International Health 2025; **0**: 1–12
https://doi.org/10.1093/inthealth/ihaf076 Advance Access publication 0 2025

ORIGINAL ARTICLE

Cross-sectional study of maternal iodine nutrition and salt iodization in Kyrgyzstan: urban–rural and socioeconomic factors

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Received 25 December 2024; revised 1 May 2025; editorial decision 17 June 2025; accepted 25 June 2025

Background: Iodine deficiency remains a public health concern, especially among vulnerable populations such as pregnant women. Despite global efforts to address iodine deficiency disorders (IDDs) through universal salt iodization programs, gaps in coverage and effectiveness persist in countries like Kyrgyzstan. This study evaluated the iodine status of pregnant women and the effectiveness of Kyrgyzstan's national salt iodization program. We investigated sociodemographic factors associated with iodine deficiency.

Methods: A cross-sectional study was conducted in Kyrgyzstan. Urine and salt samples were collected from a stratified random sample of 388 pregnant women to measure urinary iodine concentration (UIC) and iodine concentration in salt (ICS). Descriptive statistics, t tests and logistic regression were used.

Results: Most salt samples had adequate ICS levels. Median UIC levels were adequate, but a significant share of insufficient UIC levels indicated widespread iodine deficiency. Urban residents showed higher UIC and ICS levels. Higher education and income levels were associated with better iodine status. Ethnic differences in UIC and ICS levels were observed.

Conclusions: Despite Kyrgyzstan's salt iodization program's success, iodine deficiency remains prevalent among pregnant women, particularly in rural and lower-income groups. Targeted public health interventions, monitoring and tailored strategies are essential to improve iodine intake and reduce IDDs in these populations.

Keywords: cross-sectional study, iodine deficiency disorders, salt iodization, sociodemographic factors, urinary iodine concentration.

Introduction

Iodine, a trace element vital for thyroid hormone production, is crucial for metabolism, growth and brain development. Its deficiency can cause a range of disorders, including goiter, hypothyroidism, impaired mental function and developmental anomalies.[1] Iodine deficiency disorders (IDDs) remain a significant global health challenge, particularly in countries like Kyrgyzstan.

Despite global efforts such as salt iodization programs, disparities persist in regions with limited iodized salt access, especially in developing countries. The WHO, UNICEF and the Global Network on Iodine report progress in reducing IDDs, yet some populations remain underserved.[2] Evaluations indicate that while the global burden has declined, disparities remain, including in Kyrgyzstan.[3,4] Legislative measures, such as salt iodization laws, have significantly mitigated deficiencies.

In 2024, 13.8% of Kyrgyzstan's population consumed non-iodized salt, and 6.9% consumed insufficiently iodized salt (<15 μg/g).[5] Jalal-Abad (36.2%), Batken (18.6%) and Naryn (20.6%) regions had the highest rates. Previous studies revealed low median urinary iodine concentrations (UICs): 103 μg/L in pregnant women and 91.6 μg/L in breastfeeding women.[4] Additionally, iodine deficiency diseases affected 15.8% of school-age children,[6] emphasizing the urgency for targeted interventions, particularly given their impact on fetal development. Sociocultural and economic disparities between urban and rural areas exacerbate deficiencies, necessitating comprehensive data for informed public health action.

This study aims to:

1. Evaluate the iodine status of pregnant women in Kyrgyzstan, comparing urban and rural populations.
2. Assess the effectiveness of the national salt iodization program in providing adequate iodine intake.
3. Identify sociodemographic factors associated with iodine deficiency to inform targeted public health interventions.

By addressing these objectives, the study seeks to fill knowledge gaps, inform policy and contribute to the global efforts to eliminate IDDs.

Participants and methods

Study design

A cross-sectional study was conducted to evaluate the iodine status of pregnant women and the quality of the iodized salt they use in Kyrgyzstan. Urine and salt samples were collected and correlated with sociodemographic characteristics.

Study site

Kyrgyzstan, a Central Asian country with seven administrative regions, had a population of 6.936 million in 2022, comprising 65.3% rural residents, 51.4% women and 34.6% aged <15 y. The study was conducted from June 2021 to April 2022 across all regions, including urban areas such as Bishkek and Osh, and rural areas representing diverse socioeconomic characteristics.[7]

Sampling method

A multistage stratified sampling method was employed, stratifying the population into urban and rural areas.

The sample size was calculated using Cochran's formula for cross-sectional studies, adjusted for a finite population size. The calculation was informed by prior data on UICs from pregnant women in Kyrgyzstan, where a median UIC of 103 μg/L (IQR: 68–145) was reported.[4] To achieve a 95% confidence level (Z=1.96) and a 5% margin of error (d=0.05) for estimating the proportion of women with insufficient iodine intake (assumed prevalence *PV*=50% for maximum variability), the initial sample size was estimated as:

$$n = \frac{Z^2 \cdot \mathrm{PV} \cdot (1 - \mathrm{PV})}{d^2} = \frac{1.96^2 \cdot 0.5 \cdot 0.5}{(0.05)^2} = 384.16$$

This was adjusted for the finite population of pregnant women in Kyrgyzstan (N≈150 000) using:

$$n_{adjusted} = \frac{n}{1 + \frac{n}{N}} = 388$$

Stratification by urban and rural residence further ensured proportional representation across subgroups.

Due to logistical feasibility and population density, urban clusters were prioritized in the initial sampling stages to ensure adequate representation from the more densely populated urban areas. However, the study also included rural regions in an effort to capture iodine status across both urban and rural populations. Despite this, we acknowledge that the prioritization of urban clusters could lead to an under-representation of rural areas, where iodine deficiency may be more prevalent. This could potentially skew the results and limit the generalizability of our findings, especially when comparing iodine status between urban and rural populations.

One eligible participant per household was randomly selected. The sample size was calculated using standard cross-sectional study formulas and adjusted for a finite population size: 388 participants.

Inclusion and exclusion criteria

Pregnant women residing in the selected area for at least 1 y who provided urine and salt samples were included. Excluded were individuals with cognitive impairments or those living in the area for <1 y.

Data collection instruments and procedure

To assess dietary habits related to iodine intake, a semistructured questionnaire was used to determine the frequency of consumption of iodine-rich foods. The questionnaire was adapted from the food and agriculture organization of the United Nation nutrition-related iodine deficiency questionnaire,[8] which is designed to capture dietary behaviors that may influence iodine status. The questionnaire included questions on demographic and socioeconomic characteristics, health, as well as the frequency of consumption of common iodine-rich foods, such as dairy products, seafood, eggs and other iodine-fortified foods.

Specific questions included:

- 'How often do you consume seafood (e.g. fish, shellfish)?'
- 'How often do you consume dairy products (e.g. milk, cheese)?'
- 'How often do you consume eggs?'
- 'Do you regularly consume foods fortified with iodine?'

Responses were recorded in predefined categories, such as daily, weekly, monthly or never. The data collected from these responses were then analyzed to estimate the intake of iodine-rich foods and its potential impact on iodine status among the study participants.

The question 'Have you ever been diagnosed with any iodine deficiency disorder?' was included in the survey to assess participants' awareness of iodine-related health conditions. However, it is important to note that the term 'iodine deficiency disorder' may not be commonly recognized by the general population. Therefore, this question was intended to capture whether participants had received any medical diagnosis related to iodine deficiency, such as goiter or hypothyroidism, which may have been discussed with their healthcare provider. The responses to this question were self-reported and may not necessarily reflect formal clinical diagnoses of IDDs.

The questionnaire also included questions regarding the supplement intake of iodine, specifically referring to vitamin and mineral supplements containing iodine that were either prescribed or recommended to participants during pregnancy. These supplements, often provided as part of routine prenatal care, are commonly used to address iodine deficiency or to ensure adequate iodine intake during pregnancy, especially in regions where iodine deficiency is prevalent.

Participants were asked whether they had taken iodine-containing prenatal vitamins or supplements during their pregnancy. The responses were categorized as ‘yes’ or ‘no’, and the frequency and dosage of supplementation were not specifically assessed in this study.

A pilot study ensured clarity and reliability. Urine samples were collected to assess iodine status.

Urine sampling and analysis

Midstream urine samples were collected in sterile containers, stored at 4°C and analyzed within 24 h using the Sandell–Kolthoff reaction to measure the UIC.[9] WHO reference values categorized iodine sufficiency.[10]

Salt sampling and analysis

Household salt samples (50–60 g) were analyzed using iodometric titration as per state standards to measure the iodine concentration in salt (ICS).[11] Iodine content in salt was categorized as insufficient (<25 mg/kg), sufficient (25–55 mg/kg) or excessive (>55 mg/kg).[12]

Statistical analysis methods

The collected data were analyzed via IBM SPSS 29.0 (SPSS 29.0, IBM Corporation, Armonk, NY, USA). Descriptive statistics were used to summarize demographic characteristics and UIC levels. Median UIC and ICS with 95% CIs were compared using Kruskal–Wallis and Mann–Whitney U tests. These non-parametric tests were chosen because the data did not meet the assumptions of normality, as evidenced by Shapiro–Wilk tests for normality and visual inspection of data distribution. Non-parametric methods are more robust when the data are skewed or contain outliers, which was the case with our variables of interest.

We acknowledge that the use of non-parametric tests may limit statistical power compared with parametric alternatives such as ANOVA or the Student’s t test. However, given the non-normal distribution of our data, non-parametric tests were deemed the most appropriate. In future studies, we will consider the application of parametric tests where appropriate, after confirming the normality of the data, and may report effect size measures to provide a better understanding of the magnitude and practical significance of any observed differences. Multivariate logistic regression identified predictors of iodine status and salt iodine content. Statistical significance was set at $p<0.05$, with adjustments for multiple comparisons.

Results

Sociodemographic characteristics of the participants

The demographic and socioeconomic characteristics of the study population, which was divided into urban and rural categories, are presented in Table 1 .

The table highlights disparities between urban and rural populations in terms of age, education, income and employment. The population is nearly evenly split between urban and rural areas, with a slight majority in rural areas. Rural areas have a greater proportion of older individuals, lower educational attainment, lower income and higher unemployment rates. By contrast, urban areas have a younger population, higher educational levels, higher income and lower unemployment rates. The ethnic composition is relatively similar across both areas, with a majority being Kyrgyz, and a higher proportion of Uzbeks and Russians in the urban area.

UIC and ICS levels of the study participants

The analysis of the UIC and ICS based on the WHO reference values is presented in Table 2.

The median UIC in the population falls within the WHO-recommended adequacy interval. However, more than one-half of the participants had insufficient UIC levels, indicating widespread iodine deficiency, while almost one-half showed adequate levels, leaving a significant portion at risk. The median ICS was 39.10 mg/kg, with the mean and SD indicating a relatively symmetric distribution. A minority of the population had insufficient ICS levels, suggesting limited use of iodized salt, while the majority had adequate levels, reflecting widespread usage. A small percentage had excessive ICS levels, potentially due to overuse of highly iodized salt.

Measuring iodine content in individuals with IDDs helps identify gaps in iodization program coverage. Those with IDDs had lower UIC and ICS levels, suggesting inadequate iodine intake, while those without IDDs showed levels closer to the population median, reflecting better iodine status. Higher UIC in individuals consuming iodine-rich foods highlights the positive influence of dietary intake on iodine sufficiency. Similarly, these individuals tended to use salt with higher iodine content, reflecting better nutritional awareness or choices.

Characteristics of pregnant women with low UIC

Upon further analysis, we focused on the characteristics of pregnant women with very low UIC in the lower quartiles (<25 and 25–50 μg/L). This group represents a critical subset of the population, as these women and their children are at a higher risk of IDDs.

Sociodemographic factors

A small proportion of the study participants (approximately 15% of the total sample) had UIC levels <50 μg/L. Among these women, a higher percentage were from rural areas (approximately 60%) compared with urban areas (approxi-

Table 1. Sociodemographic characteristics of the pregnant women in the study population

Variables	Characteristic	Rural		Urban		Total	
		N	%	N	N	%	N
Area of residence		202	52.20	186	47.80	388	100
Age (y)	18–25	27.25	51	27.42	102	26.29	51
	26–35	45.54	96	51.61	188	48.45	96
	36–45	29.21	39	20.97	98	25.26	39
Education level	Primary school	5.44	0	0	11	2.84	0
	Secondary school	12.87	7	3.76	33	8.51	7
	High school	69.31	131	70.43	271	69.85	131
	Higher education	12.38	48	25.81	73	18.81	48
Ethnicity	Kyrgyzs	91.09	103	55.38	287	73.97	103
	Uzbeks	3.47	26	13.98	33	8.51	26
	Russians	1.49	31	16.67	34	8.76	31
	Dungans	1.49	5	2.69	8	2.06	5
	Others	2.48	21	11.29	26	6.70	21
Monthly family income per capita, KGS	<8000	48.02	38	20.43	135	34.79	38
	8001–16 000	30.20	51	27.42	112	28.87	51
	16 001–30 000	14.85	39	20.97	69	17.78	39
	>30 000	6.93	58	31.18	72	18.56	58
Employment status	Student	11.88	24	12.90	48	12.37	24
	Employed	47.53	100	53.76	196	50.52	100
	Unemployed	40.59	62	33.34	144	37.11	62

Abbreviation: KGS: Kyrgyz som.

Table 2. Analysis of the UIC and ICS of pregnant women based on WHO reference values

Parameter	UIC	ICS
Median	142.90 μg/L	39.10 mg/kg
95% CI	143.40; 156.45 μg/L	37.14; 39.95 mg/kg
Mean±SD	149.92±65.30 μg/L	38.54±14.10 mg/kg
Diagnosed with IDD*	124.66±70.25 μg/L	31.78±13.56 mg/kg
Not diagnosed with IDD*	152.90±64.24 μg/L	39.34±13.98 mg/kg
Taking iodine supplements	125.12±61.71 μg/L	33.97±13.73 mg/kg
Not taking iodine supplements	155.38±64.99 μg/L	39.83±14.02 mg/kg
Including iodine-rich foods	166.73±89.29 μg/L	37.65±16.16 mg/kg
Including iodine-rich foods sometimes	95.81±43.34 μg/L	23.18±11.91 mg/kg
Not including iodine-rich foods	84.35±36.87 μg/L	24.69±4.91 mg/kg

Abbreviations: ICS: iodine concentration in salt; IDD: iodine deficiency disorder; UIC: urinary iodine concentration.
*—according to responses to the question ‘Have you ever been diagnosed with any iodine deficiency disorder?’

mately 40%). In terms of education, 35% of these women had completed primary or secondary school, while 65% had completed higher education. Furthermore, this group had a lower average monthly family income (mean income: 9410 KGS), with 62.4% of them falling within the lower-income bracket (<8000 KGS) compared with 38.2% in the higher quartiles.

Iodine supplement and dietary intake

Among the women in the lower UIC quartiles, only 28.7% reported taking iodine supplements during pregnancy, compared with 55.3% in the higher UIC quartiles. Additionally, dietary intake of iodine-rich foods (e.g. fish, dairy, seaweed) was lower in this group, with only 35.8% reporting regular consumption compared with 58.4% of women in the higher quartiles.

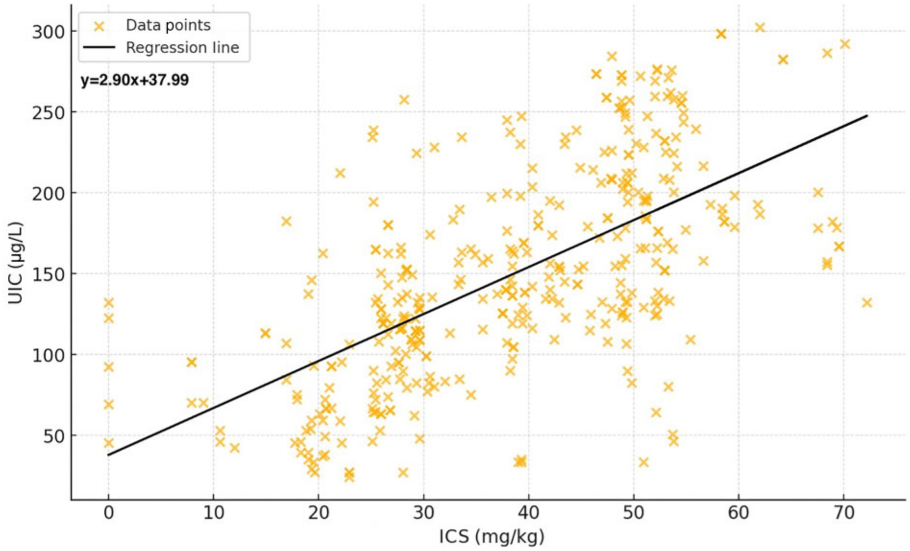

Figure 1. Associations between UIC and ICS in pregnant women. ICS: iodine concentration in salt; UIC: urinary iodine concentration.

Iodine status and risk of IDDs

While the overall proportion of women with very low UIC was small, these women did represent a potentially at-risk group for IDDs, especially in rural and low-income areas. They also had lower ICS, which might contribute to their low iodine status. This suggests that public health interventions targeting this subgroup, especially in rural and lower-income populations, would be crucial to prevent long-term IDDs for both the mothers and their children.

Figure 1 presents the relationship between ICS and UIC, with a strong positive correlation indicating that higher iodine content in salt corresponds to increased UIC. The equation on the graph is $y=2.90x+37.99$. Points concentrated around specific iodine levels in salt (e.g. 0–20 mg/kg), reflecting dietary behaviors or limited access to iodized salt. Outliers above the regression line may represent individuals consuming additional iodine-rich sources.

We performed independent t tests to compare the UIC and ISC between groups: those diagnosed with IDDs and those who were not, individuals taking iodine supplements and those who were not, as well as those consuming iodine-rich foods and those who were not. A statistically significant difference in UIC was found between the diagnosed and non-diagnosed groups ($t=-2.64$, $p\approx0.0087$), as well as for ICS ($t=-3.39$, $p\approx0.0011$). Figure 2 illustrates the distributions of UIC and ICS for these groups.

For iodine supplement users, UIC ($t=-3.56$, $p\approx0.0004$) and ICS ($t=-3.03$, $p\approx0.0026$) differences were statistically significant, suggesting that supplement intake impacts both measures. However, the observed lower UIC in supplement users warrants further investigation. Comparing UIC between those including iodine-rich foods in their diet and those not, a t-statistic of 3.58 ($p\approx0.0004$) was observed. For ICS, the t-statistic was 4.25 ($p\approx0.00003$), indicating significant differences between the two groups.

Figure 3 illustrates the association between dietary iodine intake and UIC, with the x-axis showing the frequency of iodine-rich food consumption and the y-axis representing UIC (in µg/L). Higher values indicate more frequent consumption of iodine-rich foods such as fish, dairy and seaweed. The red trend line shows a moderate positive correlation, confirming that higher intake of these foods is associated with increased UIC levels. This relationship aligns with expectations, as consuming more iodine-rich foods naturally boosts iodine levels in the body.

UIC and ICS across various subgroups

Table 3 summarizes UIC and ICS across various subgroups: age, education, residence, ethnicity, income and occupation. Each subgroup's data are presented with the mean, SD and 95% CI to indicate variability and reliability.

As shown, UIC and ICS are generally consistent across age groups, with minor variations. No significant associations between age and UIC categories suggest a relatively uniform distribution. High school and higher education levels correlate with higher UIC and ICS, indicating that education positively impacts iodine nutrition. Urban residents show significantly higher UIC and ICS levels compared with rural residents, reflecting better access to iodized salt and health resources.

Variations are evident among ethnic groups, with Uzbek, Russian and other ethnicities showing higher levels, likely influenced by dietary habits. Higher income is linked to better iodine nutrition, as indicated by higher UIC and ICS, reflecting the impact of economic status on dietary quality. Students tend to have lower iodine levels, likely due to dietary and resource access differences tied to occupational status.

Table 4 presents the results of multiple linear regression, examining predictors (education, occupation, residence, income and ethnicity) and their relationship with UIC.

The ANOVA statistics at the top of the table indicate the model's significance. The model summary statistics (R, R square,

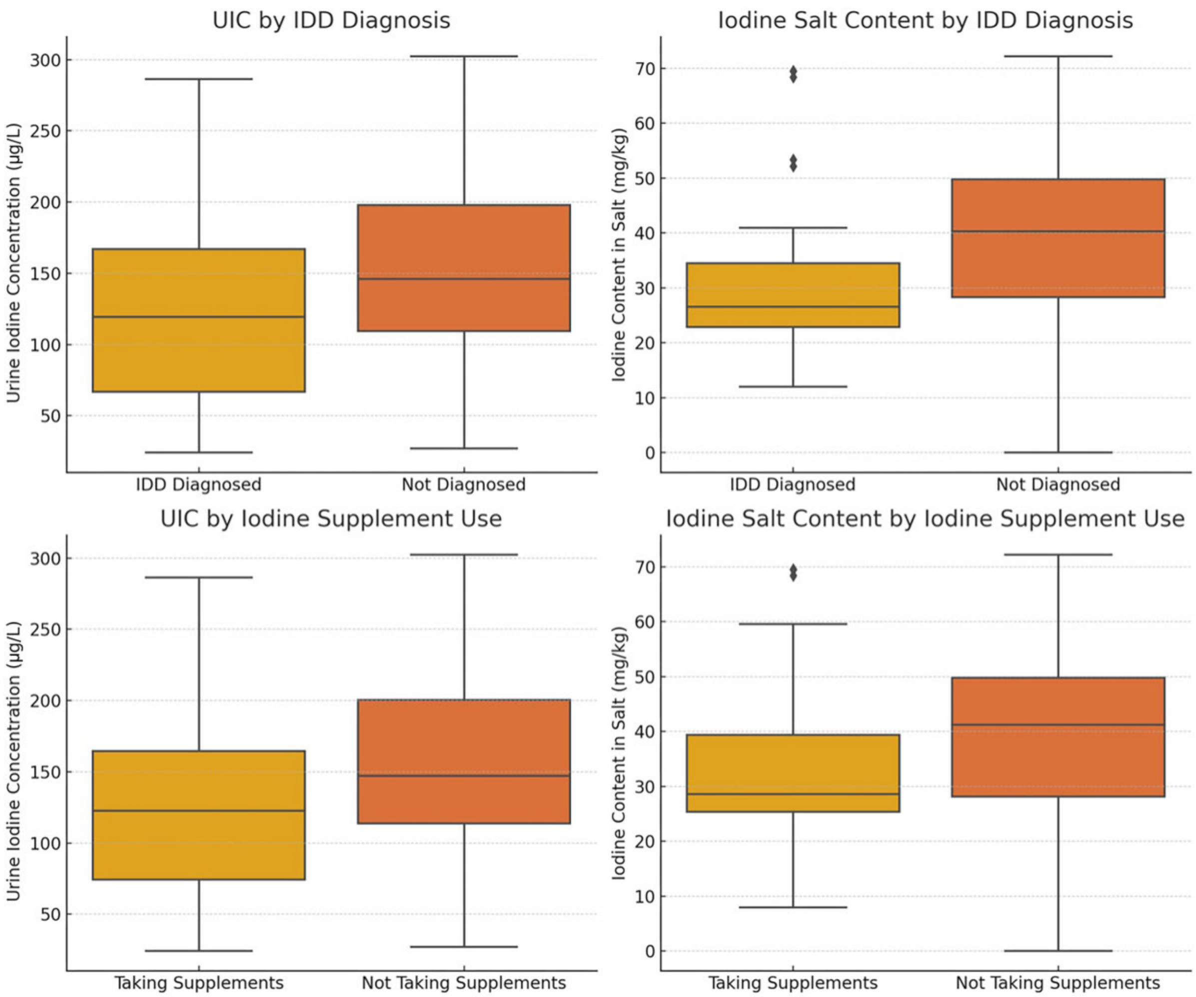

Figure 2. Distribution of urinary iodine concentration (UIC) and iodine concentration in salt (ICS) for patients diagnosed with IDD and those not diagnosed with IDD, as well as those taking and not taking iodine supplements. IDD: iodine deficiency disorder.

adjusted R square and SE of the estimate) in the first row provide an overview of the model's fit.

Table 4 shows a moderate positive correlation (R=0.439) between the independent variables (family income per capita, education, occupation, ethnicity and residence) and the dependent variable (UIC). An R-square of 0.193 indicates that 19.3% of the variability in UIC levels is explained by the model, leaving 81.7% unexplained. The adjusted R-square of 0.182 reflects a slight decrease in explanatory power when accounting for the number of predictors.

The regression model is statistically significant ($p<0.0001$), confirming the predictors' substantial influence on UIC. However, the remaining unexplained variance suggests the presence of additional factors not included in the analysis.

Discussion

Iodine deficiency remains a critical public health issue, particularly for pregnant women in endemic areas such as Kyrgyzstan, where inadequate iodine levels profoundly affect both maternal and fetal health.[13] Universal salt iodization remains a key strategy for maintaining adequate iodine levels globally.[1,14] The 2022 systematic review by Patriota et al. indicated widespread iodine insufficiency during pregnancy worldwide, emphasizing the need for robust iodine supplementation programs.[15] The Global Scorecard of Iodine Nutrition (2020) by the Iodine Global Network reported varying levels of iodine sufficiency across Central Asia, with persistent deficiencies among vulnerable populations such as pregnant women and children.[16] Despite significant progress in iodine nutrition, challenges remain in regions such as Russia, Ukraine, Kazakhstan and Kyrgyzstan.[15]

The current study assessed the iodine status of pregnant women across various demographic groups in Kyrgyzstan. Higher education levels were associated with improved iodine nutrition, likely due to greater dietary awareness. Urban residents presented higher UICs and ICSs, reflecting possible disparities in access to iodized salt and healthcare. Differences in UIC and ICS levels across ethnic groups highlighted the impact of cultural and dietary practices on iodine intake. Higher family income

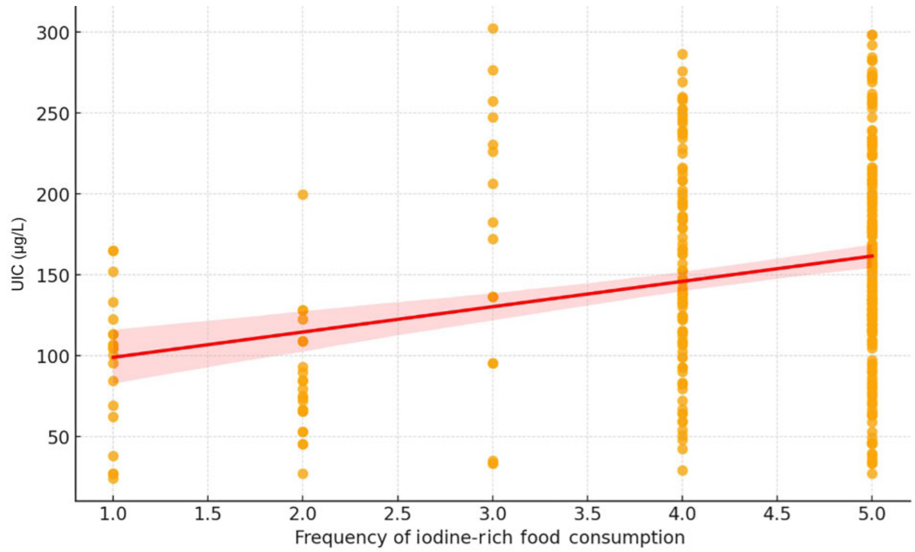

Figure 3. Association between dietary iodine intake and urinary iodine concentration.

correlated with better iodine nutrition, underscoring the role of economic factors, while employment status was linked to higher iodine levels. However, individuals who were diagnosed or tested for iodine deficiency generally had lower iodine levels, reaffirming persistent gaps among vulnerable populations.

A study conducted by Urmatova et al. (2021) on school children in new settlements in Kyrgyzstan reported iodine deficiencies, highlighting the effectiveness of the national iodization program while noting gaps in population coverage.[6] Similarly, the current salt iodization strategy ensures sufficient iodine for school-aged children but not pregnant women, due to enforcement challenges and illegal non-iodized salt imports.[17]

Dietary habits also significantly impact iodine nutrition. Yamada et al. (2000) noted the need to adjust iodine levels in salt for increased consumption, mirroring findings in Kyrgyzstan.[19] Zou et al. (2015) found a strong correlation between salt iodine levels and UIC in China, consistent with this study's results, reinforcing the role of state-led iodization programs.[20] Ren et al. (2008) demonstrated a novel method of using potassium iodate in irrigation water in Xinjiang, which increased iodine levels in soil, crops and urine, offering a promising alternative for areas with less effective iodized salt programs.[21]

Although studies linking socioeconomic status and iodine intake are rare, findings align with this study in showing that higher socioeconomic status improves iodine nutrition.[20–23] However, some evidence suggests that socioeconomic factors may not significantly affect iodine supply.[24]

Iodine status across various sociodemographic groups

Education and iodine status

Education level is strongly linked with higher UICs and ICSs, as shown in this study and supported by Sultanalieva et al. (2016), Dold et al. (2018), Völzke et al. (2013), and Gunnarsdóttir and Brantsæte (2023).[4,14,26,27] These findings highlight the importance of targeted interventions to improve awareness and dietary choices among less-educated populations.

Urban vs rural differences

Our findings align with global evidence showing significant disparities in iodine status between urban and rural populations. Studies by Galvan et al. (2020), National Health and Nutrition Examination Survey (NHANES) in USA, Sultanalieva et al. (2016), and Uraimova (2019) consistently report higher UICs in urban areas due to better access to iodized salt and health resources.[4,24,25,28]

Ethnic variations

Univariate analysis revealed differences in UIC across ethnic groups, aligning with NHANES findings that identified disparities in iodine intake among racial/ethnic groups.[29,30] However, multivariate regression (Table 4) demonstrated that ethnicity was not a statistically significant predictor of iodine status when adjusting for covariates such as education, residence and income. This suggests that socioeconomic and geographic factors, rather than ethnicity itself, may primarily explain the observed variations. While cultural and dietary practices could contribute to iodine intake patterns, our findings emphasize the need to contextualize ethnic differences within broader structural determinants, such as access to iodized salt and health resources, which are often intertwined with socioeconomic status and geographic location.

Income and socioeconomic status

Higher-income families consistently show better iodine nutrition, reflected in higher UICs and ICSs. This trend is supported by studies linking economic status to improved access to iodized salt and health resources.[21–23,26]

Table 3. Detailed statistics for UIC and ICS across different subgroups

Category and subgroup	UIC median	UIC (95% CI)	H- and U-statistics*	p value	ICS median	ICS (95% CI)	H- and U-statistics*	p value
Age (y)			1.54	0.463			2.62	0.269
18–25	136.55	128.7; 157.4			35.5	29.6; 44.5		
26–35	146.15	137.9; 155.9			40.95	38.4; 44.1		
36–45	132.35	116.7; 163.9			37.45	30.7; 40.3		
Education			35.99	0.000			37.18	0.001
Primary school	45.5	27.2; 106.5			20.4	17.9; 22.9		
Secondary school	104.7	65.8; 116.7			29.1	25.8; 34.5		
High school	152.2	134.4; 162.2			42.9	39.4; 47.0		
Higher education	150.5	140.2; 162.0			37.9	37.5; 42.0		
Residence			27 167.5	0.000			28 327.0	0.000
Rural	119.4	108.9; 125.6			29.00	28.0; 30.8		
Urban	165.7	156.9; 178.4			47.85	45.7; 49.2		
Ethnicity			29.02	0.001			33.62	0.001
Kyrgyz	132.4	124.3; 142.6			34.5	29.6; 38.5		
Uzbek	163.2	154.7; 215.2			44.9	38.4; 47.9		
Russian	182.3	146.0; 208.0			48.55	42.6; 51.0		
Dungan	150.15	102.1; 152.2			46.05	25.4; 52.9		
Other	165.5	138.4; 183.9			50.05	44.0; 52.2		
Family income per capita, KGS			14.02	0.003			51.13	0.001
<8000	128.4	119.4; 152.9			29.6	28.4; 37.5		
8001–16 000	138.9	123.4; 154.9			35.6	31.0; 42.1		
16 001–30 000	138.2	132.2; 146.0			39	37.8; 40.9		
>30 000	164.65	153.5; 178.9			49.8	47.9; 51.8		
Employment status			7.49	0.024			1.58	0.454
Student	132.5	114.9; 169.7			40.9	30.8; 48.6		
Employed	141.2	132.8; 152.2			37.9	32.2; 38.6		
Unemployed	152.9	135.6; 176.3			41.95	39.0; 46.4		

Abbreviations: ICS: iodine concentration in salt; KGS: Kyrgyz som; UIC: urinary iodine concentration.
*—H-statistic for age, education, ethnicity, family income per capita and employment status groups; U-statistic—for residence groups.

Employment status

Occupation or employment status influences iodine nutrition by affecting dietary habits and access to iodized products, as highlighted in our study. This area warrants further research to better understand its impact.

Health conditions

The data clearly show that dietary habits significantly impact both UIC and ICS. Individuals consuming iodine-rich foods exhibit higher iodine levels and are more likely to use iodized salt, reflecting better overall iodine status. These findings underscore the importance of public health interventions promoting iodine-rich foods and iodized salt, particularly in areas with iodine deficiency concerns. Despite generally adequate ICS levels, a significant portion of the population has insufficient UIC, indicating ongoing risks of deficiency. Those diagnosed with IDD or taking iodine supplements showed lower UIC and ICS levels, suggesting they may be managing or recovering from deficiency.

A previous study found a positive correlation between salt iodine content and UIC,[18] confirming that iodized salt significantly contributes to body iodine levels. These results indicate that Kyrgyzstan's iodized salt program has effectively improved iodine status but highlight areas needing further attention.

Interestingly, individuals taking iodine supplements had lower mean UIC and ICS than non-users. This counterintuitive finding may reflect that supplement users were previously identified as iodine-deficient or variability in iodine absorption or retention.[19] Lower ICS among this group could suggest a reliance on supplements rather than iodized salt for iodine intake.

Findings related to thyroid disorders align with studies showing that individuals with diagnosed conditions often have altered iodine levels. For example, research on iodine nutrition and thyroid function highlights the necessity of adequate iodine intake for managing conditions such as Graves' disease, further validating these observations.[30–34]

Strengths and limitations

The current study's strengths include a substantial participant sample, enhancing result reliability. Ethical considerations, including informed consent, ensured confidentiality and voluntary

Table 4. Summary of regression analysis for predicting UIC (μg/L)

ANOVA[a] F=18.23 p<0.0000[b]				
Variable	Coefficient	SE	t-statistic	p value
Intercept (constant)	115.70	26.10	4.43	0.000
Education	18.85	5.04	3.74	0.000
Occupation	15.63	4.62	3.38	0.001
Residence	−40.54	6.92	−5.86	0.000
Family income per capita, KGS	−1.96	3.04	−0.65	0.519
Ethnicity	4.82	2.87	1.68	0.094

Abbreviation: UIC: urinary iodine concentration.
[a]Dependent variable: UIC (μg/L).
[b]Predictors: education, occupation, residence, family income per capita (KGS) and ethnicity.

participation. Standardized and validated methods were used to measure UIC and ICS, and multiple potential confounders, such as education, residence, ethnicity, occupation and health conditions, were considered. The analysis aligns with global standards, ensuring its findings are internationally relevant.

However, the cross-sectional design provides a snapshot of iodine status at a specific point in time and does not allow for the establishment of causal relationships. For example, while we observed a correlation between iodine status and salt iodization, this correlation cannot definitively prove causality. Other factors, such as dietary habits, access to iodine-rich foods and regional differences in healthcare and nutrition, may also influence iodine status. Therefore, while the study highlights important associations, future longitudinal studies would be needed to investigate the causal impact of salt iodization and other interventions on iodine status and related health outcomes.

Additionally, this study does not track changes in iodine status or salt iodization practices over time, which could potentially miss trends or fluctuations that may occur due to seasonal variations, shifts in public health interventions or changes in dietary habits. A longitudinal approach would provide a more dynamic view of iodine nutrition in the population, allowing for the identification of long-term trends and an assessment of the effectiveness of ongoing salt iodization programs. Future research using a longitudinal design could provide more robust insights into how iodine status evolves over time and the impact of interventions on this key public health issue.

Another limitation is that this study did not account for gestational age or trimester-specific variations in iodine metabolism among pregnant participants. Iodine requirements increase as pregnancy progresses, particularly during the second and third trimesters, due to heightened thyroid hormone production and fetal demands.[35] The absence of trimester-specific analysis may introduce variability in UIC measurements, as iodine sufficiency thresholds differ across pregnancy stages.[36] For instance, UIC levels deemed adequate in early pregnancy might reflect insufficiency in later stages, potentially leading to misclassification of iodine status. This limitation could influence the interpretation of results, including the observed prevalence of deficiency and associations with sociodemographic factors. Future studies should incorporate trimester-specific assessments to refine the accuracy of iodine status evaluations in pregnant populations.

Also, the responses to the question 'Have you ever been diagnosed with any iodine deficiency disorder?' should be interpreted with caution, as it reflects participants' self-reported awareness of iodine-related health conditions rather than formal clinical diagnoses of IDDs. This question aimed to assess awareness of iodine deficiency in the population, but the term 'iodine deficiency disorder' may not be widely understood by all participants, particularly those with limited access to healthcare or health literacy. Self-reported health and dietary information may be subject to recall bias, and the findings have limited generalizability beyond the study area. Additionally, other factors influencing iodine levels, such as dietary sources beyond salt, were not considered.

Public health implications

The findings highlight the need for stricter enforcement of salt iodization laws and policies, particularly in rural areas. Revising standards for iodized salt production, distribution and monitoring can ensure uniform coverage. This study underscores the continued challenge of iodine deficiency among pregnant women in Kyrgyzstan, particularly in rural and low-income populations. While the overall iodine status of the population has improved due to the national salt iodization program, there remains a significant subset of pregnant women with very low UIC, which poses a long-term risk to both maternal and fetal health.

Targeted public health interventions should focus on raising awareness about iodine nutrition, improving access to iodized salt and promoting iodine supplements, especially among rural residents and those with lower education levels. To support women in the lower UIC quartiles, targeted iodine supplementation should be implemented. Pregnant women with low iodine status should receive iodine supplements through public health programs, particularly in areas where iodine deficiency is prevalent. This supplementation should be closely monitored to ensure that the intake is adequate but not excessive. Integrating iodine education into prenatal care and maternal health programs can provide consistent messages about adequate iodine intake during pregnancy.

Disparities between urban and rural areas and across income levels emphasize the need for targeted interventions in rural and low-income communities. A regional approach to salt iodization should be adopted, with adjustments made based on local iodine status. In urban and higher-income areas where iodine intake might already be sufficient, the iodization levels in salt may need to be reduced to prevent excessive iodine intake. Conversely, in rural areas with lower iodine levels, the focus should be on ensuring sufficient iodization to meet the needs of the population. Strategies such as subsidized iodized salt, iodine supplement distribution and mobile health units can help reach remote populations. Differences in iodine status among ethnic groups suggest that culturally tailored interventions are necessary, with public health initiatives considering dietary habits, cultural practices and language preferences to enhance effectiveness.

While encouraging the consumption of iodine-rich foods such as dairy, seafood and eggs is essential for promoting a balanced diet, public health campaigns must ensure moderation and balance. This is particularly important for individuals in higher quartiles of iodine intake, who may already have sufficient iodine levels. Educational campaigns should stress the importance of dietary variety and adequate iodine intake, with clear guidelines on recommended food choices.

Addressing iodine deficiency among pregnant women can reduce long-term health burdens, including cognitive impairments and developmental delays in children, thereby improving overall health and economic productivity. Children born to mothers with very low UIC are at higher risk for cognitive impairments, developmental delays and other long-term health consequences due to iodine deficiency during pregnancy. Ensuring adequate iodine intake during pregnancy is crucial for fetal neurological development and can positively impact early childhood development, educational outcomes and quality of life. This can help break the cycle of poverty and poor health outcomes.

This study underscores the importance of ongoing iodine status monitoring across population groups. Pregnant women should be routinely screened for iodine status during prenatal visits, and personalized recommendations should be provided based on individual iodine needs. This individualized approach would allow for precise interventions, avoiding unnecessary iodine supplementation in women with sufficient iodine levels while ensuring that those with low iodine concentrations receive the necessary support. Establishing a robust surveillance system for tracking iodine levels in pregnant women and other vulnerable groups can guide resource allocation, identify high-risk areas and support evidence-based health policies. Regular monitoring of UICs and salt iodine levels should be used to inform these adjustments. Regularly updated data can inform targeted public health actions and improve outcomes.

Given the interconnected nature of micronutrient deficiencies, integrating iodine interventions into broader nutritional programs addressing deficiencies such as iron or vitamin A can maximize health benefits. Collaborating with international organizations such as the WHO and UNICEF can enhance the effectiveness of iodine deficiency prevention programs. Leveraging global expertise and resources can strengthen national efforts and align them with international best practices.

In conclusion, to effectively combat iodine deficiency, particularly among pregnant women, a multipronged strategy that combines targeted supplementation, iodine-rich food promotion, regional salt iodization adjustments and educational campaigns is essential. This will ensure that those at risk receive adequate iodine while minimizing the risk of excessive intake in those who are already meeting their iodine needs.

Future research

This study provides valuable insights into the iodine status of pregnant women in Kyrgyzstan; however, several important areas for future research have been identified to address the limitations of the current study design and further enhance our understanding of iodine nutrition and its public health implications.

One of the main limitations of this study is its cross-sectional design, which offers a snapshot of iodine status at a single point in time but does not capture potential fluctuations or trends in iodine intake and salt iodization practices over time. Future research should focus on longitudinal studies that track iodine status and related public health interventions over multiple time points. This would allow for a better understanding of seasonal variations, as well as the impact of ongoing salt iodization programs and other interventions aimed at improving iodine nutrition. Long-term studies would also enable researchers to evaluate the effectiveness of iodine-related policies and monitor changes in population-wide iodine status.

Given the potential for skewed results due to the prioritization of urban clusters in our study, future research should adopt a more balanced sampling strategy to ensure equal representation of both urban and rural populations. Rural areas, where iodine deficiency might be more prevalent, should be adequately represented to avoid potential biases and enhance the generalizability of the findings. Ensuring rural populations are sufficiently included will allow for a more accurate comparison of iodine status across different geographic regions, leading to better-targeted public health interventions.

Our study excluded pregnant women who had been living in the area for <1 y, which may have resulted in missing valuable data on migrant populations or those who have recently relocated. These groups may face different nutritional challenges, including access to iodized salt and iodine-rich foods, which could influence iodine status. Future studies should explicitly include migrant and recently relocated populations, examining how relocation impacts iodine intake and deficiency. This will be important for understanding how changes in residency affect iodine nutrition, especially in regions with varying salt iodization practices or dietary habits.

While we excluded individuals with cognitive impairments from this study to maintain methodological consistency, it is crucial to recognize that cognitive impairments may be associated with unique health and dietary challenges that could influence iodine status. Future research should focus on populations with cognitive impairments, as these individuals may face particular difficulties in accessing adequate nutrition, including iodine-rich foods and supplements. A dedicated study on this group would provide valuable insights into how cognitive impairments intersect with iodine nutrition and help identify the specific nutritional needs of individuals with cognitive disabilities.

Future studies should also consider a deeper exploration of the socioeconomic factors influencing iodine status, particularly in vulnerable populations such as those with lower income, education and access to healthcare. By identifying and addressing these socioeconomic determinants, future research can contribute to the development of more effective, targeted interventions aimed at reducing iodine deficiency in high-risk groups.

In conclusion, while this study provides important data on iodine status among pregnant women in Kyrgyzstan, there is a clear need for future research to address the limitations outlined above. Longitudinal studies, more inclusive sampling and a focus on vulnerable populations will provide a more comprehensive understanding of iodine nutrition and its public health impact, ultimately guiding more effective and equitable public health strategies.

Future research should also consider expanding the scope of iodine intake assessment to include all potential sources of iodine, such as processed foods, iodine-rich foods (e.g. dairy products, seafood) and supplements. While household salt is the most common and easily measurable source of iodine, it does not account for iodine obtained from processed foods or dietary supplements, which may also contribute significantly to overall iodine status. Future studies could incorporate food frequency questionnaires or dietary recall methods to assess iodine intake from a broader range of food sources and supplements. This would provide a more comprehensive understanding of iodine nutrition in the population and help better capture the full spectrum of dietary iodine intake. Furthermore, considering the bioavailability of iodine from different sources would help clarify the relative contribution of each source to iodine status and its health implications.

Conclusion

Adequate iodine intake is crucial for preventing IDDs and ensuring healthy development, particularly in vulnerable populations such as pregnant women. This study confirms ongoing challenges and successes in iodine nutrition, aligning with findings from Kyrgyzstan, Central Asia and global studies. While salt iodization programs have been effective, gaps persist, especially among pregnant women in areas with socioeconomic and enforcement challenges.

Public health strategies should focus on raising awareness of iodine nutrition and improving access to iodized salt, including subsidized or free distribution in rural and low-income areas. Supporting other iodine supplementation programs is also critical where access to iodized salt is limited.

This analysis highlights disparities in iodine nutrition across subgroups, emphasizing the need for targeted and culturally appropriate interventions to reduce iodine deficiency. Collaborative efforts and legislative support are vital for the sustainable elimination of IDDs.

Further research is needed to identify barriers to adequate iodine intake and develop effective prevention policies. Longitudinal studies can provide insights into how sustained iodine intake impacts health over time, pinpointing critical periods for intervention and optimizing program implementation.

Key points

- Despite the adequate median UIC level of the surveyed pregnant women and a majority of salt samples having adequate iodine content, there are participants with insufficient UIC. This suggests gaps in the effectiveness of the salt iodization program and highlights ongoing iodine deficiency, particularly in vulnerable populations.
- Urban residents, individuals with higher education and higher-income groups exhibited better iodine status compared with their rural, less educated and lower-income counterparts. These disparities emphasize the impact of socioeconomic factors on access to iodized salt and dietary habits.
- The study underscores the necessity for tailored public health strategies, including stricter enforcement of salt iodization laws, promotion of iodine-rich dietary practices and focused support for rural and low-income communities to address the persistent iodine deficiency among pregnant women in Kyrgyzstan.

Authors' contributions: Conceptualization: KD, DELP and IC; methodology: KD, DEPL and IC; software/data analysis: ZDz, ZDe and IC; validation: KD, DEPL and IC; investigation: ZDz, ZDe and IC; resources: KD and IC; writing (original draft): IC; writing (review/editing): KD, ZDe and DEPL; visualization: ZDz and IC; project supervision: KD. All the authors have read and agreed to the published version of the manuscript.

Funding: None.

Competing interests: None declared.

Ethical approval: The study adhered to the Declaration of Helsinki. Ethical approval was obtained (ERC-3, 21.01.2020), and participants provided written informed consent. Confidentiality and voluntary participation were assured.

Data availability: All relevant information is included in the article. The dataset will be available upon request.

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