



Excessive Iodine Status among School-Age Children in Korea: A First Report

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Background: Korea is considered an iodine sufficient country, and several studies have been conducted regarding iodine status in healthy Korean adults, pregnant women, and preschool children. However, data on iodine status in Korean school-age children are lacking. Therefore, the iodine nutrition status of Korean school-age children was investigated by measuring urine iodine concentration (UIC).

Methods: This cross-sectional study conducted between April and September 2016 comprised 373 school-age children. UIC was determined using a modified microplate method employing ammonium persulfate digestion followed by Sandell-Kolthoff reaction.

Results: The median UIC was 458.2 µg/L. Excessive iodine intake (>300 µg/L) was found in 286 children (76.7%), with extremely high values exceeding 1,000 µg/L in 19.6% of subjects. Insufficient iodine intake (<100 µg/L) was observed in eight children (2.1%). UIC values were not significantly different between sexes.

Conclusion: Korean school-age children showed excessive iodine intake. Therefore, education regarding adequate iodine intake in school-age children is needed.

Keywords: Urine; Iodine; Schools; Korea

INTRODUCTION

Iodine is an essential element needed for the synthesis of thyroid hormones [1]. Both iodine deficiency and excess may lead to thyroid dysfunction or disease [2]. More than 90% of dietary iodine is eventually excreted in the urine, therefore, median urine iodine concentration (UIC) is a good marker of recent di-

etary iodine intake [3]. World Health Organization (WHO) recommends administering iodine status surveys to school children 6 to 12 years of age due to their vulnerability and easy access [4]. In Korea, several studies have examined iodine status in healthy preschool children, adults, and pregnant women [5-7]. However, data regarding iodine status of school-age children in Korea are lacking. Therefore, in the present study, the iodine

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nutrition status of Korean school-age children was investigated by measuring UIC.

METHODS

Subjects

The present study included 373 school-age children 7 to 12 years of age from three elementary schools in Busan, the southern coastal region of South Korea. The number of students in the three schools was 290 (A school), 69 (B school), and 24 (C school). Data were collected from April to September 2016. A total of 373 subjects (182 males, 48.8%; 191 females, 51.2%) provided samples for urinary iodine analysis. Height (in cm) and weight (in kg) were measured for all participants. The urine samples were divided into two groups. Groups I and II comprised samples from subjects 7 to 9 and 10 to 12 years of age, respectively.

The study protocol was approved by the Institutional Review Board of Kosin University Gospel Hospital (IRB No: 2014-10-133). Informed written consent was obtained from the children's parents.

Measurement of urinary iodine concentration

A teacher at each school collected midstream voided urine samples (approximately 20 mL) 2 hours after a meal. After breakfast at home, urine samples were collected at school. The collected samples were stored at 4°C until transferred to the laboratory. UIC was determined using a modified microplate method employing ammonium persulfate digestion followed by the Sandell-Kolthoff reaction [8,9], a common method used by participants of Ensuring the Quality of Iodine Procedures (EQUIP) of the US Centers for Disease Control and Prevention (CDC) [10]. Briefly, all urine samples and standards (0, 20, 40, 80, 120, 200, and 300 µg/L KIO₃) were allowed to reach ambient temperature; then, 250 µL of each sample and standard were mixed with 1 mL of ammonium persulfate solution. The mixtures were incubated on a heating block for 60 minutes at 95°C and cooled to room temperature. After transferring 50 µL of each mixture to a 96-well plate in duplicate, 100 µL of arsenious acid solution and 50 µL ceric ammonium sulfate solution were added sequentially and incubated for 30 seconds and 30 minutes, respectively. After reading the absorbance at 405 nm, UIC was determined using standard curves constructed for each plate. We evaluated the iodine status according to WHO's epidemiological criteria based on the median UIC of school-age children (Table 1) [4].

Table 1. World Health Organization Epidemiological Criteria for Assessing Iodine Nutrition Based on Median UIC

Median UIC, µg/L	Iodine intake	Iodine nutritional status for school-age children (≥6 years)
<20	Insufficient	Severe iodine deficiency
20–49	Insufficient	Moderate iodine deficiency
50–99	Insufficient	Mild iodine deficiency
100–199	Adequate	Optimal
200–299	Above requirements	May pose a slight risk of more than adequate iodine intake
≥300	Excessive	Risk of adverse health consequences (iodine-induced hyperthyroidism, autoimmune thyroid disease)

UIC, urinary iodine concentration.

Statistical analysis

Values are expressed as the mean ± standard deviation (SD). Because the UIC levels did not show a normal distribution, data were analyzed using the Mann-Whitney and Kruskal-Wallis tests with the SPSS version 23.0 (IBM Co., Armonk, NY, USA). $P < 0.05$ were considered statistically significant.

RESULTS

The median UIC was 458.2 µg/L (Table 2). The median UICs for males and females were 454.4 and 465.7 µg/L, respectively. There were no significant differences in UIC between the sexes ($P = 0.423$) (Table 3). Excessive iodine intake (> 300 µg/L) was found in 286 children (76.7%), and extremely high values exceeding 1,000 µg/L were found in 73 children (19.6%). Insufficient iodine intake (< 100 µg/L) was observed in eight children (2.1%) (Fig. 1).

DISCUSSION

In the present study, the median UIC in school-age children in Busan, Korea, was 458.2 µg/L. Based on the WHO's epidemiological criteria, the results showed excessive iodine nutrition status of school-age children in Korea. The current global UIC data represent 97.7% of the world population of school-age children [11]. The median UIC of school-age children has been used as the proxy biological indicator of iodine nutrition status in the general population [4]. When data for this age group were not available, data of the next closest age group were used in the following order of priority: data from the children closest to school age, adults, the general population, preschool-age chil-

Table 2. Height, Weight, and Median and Mean UIC According to Age

Age, yr	Height, cm	Weight, kg	UIC, $\mu\text{g/L}$		
			Mean \pm SD	Median	Range
7 (n=3)	118.8 \pm 6.9	23.4 \pm 4.9	907.6 \pm 567.6	699.2	473.6–1,549.9
8 (n=101)	127.1 \pm 5.5	27.8 \pm 6.1	635.1 \pm 785.7	426.4	58.9–5,236.4
9 (n=88)	132.7 \pm 6.3	32.8 \pm 7.6	843.6 \pm 904.7	465.8	94.5–4,705.9
10 (n=4)	137.7 \pm 9.7	28.8 \pm 5.6	258.5 \pm 176.0	200.4	128.5–504.5
11 (n=94)	144.9 \pm 7.3	40.0 \pm 9.7	723.9 \pm 719.6	471.9	39.2–4,589.3
12 (n=83)	150.1 \pm 7.4	42.9 \pm 8.6	844.2 \pm 1,028.0	496.2	89.6–6,695.9
Total (n=373)	138.1 \pm 11.4	35.4 \pm 10.0	751.3 \pm 855.8	458.2	39.2–6,695.9

Values are expressed as mean \pm SD.

UIC, urine iodine concentration; SD, standard deviation.

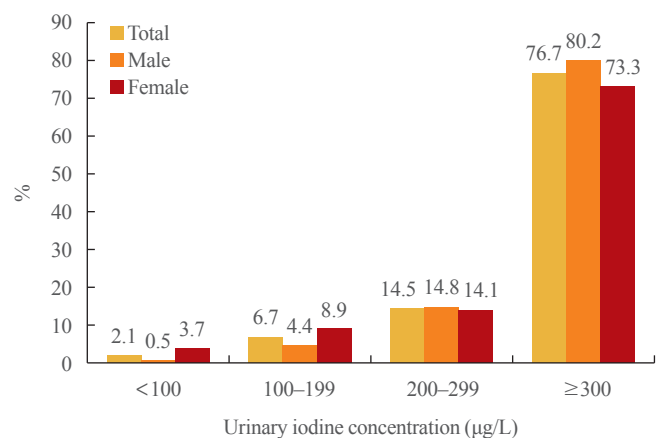
Table 3. Gender Differences in Height, Weight, and UIC According to Age Group

Variable	Male	Female	P value
Total			0.423
Number	182 (48.8)	191 (51.2)	
Height, cm	137.4 \pm 11.0	138.8 \pm 11.8	
Weight, kg	36.2 \pm 10.9	34.7 \pm 9.1	
UIC, $\mu\text{g/L}$	770.7 \pm 926.5	732.9 \pm 784.6	
MUI, $\mu\text{g/L}$	454.4	465.7	
Group I (7–9 years)			0.985
Number	105 (54.7)	87 (45.3)	
Height, cm	130.3 \pm 6.1	128.6 \pm 7.2	
Weight, kg	31.2 \pm 7.3	28.6 \pm 7.1	
UIC, $\mu\text{g/L}$	735.9 \pm 864.7	733.7 \pm 820.8	
MUI, $\mu\text{g/L}$	458.2	439.7	
Group II (10–12 years)			0.672
Number	77 (42.5)	104 (57.5)	
Height, cm	147.1 \pm 8.5	147.2 \pm 7.5	
Weight, kg	42.9 \pm 11.5	39.8 \pm 7.3	
UIC, $\mu\text{g/L}$	818.1 \pm 1,008.4	732.3 \pm 756.9	
MUI, $\mu\text{g/L}$	439.1	500.1	

Values are expressed as number (%) or mean \pm SD.

UIC, urine iodine concentration; MUI, median urinary iodine.

dren, and other population groups [4]. Several studies of iodine status in Korea have revealed that the iodine nutritional state of Koreans is more than adequate [12]. In a study of 611 healthy Korean preschool children (2 to 7 years of age), the median UIC was 438.8 $\mu\text{g/L}$ [5]. Another study including 540 healthy adults living in an urban area in Korea found that the median UIC was 268 $\mu\text{g/L}$ [6]. Recently, Cho et al. [7] reported excessive iodine

**Fig. 1.** Distribution of urine iodine concentration in school-aged children from Busan, Korea.

status in 344 Korean healthy pregnant women, reporting a median UIC of 427.3 $\mu\text{g/L}$ and creatinine (Cr)-corrected concentration of 447.9 $\mu\text{g/gCr}$.

In 2013, 111 countries had adequate iodine nutrition, 30 countries remained iodine deficient, nine that were moderately deficient and 21 that were mildly deficient, and none were considered severely iodine deficient. Only 10 countries showed excessive iodine intake [11]. The results from the present study showed that 76.7% of school-age children had values above $>300 \mu\text{g/L}$, 35.4% had values $>600 \mu\text{g/L}$, and 19.6% had extremely high values exceeding 1,000 $\mu\text{g/L}$. According to Lee et al. [5], 66.4% of Korean preschool children had UIC values $>300 \mu\text{g/L}$, and 20.9% had values exceeding 1,000 $\mu\text{g/L}$. In Japan, the median UIC is 281.6 $\mu\text{g/L}$, and values exceeding 1,000 $\mu\text{g/L}$ were found in 16% of school-age children [4]. Another study reported that the median UIC in children living in coastal Hokkaido was as high as 728 $\mu\text{g/L}$ [13]. People in Japan and

Korea generally have much higher iodine intake due to their consumption of substantial amounts of seaweed [6,14]. Although most individuals tolerate high dietary intakes of iodine, excessive iodine intake can alter thyroid function. Furthermore, many studies have shown that prolonged intake of excessive iodine can be harmful [14-16]. Excessive iodine intake in children in high iodine areas is associated with impaired thyroid function and autoimmune thyroid disease [17,18]. Li et al. [19] reported that thyroid hypofunction and endemic goiter can develop in children with UIC >800 µg/L. However, Sang et al. [17] observed no difference in the prevalence of subclinical hypothyroidism in children with UIC >800 µg/L compared with those having UIC <800 µg/L based on univariate analysis. They also observed that UIC >600 µg/L and positive anti-thyroperoxidase antibody or anti-thyroglobulin antibody in children were risk factors for subclinical hypothyroidism.

In the present study, most school-age children were iodine sufficient; however, 2.1% of the subjects showed UIC <100 µg/L, indicating iodine deficiency. A similar tendency was observed in a previous study involving Korean preschool children. Lee et al. [5] reported that 3.9% of the subjects showed UIC <100 µg/L. It is unclear why iodine levels in those children were insufficient.

Konig et al. [20] suggested median thresholds for median urinary iodine sufficiency from spot samples identified for study populations, but these should not be applied to individuals because of significant day-to-day variation in salt intake, the main source of dietary iodine in many countries. However, regular screening of UIC might be helpful in preventing iodine deficiency status.

A limitation of this study is that UIC just reflect the immediate intake of food. It could not represent the casual dietary intake. Because the contents of breakfast at home are different, the students' urinary iodine can be very different. Nevertheless, it is meaningful to report that most students are in iodine sufficiency status.

In conclusion, this is the first report of iodine status in school-age children in Korea. The median UIC was 458.2 µg/L, an iodine excess status according to WHO criteria. Although WHO made a guideline for optimal dietary intake of iodine, it is not clear whether UIC over 300 µg/L impacts on thyroid health especially in school ages, since we did not observe any endemics of thyroid disease in Korea or Japan. Therefore further studies are needed to validate this relationship between dietary iodine excess and thyroid disease in different age groups.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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