Nutritional status of iodine in schoolchildren of Islamabad, Pakistan: a comparison with the WHO references

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ABSTRACT

Background: The northern Himalayan section of Pakistan has a historical significance of iodine deficiency. The capital territory of Islamabad is in a plateau of these mountains which may be iodine deficient despite the rest of the country has improved to the optimal status of iodine in schoolchildren. We conducted this study to evaluate the iodine status in schoolchildren of Islamabad and adjacent areas by measuring urinary iodine concentrations (UIC) and thyroid volumes.

Methods: Schoolchildren of the age group from 9 to 12 years (*n* = 264) belonging to both the rural and urban areas of the region were included in this study. UIC was measured in urine samples by Sandell–Kolthoff kinetic method, and the thyroid volumes were determined by ultrasonography. A dietary history in iodine intake was recorded, and the samples of the household salt from 51 houses were also assessed for iodine content.

Results: The median of UIC was below the standard values in both boys and girls. The 97th and 50th percentiles of thyroid volumes of our population at various points of age and body surface area were significantly higher than the reference values. Dietary intake of iodine-rich food was not sufficient, and the iodine content in table salt was lower than the required value.

Conclusions: This study revealed that schoolchildren in the capital territory of Islamabad are iodine deficient. The iodine status in this region is consistent with other northern areas of Pakistan.

Keywords: Urinary iodine, iodine deficiency, thyroid volume, iodized salt, schoolchildren, Islamabad.

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Introduction

Iodine is a trace element of vital importance as a micronutrient in the human body. It is essential for the synthesis of thyroid hormones required for human development, growth, and metabolism [1]. The deficiency of iodine may result in cretinism, mental retardation, goiter, low birth weight, and child mortality [2,3]. Iodine deficiency disorder (IDD) is one of the major public health problems for populations throughout the world. It may particularly have devastating outcomes in pregnant women and young children. The population living in regions having severe IDD has intelligence quotient 13.5 points below the control population [4]. Being the cause of preventable brain damage in childhood, its elimination is a focus of international efforts [5]. Endemic goiter is a visible consequence of iodine deficiency and is its important indicator [6,7]. The iodine taken in the body is primarily excreted through the urine. Urinary iodine concentration (UIC), therefore, is a sensitive method of assessing the iodine status in the body [8]. It is economical and easy to perform. It is widely used to determine the iodine status of a population [9]. The strategy of universal salt iodization has shown substantial success in many countries since its inception in 1994 [6]. Optimal iodine intake prevents the risk of thyroid disorders in the population [10].

Regions with sloping terrain are more susceptible to the occurrence of IDD due to more rain causing soil erosion. It is more so in mountainous areas than in hilly areas, followed by plains, inland, and coastal region, respectively [11]. In the past national survey, Pakistan has shown an improvement in iodine status in all of its provinces except northern mountainous areas [12,13]. These mountains make the western section of the Himalayan range which has a historical significance in IDD. In 1908, Mc Camson reported an endemic cretinism in the Chitral and Gilgit valleys [14]. Islamabad is in the Pothwar Plateau region that lies at the skirt of this range and makes the northern part of the province of Punjab (Figure 1). It is separated by lower-lying planes of Punjab by the salt range, at an average height of 462 m above the sea level with undulated terrain and area of 22,254 km^2. The himalayas abut

Figure 1. *Map of the Pothwar Plateau showing Islamabad. AJK = Azad Jammu and Kashmir, IOK = Indian (solid line: international border, dashed line: line of control).*

at the north and east of the city as the Margalla and Murree Hills, respectively.

In this study, the iodine status of schoolchildren in Islamabad was investigated using the indicators of UIC, thyroid volume, and iodine contents in household salt, which were compared with the WHO reference levels [6,15,16].

Subjects and Methods

A cross-sectional study was conducted from October 2013 to September 2015 to seek the iodine status in the school-going children of Islamabad, the capital territory of Pakistan, and adjacent areas. The subjects included were children from class V to VIII of both the sexes. A total of 264 schoolchildren (133 boys and 131 girls) having age in the range of 9–12 years were finally selected belonging to high-, low-, and middle-class families. The UIC levels and thyroid sizes were measured and compared with their thyroid size estimated on ultrasound. Both were then compared with the WHO standard values to seek IDD in the population.

UIC was measured from the morning's first urine samples provided by the participating children. Each urine sample was transferred from a disposable cup to 1-ml cavetti and stored in a refrigerator at −10°C until required for analysis. Final evaluation was done in random order with the Sandell–Kolthoff reaction after the digestion of urine with ammonium persulfate [17]. For analysis, 250 µl of urine sample and the same amount of standard iodine solutions (0, 20, 40, 80, 120, and 200 µl) were taken in separate test tubes. About 1 ml of 1 M ammonium persulfate (Merck, Germany) solution was added in each test tube which was then heated for 60 minutes at 95°C in a dry incubator. After cooling, 3.5 ml of sulfuric acid solution of arsenic trioxide (arsenious acid solution) was added, followed by incubation for 15 minutes at room temperature. Ceric ammonium sulfate (400 ml) was added in each mixture, and the adsorbance was measured 30 minutes later using Optizen 3220 UV/Visible spectrophotometer. The procedure was performed in an isolated and dedicated laboratory room.

Thyroid volumes of 228 children (M:F = 1:1) were estimated by using an HS-2500 Ultrasonic Scanner of Honda Electronics Co., Ltd. equipped with an HLS-475M 7.5 MHz 50-mm linear transducer. All ultrasound measurements were performed by a single ultrasonologist to keep the constancy in measurements. The students were positioned supine with the neck hyperextended while imaging. The transverse and sagittal sections of each lobe were taken, and the maximum measurements in three dimensions, i.e., anteroposterior (thickness), mediolateral (width), and craniocaudal (length) were recorded in centimeters. A volume of the lobe was then calculated using the formula of rotation ellipsoid model for each lobe [6]. The thyroid volume was taken as the sum of the volumes of both lobes while the isthmus was ignored. The body surface area (BSA) was calculated using the standard formula [18].

A dietary history of the previous 3 months was obtained on an appropriate questionnaire distributed to the parents to document the consumption of iodine sources and iodized salt. Fifty-one samples of household salt were collected from the same population. An iodine concentration in the salt samples was determined by iodometric titration.

The central tendency of various parameters was expressed as mean (±SD), whereas that of UIC was presented in the median. The UIC levels of the sample were arranged according to epidemiological criteria by the WHO and International Council for Control of Iodine Deficiency Disorders (ICCIDD) for assessing iodine nutrition based on median urinary iodine concentrations of schoolchildren [6]. A histogram of thyroid volumes showed skewness toward the positive side. Its values, therefore, were transformed to a log scale to translate it in the normal distribution. These log values were further used for the calculations of mean (±SD), 97th (P97), and 50th (P50) percentiles which were then converted back to a linear scale. Log values were also used to build the regressions of thyroid volumes with UIC and iodine contents of table salts. The exponential trends of P97 and P50 were compared with P97 and P50 of the WHO, respectively. The means of various parameters were compared using the *z*-test or analysis of variance (ANOVA) in case of more than two parameters. A *p*-value of ≤0.05 was considered as significant. MS® Excel 2010 was used for the statistical analysis of data.

Results

Children studied had mean (±SD) age, weight, height, and BSA of 11.0 ± 1.0 years, 35.1 ± 7.8 kg, 143.6 ± 9.1 cm, and 1.1 ± 0.2 m^2, respectively. Median UIC was 70.5 µg/l with 65.9% of the children having iodine deficiency (boys: 66.9% and girls: 64.9%). THE maximum UIC level was 315 µg/l in a female child with a thyroid volume of 2.18 ml. The distribution of children according to the WHO/ICCIDD criteria for iodine deficiency based on UIC is shown in Table 1 and histogram in Figure 2.

Mean (±SD) thyroid volume in all children was 3.80 ± 1.57 ml, whereas, in children of age group 9, 10, 11, and 12 years, it was 2.61 ± 1.56, 3.67 ± 1.49, 4.18 ± 1.51, and 4.44 ± 1.50 ml, respectively, and all were found to be statistically different ($p < 0.001$). Thyroid volumes in boys and girls were 4.25 ± 1.50 and 3.43 ± 1.60, respectively, which also had a statistically significant difference ($p = 0.0016$). The left lobes of the thyroids were significantly larger than the right lobes (2.26 ± 1.08 *vs.* 1.97 ± 0.95 ml) with $p < 0.0001$. The maximum thyroid volume of 9.78 ml was seen in an 11-year-old boy having a UIC level of 142 µg/l, whereas the minimum was 1.31 ml in a 9-year-old girl with an iodine content of 139 µg/l of urine. Mean (±SD) of the thyroid volumes of children with iodine deficiency, i.e., UIC levels less than 99 µg/l, was 4.49 ± 1.46 ml, whereas the values for normal (100–199 µg/l) and above normal (>200 µg/l) were 3.90 ± 1.57 and 4.06 ± 1.44, respectively. No significant correlation was seen between thyroid volumes and UIC levels ($r = 0.124$). P97 and P50 trends of total thyroid volumes as the functions of age and BSA are shown in Figures 3 and 4, respectively, and compared with standard values referenced by the WHO.

Diet record from parents showed that most of the iodine sources consumed daily or weekly were milk, its dairy products, and eggs, whereas seafood was rarely consumed in 95% of homes (Table 2). Only 28 out of 51 houses were using iodized salt. About 78% of all 51 samples collected had iodine content of less than 10 mg/

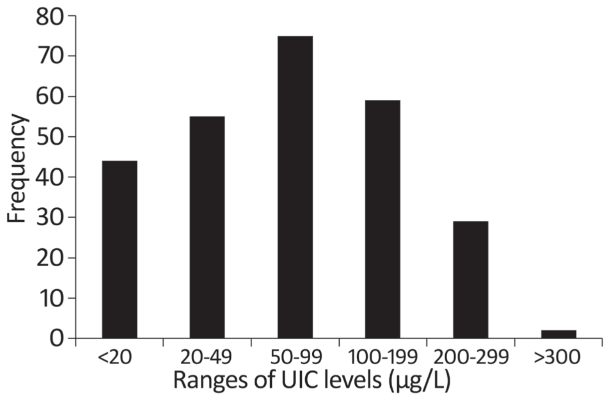

Figure 2. *Frequency distribution of schoolchildren according to UIC levels (n = 264).*

Table 1. Iodine status in the children under study (n = 264) sorted according to the WHO/ICCIDD criteria based on urinary iodine concentration (UIC).

THE WHO/ICCIDD CRITERIA (UIC LEVELS IN µg/l)	POPULATION GENDER	*N*	%	MEDIAN UIC (µg/L)
Severe deficiency (≤20)	Boys	22	16.5	5.5
	Girls	22	16.8	0.6
	Total	44	16.7	2.5
Moderate deficiency (20–49)	Boys	27	20.3	33.9
	Girls	28	21.4	36.0
	Total	55	20.8	35.0
Mild deficiency (50–99)	Boys	40	30.1	72.4
	Girls	35	26.7	73.0
	Total	75	28.4	72.9
Normal (100–199)	Boys	25	18.8	145.2
	Girls	34	26.0	135.0
	Total	59	22.3	141.8
Above requirements (200–299)	Boys	19	14.3	244.1
	Girls	10	7.6	237.3
	Total	29	11.0	242.2
Excessive (≥300)	Boys	0	-	-
	Girls	2	1.5	-
	Total	2	0.8	-
Total	Boys	133	50.4	70.3
	Girls	131	49.6	70.7
	Total	264	100	70.5

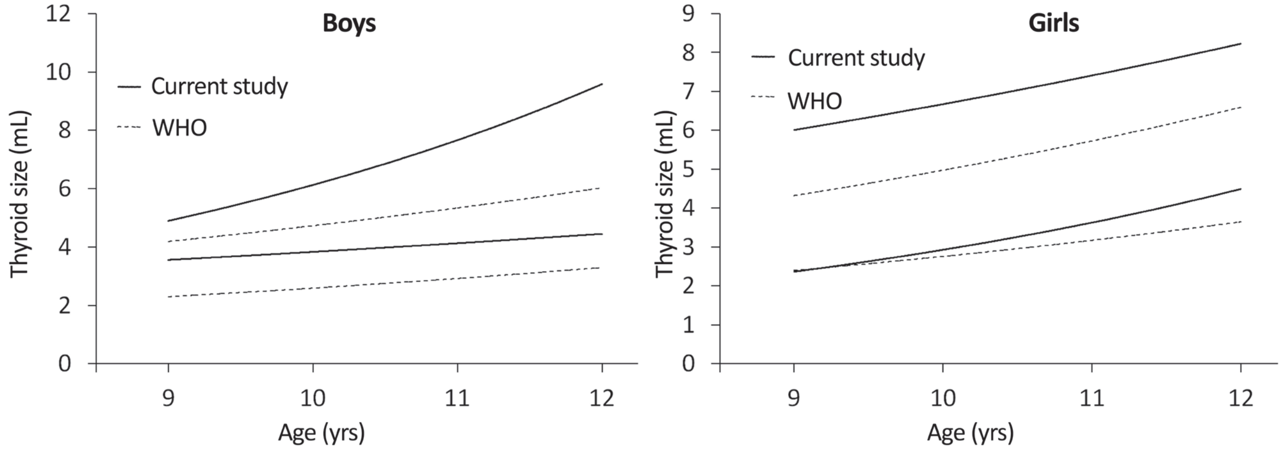

***Figure 3.** 97th percentile (P97) and 50th percentile (P50) values for thyroid volume in both sexes as a function of age in comparison with the same values referenced by the WHO (R-squared of boys: P97 = 0.8797 and P50 = 0.9643, and of girls: P97 = 0.8186 and P50 = 0.9177).*

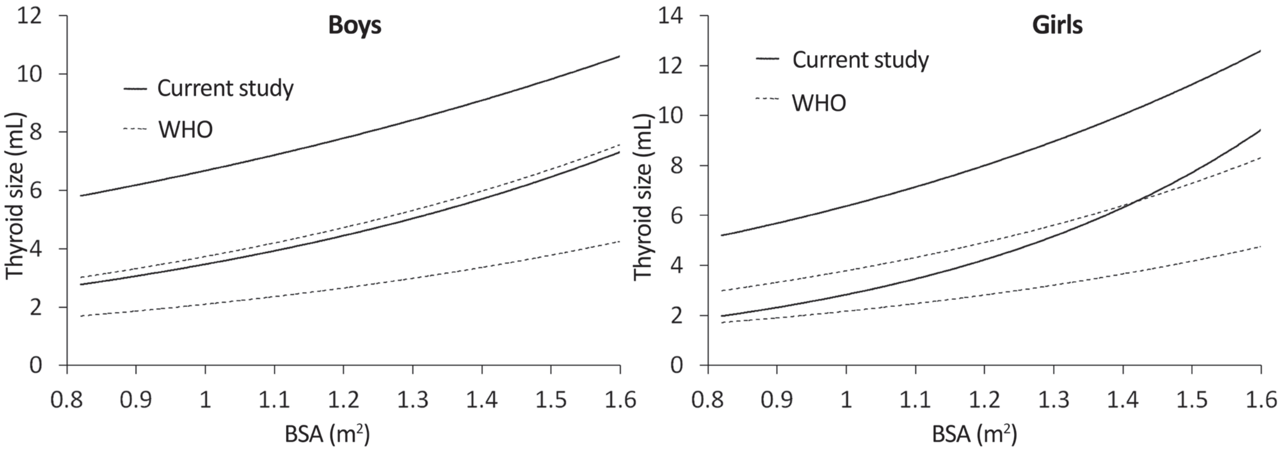

***Figure 4.** 97th percentile (P97) and 50th percentile (P50) values for thyroid volume in both sexes as a function of body surface area in comparison with the same values referenced by the WHO (R-squared of boys: P97 = 0.509 and P50 = 0.8714, and of girls: P97 = 0.9811 and P50 = 0.9245).*

Table 2. Frequency of consumption of foods over the previous 3 months.

FOOD ITEMS	DAILY (%)	WEEKLY (%)	MONTHLY (%)	RARELY (%)
Milk	37	53	<1	10
Dairy Products	35	58	<1	6
Red meat	2	85	3	11
Chicken	3	87	2	9
Seafood	0	1	4	95
Eggs	29	58	0	13

kg of salt. Nearly 61% of children, who were using the salt labeled as iodized, had iodine deficiency (UIC level of <100 µg/l), whereas they were 72% in those not using iodized salt. Median UIC levels of the children consuming and not consuming iodized salt were 77.9 and 73.8 µg/l, respectively ($p = 0.35$). The iodine contents varied notably in both the iodized and not iodized salts. The iodized samples had an iodine content of 12.67 ± 17.32 mg/kg (range = 1.06–53.34 mg/kg), whereas in uniodized, it was 9.24 ± 9.20 mg/kg (range = 0–25.6 mg/kg). The mean iodine content of all the salt samples was 8.13 ± 12.65 mg/kg with 7.28 ± 11.62 mg/kg in children having iodine deficiency and 9.51 ± 14.13 mg/kg in those with adequate UIC levels. The trend lines of correlations showed that UIC increased while thyroid size decreased with an increase in the amount of iodine in salt consumed (Figure 5).

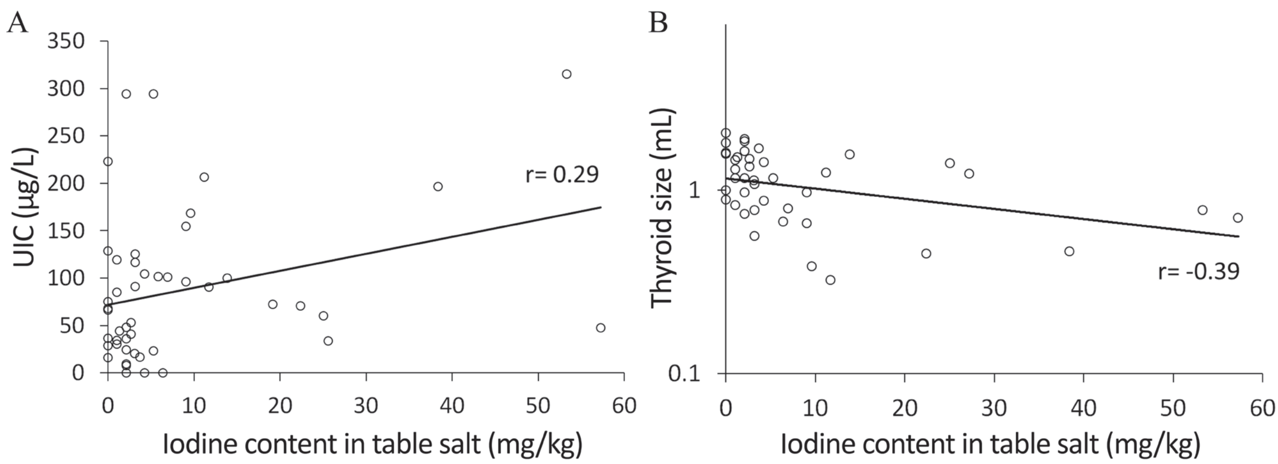

Figure 5. *Correlations of the iodine content of salt consumed with UIC levels and thyroid size (n = 51).*

Discussion

The elimination of IDD is achievable and cost-effective. There has been significant success in a worldwide campaign in the improvement of the nutritional iodine status of schoolchildren [12]. In the initial WHO reports of 1993 (based on total goiter rate) and 2004, Pakistan was among the countries with severe IDD [7,19]. The status improved to a mild deficiency in 2007 [20] and an optimal level in 2011 [13]. The National Nutrition Survey showed that the iodine-sufficient population of schoolchildren increased from 36.3% of the previous survey in 2001 to 63.3% in the present [13]. There was a remarkable overall reduction of severe iodine-deficient children (UIC < 20 µg/l) from 23.4% to 2.2%. The median UIC levels of schoolchildren from all regions also improved from 78 µg/L (mean ± SD = 88.7 ± 82.2 µg/l) to 124.2 µg/l with the change in the national status of mild iodine deficiency to optimal iodine nutrition.

Islamabad is among the five districts of Pothwar Plateau that is at the edge of iodine-deficient belt of the Himalayan Mountains. The iodine salts of soil are highly soluble in water wash away from hills to the low lying areas during the rainy seasons leaving the soil deficient in iodine. The source of water supply in this area is either from small dams or underground water. The market supply of most of the vegetables and crops grown in this area is anticipated to contain lesser iodine than normal values [11]. All these factors contribute to iodine deficiency in this region. The National Nutrition Surveys are not performed separately for Pothwar Plateau; rather, this region is integrated with adjacent planes in the province of Punjab showing improvement in the iodine status. The Islamabad and adjacent confined population of this study showed a lower percentage of children having nutritionally adequate iodine levels (34.1%) than the planes of Punjab. The northern areas of Azad Jammu Kashmir (AJK) and Gilgit (Figure 1) had a similar percentage of iodine-sufficient children (34.6% and 30.1%, respectively). Moreover, severe, moderate, and mild deficiencies in our population (Table 1) were also consistent to the areas of AJK (6.5%, 30.5%, and 28.5%, respectively) and Gilgit (18.2%, 20.3%, and 31.3%, respectively) in the survey of 2011. Similarly, the median UIC level of our population (i.e., 70.5 µg/l) also matched with AJK (63.9 µg/l) and Gilgit (68.2 µg/l) rather than Punjab (115.9 µg/l).

There is a dearth of published data regarding the thyroid volumes in Pakistani schoolchildren. In this study, lower urinary iodine levels were also reflected as high thyroid volumes than the standard values. P97 values of thyroid volumes on an average were 43% higher in boys and 32% in girls compared to those referenced by the WHO [9]. The values of P97 showed a higher trend of thyroid volumes than the values of the WHO in older male children than youngers ($p = 0.002$), whereas, in the case of females, the trend was consistently higher parallel to P97 in all ages ($p < 0.001$). Similarly, thyroid sizes sorted according to BSA, which also showed a significantly higher tendency in both genders ($p < 0.001$).

The iodine-rich food contents were inadequate in meals of the selected population. One cup of milk provides nearly 40%, whereas an egg gives only 16% of the daily requirement of iodine. Only one-third of the population was daily consuming milk, its products, or eggs. Seafood, which may provide 66% of daily iodine requirements, was taken rarely by 95% of children, whereas none of them were taking it daily.

The table salts used also lacked in iodine. The WHO considers 15–40 mg of iodine in each kilogram of household salt to be adequate in iodine content. Only 16% of samples had iodine contents of more than 15 mg/kg of salt despite being labeled as iodized, which was even less than the values of a study conducted in the hilly areas of Swat [21]. Surprisingly, the mean of the iodine contents in the samples of so-called iodized salt was also less than the required standards. This explains the relatively slow progress of achieving optimal iodine status even in the other areas of Pakistan. Moreover, this may also be the reason that iodine-sufficient areas of the country are only borderline sufficient with no margin for thyroidal stress such as pregnancy, lactation, and neonatal and pubertal growth [22]. Due to these low levels of iodine in salts, there was no significant difference between the UIC levels of those children taking supplemented or unsupplemented salt ($p = 0.35$).

Conclusion

The urinary iodine concentration and the thyroid sizes in schoolchildren of the capital territory of Pakistan and adjacent regions are consistent with iodine deficiency when compared to the WHO recommended values. The iodine content in most of the marketed table salt brands sold in the region is also less than the standard values.

Suggestions and Recommendations

The data of this region should be documented and interpreted with the iodine-deficient belt of the Himalayan Mountains rather than the plains of Punjab. It is further recommended that a strict policy is essentially required to ensure that all edible salt marketed in the region should be verified for its recommended iodine content. Efforts should also be made to raise public awareness, informing them about the benefits of consuming iodized salt and general intake of balanced diet containing a required amount of iodine.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent for publication

The parents/guardians of the children included in the study signed the consent forms before any procedure was initiated. It was conducted after considering the minimal physical risk and psychological harm and ensuring the respect of the volunteers in the study.

Ethical approval

Ethical approval was granted by the PIEAS Ethics Committee, PIEAS, Islamabad (dated: Dec 19, 2007).

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