ISSN 1669-9106 MEDICINA (Buenos Aires) 2025: 00: 00-00

Original article

ASSESSMENT OF IODINE INTAKE IN RURAL SCHOOLCHILDREN FROM LA PAMPA, ARGENTINA: A COMPARATIVE ANALYSIS BETWEEN 2002 AND 2023

JORGE L. OLIVARES[1], MARÍA DEL CARMEN SILVA CROOME[2], MARÍA JULIA GUTIERREZ[3], FANY ARRESE[1], MARINA VILLARREAL[1], LUIS A. RAMÍREZ STIEBEN[4]

[1]Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, La Pampa, [2]Servicio de Endocrinología, Hospital General de Agudos José María Ramos Mejía, Buenos Aires, [3]Laboratorio de Endocrinología, Hospital General de Agudos Dr. Carlos G. Durand, Buenos Aires, [4]Laboratorio de Biología Ósea, Facultad de Ciencias Médicas, Universidad Nacional de Rosario, Rosario, Santa Fe, Argentina

Postal address Jorge L. Olivares, Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa, Av. Uruguay 151, 6300 Santa Rosa, La Pampa, Argentina
E-mail: jorgeluis57.olivares@gmail.com
Received: 13-XI-2024
Accepted: 26-XI-2024

Abstract

Introduction: Iodine is an essential micronutrient for the synthesis of thyroid hormones, crucial for neurological development. In 2002, a mild iodine deficiency was identified in schoolchildren from La Pampa, Argentina. This study aims to reassess iodine intake in the same rural school population in 2023 by analyzing urinary iodine concentration (UIC), goiter prevalence, and salt iodization.

Materials and methods: A cross-sectional study was conducted in 6- to 12-year-old schoolchildren from School No. 45 in Ataliva Roca, La Pampa. Parents provided informed consent. UIC, weight, height, blood pressure, and goiter were assessed. UIC was measured using the modified Sandell-Kolthoff method, and salt iodization was analyzed using sodium thiosulfate titration. The results were compared with those from 2002.

Results: A total of 74 schoolchildren were evaluated in 2023. The median UIC was 145.45 µg/L, with 28.8% of students showing levels below 50 µg/L. Goiter prevalence was 21.6%, compared to 17.9% in 2002. In 85.5% of the salt samples, iodine levels were adequate. There were no statistically significant differences between the 2002 and 2023 cohorts in the prevalence of goiter or iodine fortification of salt.

Discussion: Despite improvements in iodine intake since 2002, a considerable percentage of schoolchildren still show moderate iodine deficiency.

Key words: goiter, iodine, iodine deficiency, nutrients, salt

Resumen

Evaluación de la ingesta de yodo en escolares rurales de La Pampa, Argentina: análisis comparativo entre 2002 y 2023

Introducción: El yodo es un micronutriente esencial para la síntesis de hormonas tiroideas, vitales para el desarrollo neurológico. En 2002, se identificó una deficiencia leve de yodo en escolares de La Pampa, Argentina. Este estudio tiene como objetivo reevaluar el estado de la ingesta de yodo en la misma población escolar rural en 2023, analizando la concentración urinaria de yodo (CUY), la prevalencia de bocio y la fortificación de la sal.

Materiales y métodos: Se realizó un estudio transversal en escolares de 6 a 12 años de la Escuela N°45 de Ataliva Roca, La Pampa. Los padres otorgaron consentimiento informado. Se evaluaron CUY, peso, talla, presión arterial y bocio. La CUY se determinó mediante el método de Sandell-Kolthoff y la fortificación de la sal se midió con titulación de tiosulfato de sodio. Los resultados se compararon con los obtenidos en 2002.

Resultados: Se evaluaron 74 escolares en 2023. La mediana de CUY fue de 145.45 µg/l, con un 28.8% de los estudiantes mostrando niveles inferiores a 50 µg/L. La prevalencia de bocio fue de 21.6%, comparada con el 17.9% en 2002. El 85.5% de las muestras de sal presentaron niveles adecuados de yodo. No hubo diferencias estadísticamente significativas entre las cohortes de 2002 y 2023 en la prevalencia de bocio o la fortificación de yodo en la sal.

Discusión: A pesar de mejoras en la ingesta de yodo desde 2002, un porcentaje considerable de escolares aún presenta deficiencia moderada de yodo.

Palabras clave: bocio, yodo, deficiencia de yodo, nutrientes, sal

KEY POINTS
Current knowledge

- Iodine is essential for thyroid hormone synthesis, and its deficiency can lead to goiter and other disorders. Despite the implementation of salt fortification programs in many regions, areas with insufficient iodine intake persist, particularly in rural communities.

Contribution of the article to current knowledge

- This study, conducted in a rural school population in La Pampa, Argentina, shows that despite improvements in iodine intake since 2002, a considerable proportion of schoolchildren continue to exhibit iodine deficiency. The findings suggest that obesity and the use of non-iodized salt in some processed foods may be contributing to the increased prevalence of goiter.

Iodine is an essential trace element that plays crucial roles both in thyroid and extrathyroidal functions. Among its extrathyroidal functions, its antioxidants, antiproliferative, and proapoptotic effects stand out, suggesting that preventing iodine deficiency could have protective effects against cardiovascular diseases and certain types of cancer[1]. However, its primary role lies in the synthesis of thyroid hormones, which are essential for neurological development, particularly during pregnancy, lactation, and early childhood[2].

The World Health Organization (WHO) identifies the key impact indicators for assessing iodine deficiency as urinary iodine concentration (UIC), thyroid size, thyroid-stimulating hormone (TSH), and thyroglobulin[2]. UIC is the most reliable indicator for reflecting current iodine intake, especially after the implementation of salt iodization programs, while thyroid size, evaluated by ultrasound, is more useful in the initial assessment of iodine deficiency disorders (IDD) severity and for long-term monitoring. Neonatal TSH is particularly sensitive to iodine deficiency, and recent data show that the prevalence of neonatal hyperthyrotropinemia in La Pampa during 2021 and 2022 reached 9.6%, exceeding the 3% threshold established by WHO, indicating a possible mild iodine deficiency in the Pampean population[3]. Although mass neonatal TSH screening is costly, it remains relevant in monitoring contexts.

In Argentina, salt iodization was mandated by National Law 17.259 in 1967 to ensure adequate iodine intake in the population[4]. WHO recommends that iodine content in salt be between 20 and 40 parts per million (ppm) and that at least 90% of table salt meet these standards[2]. However, it is crucial to monitor not only iodine content in salt but also its consumption, as excessive intake can have adverse effects. In 2002, in the town of Ataliva Roca, the median urinary iodine concentration was slightly below the recommended cutoff of 100 µg/L, suggesting marginal iodine intake in a significant portion of the population[5].

The aim of this study was to evaluate the iodine nutritional status and urinary iodine concentration in schoolchildren aged 6 to 12, analyze the fortification of table salt, determine the prevalence of goiter, and compare these indicators with those obtained in 2002 in the town of Ataliva Roca.

Materials and methods

A cross-sectional, observational, descriptive, and analytical study was conducted in 2023, including all students enrolled at School No. 45 in Ataliva Roca, in the province of La Pampa. The results obtained from 74 students in 2023 were compared with those of 67 students from the same school and evaluated locality in 2002[5].

Weight and height were measured, and body mass index (BMI, weight/height^2) was calculated. Blood pressure (BP) was measured while seated, distinguishing between systolic blood pressure (SBP) and diastolic blood pressure (DBP). Percentiles for weight, height, and BP were determined according to the guidelines of the Argentine Society of Pediatrics (2013).

For urine sample collection, students were provided with a set of materials and could collect the sample at any time of day without fasting. Parents received information on the importance of the sample and instructions for proper identification. Urinary iodine concentration (UIC) was determined using the modified Sandell-Kolthoff method[6]. Iodine intake was classified based on UIC as follows: insufficient (median <100 µg/L and/or more than 20% with UIC <50 µg/L), adequate (100-199 µg/L), more than adequate (200-299 µg/L), and excessive (≥300 µg/L)[2].

Thyroid gland size was assessed by manual palpation and classified as normal (grade 0) or enlarged (goiter grade 1 or 2), according to WHO criteria[2]. Evaluations were performed by a single operator. In cases where there were doubts about the classification of thyroid enlargement, a second evaluator performed another palpation without knowledge of the first observer's results. The two evaluators then compared the results and reached a consensus.

To analyze the iodine fortification level in household salt, a second set of materials was provided with instructions to collect at least 30 g of salt. Iodine content in salt was measured through titration with sodium thiosulfate, employing a duplicate technique with an intra-assay coefficient of variation (CV) between 0.75 and 1.25 parts per 30 000. Adequate iodine levels were defined as those within the range of 25 to 41.7 ppm[2].

Statistical analysis

Statistical analysis was performed using R version 4.2.3. Quantitative variables were expressed as mean±SD or median and interquartile range and were evaluated using parametric or non-parametric tests, depending on normality and homoscedasticity of variances. Qualitative variables were expressed as numbers and percentages (%) and analyzed using the χ^2 test or Fisher›s exact test, depending on expected frequencies. Spearman correlation tests were performed. A multivariate linear regression model was used to determine variables associated with UIC. A Receiver Operating Characteristic (ROC) analysis was conducted to determine a specific age threshold that optimizes the detection of insufficient iodine intake (<100 µg/L). A p-value of <0.05 was considered statistically significant.

All parents or legal guardians of the students signed an informed consent. The study was approved by the Research Ethics Committee of Hospital Dr. Lucio Molas, Santa Rosa, La Pampa.

Results

A total of 74 children were evaluated, representing 93.6% of the total school enrollment of 79 students, with a predominance of boys (n=40, 54.1%). The mean age of the participants was 9.18±1.76 years. Of the schoolchildren, 31.1% were overweight (BMI percentile ≥85), and 39.2% were obese (BMI percentile ≥97). Table 1 shows the anthropometric and clinical characteristics, differentiated by sex.

The median UIC in schoolchildren was 145.45 µg/L (interquartile range: 47.73-249.84). In boys, the UIC was 139.7 µg/L (29.1-256.9), while in girls it was 149.3 µg/L (61.5-209.5) (Mann-Whitney test, p=ns). The distribution of UIC categories in schoolchildren based on WHO guidelines is shown in Figure 1.

Table 2 shows the UIC categories in relation to BMI percentiles.

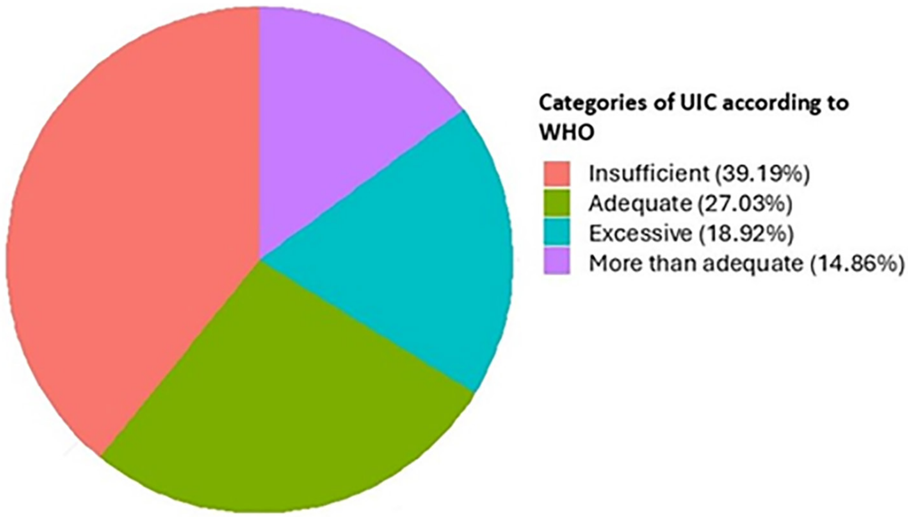
UIC correlated negatively with age (rho=-0.272, p=0.02), height (rho=-0.279, p=0.01), and body weight (rho=-0.219, p=0.06). In the multivariable linear regression model, UIC showed a significant association with age (intercept 344.57, coefficient: -20.10; p=0.015). Using ROC analysis, the Youden index obtained for age was 8.5 years for detecting insufficient iodine intake (Fig. 2).

Table 1 | Anthropometric, clinical, and Iodine parameters in evaluated schoolchildren

	Male (n = 40)	Female (n = 34)	p-value
Age (years)	8.95 ± 1.79	9.47 ± 1.70	0.19
Body weight (kg)	39.53 ± 12.30	38.24 ± 11.20	0.64
BMI (kg/m²)	20.65 ± 4.51	20.19 ± 3.48	0.61
SBP (mmHg)	118.2 ± 11.7	115.5 ± 11.1	0.32
DBP (mmHg)	75.5 ± 9.25	74.7 ± 7.37	0.68
Goiter (%)	12 (30)	4 (11.8)	0.06

BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; UIC: urinary Iodine concentration

Figure 1 | Distribution of urinary iodine concentration categories in schoolchildren according to WHO guidelines



UIC: urinary iodine concentration; WHO: World Health Organization

Table 2 | Relationship between urinary Iodine concentration and body mass index percentiles in schoolchildren

UIC (μg/L)	BMI percentile <10 (%)	BMI percentile ≥10-<85 (%)	BMI percentile ≥85 (%)	Total (%)
<100	0 (0)	6 (35.3)	23 (42.6)	29 (39.18)
100-299	3 (100)	9 (52.9)	19 (35.2)	31 (41.89)
≥300	0 (0)	2 (11.8)	12 (22.22)	14 (18.91)

UIC: urinary Iodine concentration; BMI: body mass index
Fisher's exact test (p = 0.26)

Goiter grade 1 was observed in 21.6% of the schoolchildren, and within this group, a small number of children exhibited increased consistency and irregularity between the two thyroid lobes. Table 3 presents the presence of goiter according to UIC categories.

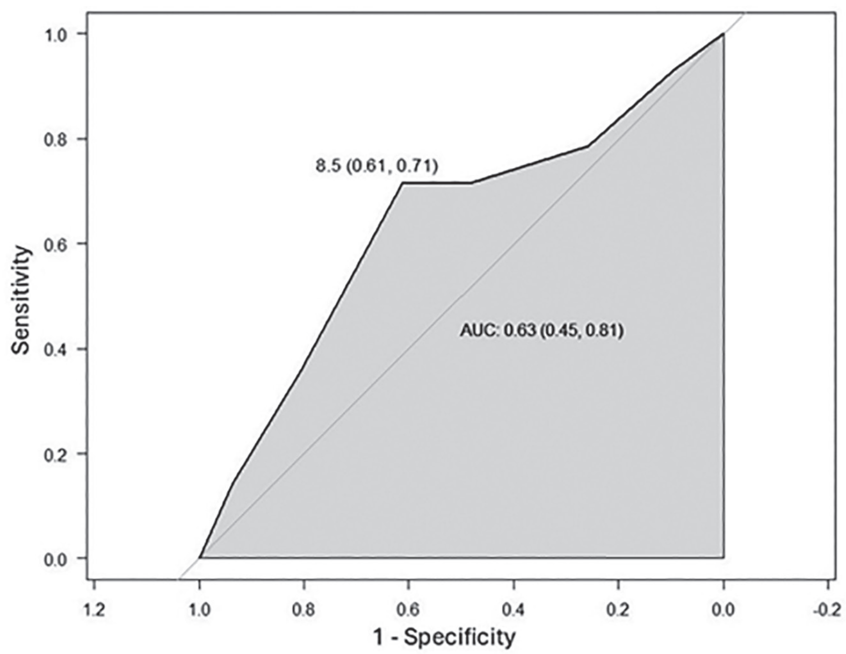
With respect to iodine fortification in household salt, 97.3% (n=72) of the schoolchildren provided salt samples for analysis. Three of these samples were insufficient for evaluation, and despite repeated requests, no further samples were obtained. Therefore, the total number of samples analyzed was 69 (93.3%). Of the samples examined, 85.5% had an adequate iodine level, ranging from 21.99 to 60.91 parts per million (ppm). Among the 14.5% of salt samples that did not meet national standards, 3 samples (4.3%) had insufficient iodine fortification, 5 (7.2%) contained excess iodine, and 2 (2.9%) were non-iodized industrial salts with less than 5 ppm of iodine.

Table 4 shows the comparison of the three indicators evaluated in the schoolchildren from Ataliva Roca, distinguishing between the cohorts from 2002 and 2023.

Discussion

The WHO (2007) established that the main indicators for assessing iodine intake in a community are neonatal TSH, UIC, goiter prevalence, and the monitoring of iodized salt [2,7]. Two decades ago, in a farming community in La Pampa,

Figure 2 | Receiver Operating Characteristic analysis curve for age as a predictor of insufficient iodine intake



AUC: area under the curve

Table 3 | Relationship between urinary Iodine concentration and the presence of goiter in schoolchildren

	Goiter		
UIC (µg/L)	Yes (%)	No (%)	Total (%)
<100	4 (25)	25 (43.1)	29 (39.19)
100-299	7 (43.8)	24 (41.4)	31 (41.89)
≥300	5 (31.2)	9 (15.5)	14 (18.92)

UIC: urinary Iodine concentration
Fisher's exact test (p = 0.2)

Table 4 | Comparison of Iodine deficiency indicators in schoolchildren from Ataliva Roca: 2002 vs. 2023

Variable Median UIC (µg/L)	2002 Cohort (n=67) 95 µg/L	2023 Cohort (n=74) 145.45 µg/L	p-value -
Goiter (%)	12 (17.9)	16 (21.6)	0.5
Iodine fortification with <25 ppm	7 (12.5)*	10 (14.6)**	0.7

UIC: urinary Iodine concentration; ppm: parts per million
χ^2 test. *Number of schoolchildren analyzed in the 2002 cohort for this variable: 56.
**Number of schoolchildren analyzed in the 2023 cohort for this variable: 69

mild iodine deficiency was detected in schoolchildren[5]. This study, conducted 20 years later, aims to reassess iodine intake in the same rural school population by using UIC, goiter prevalence, and the iodization of table salt to determine the status of iodine deficiency.

Two primary methods are used to assess iodine nutrition: goiter prevalence and UIC[2]. Since more than 90% of ingested iodine is excreted in the urine, UIC is a reliable indicator of recent iodine intake (days or weeks), while changes in goiter prevalence reflect long-term iodine nutrition (months or years)[8]. In children and non-pregnant women, a median UIC between 100 µg/L and 299 µg/L defines a population without iodine deficiency. Additionally, no more than 20% of samples should be below 50 µg/L. Recent data suggest that the WHO median UIC categories for "adequate" and "more than adequate" iodine intake recommended in children can be combined into a single category (100–299 µg/L) to indicate adequate iodine nutrition[9]. For statistical analysis, due to the limited cohort size, we used this classification. Our results suggest that in 2023, iodine intake among schoolchildren in the studied community is generally adequate, with a median UIC of 145.45 µg/L, above the 100 µg/L threshold set by WHO. However, 28.77% of the schoolchildren had UIC below 50 µg/L, indicating insufficient iodine intake in a significant portion of the population. This percentage is considerably higher than reported in other studies, such as in Salta (10,6%)[10] and Colombia (2.2%)[11], highlighting the persistence of iodine deficiency in this rural community. Furthermore, these findings require special attention, as prolonged iodine deficiency can negatively affect children's cognitive and physical development.

In our cohort, 21.6% of the schoolchildren had grade 1 goiter, representing an increase compared to 17.9% reported in 2002[5], although this increase was not statistically significant. However, this finding is consistent with the prevalence of neonatal hyperthyrotropinemia, which is compatible with mild iodine deficiency in the same region[3].

Although, like McDonell[12], we did not find a significant relationship between low iodine intake and goiter prevalence, other studies with larger sample sizes have reported a significant association in cases with UIC below 50 µg/L. It is also noteworthy that, as reported by other authors[13], a significant proportion of schoolchildren with a UIC above 100 µg/L also had goiter, suggesting that other factors, such as overweight and obesity, may contribute to its prevalence, as observed in other studies[14]. The lack of correlation between iodine intake and goiter could be explained by the fact that UIC is an indicator of recent iodine intake, while goiter reflects a more prolonged deficiency[2,15]. In our study, 39.2% of the schoolchildren were obese, and several studies have demonstrated that excess weight is associated with a higher risk of developing goiter. Additionally, Zimmermann and Andersson[8] noted that although median UIC is a good population-level indicator of iodine intake, it may be misinterpreted at the individual level, and it is common to erroneously assume that all individuals with a UIC below 100 µg/L are iodine deficient[14]. Daily iodine intake can vary by 30% to 40%[8,16], suggesting that using a single urine sample may have overestimated the percentage of schoolchildren with a UIC below 100 µg/L in our study[16-19].

Another interesting finding is the negative correlation between UIC and age, indicating that older children may have lower iodine intake, a finding consistent with other studies such as that by Galindo et al.[11], which suggests that supplementation guidelines may not adequately cover the needs of this population. Moreover, ROC analysis showed that an age of 8.5 years is an optimal cutoff for identifying children at higher risk of iodine deficiency, highlighting the need for more personalized approaches to iodine supplementation.

In terms of salt iodization, 85.5% of the samples analyzed had adequate iodine levels. However, there was a significant discrepancy, as the high percentage of schoolchildren with UIC below expected levels could be related to the consumption of products that do not contain iodized salt, such as bread and processed meats, as evidenced in our study. Despite adequate salt iodization, 14.5% of the samples did not meet standards, which may contribute to the persistence of iodine deficiency in some children. It was also detected that the bread consumed in the community is made with non-iodized industrial salt. However, most of the salts evaluated were industrially produced, and the community has a salt production plant with regular controls, ensuring an iodization level close to 90% recommended by UNICEF/WHO/ICCIDD[2].

The comparison of the indicators evaluated in the cohorts of schoolchildren from Ataliva Roca between 2002 and 2023 reveals significant changes in iodine intake. Although the UIC median increased (95 µg/L in the 2002 cohort versus 145 µg/L in the 2023 cohort), the percentage of the schoolchildren with a UIC below 50 µg/L was high. On the other hand, goiter prevalence showed a slight increase in 2023 (21.6%) compared to 2002 (17.9%), although this difference was not significant. The persistence of goiter in a significant proportion of the population could suggest that long-term iodine deficiency may have left residual effects or that other environmental or nutritional factors are contributing to its prevalence. Finally, regarding the third indicator evaluated, the percentage of adequately iodized salt was like that in 2002 (87.3% versus 85.5%), suggesting that the monitoring program in the province of La Pampa is effective.

The main limitations of this study include the cohort size, which may have reduced the statistical power to detect significant differences. Additionally, UIC was evaluated using a single urine sample, which could have either overestimated or underestimated iodine intake due to daily variability. No ultrasound assessment was included for the diagnosis of goiter, which could have increased the accuracy in detecting thyroid abnormalities. Lastly, although salt samples were analyzed, other dietary sources of iodine, such as processed foods, were not evaluated, which could influence the results obtained.

Our study reveals that, despite improvements in iodine intake since 2002, a significant percentage of schoolchildren still exhibit urinary iodine concentrations below the recommended levels, indicating an ongoing deficiency within this population. Additionally, the high prevalence of goiter suggests potential contributing factors such as being overweight, obesity, or exposure to goitrogens. Although salt fortification is generally sufficient, the use of non-iodized salt in certain processed foods may be exacerbating the issue. These findings underscore the importance of ongoing monitoring and reinforcement of iodine supplementation programs, along with exploring more comprehensive strategies to ensure adequate intake for the entire school-aged population.

Conflict of interest: None to declare

References

1. Winder M, Kosztyła Z, Boral A, Kocełak P, Chudek J. The impact of iodine concentration disorders on health and cancer. *Nutrients* 2022; 14: 2209.
2. World Health Organization/UNICEF/International Council for the Control of Iodine Deficiency Disorders. Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers, 3rd ed. Geneva: WHO, 2007.
3. Olivares JL, Villarreal M, Ramírez Stieben LA, Silva Croome MDC. Prevalence of high neonatal thyroid stimulating hormone levels as an indicator of iodine deficiency in the province of La Pampa: An epidemiological analysis. *Arch Argent Pediatr* 2024; 122: e202310288.
4. Salvaneschi J, García J. El bocio endémico en la República Argentina. Antecedentes, extensión y magnitud de la endemia, antes y después del empleo de la sal enriquecida con yodo: segunda Parte. *RAEM* 2009; 46: 35-57.
5. Melado GE, Castro TE, Beierbach NL, et al. Monitoreo de DDI en la provincia de La Pampa. RAEM 2006; 43:110-5.
6. Pino S, Fang SL, Braverman LE. Ammonium persulfate: a safe alternative oxidizing reagent for measuring urinary iodine. Clin Chem 1996; 42: 239-43.
7. Zimmermann MB, Hess SY, Adou P, Toresanni T, Wegmüller R, Hurrell RF. Thyroid size and goiter prevalence after introduction of iodized salt: a 5-y prospective study in schoolchildren in Côte d'Ivoire. Am J Clin Nutr 2003; 77: 663-7.
8. Zimmermann MB, Andersson M. Assessment of iodine nutrition in populations: past, present, and future. Nutr Rev 2012; 70: 553-70.
9. Zimmermann MB, Aeberli I, Andersson M, et al. Thy-

roglobulin is a sensitive measure of both deficient and excess iodine intakes in children and indicates no adverse effects on thyroid function in the UIC range of 100-299 µg/L: a UNICEF/ICCIDD study group report. *J Clin Endocrinol Metab* 2013; 98): 1271-80.
10. López Linares S, Vilte C, Cappelen L, et al. Evaluar la ingesta de yodo en sal y determinar el estado nutricional del yodo en mujeres de edad fértil del Chaco Salteño – Argentina. *Actualización en Nutrición* 2024; 25: 3-8.
11. Galindo M, Forero AY, Romero J. Características de las concentraciones elevadas de yoduria en escolares y adolescentes de Colombia. *Rev Peru Med Exp Salud Publica* 2021; 38: 24-32.
12. McDonnell CM, Harris M, Zacharin MR. Iodine deficiency and goitre in schoolchildren in Melbourne, 2001. *Med J Aust* 2003; 178: 159-62.
13. Xiu L, Zhong G, Ma X. Urinary iodine concentration (UIC) could be a promising biomarker for predicting goiter among school-age children: a systematic review and meta-analysis. *PLoS One* 2017; 12: e0174095.
14. Zimmermann MB, Hussein I, Al Ghannami S, et al. Estimation of the prevalence of inadequate and excessive iodine intakes in school-age children from the adjusted distribution of urinary iodine concentrations from population surveys. *J Nutr* 2016; 146: 1204-11.
15. Bath SC, Steer CD, Golding J, Emmett P, Rayman MP. Effect of inadequate iodine status in UK pregnant women on cognitive outcomes in their children: results from the Avon Longitudinal Study of Parents and Children (ALSPAC). *Lancet* 2013; 382: 331-7.
16. König F, Andersson M, Hotz K, Aeberli I, Zimmermann MB. Ten repeat collections for urinary iodine from spot samples or 24-hour samples are needed to reliably estimate individual iodine status in women. *J Nutr* 2011; 141: 2049-54.
17. Andersen S, Karmisholt J, Pedersen KM, Laurberg P. Reliability of studies of iodine intake and recommendations for number of samples in groups and in individuals. *Br J Nutr* 2008; 99: 813-8.
18. UNICEF. Guidance on the monitoring of salt iodization programmes and determination of population iodine status. New York, NY: United Nations Children’s Fund, 2018.
19. Leung AM, Braverman LE. Consequences of excess iodine. *Nat Rev Endocrinol* 2014; 10: 136-42.