 100 μg/L). The reason on the one hand may be related to the increased consumption of processed foods for children. At present, various foods with high salt content were produced on the market for children's tastes, such as potato chips, seaweed, instant noodles, mustard, bacon and so on. Children may consume more iodine when they eat these high-salt foods regularly, which can cause excessive iodine intake. Thus they should be instructed appropriately to adjust the intake of iodine-containing foods and carried out long-term dynamic monitoring to ensure their proper iodine nutritional status since excess iodine nutrition could result in iodine-induced thyroid disease, such as hyperthyroidism and autoimmune [21]. On the other hand, the ability of detection of iodine deficiency laboratory varied in different district, which may also lead to too high or too low UIC detection value of children. There were statistically significant differences in UIC among children of different genders, ages and administrative districts, but not with height, BSA and Tvol .

UIC assesses iodine nutrition only at the time of measurement, whereas thyroid size reflects long-term iodine nutrition of an individual or a population. Moreover, goiter prevalence responds slowly to changes in iodine intake as thyroid size may not return to normal for months or years [5].In our present work, Tvol determinations were made by a single experienced operator which free of inter- observer variation, a factor known to be one of the reasons resulting in the current disagreements surrounding normal Tvol values for children[22] .The median Tvol of Wuhan in boys and girls were 2.57 ml and 2.56 ml respectively, smaller than that of African boys and girls, which found to be 3.32 ml and 3.53 ml which may due to genetic or environmental factors, and smaller than that of 2.9 ml in Chongqing and 3.1 ml in Zhejiang Province observed in 2013[23].In 3–14 year-old Spanish children, significant sex differences in Tvol were found for 8–12 years of age[1].However, no such gender differences were found in our study and in most iodine-sufficient areas' studies[24].In the Netherlands, Wiersinga et al observed that, it was not until the age of 14 that the gender difference in thyroid volume began to be greater than the BSA difference [25].

In our present finding, although positive correlation was observed between thyroid volume and either age or body surface consistent with other study[26],a multiple linear regression showed that only BSA significantly predicted thyroid volume. However, in the Ashanti Region of Ghana, Daniel Gyamfi showed that only age significantly predicted thyroid volume which was conducted in 6–12 years old children, although which factor had the greatest impact on thyroid volume remained to be studied[27]. It may be that the years of 8–10 cannot be enough to reflect the difference in Tvol, and the result may be different after expanding the age range in our study.

There were many factors that affected thyroid volume, among which the relationship between UIC and thyroid volume was controversial. Some previous researches indicated that the relationship between them varied significantly in different regions. High goiter rate in children with high median UIC was observed in China with high iodine content in drinking water[28]. In China's Hebei, Shandong and other areas where iodine deficiency, iodine adequate, and iodine excess coexist, urinary iodine and thyroid volume have a "U"-shaped curve relationship, that is, both insufficient and excess iodine nutrition can cause glands to become enlarged[29]. Multivariate linear regression in the present study found that BSA could explain only 20.7% of the thyroid volume, which meant that 79.3% of thyroid volume was determined by other factors, such as race, geographical area and diet habits[16].Some researches indicated that iodine nutrition was the most important factor affecting thyroid volume in iodine-deficient areas, while dietary habits and genetic differences in growth and development played the most important role in thyroid volume in an iodine-sufficient area[25].And some studies showed that the differences in thyroid volume were related to genetic and environmental factors[30].In our study, the thyroid volume was not in significant correlation with UIC, indicating that iodine nutritional status had little effect on Tvol of school-aged children in Wuhan, consistent with the result of Zhejiang Province[23].

In the present study, consistent with several other studies[27], we presented the data on BSA and age-specific thyroid volumes. The P97 thyroid volumes of both boy and girl of school-aged children observed in this study were generally higher than that reported by WHO/ICCIDD in 2007 irrespective of whether it was expressed as a function of age and BSA.

The Chinese criteria employed in this study only considered the factor of age without adjusting for BSA and gender, which may be high for iodine deficiency areas like Wuhan, and ignored gender differences and children's variant body development of the same age [17]. Thus the goiter prevalence using the criteria may be underestimated. But whether the standards of WHO were appropriate to assess the goiter of children in Wuhan remained to be further studied. Formal international recommendations advised that standard references of thyroid volumes should be established based on a nation or a region [1].Therefore, larger studies were needed to gather more data to explore the population-specific reference range such as that done in Sweden on BSA-specific reference by age[31].

There were some limitations in this study. Firstly, we didn't collect the thyroid function and anti-thyroid antibody of children, which may be useful for thyroiditis diagnose and explain some of the identified goiter [32].Secondly, some BSA groups have insufficient sample size, such as 0.7 m^2 of boys and 1.6 m^2 of girls, so the values of P97 for such BSA could not be presented in the Fig. 2 and some outliers made the Tvol not increase steadily with the increase of BSA.

Conclusions

In conclusion, the present study indicated that the iodine nutrition among school-aged children in Wuhan was generally adequate with a relatively low goiter rate, while some of them have excessive iodine nutrition. Thyroid volume in our study was higher than the reference of WHO and showed a significant correlation with BSA. So further researches were needed to evaluate the thyroid function in children with iodine excessive and the applicability of WHO reference in goiter diagnose. It was also highly recommended to establish the local reference values for thyroid volume that might be applicable to precisely define goiter prevalence in Wuhan.

Abbreviations

IDD
iodine deficiency disorders;
USI
universal salt iodization;
WHO/ICCIDD
World Health Organization/International Council for the Control of Iodine Deficiency Disorders;
UNICEF
United Nations International Children's Fund;
UIC
urinary iodine concentration;
MUI
median urinary iodine;
BMI
body mass index;
BSA
body surface area;
IGN
Iodine Global Network; Tvol:thyroid volume;
IQR
interquartile range.

Declarations

Ethics approval and consent to participate

Written informed consents were obtained from all subjects and the study was approved by the Ethics Committee of Wuhan Center for Disease Control and Prevention.

Consent for publication

Written informed consent was received from the parents or legal guardians of participants before the study.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Competing interests

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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Authors' contributions:

FC wrote the manuscript. MX X and YY were involved in the design and conduction of the study. KW were involved in collecting materials. All authors read and approved the final manuscript.

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Figures

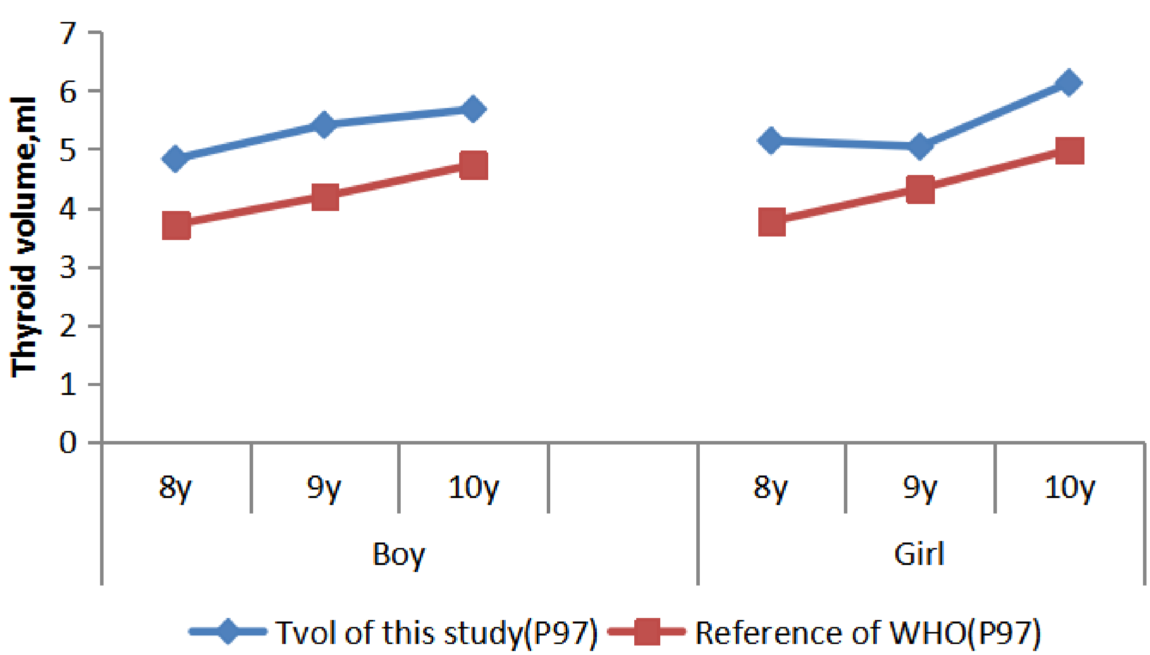

Figure 1

Comparison of P97 of thyroid volume between this study and WHO/IGN recommended references by age.

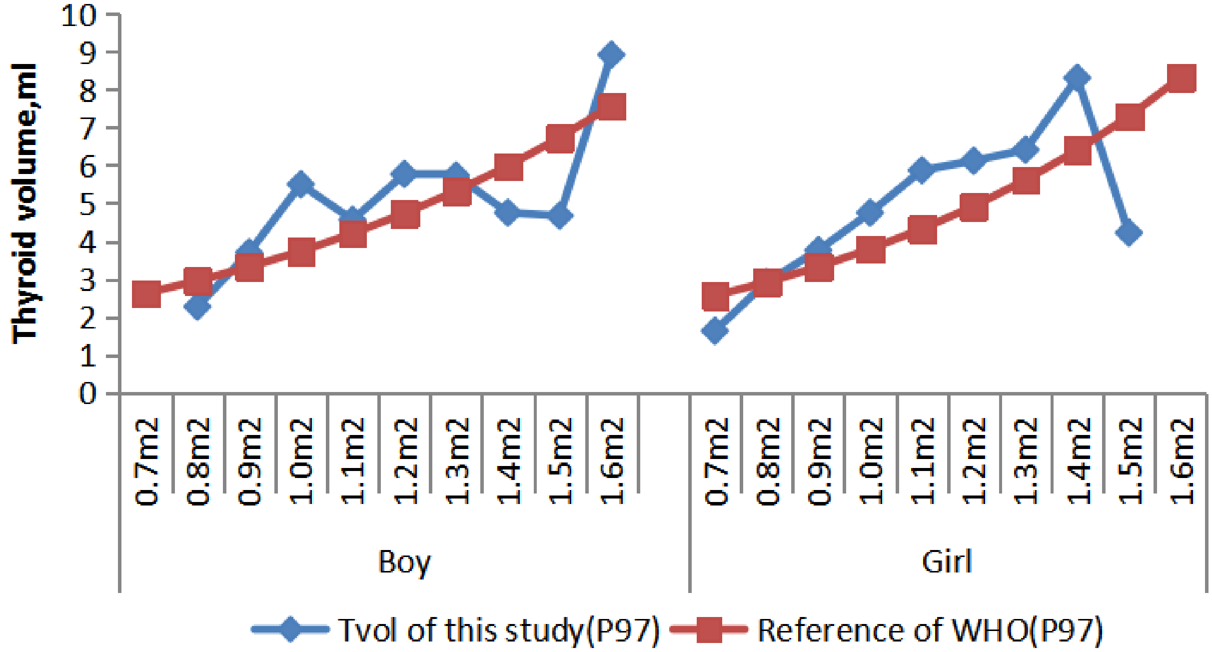

Figure 2

Comparison of P97 of thyroid volume between this study and WHO/IGN recommended references by BSA.