The Journal of Nutrition 153 (2023) 2717–2725

THE JOURNAL OF NUTRITION

journal homepage: https://jn.nutrition.org/

Community and International Nutrition

National and Sub-National Estimates of Household Coverage of Iodized Salt and Urinary Iodine Status among Women of Reproductive Age in India: Insights from the India Iodine Survey, 2018–19

Ranjan Kumar Jha [1], Susmita Das [2], Suvabrata Dey [2], Sucharita Dutta [1], Noor Khan [3], Suresh Lakshminarayanan [1], Chandrakant S Pandav [4], Aarati Pillai [2], Manoj Kumar Raut [2,*], J.C. Reddy [2], Mini Varghese [1]

[1] *Nutrition International, India Country Office, New Delhi, India;* [2] *Nutrition International, Asia Regional Office, New Delhi, India;* [3] *Nutrition International, Headquarters, Ottawa, Canada;* [4] *The International Council for Control of Iodine Deficiency Disorder, India*

A B S T R A C T

Background: Iodine deficiency is a significant public health problem for many populations worldwide, including India, particularly during the "first 1000 days" of life. Though Universal Salt iodization (USI) is mandatory in India, prior to 2018–19, there was no state-wide survey with estimates of iodine concentrations in salt using iodometric titration. Taking cognizance of this fact, Nutrition International commissioned the first-of-its-kind national-level survey in India, titled the India Iodine Survey 2018–19.
Objectives: The study was conducted across the country to provide national and subnational estimates of iodine concentrations in household salt using iodometric titration and iodine nutrition status among women of reproductive age (15–49 y).
Methods: The survey adopted a multi-stage random cluster probability proportional to size sampling design, covering 21,406 households in all the states and union territories (UTs) of India.
Results: At the national level, the household coverage of edible salt with adequate iodine (content ≥15 parts/million) was 76.3%. At the sub-national level, the coverage varied, with 10 states and 3 UTs achieving USI and 11 states and 2 UTs falling below the national average, with the highest among all the states and UTs, being Jammu and Kashmir and the lowest being Tamil Nadu. At the national level, the median urinary iodine concentration for pregnant women was 173.4 μg/L, for lactating women was 172.8 μg/L, and for non-pregnant, non-lactating women, it was 178.0 μg/L, which is within the adequate iodine nutrition range according to the WHO guidelines.
Conclusions: The survey results can be widely used by various stakeholders, including government, academia, and industry, to understand the iodine nutrition status of the population, enable the scale-up of sustained efforts toward consolidating gains and achieving USI, leading to the reduction and elimination of Iodine Deficiency Disorders.

Keywords: universal salt iodization, median urinary iodine concentration, iodometric titration test, women of reproductive age, India Iodine Survey

Introduction

Iodine is one of the important micronutrients required on a sustained basis for optimal mental and physical development in human beings. It is needed to produce thyroid hormone, which regulates functions in the body. The human body cannot synthesize and store iodine; hence, it needs to be consumed in our daily diet. The deficiency of thyroid hormones in the body can lead to various disabilities and disorders collectively termed Iodine Deficiency Disorders (IDDs). It encompasses goiter, hypothyroidism, cretinism, abortion, stillbirth, mental retardation, and psychomotor defects. The majority of these consequences are invisible and irreversible, though fully preventable. Worldwide, iodine deficiency is the single most important preventable cause of brain damage [1].

Abbreviations: IDD, iodine deficiency disorder; IIS, India Iodine Survey; LW, lactating woman; mUIC, median urinary iodine concentration; NFHS, national family health survey; NISI, national iodine and salt intake survey; NPNLW, nonpregnant nonlactating woman; PPM, parts per million; PW, pregnant woman; UIC, urinary iodine concentration; USI, universal salt iodization; UT, union territories; WRA, women of reproductive age.

* Corresponding author. *E-mail address:* rautmanojkumar@gmail.com (M.K. Raut).

https://doi.org/10.1016/j.tjnut.2023.06.037
Received 9 November 2022; Received in revised form 23 June 2023; Accepted 27 June 2023; Available online 28 June 2023

Iodine deficiency is a significant public health problem for many populations worldwide, including India, particularly for pregnant women (PW) and young children. On average, children born in iodine-deficient regions have 13.5 intelligence quotient points less than children born in iodine-sufficient regions [2]. Adequate iodine nutrition is critical during the first 1000 d of life when most of the brain development occurs, referring to the period beginning right from an infant's conception to 2 y of age.

Economic analyses suggest that Universal Salt Iodization (USI) programs [3], a term used to denote the availability of iodized salt in >90% of households, with an estimated benefit-cost ratio of 70:1, offer the highest return on investment from public health interventions [4]. The consumption of adequately iodized salt at the household level improves children's height-for-age by 0.664 SDs and height by 1.845 cm, on average [5]. In cognitive development, among children aged 5–10 y in rural India, exposure to higher availability of iodized salt in early life improved basic numeracy skills by 4.81% for girls and by 2.67% for boys [6].

Based on the initial results from a study conducted between 1956 and 1968 in Kangra Valley (Himachal Pradesh) [7], India launched the National Goitre Control Program, a public health program, in 1962. Later surveys conducted till 2007 by various bodies at different points in time revealed that there were multiple manifestations of IDDs apart from goiter and that out of 414 districts surveyed in all the 29 states and 7 Union Territories (UTs), 337 districts were found to be goiter endemic, i.e., the prevalence of goiter is >5% (source: https://dghs.gov.in/content/1348_3_NationalIodineDeficiency.aspx). The findings of the surveys contributed to the renaming of the National Goitre Control Program in 1992 as the National IDDs Control Program. USI was adopted as a strategy of choice. Further, to improve regulatory monitoring and enforcement of iodized salt standards, the Prevention of Food Adulteration Act 1954 was amended in 1997 [5] to include the standard. This was later continued with the Food Safety and Standard Act 2006 and its regulations.

Nutrition International, along with technical support from the Association for the Indian Coalition for the Control of IDDs, commissioned a first-of-its-kind national-level survey titled "India Iodine Survey (IIS) 2018–19" across all 29 states and 7 UTs [8] in India (prior to October 2019) to assess the impact of the National IDDs Control Program in improving the iodine nutrition status of the population, to develop strategies for the improved and effective implementation of the program.

Study objectives

- The study's primary objective was to estimate the household coverage of iodized salt at the state and UT levels.
- The secondary objective of the study was to assess the iodine nutrition status of women of reproductive age (WRA) (15–49 y): PW, lactating women (LW) with an infant <6 mo, and nonpregnant, nonlactating women (NPNLW) by measuring their median urinary iodine concentration (mUIC) at the zonal level [9].

Methods

Study design

The study followed a 1-time cross-sectional survey using a multi-stage random cluster sampling methodology. The primary sampling units were selected with probability proportional to population size. The survey was designed to estimate household coverage of iodized salt as the primary objective in the state/UT domain, which includes both rural and urban areas within the state/UT.

Sample size

The sample size for the survey's primary objective was determined with the aim of providing state/UT-wise estimates of households using adequately iodized salt at the national and state levels. The sample size per state/UT is determined based on an assumed value of 78.1% National Iodine and Salt Intake Survey (NISI, 2014–15) [10] as the value of the indicator (adequately iodized salt ≥15 ppm at the household level) in the NISI. Based on this value of the indicator, the sample size worked out to be 584 and rounded ≤600. It was computed with a ±5% absolute precision, adjusted for a design effect of 2.0 to account for multi-stage cluster sampling design, and incremented for an assumed 90% probable response rate. For the secondary objective, to obtain a sample size for an assumed 50% of women with urinary iodine below the mUIC of 158μg/L according to the NISI, 2014–15, a sample size of 854 rounded up to ≤900/domain was estimated with a ±5% absolute precision, adjusted for a design effect of 2.0 to account for multi-stage cluster sampling design and incremented for a probable response rate of 90%.

Data collection

The survey fieldwork was undertaken between October 2018 and March 2019. The survey questionnaire was administered to sampled households, and salt was collected to estimate the iodine concentration in the salt, and urine samples were collected to estimate the urinary iodine concentration (UIC) among pregnant, lactating, and NPNLW in the reproductive age of 15–49 y. Both the samples were tested in the laboratory, salt through iodometric titration and urine through the Sandell-Kolthoff reaction, the gold standard for iodine content testing. Ethical approval for the study was obtained from the SRI-IRB (Institutional Review Board of Social Research Institute), a NIH-accredited ethics committee. Written informed consent was obtained from all the study participants in the local language.

Survey quality assurance

Quality assurance and quality control was a continuous process of systematically monitoring and evaluating the various aspects of the survey to maximize the quality standards attained. Quality checks were carried out on all the key activities of the survey – testing, recruitment, field training, data collection, team movement, data compilation, and visualization. Field supervisors conducted accompaniment spot checks for 15% of primary sampling units, and state field controllers conducted an additional 5%, followed by an immediate debriefing session to clarify all doubts. A website with a drill-down dashboard was developed for the survey to ascertain transparency in the data collection process monitoring. In addition, an external agency was hired to independently validate the reliability of data collected in line with the guidance of the ethical committee.

Data analysis methodology

As part of the methodology of data analyses, bivariate and multivariate analyses were performed on the data. In order to account for clustering and weighting, the Svyset in Stata 17.0 was used to calculate 95% CIs of percentages for the weighted data of iodine concentration in salt. Cross tabulations between demographic and socio-economic characteristics of the sampled households and the level of household coverage of iodine content in salt and mUIC at the zonal, state/UT levels were conducted. Multiple logistic regression was performed to understand the association between the independent (place of residence, type of salt in the household source of information on iodized salt, and wealth index) and dependent variable (adequately iodized salt). Multiple logistic regression was performed to understand the factors associated with adequately iodized salt. A quantile regression was performed to evaluate the association between the mUIC of the respondents and the consumption of adequately iodized salt. Quantile regression models the relationship between a set of predictors (independent) variables and specific percentiles (or "quantiles") of a target (dependent) variable, most often the median. It has 2 main advantages over ordinary least squares regression; quantile regression makes no assumptions about the distribution of the target variable, and quantile regression tends to resist the influence of outlying observations. Although linear regression can be used to model the expected value (i.e., mean) of a continuous outcome given the covariates in the model, quantile regression can be used to compare the entire distribution of a continuous response or a specific quantile of the response between groups. The advantage of the quantile regression methodology is that it allows for understanding relationships between variables outside of the conditional mean of the response; it is useful for understanding an outcome at its various quantiles and comparing groups or levels of exposure on those quantiles.

Results

Demographic and socio-economic characteristics of the households and respondents

Demographic and socio-economic characteristics play a crucial role in the standard of living. The survey covered 21,406 households across 36 states/UTs in India. The survey covered 61% of rural areas, and 75.1% of the respondents had received a formal education, i.e., attended schooling and covered major social categories. More than 83% of households having safe drinking water and sanitation facilities, and over three fourth of households have accessed a ration card and bank account (Table 1).

Household coverage of iodized salt

At the national level, the household coverage of salt with adequate iodine content (≥15 ppm) was 76.3%. Salt with ≥5 ppm iodine was found in 92.4% of households. Among 29 states and 7 UTs, the states with the highest household coverage of salt with adequate iodine content were Jammu and Kashmir (99.8%), Nagaland (99.7%), Manipur (99.5%), Mizoram (99.2%), and Meghalaya (98.4%). The states and UTs with the lowest household coverage of salt with adequate iodine content were Tamil Nadu (61.9%), Andhra Pradesh (63.9%), Rajasthan (65.5%), Odisha (65.8%), Jharkhand (68.8%) and Puducherry (69.9%). More than 41% of all household salt was found to have iodine content between 15–30 ppm, followed by 33.1% of household salt between 30–50 ppm concentrations [11]. The northeast zone reported the highest household coverage with adequately iodized salt, whereas the south zone was the last among the 7 zones. In the general social category, >23% of household salt was inadequately iodized (<15 ppm), whereas

TABLE 1
Demographic and socio-economic characteristics of the sampled households in India, India Iodine Survey, 2018–19

Study profile and household characteristics	
Geographic coverage of the India Iodine Survey, 2018–19	
Number of states and UTs covered	36
Number of primary sampling units covered	702
Number of households covered	21,406
Type of residence	
Rural	61.3
Urban	38.7
Mean age of the respondent (y)	26.0
Year of Schooling of the respondent (completed)	
No schooling	24.9
<5 y	6.0
5–7 y	12.7
8–9 y	16.2
10–11 y	17.3
≥12 y	19.7
Caste/tribe	
Scheduled caste	25.4
Scheduled tribe	13.0
Other backward class	34.3
General	25.0
Others	2.3
Wealth index	
Lowest	19.7
Second	19.8
Middle	20.0
Fourth	20.0
Highest	20.4
Safe drinking water and sanitation facilities	
Improved drinking-water source[1]	94.8
Improved sanitation facility[2]	83.2
Access to the health facility	
Public	56.1
Private	43.0
Others	0.9
Access to ration card	77.4
Access to the bank account	86.0

UTs, union territories.
[1] Piped water into dwelling/yard/plot, piped to neighbor, public tap/standpipe, tube well or borehole, protected dug well, protected spring, rainwater, tanker truck, cart with small tank, bottled water, community Reverse osmosis plant.
[2] Flush to piped sewer system, flush to septic tank, flush to pit latrine, flush to don't know where, ventilated improved pit (VIP)/biogas latrine, pit latrine with slab, twin pit/composting toilet, which is not shared with any other household.

TABLE 2
Distribution of household coverage of iodized salt by zones, demographic and socio-economic characteristics in India, India Iodine Survey, 2018–19 (%)

Covariates		Unweighted *N*	Distribution of iodized salt (ppm)					≥15 ppm[1]
			<5 ppm	5 to <15 ppm	15–30 ppm	30–50 ppm	>50 ppm	
All India		21,406	7.6	16.1	41.4	33.1	1.8	76.3
Zone	North	3971	5.5	16.9	35.7	40.8	1.2	77.6
	Central	2403	7.8	16.9	43.5	30.2	1.7	75.4
	East	2401	6.4	20.0	46.6	25.7	1.4	73.7
	North-East	4817	0.6	11.9	46.6	38.4	2.4	87.5
	West	3002	1.3	15.6	47.6	34.6	1.0	83.1
	South	4812	14.8	12.8	33.7	35.6	3.2	72.1
Place of residence	Urban	8311	6.4	10.8	39.6	41.1	2.1	82.9
	Rural	13,095	8.3	19.5	42.6	28.0	1.7	72.2
Social category	SC	4739	7.4	17.6	44.6	29.1	1.3	74.9
	ST	4893	5.4	18.9	43.8	30.4	1.6	75.7
	OBC	5911	6.5	16.3	40.8	34.2	2.2	77.2
	General	5548	10.5	12.7	37.0	37.6	2.1	76.8
	Others	315	4.9	17.3	49.6	25.7	2.5	77.8
Religion	Hindu	14,728	8.0	16.6	41.7	31.9	1.8	75.4
	Muslim	3023	6.4	13.9	40.3	37.3	2.2	79.7
	Christian	2577	6.3	9.7	30.7	49.5	3.9	84.0
	Others	1078	2.6	16.9	45.6	33.5	1.0	80.1
Education	Illiterate	4121	8.6	20.4	42.9	26.5	1.7	71.1
	Below primary	1386	4.8	16.7	46.6	31.1	0.8	78.5
	Primary	2764	7.6	15.9	43.3	31.4	1.8	76.5
	Upper primary	3372	7.8	15.5	41.0	34.2	1.6	76.8
	Secondary school	3934	6.1	14.5	40.0	37.4	2.0	79.4
	Senior secondary	3899	8.3	13.9	37.5	37.9	2.3	77.8
	Graduate	1626	8.4	10.8	41.7	36.5	2.7	80.8
	Postgraduate	304	4.9	13.7	37.2	41.5	2.6	81.3
Wealth quintiles	Lowest	2692	6.9	22.3	45.9	23.3	1.7	70.9
	Second	3657	8.6	16.8	43.6	29.3	1.7	74.7
	Middle	4271	8.9	15.0	41.5	32.4	2.2	76.1
	Fourth	5112	7.5	13.8	39.5	37.2	2.0	78.7
	Highest	5674	6.1	12.9	36.7	42.7	1.6	81.1
Type of salt	Crystal	1676	30.1	20.2	27.6	18.9	3.3	49.7
	Crushed	1243	16.7	40.8	35.0	6.9	0.6	42.7
	Refined	18,487	3.5	13.9	44.0	36.9	1.7	82.6

OBC, Other Backward Class; SC, Scheduled Caste; ST, Scheduled Tribes.
[1] The recommended daily intake of iodine for adolescents (above 12 y) and adults is 150 μg. Considering an average per capita daily salt consumption of 10g, the salt standard is fixed at 15 ppm or 150 mg/1 kg of iodized salt.

this was the case in >29% of households in the lowest wealth quintile nationally. Low coverage of adequately iodized salt was observed among households of scheduled caste, scheduled tribes, individuals with no literacy, and lowest wealth quintile groups. More than 82.61% of households consuming refined salt had ≥15 ppm of iodine (Table 2).

mUIC among WRA

According to the IIS 2018–19, at the national level, the mUIC for PW was 173.4 μg/L, for LW was 172.8 μg/L, and for NPNLW, it was 178.0 μg/L. The mUIC (μg/L) of all the respondent groups was adequate as per WHO guidelines. Across rural and urban regions, only a slight variation was observed, with urban areas having higher mUIC (180.2 μg/L among PW, 178.6 μg/L among LW, and 182.0 among NPNLW) compared to rural areas (168.9 μg/L among PW, 166.6 μg/L among LW and 176.2 μg/L among NPNLW) (see Table 3). Figure 1 depicts the state and UT-wise household coverage of adequately iodized salt in India.

Results of the multiple logistic regression with the concentration of salt iodization as the dependent variable

The multiple logistic regression results revealed that those who reside in urban areas are more likely to consume adequately iodized salt (≥15 ppm). The source of information - public announcements were found to have a positive association with a higher likelihood of iodized salt consumption. There was no significant difference between households in the different wealth quintiles with regard to the likelihood of consuming adequately iodized salt (Table 4).

TABLE 3
Median urinary iodine concentration (μg/L) among pregnant women, lactating women, and nonpregnant, nonlactating women by type of residence, wealth quintile, and zones in India, India Iodine Survey, 2018–19

India /states/UTs	Pregnant women		Lactating women		Nonpregnant nonlactating women	
	Unweighted *n*	Median	Unweighted *n*	Median	Unweighted *n*	Median
All India (Unweighted $n = 21{,}406$)	7140	173.4	7142	172.8	7124	178.0
Type of residence						
Rural	4372	168.9	4359	166.6	4364	176.2
Urban	2768	180.2	2783	178.6	2760	182.0
Wealth quintile						
Lowest	830	169.8	944	157.8	918	164.5
Second	1228	177.0	1219	174.6	1210	170.5
Middle	1481	166.8	1399	175.7	1391	194.5
Fourth	1721	179.1	1678	175.0	1713	185.8
Highest	1880	177.8	1902	176.5	1892	181.5
Zones						
North	1321	171.3	1331	168.9	1319	177.8
Central	802	177.0	801	187.2	800	167.1
East	801	159.2	800	151.5	800	172.8
North-East	1606	165.1	1607	155.1	1604	154.2
West	1000	164.4	1002	155.4	1000	163.7
South	1610	204.2	1601	191.9	1601	213.6

UTs, union territories.
Source: WHO. Urinary iodine concentrations for determining iodine status deficiency in populations. Vitamin and Mineral Nutrition Information System. Geneva: World Health Organization; 2013. Available from https://apps.who.int/iris/bitstream/handle/10665/85972/WHO_NMH_NHD_EPG_13.1_eng.pdf

Results of the quantile regression with the amount of UIC as the dependent variable

In order to understand the relationship between the UIC and iodized salt consumed in the sampled households, we conducted a quantile regression. Quantile regression can be used to compare the entire distribution of a continuous response or a specific quantile of the response between groups. The continuous response considered here is the mUIC among WRA. Performing quantile regression on quantiles across the distribution of urinary iodine allows us to gain a better understanding of the association between iodized salt and urinary iodine, whereas linear regression only informs us about the effect of iodized salt consumption at the mean of urinary iodine (Table 5). The quantile regression results indicate that the reported consumption of adequately iodized salt is significantly associated with higher mUIC ($P < 0.001$). We estimated that the mUIC is 39.2 units higher (95% CI: 33.24–45.15) among those who consumed salt iodized at ≥15 ppm, either pregnant, lactating, or NPNLW, compared to those who consumed iodized salt <15 ppm ($P < 0.001$). The reported consumption of adequately iodized salt is significantly associated with higher UIC at the 75th quantile ($P < 0.001$) as well. We estimated that the 75th quantile of UIC is 46.6 units higher (95% CI; 37.24–55.95) among those who consumed salt iodized at ≥15 ppm compared to those who consumed iodized salt of <15 ppm among all WRA. It varies with the status of the WRA surveyed: PW, LW, and NPNLW. Among PW, we estimated that the mUIC is 42.0 units higher (95% CI: 31.48–52.51) among those who consumed salt iodized at ≥15 ppm compared to those who consumed iodized salt <15 ppm ($P < 0.001$). The reported consumption of adequately iodized salt is significantly associated with higher UIC at the 75th quantile ($P < 0.001$) as well. Among LW, we estimated that the mUIC is 38.1 units higher (95% CI: 28.70–47.49) among those who consumed salt iodized at ≥15 ppm compared to those who consumed iodized salt <15 ppm ($P < 0.001$). The reported consumption of adequately iodized salt is significantly associated with higher UIC at the 75th quantile ($P < 0.001$) as well. Among NPNLW, we estimated that the mUIC is 37.3 units higher (95% CI: 25.97–48.62) among those who consumed salt iodized at ≥15 ppm compared to those who consumed iodized salt <15 ppm ($P < 0.001$). The reported consumption of adequately iodized salt is significantly associated with higher UIC at the 75th quantile ($P < 0.001$) as well. It is evident that iodized salt is a statistically significant predictor of UIC at different quantiles. The sampling errors for the indicator of household availability of iodized salt for all the states and union territories are presented in Table 6.

Discussion

The survey findings indicate that there has been a tremendous improvement in the coverage of iodized salt (with any iodine) from 49% in 1998–99 as per National Family Health Survey (NFHS)-2 [12] to 94.3% in NFHS-5 (2019–21) [13], tested through a qualitative test protocol (rapid spot test kit). As we move from assessing the mere presence of iodine to its adequacy, the household coverage of adequately iodized salt results has started to plateau at around 76 (–78%). This is revealed by 2 of the recent surveys [10,14], tested through iodometric titration, a gold standard for quantitative test protocol. At the sub-national level, states are at different levels of achieving USI, with Jammu and Kashmir and North-Eastern states at 99% and salt-producing states of Andhra Pradesh, Odisha, Rajasthan, and Tamil Nadu at the bottom of the table, with coverage pegged

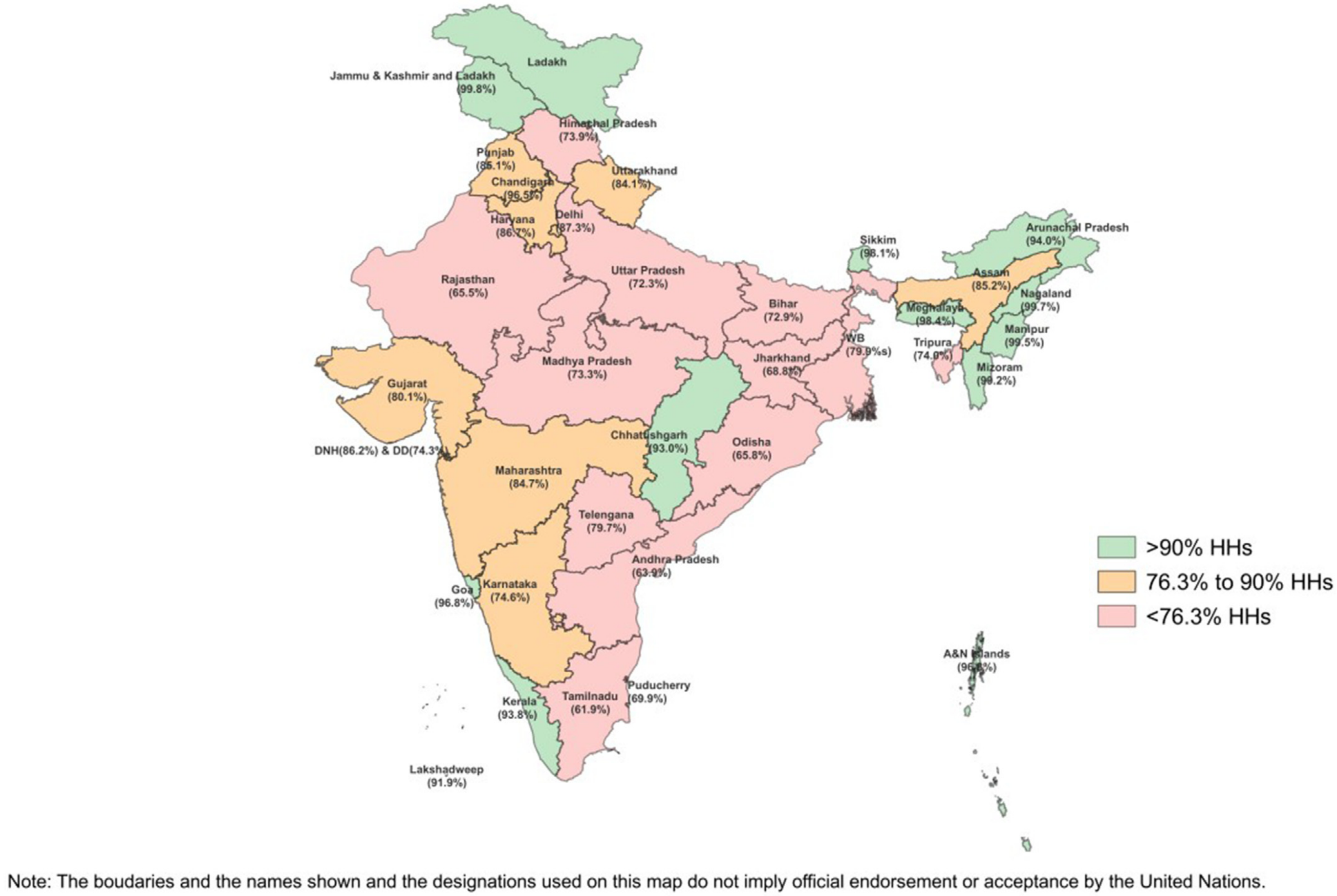

FIGURE 1. Household coverage of adequately iodized salt (≥15 ppm)[1,2] by state/union territories in India, India Iodine Survey, 2018–19 (%). PSU, primary sampling units. [1]The recommended daily intake of iodine for adolescents (above 12 y) and adults is 150 μg. Considering an average per capita daily salt consumption of 10 g, the salt standard is fixed at 15 ppm or 150 mg/1 kg of iodized salt. (https://www.who.int/nutrition/publications/en/idd_assessment_monitoring_eliminination.pdf). [2]Because of some unforeseen circumstances beyond the control of the survey team, the data collection could only be completed in 12 out of 20 PSUs in Jammu and Kashmir state. These 12 PSUs belong to the Kashmir area.

between 61–65%. Similarly, states in the Hindi heartland, such as Uttar Pradesh, Madhya Pradesh, Bihar, and Jharkhand, have lower coverage than the national average.

There has been a change in the consumer preference for packed salt, with 81% of the population preferring refined salt (83% adequately iodized) over other types of salt. Respondents in the salt-producing southern states continue to prefer their traditional crystal salt. Unfortunately, this crystal salt is largely produced by small and marginal salt processors and may not be adequately iodized (49.7% adequately iodized). One potential reason could be that these processors have very limited pricing power to pass on the incremental cost to the consumers.

Improved road infrastructure, combined with higher tonnage carrying capacity of the trucks, has contributed to states in the Hindi heartland and elsewhere being supplied iodized salt through road. This leg of the distribution channel is currently not part of any regulatory monitoring agencies and may be the single most important contributing factor to the supply of non-adequately iodized salt to these states. In 1995, effective road monitoring of the edible salt coming to Madhya Pradesh contributed to the state temporarily achieving USI [15]. Subsequent de-prioritization of the USI program led to a relapse of the adequately iodized salt coverage in the state, dropping from >90% in 1996 to 73.3%, as revealed by the IIS 2018–19.

In September 2018, when the survey described herein was conducted, the standard for minimum iodine content of edible salt was 15 ppm at the retail level, including the distribution channel, and 30 ppm at the production level [16]. This survey found that 34.9% of the salt samples were >30 ppm. In the last 2 y, there have been multiple revisions to the iodine standard, leading to current 15–30 ppm standards at all levels (retail and production). It will be interesting to see whether these changes in standards result would impact on population's iodine nutrition status, considering iodized salt continues to be the primary source of iodine in local diets.

Household coverage of iodized salt was assessed first in NFHS-2 to institutionalize monitoring of the iodine nutrition status of the population. This continued in the subsequent national surveys. As we move to the last mile, the qualitative test protocol (salt tested through Rapid Spot Test Kit) needs to be replaced with iodometric titration, which is the gold standard for quantitative test protocol to assess the adequacy of the iodine in salt. This would help better monitor the iodine nutrition status of the population and prevent relapse, as seen in the case of many countries globally. Also, adopt

TABLE 4
Adjusted OR from a multiple logistic regression of household availability of iodized salt in India, India Iodine Survey, 2018–19

Predictors used in the model	AOR	95% CI of AOR		P value	Significance
n (unweighted) = 21,406		Lower	Upper		
Place of residence					
Rural[ref]					
Urban	1.844	1.298	2.621	0.001	***
Type of salt in the household					
Crushed[ref]					
Crystal	1.617	0.947	2.762	0.078	NS
Refined	9.688	6.259	14.99	0.000	***
Source of information on iodized salt					
No[ref]					
Radio	1.269	0.903	1.784	0.169	NS
No[ref]					
Public announcements	1.872	1.169	2.997	0.009	***
Wealth index					
Lowest[ref]					
Second	1.009	0.720	1.415	0.957	NS
Middle	0.908	0.637	1.294	0.593	NS
Fourth	1.008	0.695	1.462	0.966	NS
Highest	0.784	0.516	1.192	0.255	NS

Dependent variable: Household availability of iodized salt <15 ppm = 0 and ≥15 ppm = 1.
AOR, adjusted odds ratio; [ref]refers to reference category.
P value: ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

programs and policies to factor-in changes such as reduced iodine standard for edible salt, increased consumption of processed food, reduction in salt consumption as preventive guidance for the increased incidence of noncommunication disease, preference for healthy organic/traditional salt, etc.

As we proceed in our effort toward sustaining the gain and achieving USI, there is a need to document what has been working well in high-coverage states and not working in poor-performing states, considering the unique position of each state in the distribution channel. This would help develop state-specific strategies and periodic reviews to improve coverage of adequately iodized salt. Also, these knowledge documents would help address future challenges as we move toward a more liberalized policy environment, such as the closure of the Salt Department, a dedicated agency to provide 1-stop support to the industry for regulatory compliance, monitoring, and training. With the FDA burdened with ensuring compliance with all food articles, the closure would leave it to the market forces to ensure the salt is adequately iodized. This would be more challenging as iodine in salt is not the preferred indicator for the consumer to purchase salt, and they don't have any tools to test it either. Lately, there has also been an increased preference for non-iodized salts, such as rock salt and organic salt, positioned as "healthy salt" and sold as "proprietary food."

The survey data shows that 13 states/UTs have achieved USI, and so it is recommended that the successful strategies from these states could be contextualized and replicated in the remaining states/UTs to achieve and sustain USI nationally. The findings suggest the following way forward: *1*) Enforcement and monitoring of iodized salt quality could be reprioritized by government agencies at the state level; *2*) Inclusion of estimation of UIC at national surveys as an indicator to report the iodine status of the population along with household coverage of adequately iodized salt tested through iodometric titration could be considered by the

TABLE 5
Model estimates from a quantile regression of urinary iodine concentration among pregnant, lactating, nonpregnant, nonlactating women of reproductive age in India, India Iodine Survey, 2018–19

Predictor used in the model	Linear regression mean	P value	25th quantile (Q1)	P value	50th quantile (Median)	P value	75th quantile (Q3)	P value
N (unweighted) = 21,406								
Intercept	178.33		74.80		137.20		242.10	
Household availability of iodized ≥15 ppm	40.34 (30.30–50.38)	0.00***	26.4 (22.27–30.52)	0.00***	39.2 (33.24–45.15)	0.00***	46.6 (37.24–55.95)	0.00***
Pregnant women n (unweighted) = 7140								
Intercept	169.27		70.00		128.90		236.00	
Household availability of iodized ≥15 ppm	35.62 (27.09–44.16)	0.00***	28.4 (21.84–34.95)	0.00***	42.0 (31.48–52.51)	0.00***	49.1 (32.53–65.66)	0.00***
Lactating women n (unweighted) = 7142								
Intercept	171.25		72.50		134.60		237.80	
Household availability of iodized ≥15 ppm	32.98 (24.61–41.35)	0.00***	28.4 (21.41–35.38)	0.00***	38.10 (28.70–47.49)	0.00***	40.60 (24.38–56.81)	0.00***
Nonpregnant and nonlactating women n (unweighted) = 7124								
Intercept	183.50		85.70		150.60		254.70	
Household availability of iodized ≥15 ppm	36.41 (26.72–46.09)	0.00***	19.70 (12.03–27.36)	0.00***	37.30 (25.97–48.62)	0.00***	48.40 (30.85–65.94)	0.00***

Dependent variable: Urinary Iodine Concentration. Independent variable: Household availability of iodized salt <15 ppm = 0 and ≥15 ppm = 1
P value: ***$P < 0.01$, **$P < 0.05$, *$P < 0.1$.

TABLE 6
Sampling errors of household availability of iodized salt in India and states/union territories for salt iodized at ≥15 ppm and 15 ppm to 30 ppm, India Iodine Survey, 2018–19

India/states/UTs	Value (*r*) Proportion of household availability of iodized salt (≥15 ppm)	SE	Relative SE (SE/r)	95% CI		Value (*r*) Proportion of household availability of iodized salt (15–30 ppm)	SE	Relative SE (SE/r)	95% CI	
				Lower	Upper				Lower	Upper
All India	0.7633	0.0112	0.0146	0.7407	0.7845	0.4140	0.0100	0.0243	0.3945	0.4339
Andaman and Nicobar Islands	0.9685	0.0111	0.0114	0.9379	0.9843	0.3100	0.0494	0.1594	0.2220	0.4142
Andhra Pradesh	0.6389	0.0598	0.0937	0.5153	0.7465	0.4169	0.0431	0.1033	0.3355	0.5031
Arunachal Pradesh	0.9404	0.0147	0.0156	0.9042	0.9635	0.5140	0.0601	0.1170	0.3973	0.6291
Assam	0.8519	0.0216	0.0254	0.8043	0.8896	0.5531	0.0153	0.0276	0.5229	0.5829
Bihar	0.7289	0.0415	0.0570	0.6402	0.8024	0.4738	0.0459	0.0968	0.3855	0.5637
Chandigarh	0.9647	0.0085	0.0088	0.9435	0.9781	0.2971	0.0266	0.0897	0.2476	0.3520
Chhattisgarh	0.9298	0.0135	0.0145	0.8982	0.9521	0.5732	0.0225	0.0392	0.5286	0.6167
Dadar and Nagar Haveli	0.8622	0.0292	0.0338	0.7944	0.9102	0.4676	0.0349	0.0747	0.4001	0.5363
Daman and Diu	0.7426	0.0356	0.0480	0.6667	0.8063	0.3563	0.0465	0.1304	0.2710	0.4517
Delhi	0.8726	0.0420	0.0481	0.7654	0.9350	0.2811	0.0388	0.1380	0.2115	0.3631
Goa	0.9681	0.0114	0.0118	0.9363	0.9843	0.6633	0.0568	0.0856	0.5447	0.7644
Gujarat	0.8014	0.0354	0.0442	0.7228	0.8620	0.4817	0.0370	0.0768	0.4100	0.5542
Haryana	0.8672	0.0179	0.0206	0.8280	0.8986	0.3832	0.0351	0.0915	0.3171	0.4539
Himachal Pradesh	0.7390	0.0456	0.0617	0.6403	0.8183	0.3739	0.0479	0.1280	0.2856	0.4715
Jammu and Kashmir	0.9982	0.0018	0.0018	0.9873	0.9998	0.0233	0.0136	0.5838	0.0073	0.0716
Jharkhand	0.6884	0.0536	0.0779	0.5749	0.7830	0.4157	0.0441	0.1060	0.3326	0.5039
Karnataka	0.7460	0.0418	0.0560	0.6558	0.8192	0.4118	0.0319	0.0775	0.3508	0.4755
Kerala	0.9381	0.0172	0.0184	0.8944	0.9645	0.2737	0.0345	0.1261	0.2114	0.3464
Lakshwadeep	0.9192	0.0168	0.0183	0.8796	0.9466	0.3448	0.0416	0.1206	0.2683	0.4303
Madhya Pradesh	0.7326	0.0380	0.0519	0.6517	0.8004	0.4052	0.0287	0.0709	0.3503	0.4626
Maharashtra	0.8472	0.0287	0.0339	0.7819	0.8955	0.4691	0.0404	0.0862	0.3911	0.5486
Manipur	0.9954	0.0026	0.0027	0.9858	0.9985	0.1366	0.0217	0.1591	0.0992	0.1851
Meghalaya	0.9843	0.0072	0.0073	0.9619	0.9936	0.2734	0.0651	0.2382	0.1651	0.4173
Mizoram	0.9919	0.0047	0.0048	0.9747	0.9974	0.0153	0.0077	0.5047	0.0056	0.0407
Nagaland	0.9970	0.0029	0.0029	0.9799	0.9996	0.2802	0.0576	0.2056	0.1818	0.4054
Odisha	0.6583	0.0654	0.0994	0.5212	0.7733	0.5206	0.0615	0.1182	0.4009	0.6380
Puducherry	0.6992	0.0302	0.0432	0.6368	0.7551	0.2858	0.0301	0.1053	0.2305	0.3483
Punjab	0.8512	0.0374	0.0439	0.7622	0.9108	0.4084	0.0387	0.0948	0.3351	0.4860
Rajasthan	0.6546	0.0495	0.0756	0.5522	0.7444	0.3959	0.0284	0.0718	0.3416	0.4528
Sikkim	0.9814	0.0062	0.0063	0.9643	0.9904	0.4438	0.0487	0.1097	0.3514	0.5403
Tamil Nadu	0.6190	0.0632	0.1021	0.4898	0.7333	0.2357	0.0360	0.1528	0.1724	0.3134
Telangana	0.7974	0.0479	0.0601	0.6874	0.8757	0.3355	0.0394	0.1176	0.2629	0.4168
Tripura	0.7400	0.0314	0.0424	0.6738	0.7968	0.4514	0.0262	0.0581	0.4006	0.5032
Uttar Pradesh	0.7233	0.0368	0.0508	0.6458	0.7895	0.4220	0.0242	0.0573	0.3753	0.4700
Uttarakhand	0.8410	0.0381	0.0454	0.7513	0.9025	0.4214	0.0699	0.1660	0.2931	0.5612
West Bengal	0.7994	0.0302	0.0378	0.7336	0.8523	0.4516	0.0422	0.0935	0.3708	0.5351

UTs, union territories.

Ministry of Health and Family Welfare, Government of India; *3*) The survey also reveals that a larger proportion of refined salt is adequately iodized and hence efforts are needed to promote production and consumption of refined iodized salt.

Limitations of the study

The limitation of the survey was that it was powered to provide data at the state level for household coverage and data at the zonal level for mUIC, considering the budget available for the same. Further, we did not investigate the alternate sources of iodine in the diet and the quality of salt consumed by the household (through sodium intake).

In conclusion, the survey findings provide significant insights that have the potential to impact policy and influence government programs to reduce IDD across the country, with emphasis on UTs and states with the lowest mUIC and/or salt iodization concentrations. We are certain that the results of this survey will be widely used for strengthening the salt iodization program in India and will reinforce the discussions and efforts among various stakeholders, including government, academia, industry, development partners, and media.

Further, the findings would be used to develop actionable strategies to improve regulatory monitoring of iodized salt as it moved from production units to retail points, create a conducive policy environment for the production and consumption of refined salt and conduct formative research to understand the role of small-scale salt producers in the supply chain, to develop an inclusive approach to mainstream them and ensure that they produce adequately iodized salt.

Implementation research, including qualitative formative research, process evaluation, and outcome evaluation of the salt iodization program, is recommended to be done for a better understanding of the evolving landscape and contributory factors for better program management.

Lastly, for regular tracking of the progress of salt iodization and UIC in the population, it should be included in the regular demographic and health surveys like NFHS in India, which can provide estimates sub-nationally, up to the district level regularly for program and policy improvement.

We, with all these efforts, would contribute to the scale-up of sustainable efforts to achieve USI, which will then lead to the reduction in and elimination of IDD as we tread the path toward reaching the last mile to achieve and sustain USI in the country.

Funding

This work was undertaken with the financial support of the Government of Canada through Global Affairs Canada (GAC).

Author contributions

The authors' responsibilities were as follows– MKR, JCR, and RKJ: conducted the literature review; MKR conceptualized the data analytical framework; MKR: conducted the multivariable logistic regression and quantile regression analyses;and JCR: carried out the cross tabulations; MKR: wrote the abstract, introduction, and methods; interpreted the data and wrote the findings section and critically revised the article; RKJ: wrote the discussion and conclusions sections; JCR: organized the references and all authors: read and approved the final manuscript.

Conflict of Interest

The authors report no conflicts of interest.

Data availability

The data is from a pan India survey, which can be made available on request based on certain required permissions.

Acknowledgments

We thank all the stakeholders – national and state governments, development partners, academic experts, and researchers, who contributed to making this survey a success. They have played a critical role in the development of this study, and we look forward to continuing our collaboration with them to achieve and sustain USI and to shape the future of the IDD control program in the country. We also thank all the survey participants and respondents who have dedicated their time and consented to provide requisite details and samples for the successful completion of the study.

References

[1] B.S. Hetzel, Iodine deficiency disorders (IDD) and their eradication, Lancet 322 (8359) (1983) 1126–1129, https://doi.org/10.1016/S0140-6736(83)90636-0.

[2] N. Bleichrodt, M.Ph. Born, A meta-analysis of research on iodine and its relationship to cognitive development, in: J.B. Stanbury (Ed.), The damaged brain of iodine deficiency, Cognizant Communication Corporation, 1996, pp. 195–200.

[3] UNICEF, Sustainable Elimination of Iodine Deficiency Progress since the 1990, in: World Summit for Children, UNICEF, 2008. Available from: https://data.unicef.org/resources/sustainable-elimination-of-iodine-deficiency/. (Accessed 1 August 2022).

[4] S. Horton, The economic impact of micronutrient deficiencies, 2004, https://doi.org/10.1159/000080611.

[5] W. Tafesse, The causal effect of iodised salt consumption on children's height in rural India, Centre for Health Economics, University of York, Heslington, York. UK, 2018, p. 5DD Available from: https://www.isid.ac.in/~epu/acegd2018/papers/WiktoriaTafesse.pdf. (Accessed 1 August 2022).

[6] W. Tafesse, The effect of mandatory iodine fortification on cognitive test scores in rural India, 2018. Available from: SSRN: https://ssrn.com/abstract=3170585, http://dx.doi.org/10.2139/ssrn.3170585.

[7] C.S. Pandav, K. Yadav, R. Srivastava, R. Pandav, M.G. Karmarkar, Iodine deficiency disorders (IDD) control in India, Indian J. Med. Res. 138 (3) (2013) 418–433. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3818611/pdf/IJMR-138-418.pdf. (Accessed 1 August 2022).

[8] The Jammu and Kashmir reorganisation act, 2019. Available from: https://egazette.nic.in/WriteReadData/2019/210407.pdf. (Accessed 1 August 2022).

[9] The States reorganisation act, Government of India, 1956. Available from: https://legislative.gov.in/sites/default/files/A1956-37.pdf. (Accessed 1 August 2022).

[10] C.S. Pandav, K. Yadav, H.R. Salve, R. Kumar, A.D. Goel, A. Chakrabarty, High national and sub-national coverage of iodised salt in India: evidence from the first National iodine and Salt Intake Survey (NISI) 2014-2015, Public Health Nutr 21 (16) (2018) 3027–3036. Available from: https://www.cambridge.org/core/services/aop-cambridge-core/content/view/88F4E20287003460F4C8E2A664C30A71/S1368980018002306a.pdf/div-class-title-high-national-and-sub-national-coverage-of-iodised-salt-in-india-evidence-from-the-first-national-iodine-and-salt-intake-survey-nisi-2014-2015-div.pdf.

[11] Food safety and standards act, 2006. Available from: https://www.fssai.gov.in/upload/uploadfiles/files/Food_Additives_Regulations.pdf. (Accessed 1 August 2022).

[12] International Institute for Population Sciences (IIPS) and ORC Macro, National Family Health survey (NFHS-2), 2000, pp. 1998–1999.

[13] India, Mumbai: IIPS. International Institute for Population Sciences (IIPS) and ICF, in: National family health survey (NFHS-5), 2019-India: Volume I, IIPS, Mumbai, 2021.

[14] India iodine survey 2018-19. Available from: https://www.nutritionintl.org/wp-content/uploads/2021/06/India-Iodine-Survey-2018-19-final-report.pdf. (Accessed 1 October 2022).

[15] WHO, First Meeting of the Regional Working Group for IDD Elimination, A report WHO/SEARO, New Delhi, India, 2005, p. 16. Available from: http://apps.who.int/iris/bitstream/handle/10665/205114/B0154.pdf?sequence=1.

[16] Food safety and standards (labelling and display), Regulations, 2020. https://www.fssai.gov.in/upload/uploadfiles/files/Compendium_Food_Additives_Regulations_08_09_2020-compressed.pdf. (Accessed 1 August 2022).