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ORIGINAL ARTICLE

Iodized Salt Consumption and its Association with Intelligence Quotient (IQ) Among 6–12 years Age Group Children in Bihar

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Abstract

Objectives To estimate the proportion of households using adequately iodized salt, total goitre rate and intelligence quotient (IQ) and to assess association, if any, between consumption of iodized salt and intelligence quotient of children aged 6–12 y in the selected districts of Bihar.

Methods Community based cross-sectional study was conducted in three districts of Bihar by using cluster sampling technique.

Results Consumption of iodized salt was 73.5% out of 1263 households surveyed and the prevalence of goitre among children was 2.9%. The mean IQ of study population was 82.6 and it was 9 points lower in children consuming inadequately iodized salt in comparison to children consuming adequately iodized salt. Presence of goitre, inadequately iodized salt consumption and increasing age were the factors which were significant predictors of low IQ level.

Conclusions The prevalence of goitre has declined from the past but the target of iodized salt consumption has not yet achieved in these districts. This study reinforces the belief that IQ in children is linked to iodine.

Keywords Iodized salt consumption · Total goitre rate · Intelligence quotient (IQ) · Bihar

Introduction

Micronutrient deficiencies are also known as "hidden hunger" and it forms a significant component of burden of malnutrition worldwide, more so in developing countries like India. Deficiencies of iodine, iron, folic acid, zinc and vitamin A are the five leading causes of micronutrient deficiencies which constitute a global public health problem [1]. The spectrum of iodine deficiency disorders (IDD) includes goitre, cretinism, hypothyroidism, brain damage, abortion, still birth, mental retardation, psychomotor defects and hearing and speech impairment [2]. Most consequences of IDD are invisible and irreversible but at the same time preventable. Iodine deficiency disorders (IDD) are estimated to result in loss of 2.5 million disability adjusted life-years (DALYs) (0.2% of total) globally [3].

The association between dietary iodine deficiency and poor mental and psychomotor development is well known. Intelligence has been defined in many different ways including abstract thought, understanding, self-awareness, communication, reasoning, learning, retaining, planning and problem solving [4]. There are several factors apart from genetic factors which influence intelligence of a child. Iodine deficient children suffer from poor concentration, impaired coordination and sluggishness, which results in poor school performance [5]. Globally, 29.8% of School age children (241 million) are estimated to have insufficient iodine intakes in which southeast Asia has the largest number of children with low iodine intakes (76 million) [6]. It has been reported that, on an average, intelligence quotient (IQ) of school children living in iodine-deficient areas is 13 points lower than children living in iodine-sufficient areas [7].

Recognizing the importance of preventing IDD, the World Health Assembly adopted in the year 1990 the goal of eliminating iodine deficiency as a public health problem. In 1993, WHO and UNICEF recommended universal salt iodization (USI) as the main strategy to achieve elimination of IDD and district survey every 5 years to track progress towards elimination [8].

In India, compulsory iodization of all edible salts was introduced in 1983 and sale of non-iodized salt for direct human consumption was banned in the entire country since 2006. No

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study has been conducted in Bihar to see the impact of the ban and its effect on IDDs. Taking all these into account this study was conducted with following objectives: To estimate the proportion of households using adequately iodized salt; to estimate total goitre rate and IQ of children aged 6–12 y and to assess association, if any between consumption of iodized salt and IQ of children aged 6–12 y in the selected districts of Bihar.

Material and Methods

This was a community based cross -sectional study conducted in Gopalganj, East Champaran and West Champaran districts which come under traditional goitre belt of Bihar. The study was conducted from January 2018 through March 2018. Department of Community Medicine, Patna Medical College, Patna was entrusted to do an IDD survey in these three districts by State Health Society, Bihar under National Iodine Deficiency Disorders Control Programme (NIDDCP). The target population for IDD survey are children of 6–12 y and pregnant women [8]. Children (6–12 y) were taken as study population.

Sample size was calculated using population estimates, where 66% is the assumed coverage of adequately iodized salt consumption in rural area [9], 95% confidence level, 10% margin of error and a design effect of 2. Thus a sample size of 412 households per district and 1236 households for this study was calculated. Cluster sampling was adopted for selection of village as a cluster.

In selected districts, block wise village list was collected for preparing a sampling frame. Three blocks were randomly selected from each district and from each block 10 villages were randomly selected assuming village as cluster. From each selected village, 14 household were selected randomly and from each household one child of 6–12 y age group was selected. If in a house a child of desired age group was not present the neighbouring house was selected for the study.

A pretested semi-structured questionnaire was used for data collection. It consisted of socio-demographic details of study participants, clinical examination and IQ determination of children. The socio-economic status was assessed by Modified BG Prasad classification and then classified into upper, middle and lower class [10].

The enlargement of thyroid gland was assessed clinically by standard palpation method. Goitre grade was scored according to WHO/UNICEF/ ICCIDD criteria. The sum of grade 1 and grade 2 provided the total goitre rate (TGR) prevalence [8].

IQ was assessed by Seguin Form Board (SFB) test which is a validated tool and classified according to WHO criteria. The IQ was categorised into normal IQ level for the score 80 and above and subnormal for the score less than 80 points [11–13].

This Seguin Form Board (SFB) test tool consisted of ten differently shaped wooden blocks and a large form board with recesses corresponding to these shapes [12]. The testing was administered individually to each child, in compliance with the guidelines and direction of the SFB test manual. The children were instructed about the procedure before the commencement of test.

The test was repeated 3 times for every child and the time, in seconds was obtained for each trial by investigator. The shortest time score and the total time score of each subject in 3 trials were noted.

Salt samples were collected from all the households in air tight polythene pouches for estimation of iodine content. Iodine concentration of salt samples was determined by iodometric titration method at PMCH USI lab. Iodometric titration method is a quantitative method and it still remains the reference method for determining the iodine concentration in salt. The values obtained were shown in parts per million (ppm). The iodine level in salt 15 ppm or above is considered as adequate and below 15 ppm as inadequate [8].

Statistical analysis was performed by statistical software SPSS version 22. Frequency distribution (percentage), mean and Standard deviation were expressed according to categorical and continuous variables. Independent t test and ANOVA test were applied to see the association of mean IQ with different factors. Categorical variables were compared by chi-square test. The strength of association between variables was measured by calculating the odds ratio (OR) from multivariable logistic regression models. In all cases the level of rejection of a null hypothesis was 0.05.

The study was approved by Institute ethical committee of Patna Medical College, Patna. Head of the households were informed about the purpose of the study and written consent was taken from them.

Results

A total of 1263 households and same number of children were included in the study in which 415 were taken from Gopalganj, 426 from East Champaran and 422 were taken from West Champaran district. There was a slight preponderance of male children (53%) in the study sample which is in accordance to the census data of India and Bihar. Hindus were around 82% and most of the study population belonged to lower socio-economic status (55%). Father's literacy was 53% while mother's literacy was just 28%. Adequately iodized salt consumption was 77.1% in Gopalganj district, 74.2% was in East Champaran district and 69.2% was in West Champaran district. So, the total adequately iodized salt consumption was 73.5%. The use of non-iodized salt was not found in any household. On neck examination, the prevalence of goitre among children was 2.9%. The total goitre rate in

Gopalganj district was 1.8%, in East Champaran district was 4.5% and in West Champaran district was 2.1%. (Table 1).

The mean IQ of boys was 83.6 which were significantly higher than girls in which it was 81.5. The present study showed that as the age of child increases the corresponding IQ level decreases ($F = 51.10$, $p < 0.001$). The mean IQ in children of literate fathers was 83.8 which was significantly higher than children of illiterate fathers (mean IQ: 81.2). The mean IQ level was around 9 points higher in children from households where adequately iodized salt was used in comparison to children with inadequate iodized salt consumption (mean IQ level 76.0). The children with Goitre had significantly lower IQ level (mean IQ level: 71.2) than normal children (mean IQ - 82.9). The mean IQ level was not significantly associated with other factors like religion, category, socio-economic status, mother's literacy and birth order of child. (Table 2).

On applying chi-square test the association of intelligence quotient category was significant with age, goitre status and salt iodine content. The authors have not found any significant association of intelligence with gender, religion, socio-economic status, father's and mother's literacy and birth order of child. The logistic regression analysis showed that increasing age, presence of goitre and inadequately iodized salt consumption were the factors which were significant predictors of low IQ level (Tables 3 and 4).

Table 1 District wise distribution of participant profile, iodized salt consumption and Total goitre rate (TGR) ($N = 1263$)

Variables	Gopalganj ($n = 415$)	E. Champaran ($n = 426$)	W. Champaran ($n = 422$)	Total (N = 1263)
Gender				
Male	227 (54.7)	225 (52.8)	222 (52.6)	674 (53.4)
Female	188 (45.3)	201 (47.2)	200 (47.4)	589 (46.6)
Age (years)				
6	95 (22.9)	35 (8.2)	28 (6.6)	158 (12.5)
7	52 (12.5)	61 (14.4)	59 (14.0)	172 (13.6)
8	53 (12.8)	59 (13.8)	93 (22.0)	205 (16.2)
9	32 (7.7)	70 (16.4)	73 (17.3)	175 (13.9)
10	71 (17.1)	75 (17.6)	77 (18.2)	223 (17.7)
11	41 (9.9)	71 (16.7)	44 (10.4)	156 (12.4)
12	71 (17.1)	55 (12.9)	48 (11.5)	174 (13.7)
Religion				
Hindu	333 (80.2)	377 (88.5)	320 (75.8)	1030 (81.6)
Muslim	82 (19.8)	49 (11.5)	102 (24.2)	233 (18.4)
Father's literacy	284 (68.4)	173 (40.6)	217 (51.4)	674 (53.4)
Mother's literacy	150 (36.1)	81 (19.0)	125 (29.6)	356 (28.2)
Socio-economic status				
Upper	66 (15.9)	23 (5.4)	35 (8.3)	124 (9.8)
Middle	152 (36.6)	143 (33.6)	151 (35.8)	446 (35.3)
Lower	197 (47.5)	260 (61.0)	236 (55.9)	693 (54.9)
Birth order				
2 or less	223 (53.7)	227 (53.3)	271 (46.2)	721 (57.1)
3 or more	192 (46.3)	199 (46.7)	151 (35.8)	542 (42.9)
Salt iodine content				
< 15 ppm	95 (22.9)	110 (25.8)	130 (30.8)	335 (26.5)
> 15 ppm	320 (77.1)	316 (74.2)	292 (69.2)	928 (73.5)
Goitre grading				
Grade 0	407 (98.2)	407 (95.5)	413 (97.9)	1227 (97.2)
Grade 1	4 (0.9)	15 (3.6)	8 (1.9)	27 (2.1)
Grade 2	4 (0.9)	4 (0.9)	1 (0.2)	9 (0.7)
TGR (Grade 1 + 2)	8 (1.8)	19 (4.5)	9 (2.1)	36 (2.8)

The figures in parenthesis denote percentage

OBC Other backward class, *SC* Scheduled caste, *ST* Scheduled tribe, *TGR* Total goitre rate

Table 2 Association of mean IQ with different factors using Independent t test and ANOVA test

Variables	Frequency	I.Q. Level		*p* value
		Mean (S.D.)	t/F value	
Gender				
Male	674	83.6 (17.7)	2.121	**0.03**
Female	589	81.5 (17.3)		
Age				
6–7 y	330	88.8 (19.8)	51.107	**<0.001**
8–9 y	380	84.7 (15.9)		
10–12 y	553	77.4 (15.7)		
Religion				
Hindu	1030	82.8 (17.4)	0.655	0.51
Muslim	233	81.9 (18.4)		
Socio-economic status				
Upper	124	82.6 (18.3)	0.296	0.74
Middle	446	83.1 (17.4)		
Lower	693	82.3 (17.6)		
Father's literacy				
Illiterate	589	81.2 (16.9)	2.597	**0.01**
Literate	674	83.8 (18.0)		
Mother's literacy				
Illiterate	907	82.1 (17.4)	1.764	0.08
Literate	356	84.0 (18.1)		
Birth order				
2 or less	721	82.2 (18.1)	1.005	0.31
3 or more	542	83.2 (16.8)		
Salt iodine content				
Inadequate	335	76.0 (16.6)	8.180	**<0.001**
Adequate	928	84.9 (17.3)		
Neck examination				
Goitre Absent	1227	82.9 (17.6)	3.986	**<0.001**
Goitre Present	36	71.2 (13.7)		

It denotes that p value is less than 0.05

Discussion

The prevalence of IDD in a community are assessed by three indicators; (i) prevalence of goitre in 6–12 y which indicates past iodine status of population, (ii) iodine content of salt consumed by the population, which indicates the current intake of iodine and (iii) urinary iodine excretion which also indicates current iodine intake. The authors have studied prevalence of goitre and iodine content of salt but were unable to estimate urinary iodine excretion due to financial constrains. However, intelligence also depends on iodine status and hence authors have studied association of IQ with iodized salt consumption.

In the present study, the proportion of household using adequately iodized salt was 73.5% and the use of non-iodized salt was not found in any household. The goal of universal salt iodization (USI) is to cover more than 90% of households to consume adequately iodized salt [8]. The target of universal salt iodization is yet to be achieved at the consumer level in the surveyed district of Bihar.

There are various studies done from different parts of India from time to time regarding status of IDD. The consumption of adequately iodized salt from a range of 42% to 85% was reported from different parts of India in the recent past [14–18]. According to the IDD newsletter, iodized salt consumption was 71.1% at the recommended level in Indian households [19].

A survey of Iodine deficiency disorders (IDD) status of seven States (Kerala, Tamilnadu, Orissa, Rajasthan, Bihar, Goa & Jharkhand) reported that adequately iodized salt was consumed in 40.1% households in Bihar [20]. Kapil et al. in their study found that 27% and 34% of the subjects in East and West Champaran districts, respectively were consuming salt with less than 15 ppm iodine [21].

According to the findings of National Family Health Survey for Bihar (NFHS-4 2015–16), adequately iodized salt was consumed in around 93% of rural households which is more than the present study. In NFHS 4, the iodine content of cooking salt was qualitatively measured, so exact quantitative estimate of salt iodization was not possible [22].

It is clear from these findings that status of adequately iodized salt consumption has improved in Bihar. The use of non-iodized salt was not found in any household in this study. This finding reveals that although salt is being iodised; either iodine is added in inadequate quantity or there are losses of iodine at different points in the distribution system.

In the present study total goitre prevalence was 2.9% among 6–12 y children. Based on WHO/UNICEF/NIDDCP criteria the district is declared as Goitre endemic district if the total goitre rate (TGR) is above 5% in children of the age group 6–12 y surveyed. Severity of public health is graded as: Mild (TGR 5–19.9%); moderate (TGR 20–29.9%) and severe (TGR >30%). The total goitre rate was less than 5% in all the three districts, hence Iodine deficiency disorders (IDD) does not seem to be much more a public health concern in these districts. A total goitre rate ranging from 4.29% to 12% has been reported from different parts of India in the recent past [14, 15, 23–25].

Re-evaluation of IDD status after introduction of iodised salt was done in the districts of East and West Champaran. These surveys revealed significant decrease in the goiter prevalence. From the year 1979 to 1993–94, the goiter prevalence decreased from 64.5% to 24.6% in East Champaran and from 57.2% to 25.1% in West Champaran [26].

In a study done by Kapil et al. in East and West Champaran districts, the total goitre prevalence reported was 11.6%. The goitre prevalence in school children was 12.8% and 10.4% in East and West Champaran districts, respectively [21]. A survey done between 2000 and 2006 in seven states of India reported a prevalence of 5.2% of goitre among children in Bihar [20]. This declining trend seems to be due to the effect of iodization of salt and complete ban on the sale of non-iodised salt.

Table 3 Association of IQ level category with different factors using chi-square test

Variables	Subnormal IQ level	Normal IQ level	Chi-square value	*p* value
Gender				
Male	272 (40.4)	402 (59.6)	1.116	0.29
Female	255 (43.3)	334 (56.7)		
Age				
6–7 y	89 (27.0)	241 (73.0)	68.339	**<0.001**
8–9 y	139 (36.6)	241 (63.4)		
10–12 y	299 (54.1)	254 (45.9)		
Religion				
Hindu	428 (41.6)	602 (58.4)	0.068	0.79
Muslim	99 (42.5)	134 (57.5)		
Socio-economic status				
Upper	56 (45.2)	68 (54.8)	2.316	0.31
Middle	174 (39.0)	272 (61.0)		
Lower	297 (42.9)	396 (57.1)		
Father's literacy				
Illiterate	251 (42.6)	338 (57.4)	0.358	0.55
Literate	276 (40.9)	398 (59.1)		
Mother's literacy				
Illiterate	387 (42.7)	520 (57.3)	1.175	0.28
Literate	140 (39.3)	216 (60.7)		
Birth order				
2 or less	302 (41.9)	419 (58.1)	0.018	0.89
3 or more	225 (41.5)	317 (58.5)		
Neck examination				
Goitre Absent	500 (40.7)	727 (59.3)	16.873	**<0.001**
Goitre Present	27 (75.0)	9 (25.0)		
Salt iodine content				
Inadequate	217 (64.8)	118 (25.2)	99.624	**<0.001**
Adequate	310 (33.4)	618 (66.6)		

The figures in parenthesis denotes percentage

It denotes that p value is less than 0.05

In the present study mean IQ level was around 9 points lower in children from houses where inadequately iodized salt was used in comparison to children with adequate iodized salt consumption. Logistic regression analysis also showed that inadequate iodized salt consumption is significant predictor of low IQ level (Table 4). It has been reported that, on an average, the IQ of iodine deficient children is 13 points lower than iodine sufficient children [5]. A meta-analysis also showed that the intelligence of children who lived in iodine deficiency had an average of 12.45 IQ points lower than that of children who lived in iodine sufficient environment [27]. Ghazi et al. reported that both low and normal IQ groups showed a large difference in iodine intakes [28].

The present results show that presence of goitre has a significant effect on the IQ. The mean IQ level in normal children was 12 points higher in comparison to children suffering from goitre. Another study reported that the average IQ in the normal group was 25 score more than hypothyroidism group [29].

The present study showed that increasing age, presence of goitre and inadequately iodized salt consumption are significant predictors of low IQ. Singh et al. found that prevalence of goitre was high in children consuming salt with insufficient iodine ($P < 0.0002$), similar to the present study [15]. Tang et al. in their study reported that IQ scores correlated negatively with age ($p < 0.0001$), similar to the present study [30]. In an another study, parental working status, iodine level and child's nutritional status were the most important factors influencing child's IQ [28].

The authors had covered three districts which were in the list of goitre endemic belt with adequate sample size. The titration method was used to estimate iodine level in salt, which still remains the reference method for determining the iodine concentration in salt [8]. These should be considered as the strength of present study.

Table 4 Logistic regression analysis showing predictors of subnormal IQ level

Factors	B	Significance	Odd's ratio	95% C.I.
Male	0.108	0.387	1.115	0.872–1.425
Female		Reference		
Age 6–7 y	1.196	**<0.001**	3.306	2.412–4.530
Age 8–9 y	0.847	**<0.001**	2.332	1.747–3.113
Age 10–12 y		Reference		
Father illiterate	.020	0.895	1.021	0.755–1.378
Father literate		Reference		
Mother illiterate	−0.064	0.711	0.938	0.670–1.313
Mother literate		Reference		
Goitre absent	1.409	**0.001**	4.091	1.817–9.212
Goitre present		Reference		
Inadequately iodized salt	−1.415	**<0.001**	0.243	0.184–0.321
Adequately iodized salt		Reference		

It denotes that p value is less than 0.05

Limitations of the study are: Urinary iodine excretion is a better estimate for adequate iodine consumption than salt iodine content. Due to financial constrains authors were unable to estimate urinary iodine excretion and thus might have been unable to see the exact status of iodine consumption in this study. Being a cross-sectional study, it lacks temporal relationships.

Conclusions

The prevalence of goitre was below the set target but the target of iodized salt consumption has not yet achieved in these districts. The districts in the present study are in a transition phase from iodine deficiency to sufficiency. The evidence here shows that there is a need to increase the supply of adequately iodized salt to meet the goal for monitoring progress towards sustainable elimination of IDD. Hence, regular monitoring and surveys are required to sustain the total goitre rate below the target and to achieve the level of desired iodine content at consumption point.

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Compliance with Ethical Standards

Conflict of Interest None.

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