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DETERMINANTS OF IODINE DEFICIENCY IN SCHOOL CHILDREN IN DIFFERENT REGIONS OF ETHIOPIA

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ABSTRACT

Objective: **To determine the magnitude of goitre in school children and measure indicators of iodine deficiency including the most commonly consumed staple foods.**
Design: **A cross-sectional study.**
Setting: **Ten villages from four administrative regions of Ethiopia.**
Subjects: **A total of 2485 randomly selected elementary school children were examined for clinical signs of goitre. Indicators of iodine deficiency disorders (IDD) assessed were urinary iodine excretion (UIE) rate, iodine concentration in water, the commonly consumed individual foods of plant origin and milk, and bacterial contamination of drinking water.**
Results: **The gross prevalence (mean of male and female values) among school children was 53.3%. The prevalence was higher in females (56.1%) than in males (50.8%). The highest prevalence (82 and 91%, respectively) were observed in the villages of Lotte and Kodowono and the lowest (31%) in the village of Abossara. Of the urinary measurements, 70% of the samples showed moderate and 30% mild iodine deficiency. Levels of iodine in water and individual food samples were low in general. Breast milk iodine content was similarly low and related to the maternal daily iodine intake which may affect the nutritional status of the nursing infant. The study also provides further evidence that coliforms and *E. coli* isolated from drinking water contribute to the high incidence of endemic goitre other than iodine deficiency.**
Conclusion: **It is difficult to obtain a sufficient iodine intake in the survey villages as the individual foods are very low in the element. However, IDD can be prevented by ensuring normal iodine nutrition through instituting ways that avail iodinated salt to the survey population.**

INTRODUCTION

Iodine deficiency is the major preventable cause of irreversible mental retardation in the world(1). Ethiopia is a country with a high prevalence of iodine deficiency disorders which continue to affect a large number of the country's population. From a national survey conducted among school children and household members, the national goitre prevalence rate ranged from 0.4 to 66.3%, with a mean value of 35%(2,3). Goitre prevalence rates vary significantly from region to region in Ethiopia and in certain areas the prevalence rate may be as high as 71% indicating that a single national estimate many times does not reflect sub-national variability in the prevalence of IDD(4). Identifying such areas of iodine deficiency and determining the iodine status of the population will help in the accurate planning and evaluation of intervention programmes. The present study was carried out to determine the goitre prevalence rate and the iodine content in most commonly consumed staple foods in four regions of Ethiopia.

MATERIALS AND METHODS

The study was designed as a cross-sectional study to measure indicators of iodine deficiency in school children. The study covered 10 villages within four regions. Selection of the villages was based on the absence of data on the prevalence of IDD from previous similar studies. All of the selected villages have never been introduced to iodination programmes and from each village all accessible public elementary schools were identified as survey sites. The survey involved goitre assessment and measurement of iodine concentration in urine, food, water and milk samples. Clinical examination for thyroid size estimation was done among 2485 randomly selected elementary school children. Thyroid gland size was graded by the principal investigator and health personnel using palpation techniques as recommended by the WHO/UNICEF/ICIDD(5). Before beginning the study, the examiners agreed on a standardised palpation technique. The palpated goitre size was classified as grade 0, I and II. Measurement of urinary iodine excretion (UIE) was based on the iodine concentration in urine samples that were collected during the morning of the school visit. The school children from each survey village were randomly selected for collection of casual (untimed) urine samples. Urine was collected in clean bottles which had been rinsed with acid and deionised water before use. A sample of each urine was refrigerated (-20°C) until analysis.

Food samples were collected from individual survey villages selected randomly to be representative of the survey area. Water samples from drinking sources were collected in sterile brown bottles and refrigerated (4°C) until analysis. The food samples were dry-ashed at 550°C in the presence of K_2CO_3 and $ZnSO_4$. The residue was dissolved in deionised water for subsequent colorimetric measurement according to the method of Maxon and Dixon(6).

Iodine in urine was quantified following the method of Sandell-Kolthoff as modified by Bourdoux(7). The method is based on the catalytic action of iodine on the reduction of ceric ion coupled to the oxidation of arsenite to arsenic. Before measurement, urine samples were digested using alkali-ashing techniques to destroy interfering substances and organic matter that can alter the reaction rate. The urinary iodine was expressed in µmol/L urine as recommended by Dunn *et al* (8). Iodine concentration in water was measured by the method of Dubravcic(9). Determination of microorganisms was carried out following the method of Harrigan(10). The results were expressed as number of cells count in milliliter of water sample. Data were analysed using ANOVA and significant differences were assessed with a given significance at $p<0.05$.

RESULTS

Among a total of 2485 school children, the group's breakdown by sex was 30% for girls and 70% for boys (Table 1). The gross goitre prevalence (mean male and female values) among school children measured by palpation was 53.3%. The prevalence was higher in females (56.1%) than in males (50.8%). Of the 10 villages surveyed, two (20%) showed a total goitre prevalence rate of less than 30%, four (40%) had a prevalence rate of between 31 and 52%, and four (40%) had a prevalence rate of more than 60%. The prevalence of goitre was more than two-fold higher in school children living in Kodowono and Lotte (91 and 82%, respectively) than those in Abossara. The number of goitrous subjects was higher among girls than boys and the sex (male: female) ratio for total goitre prevalence rate was 1:1.1.

Table 2 compared the UIE rate with total goitre prevalence rate. The UIE rate values ranged from 0.33 ± 0.02 to 0.70 ± 0.02 µmol/L. School children from Wonchi, Lotte and Kodowono had UIE rates less than 0.40 µmol/L whereas, school children from Sankura had UIE rate of 0.70 µmol/L. The data also indicate that the school children with the highest goitre prevalence rates had the lowest UIE rates and UIE rate is inversely correlated with total goitre prevalence rate. However, estimates of the severity of iodine deficiency based on the concentration of iodine in urine and total goitre prevalence rate were not identical. The proportion of school children classified as at moderate risk according to the goitre prevalence rate classification was significantly greater ($p<0.05$) than when UIE rate was measured. However, no school children were classified as at severe risk according to UIE criteria.

Table l

Prevalence of goitre by sex amongst school children at various regions of Ethiopia

Region	Survey village	Examined Male(n)	Examined Female(n)	Gross goiter(%) Male	Gross goiter(%) Female	Overall Prevalence (%)
Shoa	l. Regdina	301	49	28	34	28.9 (350)
	2. Sankura	368	61	20	33	24.0 (429)
	3. Wonchi	115	36	76.5	77.8	76.8 (151)
Jimma	4. Kasha	101	39	66	61.5	65.0 (140)
	5. Tebmenjayaz	276	52	36	59.6	48.8 (328)
Arsi	6. Billalo	63	76	38	24.5	34.0 (139)
	7. Abossara	119	169	29	32	31.0 (288)
Gamo-Gofa	8. Kodowono	103	99	80	97	91.0 (202)
	9. Lotte	202	126	79	87	82.0 (328)
	10. Wodewoshe	92	38	50	55	51.5 (130)
	Overall cases			50.8 (508)	56.1 (561)	53.3 (533)
Total subjects		1740	745	170	745	2384

n= Number of people examined in parenthesis.

Table 2

*Goitre prevalence and UIE rate in school children from various regions of Ethiopia**

Region	Study area	Goitre prevalence, %	Urinary iodine exertion** µmol/L
Shoa	1. Regdina	29 (350)	0.66 ± 0.03 (50)
	2. Sankura	24 (429)	0.70 ± 0.02 (54)
	3. Wonchi	77 (151)	0.33 ± 0.05 (41)
Jimma	4. Kasha	65 (140)	0.44 ± 0.03 (42)
	5. Tebmanjayaz	49 (328)	0.51 ± 0.01 (60)
Arsi	6. Billalo	34 (139)	0.40 ± 0.06 (43)
	7. Abossara	31 (288)	0.63 ± 0.03 (65)
Gamo-Gofa	8. Kodowono	91 (202)	0.35 ± 0.01 (53)
	9. Lotte	82 (328)	0.37 ± 0.02 (53)
	10. Wodeweisho	52 (130)	0.46 ± 0.04 (51)

*Number of people examined in brackets. **Mean ± SE

The iodine concentration of drinking water samples are shown in Table 3. Of the fourteen sources of drinking water surveyed, 79% had iodine concentration between 8 and 16 µg/L and 21% of the drinking water sources contained between 22 and 24 µg/L. Drinking water commonly used by the study population is also contaminated with microorganisms (Table 3). Coliforms were isolated from 79% of sources of drinking water whereas, *E.coli* which should be absent in drinking water was isolated from 71% of water samples. The prevalence of goitre was higher among the subjects using polluted water as the major drinking water source. There was a positive correlation between goitre prevalence and bacterial contamination of drinking water.

Table 3

Bacterial count, goitre prevalence and Iodine content of drinking water by survey villages.

Region	Survey village	Water source	TBC	Coliform count	*E. coli* count	Goitre rate %	Iodine µg/L
Shoa	1. Sankura	Pond	$2x10^5$	$2x10^3$	$1x10^3$	24	22
	2. Wonchi	Mineral water	$1x10^5$	$3x10^2$	$6x10^1$	76.8	14
		Lake	$1x10^5$	$7x10^1$	$3x10^1$	76.8	10
		Spring	$1x10^5$	$2x10^2$	$5x10^1$	76.8	22
Jimma	4. Kasha	Spring	$3x10^4$	$8x10^1$	$2x10^1$	65	16
Arsi	5. Billalo	River	-	-	-	34	14
		Spring	-	-	-	34	16
	6. Abossara	River	-	-	-	31	14
Gamo Gofa	7. Lotte	Well	$3x10^5$	$1x10^3$	$2x10^1$	82	10
		River	$3x10^6$	$2x10^2$	$3x10^2$	82	8
	8. Woideweishe	Spring	$3x10^4$	$7x10^2$	$1x10^1$	51.5	14
		River	$6x10^5$	$1x10^3$	-	51.5	10
	9. Kodowono	Spring	$2x10^5$	$2x10^3$	$8x10^2$	91	24
		Spring	$8x10^3$	$7x10^2$	$2x10^2$	91	16

MPN-most probable number count

Table 4

Iodine concentration of individual food samples from various regions of Ethiopia

Name	Village	µg/kg (dm)	Name	Village	µg/kg(dm)
Sorghum	Kodowono	40.4	Field peas	Kasha	70.0
	Sankura	64.8		Abossara	52.3
	Kasha	68.3	Broad beans	Kasha	32.3
Maize	Kodowono	72.2		Billalo	3.8
	Wodeweisho	22.9		Abossara	13.1
	Sankura	47.1	Lentils	Wonchi	44.0
	Sankura	47.1	Cassava	Kodowono	12.3
Tef	Kodowono	70.6	Sweet potato	Kodowono	18.0
	Wodeweisho	74.6	Ensete	Kodowono	24.0
	Sankura	67.4	Shiro	Kodowono	48.6
	Kasha	78.0	Anchote	Kodowono	30.4
Wheat	Wonchi	44.1	Bliboye	Kodowono	10.0
	Sankura	71.9	*Human milk (µg/L)*		
	Billalo	65.6		Kodwono	12.7 ± 4.2
	Abossara	50.6		Sankura	14.4 ± 3.0
Barley	Sankura	96.6		Tebmenjayaz	5.4 ± 1.7
	Kasha	53.3		Billalo	15.7 ± 1.3
	Billalo	15.9	*Cow milk (µg/L)*		
	Abossara	16.5		Kodowono	15.5 ± 2.2
	Wonchi	14.5		Sankura	22.5 ± 3.0
Kidney				Tebmenjayaz	19.5 ± 2.1
beans	Kodwono	42.5		Billalo	16.2 ± 1.2
	Kasha	10.9			

The iodine content in the commonly consumed individual foods in the raw state are given in Table 4. The highest iodine levels were found in cereals and legumes. However, iodine concentration in tubers is low and varied between 12 and 30 µg/kg. Levels of iodine found in human and cow milk are also given in Table 4. The iodine content of milk from cows ranged from 16 µg/L in Kodowono to 23 µg/L in Sankura. Breast milk was also poor in iodine which ranged from 5 µg/L in Tebmenjayaz to 16 µg/L in Bilallo.

DISCUSSION

Studies carried out in the past have demonstrated that iodine deficiency disorders existed in Ethiopia and that in certain areas the prevalence may be as high as 71%(2,4). In this study, we assessed the total goitre prevalence rate among school children and found a percentage of 53.3% which is regarded as severe according to the classification of WHO/UNICEF/ ICCIDD(5). This rate is as high as that reported from other regions of Ethiopia such as Adaba (Bale) and Felegeniway (Gamo Gofa) with 57 and 65%, respectively(2).

Since almost all iodine in the body is eventually excreted in the urine, daily urinary excretion of iodine closely reflects iodine intake and remains a valuable index for assessing current iodine status in a population, especially when possibilities for the assessment of blood index are absent(11). WHO/UNICEF/ICCIDD recently suggested modified cut-off points to assess the severity of iodine deficiency by measuring the iodine concentration in casual urine samples(5). On the basis of their criteria, all the school children in the present study sites were regarded as deficient (UIE < 0.79 µmol/L), of whom those living in 70% of the study areas were classified as mildly deficient (UIE 0.40 µmol/L to 0.79 µmol/L) and 30% as moderately deficient (UIE<0.40 µmol/L). However, no area was classified as severely deficient according to these criteria. On the other hand, UIE was associated significantly with the goitre prevalence rate and the results are consistent with previous observations(12,13). In spite of the high goitre prevalence in the survey villages, UIE results indicated that most of the samples were mildly iodine deficient. The prevalence of iodine deficiency in the survey villages as assessed by the two indicators was inconsistent because UIE rate reflects current iodine concentrations and goitre indicates a chronic situation of iodine deficiency similar to observations reported previously(13).

Studies in other areas of the world have suggested that goitre prevalence is associated with bacterial contamination of drinking water and sub-optimal iodine intake. Bacteriological studies of drinking water exhibited significantly higher prevalence of goitre in villages using water polluted with coliforms and *E.coli* than those villages using non-polluted drinking water. This is particularly true for Kodowono and Lotte villages. Similar previous studies have indicated that the drinking water in villages with high goitre prevalence was polluted with *E.coli* and *E. coli*-like organisms(14). Our results thus, provide further support for the hypothesis that microorganisms, such as coliforms and *E.coli*, are involved in the pathogenesis of endemic goitre.

Although drinking water provides a poor, insufficient source of iodine its content in the present study was of noticeable importance. The iodine concentration of water in the survey villages is lower than that from Lake Awassa and Lake Zewai, but significantly higher than the iodine concentration of tap water from Garataka(19).

In the survey villages, the iodine content of the common individual food plants showed great variation and fluctuation. Not only does one food item differ in iodine content from others, but also iodine content of food samples of the same item differ greatly according to the place of production. Such variation is expected since iodine concentration in food plants is dependent from the iodine concentration in the soil. This is true of maize from Sankura and Woidewoshe which contained 47 and 23 µg/kg, respectively. However, the present results of individual food samples of plant origin are in accordance with the general levels of iodine concentration in cereals and legumes(15).

The villages of Lotte and Kodowono have a high prevalence of iodine deficiency disorders (82% and 91%, respectively). Although iodine deficiency and use of polluted drinking water could be considered as causative factors of endemic goitre in these villages, consumption of cassava may be an additional factor producing important epidemiological variations. Cassava is widely cultivated and consumed on a large scale in villages of Lotte and Kodowono(16). However, boiling cassava roots is less effective in detoxifying the roots as compared to fermentation process. Cassava contains linamarin, a cyanogenic glucoside which is a known antagonist of the thyroid gland (17).

The iodine supply of animals is mainly determined by their habitat and their food. In the present study, iodine levels in cow's milk are eight-fold lower than those found in Great Britain(18) since cows in Ethiopia are in open pasture throughout the year and the pasture is low in iodine content. The amount of iodine entering the human food chain depends on levels of consumption of key foodstuffs. In the case of the present study, all food items consumed by the study population contained significantly low iodine which is reflected in the iodine content of human breast milk. In Europe and the USA, human milk contains an average 80 and 160 µg/dl, and thus more than 7 and 13-fold as compared to the present findings(19). Thus an infant consuming an average breast milk volume of 700ml daily receives about 8.4 µg iodine daily in Ethiopia. Breast milk composition in the present study therefore, indicates maternal deficiency of iodine which affects the nutritional status of the nursing infant.

The farming population of Ethiopia relies predominantly on cereals such as maize, sorghum, barley, wheat and tef *(Eragrostis tef)* which provides 70% of daily energy intake(20). About 5% of the dietary energy comes from pulses, roots and tubers. Nevertheless, it is common to consume *injera* or bread prepared from the cereals with various vegetable sauces.

On the basis of our study, one can estimate the daily intake of iodine when *shiro* is included in the meal. For example, 150 g of *shiro wot* (spiced legume sauce) in addition to 200g of tef prepared as *injera* will provide 24 µg of iodine. Supplemented with one litre of drinking water from the surface of a river in Kodowono will increase the intake to 40 µg/day. The intake is much lower when *injera* is consumed with sauce prepared from tubers. Estimated iodine intake by the survey population is thus far below the recommended allowance at 150 µg/day(21).

In conclusion, our study shows that it is difficult to obtain a sufficient iodine intake in the survey villages as the individual foods are very low in the element. Cereals and legumes contribute some iodine intake as compared to tubers but, the contribution of iodine from drinking water could be of importance if bacterial contamination is avoided. Even of greater importance is the availing of iodised salt to the population.

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