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Universal Salt Iodization: Is it a Double Edged Sword?

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Abstract

Background: Iodine deficiency disorders (IDD) was once a major public health problem when emerged need of Universal Salt Iodization (USI). A legitimate balance between deficient or excess intake is crucial as higher iodine levels are precarious to health. This study aims to evaluate the adequacy of iodine intake by assessing the prevalence of goiter and measuring the Urinary Iodine Excretion (UIE) among school going children in Chhindwara district, Madhya Pradesh.

Material and methods: A cross-sectional study with 30 cluster sampling was conducted among school-going children (6-12 years). Total of 2700 children were selected for assessing Total Goiter rate (TGR). Also 540 salt samples and 270 urine samples were collected to estimate salt iodine content from house-hold and UIE respectively.

Results: The TGR was 0.6% with prevalence of Grade I&II was 0.5% and 0.1% respectively. The median UIE level was 167 mg/L. One fifth of the population had suboptimal UIE, 33.7% population had adequate iodine nutrition and 51.6% population had either more than adequate or near about toxic levels of Iodine.

Conclusion: We conclude that the Chhindwara is non-endemic for IDD. More worrisome now is the threat posed by USI that may lead into undue excess consumption of the mineral.

Keywords: Iodine; Children; Goitre; Urine iodine excretion

Introduction

Iodine is an essential micronutrient required for the crucial functions of reproduction and growth. It's an essential element for synthesis of thyroid hormone (TH), the one with pleiotropic effects, affecting multiple biological processes [1]. Successful pregnancy and continued normal development of new-borns and infants are among the most important health outcomes. Unlike nutrients such as iron, calcium or the vitamins, iodine does not occur naturally in specific foods; rather, it is present in the soil and is ingested through foods grown on that soil. The mainstay of iodine intake is *via* consumption of foods that have been fortified with iodine, including salt, dairy products and bread, or naturally abundant sources like seafood [2]. Suboptimal intake results into a gamut of disorders.

The spectrum of iodine deficiency does not recognize geographical boundaries as was earlier thought. Hence emerged the need to gear up the efforts to encounter iodine deficiency universally. Salt was recognised to be a commendable option for introducing iodine into daily dietary intake [3]. The strategy of Universal salt iodization (USI), the iodization of all salt consumed by humans, proven to be highly cost effective and fortress iodine deficiency prevention efforts worldwide. A country is said to have achieved USI when at least 90% of households consumed adequately iodised salt (≥ 15 ppm) [4]. USI contributes significantly to tackle the world's disease and mortality burden [5,6].

Around 3-4 billion people in the world are covered by iodine supplementation programs to prevent developmental brain damage and other iodine deficiency (ID) disorders [7]. With the initiative of the Government of India, Universal Salt Iodization (USI) programme was started in 1989 and as a result the prevalence of iodine deficiency disorders decreased considerably [8]. The Prevention of Food Adulteration Act, Government of India was amended to ban the sale of un-iodized salt for human consumption with effect from May 17, 2006 [9]. Meanwhile, despite the impressive progress with regards to the provision of iodised salt, any excess intake should be restrain as surplus of this nutrient in body has its own detrimental effects [2].

Higher iodine levels are precarious to health like impaired thyroid function [10,11]. Exposure to excessive iodine through foods, dietary supplements, topical medications, and/or iodinated contrast media has resulted in thyroiditis, goiter, hypothyroidism, hyperthyroidism, sensitivity reactions, or acute responses for some individuals. Studies have also shown that excessive iodine intakes cause thyroiditis and thyroid papillary cancer [12]. The biological basis for IIH appears most often to be mutational events in thyroid cells that lead to autonomy of function. IIH may also occur with an increase in iodine intake in those whose hyperthyroidism was masked because of iodine deficiency. The risks of IIH may be more vital to the elderly with cardiac co-morbidities, and to those who live in regions where there is limited access to medical care [13]. Conclusive evidences exist favouring iodine induced hyperthyroidism (IIH) following introduction of iodised salt [14]. Even a recent (as short as 2 years) excessive intake of iodine through salt has posed the risk of IIH in few severely iodine deficient countries [15]. Also, the risk of deranged thyroid function following mandatory salt iodisation has been shown in varied population of different age groups adding to the susceptibility [16,17]. For this reason, any surplus futile consumption should be averted.

Overall iodine levels cannot be reliably measured in individuals given the considerable day to day variation in iodine intake. Instead, median urinary iodine concentrations (UIC) have been widely used as a biomarker of population iodine intake, with levels >300 mcg/l considered excessive in both, children and adults [2]. Also, as Thyroid size measurement reflects a population's history of iodine nutrition, but not present iodine status, urinary iodine is a sensitive indicator of recent iodine intake, since most of the iodine that is absorbed is excreted in the urine [18].

It's crucial to strike a legitimate balance between deficient or excess Iodine intake. With the following background it seems essential to assess the endemicity of the districts labelled as endemic for iodine deficiency as well as to assess excess intake, if any, in the population imposed by USI. The aim of the present study was to evaluate the adequacy of iodine intake by assessing the prevalence of goiter and measuring the UICamong School going children (6-12 years of age) in Chhindwara district, Madhya Pradesh, a goitre endemic district. Investigators also planned the survey to identify levels of iodine in salt consumed at the household level and interview the households and shopkeepers for awareness about salt iodization in the study area.

Material and Methods

Study site

Study was conducted in Chhindwara district of Madhya Pradesh. It is located in the south-central part of Madhya Pradesh. The district covers an area of 11,815 km^2 with a population density of 177 km^2. It stands first in rank in terms of area within the state. It is divided into 11 administrative blocks and has a total of 1965 villages. It caters a total population of 2,090,922 with literacy rate of 71.16%.

Study population and period of study

The study was conducted from June to July 2016 among school-going children aged 6-12 years, in Chhindwara district of Madhya Pradesh.

The study participants were school children in 6-12 years of age, A list of all government primary schools in Mandla district was obtained. Thirty government primary schools were selected by using the probability-proportional-to-size cluster sampling. All eligible children in the studied sample were included in the study.

The sample size was calculated considering the prevalence of goiter among school children in Baigachak area in Dindori district of Madhya Pradesh as 20% [19] assuming an alpha error of 0.05 and precision of 2.5%; the required sample size would be 2560. Assuming a non-response rate of 5%, the sample size would be 2688. Rounding off the value to nearest hundreds, a total of 2700 students were studied.

Study design: It was a cross sectional study.

Sampling method and sample size

- **Clinical goiter survey:** A sample of 30 clusters (school) was selected from the district byusing the 'probability proportionate to size' sampling technique. A sample of 90 children (45 boys and 45 girls) of age group 6-12 years was selected from each cluster. Thus a total of 2700 (90 × 30) children were examined for goiter in the district. The children were clinically examined for goiter by technical persons specially trained for the survey.
- **Salt samples:** Every 5th child, selected from the sample of 90 children in the earlier step for goiter survey, was covered for collection of salt sample by visiting his/her corresponding house. Therefore, 18 salt samples were collected from each cluster, making a total of 540 (18 × 30) salt samples for estimation of iodine level in the district. These salt samples were tested qualitatively on spot with field testing kit and iodine concentration was recorded.
- **Urine samples:** On the spot urine samples were collected from every alternate child out of those 18 selected children in the previous step. Total nine urine samples were henceforth collected for estimation of UIE level from each cluster and a total of 270 (9 × 30) urine samples were collected for estimation of UIE in the district. Iodine concentration was determined by wet digestion method i.e. Sandell Kolthoff reaction.
- **Qualitative phase:** Total 150 households and 30 shopkeepers were interviewed with the help of pre-designed semi-structured interview guide to understand the knowledge and practices on iodized salt during house visit to collect the salt samples.

Data collection and variables

Data collection was done using a structured, pretested questionnaire in local language of study population i.e. Hindi. The information about independent was obtained by interview of child by visiting the selected schools. The information was validated during house-holds visit and during interview with shopkeepers regarding USI. The assessment of goiter and its grading was done through clinical examination by technical trained survey staff. On the spot urine sample was collected from selected child at school for assessment of UIE. The sample of salt was obtained for biochemical estimation of iodine by visiting the corresponding house of selected child.

Analysis and statistics

Data was collected using a structured proforma and entered in Microsoft Office Excel 2010 and Quantitative analysis was done using software SPSS 21. The UIE >200 mcg/L was considered as 'excess Urine Iodine Excretion' and <15 ppm of Iodine in house-hold salt was considered as house-hold with 'inadequate iodized salt' [20,21].

Ethics approval

Ethics approval was obtained from the Institutional Ethics Committee of the All India Institute of Medical Sciences, Bhopal, India. The written informed consent was obtained from children and ascent from their legal guardians after explaining them the purpose of the following study.

Results

A total of 2700 primary school children aged 6-12 years from 30 different clusters were examined for TGR. The total goiter prevalence rate was found to be 0.6% with prevalence of Grade I and II was 0.5% and 0.1% respectively. No significant difference (p-value >0.05) was found in TGR amongst the male (0.6%) and female (0.5%). Analyzing goiter prevalence against age and grading of goitre is as shown in Table 1.

Out of 11 blocks in the district, Parasiya block (2.5%) had highest TGR while 6 blocks had no goiter as assessed on clinical examination (Table 2).

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Goiter grade	Age of children (Years)						
	6 Yrs.	7 Yrs.	8 Yrs.	9 Yrs.	10 Yrs.	11 Yrs.	12 Yrs.
Grade 0	510 (99.0%)	470 (99.2)%	318 (99.7%)	360 (99.4%)	388 (100.0%)	362 (99.5%)	276 (99.3%)
Grade 1	4 (0.8%)	4 (0.8%)	1 (0.3%)	2 (0.6%)	0	1 (0.3%)	2 (0.7%)
Grade 2	1 (0.2%)	0	0	0	0	1 (0.3%)	0

Table 1: Age-specific number and percentage of children examined for goiter in chhindwara district.

Sl. No	Blocks	Prevalence (%)		TGR (%)
		Grade I	Grade II	
1	Amarwara	0.8	0	0.8
2	Bichhua	0	0	0
3	Chhindwara	0	0	0
4	Chouri	0	0	0
5	Harrai	0	0	0
6	Junnardev	0.6	0	0
7	Mohkhed	0.6	0	0
8	Pandhurna	0.6	0	0
9	Parasiya	1.9	0.6	2.5
10	Sausor	0	0	0
11	Tamia	0	0	0

Table 2: Block level prevalence of goiter and distinct grading in Chhindwara district.

Out of total analyzed 267 urine samples of the children studied, the Median UIE level was 167 mcg/L. On UIE level analysis, 33.7% of the children had adequate urine iodine concentration, about 20% children had sub-optimal urine iodine concentration while 51.1% children had excess urine iodine concentration. Out of 51.1% children with more than adequate urine iodine concentration, 28.8% of children had UIE ≥ 300 mcg/L (Table 3.)

Total 94.4% of the surveyed house-holds were consuming adequate Iodised salt i.e. iodine content ≥ 15 ppm. Out of 150 households interviewed, majority (72.6%) were acquiring the edible salt from public distribution system (PDS) while a small proportion (27.4%) rely on local retail shops. Besides, all the samples from PDS were adequately iodized as per the consumption levels cut off, whereas 20% of the samples bought from retail shops did not suffice in terms of iodine levels at consumption levels. Although only 8 out of 150 samples were not packed but interestingly, 3% of the packed salt samples and 3 out of 8 loose samples were inadequately iodized (<15 ppm). Majority (89%) of the households had correct storage practice for edible salt that is using a closed container. But besides all these practices to our surprise only 36% of the surveyed households were actually aware of the benefits of salt iodization. We interviewed 30 shopkeepers from local retail shops and found that only about 67% of them were aware about benefits of salt iodization (Table 4).

Urinary iodine excretion levels (mcg/L)	Number	Percentage	Iodine status*
<20	1	0.4	Severe iodine deficiency
20-49	6	2.2	Moderate iodine deficiency
50-99	32	12	Mild iodine deficiency
100-199	90	33.7	Adequate iodine nutrition
200-299	61	22.8	May pose a slight risk of more than adequate iodine intake
≥ 300	77	28.8	Risk of adverse of health consequences
* WHO/NMH/NHD/EPG/13.1			

Table 3: Urinary iodine excretion levels in the study population (n=267).

	Source of Edible Salt in household survey	Iodine Content		Total
		<15 PPM	≥ 15 PPM	n (%)
	PDS n (%)*	0 (0)	109 (100)	109 (72.6)
1	Local Retail Shop n (%)*	8 (19.5)	33 (80.5)	41 (27.4)

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	Type of Salt packaging			
	Packed n (%)*	5 (3)	137 (97)	142 (94.6)
2	Loosen (%)*	3 (37.5)	5 (62.5)	8 (5.4)
	Storage practices in household			
	Closed Container (%)*	5 (3.7)	129 (96.3)	134 (89.3)
3	Open Container (%)*	3 (18.8)	13 (81.2)	16 (10.7)
4	**Iodine levels**	8 (5.3)	142 (94.7)	
	Knowledge about benefits of Iodized Salt:			
	Household level: (N=150)			
	Yes	54 (36)		
	No	96 (64)		
	Shopkeepers: (N=30)			
	Yes	20 (66.7)		
5	No	10 (33.3)		
# Percent depicted is column wise.				
* Percent depicted is row wise				

Table 4: Distribution of edible salt and Iodine content of salt sample in household survey/Retail shop and knowledge about benefits of iodized salt.

Discussion

As per the data released by MoHFW in revised policy guideline of NIDDCP (2006), Chhindwara district was classified to be endemic for IDD in Madhya Pradesh (MP). However, our study found the TGR in this district (0.6%) to be well below the level of endemicity (TGR >5%) hence district of Chhindwara is no more endemic for IDD [21]. Also, out of the very few goiter cases we found in the study majority were of grade I (87.5%), that is indicating subsiding severity. In past 10 years, there were no published studies to reassess goiter prevalence in Chhindwara district. A similar study form a nearby district found the TGR of 2.4% in the similar study population [22]. While Shinde et al. in a recent study from another district in the state reported much higher goitre prevalence (21.23%) among school-going children [23]. Similarly, recently Sinha et al. from Rajnandgaon district of Chhattisgarh proclaimed TGR in school going children as 17.56% i.e. highly endemic [24]. Hence, a better representative data on the national and subnational level is recommended, and more so after years of USI, to clearly depict IDD status.

In this cross-sectional study, we found the median UIC of children aged 6-12 years, using spot morning urine samples to be 167 mg/l. showing adequate iodine intake by the study population. Besides, 51.6% of the population had UIE above the levels of adequacy, which may jeopardize the benefits of USI. Among the population found to have more than adequate iodine intake, majority had an excess iodine intake at the toxic level (≥ 300 mcg/L) which may lead to adverse health consequence. About 15% population had sub-optimal Iodine nutrition. So, the major challenge for the programme will now be to bring both the section of the population ("deficient iodine nutrition" group and "more than adequate iodine nutrition" group) into "adequate iodine nutrition" category. Currently, only 33.7% of population had adequate iodine nutrition (100-199 mcg/L) as per their UIE, rest either had low or high levels well beyond the range of adequacy.

Presently, there is no national data on the iodine status of the population based on urinary iodine concentration (UIC), although a number of small-scale surveys have been carried out. The most recent weighted estimate pooled from subnational surveys indicated that the median UIC of the population was 154 mcg/L and that 34% of Indians had UIC in the range of 100-199 mcg/L [25].

Our results are in much agreement with Dilshad et al. from Iran (median UIC 161 mcg/L) who had a much larger sample size (n=18000) [26]. A study from Nepal, had reported similar levels. The median UIE was found to be 157.1 μg/L and 180.3 μg/L in two districts [27]. However, another study from the country in two districts found the median inter-quartile range (IQR) of urinary iodine as 214.04 μg/L (n=63) and 252.34 μg/L (n=91) [28,29]. These results from the neighbouring country are in much harmony with ours but have a much smaller sample size hence more representative sample need to be assessed.

In a similar study population from the district of Dahod, Gujrat, the median urinary iodine level was found to be 115 μg/dl [30]. Notably, Marwaha et al. from Delhi studied 997 school children, from upper socio economic strata, and found the median UIE in these children to be as low as 35.28 μg/dL [31]. These findings, although clearly distinct from ours, may be due to use of different estimation procedures.

Studies from adult population on iodine supplementation, too has shown much higher median UIC, in the range consistent with Iodine toxicity and found to have thyroid dysfunction [2,31]. Recent study from Tamilnadu, India in goitrous children of same age group, found a possible association between increased iodine intake and autoimmune thyroiditis aiding our results [32].

There are incidences of increase in thyrotoxicosis following periods of mandatory salt iodization, compared with when supplementation was not required, in both Spain and Zimbabwe [33,34]. However, a study from Bangladesh in a hyper-endemic iodine deficient area, shows that mandatory mass iodination of table salt consumption was found to be safe and does not cause any side effect [35]. So the long-term benefit and the safety of iodine supplementation is still questionable, especially when the levels of endemicity varies among region. A recent review from India provided a track of iodine consumption coverage reflecting the ups and downs hence any such disparity should always be cling to while questioning the adequacy or toxicity [36].

Moreover, a national level survey indicate a clear urban-rural and rich-poor differential in salt iodization, with better coverage of adequately iodized salt in urban areas and richer wealth quintile, leaving the most disadvantaged one vulnerable to IDDs. But contrasting the above, the present study pose the picture from a rural tribal district showing more than adequate consumption reaching the levels of toxicity, although findings are restricted to a particular age group [37]. Thus, widespread coverage surveys need to be implemented to clarify the vivid picture of iodine consumption.

The risks and benefits of providing iodized salt in areas with excessive iodine intake from other sources must also be carefully assessed. Additional research is needed to determine whether the small increase in iodine intake from iodized salt would substantially increase this risk. It is suggested that if the iodine level in salt is carefully controlled at 20 ppm, the contribution to the urinary iodine level would be about 100 μg/L/day and is unlikely to be detrimental [10]. However, policies to ensure that only iodized salt reaches iodine-deficient areas and only non-iodized salt reaches areas with iodine excess can be hard to implement and are likely to be confronted at production, distribution or consumption levels.

But as the response to Iodine also varies by life stages, and as seen several other factors govern the availability of iodine in the salt at consumer levels, hence consideration should be about all such issues before averting the strategy of USI [38-40].

Conclusion

The study concludes that the Chhindwara district is non-endemic for IDD. Although National Iodine Deficiency Disorder Control Programme (NIDDCP) has been very effective in reducing the goiter prevalence, more worrying situation is now the threat posed by USI that may lead into undue consumption of the mineral resulting into toxicity. Approximately 20% population is having 'Iodine deficiency' but at the same time approximately 51% population has either 'more than adequate iodine intake' or 'toxic level of iodine'.

We recommend, apart from routine activities under NIDDCP, strict implementation of monitoring and evaluation surveys to assess not only IDDs but also for Iodine-induced hyperthyroidism at regular interval in the district. Reduction of TGR to less than 5% in school children indicates successful elimination of IDD as a major public health problem but need of the hour is to plan more comprehensive surveys to monitor the adverse effects of surplus intake of Iodine in our population as the chance might be based on existing evidences. Unmasking these factors in early stages may withhold any alarming situation. Further research is advocated to generate evidences determining the toxic implications of excess intake of Iodised salt as it may warrant the legislation review. Parallel, strict quality control and monitoring of salt iodine levels need to be imposed to verify that no laxity has crept in at the production or importer level.

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Conflict of Interest and Funding Disclosure

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