Iodine Status of School-children (8-10 years) and Associated Factors in Arumeru District, Tanzania

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Abstract

A cross-sectional descriptive study was conducted in January 2003 to assess iodine status of school-children and associated factors in Arumeru District, Arusha Region, Tanzania. A pre-tested structured questionnaire was administered to 100 households having school-children aged 8-10 years to seek information on socio-demographic and socio-economic characteristics, knowledge and practices of the parents in relation to iodine nutrition. From a sub-sample of 50 households, 50 salt samples used in the homes were collected for iodine determination and 50 fasting morning urine samples were collected from the school-children for determination of urinary iodine concentration. Results of the study showed that median urinary iodine concentration of the school-children was 49.17 µg/L (range: 16.27 - 206.05 µg/L). Prevalence of mild iodine deficiency was 40%, moderate iodine deficiency 42%, and severe deficiency 8% of the sampled school-children. Majority (74%) of parents had heard of IDD and iodine (76%), but few (40%-44%) knew food sources of iodine and that goitre was caused by iodine deficiency. Almost all (96%) household salt samples were adequately iodated. Frequency of consuming selected iodine-rich foods by the children was low, while consumption of some goitrogen-containing foods was relatively high. It is concluded that inadequate knowledge regarding iodine nutrition, low consumption of iodine-rich foods coupled with high consumption of goitrogen-containing foods are the main contributing factors to iodine deficiency in the district. National IDD Control Programme should strengthen partnership with stakeholders such as district councils, salt processing industries and distributors, civic groups, and media organizations to deliver tailored iodine nutrition messages that provide the public with a solid foundation for behaviour change.

Key words: iodine nutrition, school-children, knowledge, practices, Tanzania

Introduction

Deficiencies of iron, iodine, and vitamin A are the most widespread forms of micronutrient malnutrition with public health consequences in the developing world (Kennedy *et al.*, 2003). One of the several causes of these deficiencies is lack of diversity in the habitual diet or overly dependent on a single staple food, as is the case with monotonous cereal–based or tuber–based diets (Hetzel and Maberly, 1986). Iodine is an essential mineral required by the body to synthesize thyroid hormones, the most important of which is thyroxine (Hetzel and Maberly, 1986). Thyroxine

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Accepted May, 2008

hormone has multiple functions as a regulator of cell activity and growth. It is involved in the metabolic energy flow of most of body cells, the most familiar indicator being basal metabolic rate. It influences neuronal cell growth and dendritic spine development and growth and maturation of peripheral tissues (Stanbury and Dunn, 2001). In the early stages of life, iodine deficiency retards brain development by preventing foetal brain from establishing sufficiently dense cell networks. Later, it can manifest itself as low academic test scores, reduced mental capacity and mental retardation (Wright, 2004). Other effects include abortions, stillbirths, congenital abnormalities, impaired physical development, goitre and endemic cretinism (Stanbury and Dunn, 2001).

Iodine deficiency is the primary, although not sole, cause of goiter. Other dietary factors such as the naturally innate components of particular foods contain goitrogens which interfere with utilization of iodine or functioning of thyroid gland. Foods containing goitrogens were shown to reduce the uptake of radioactive iodine by human thyroid glands. Thioglycoside linamarin, a constituent of cassava, is one of the most researched dietary goitrogens. Insufficiently soaked of inadequately cooked cassava releases linamarin in the gut and is hydrolysed to cyanide. Cyanide is metabolized to thiocyanate and inhibits thyroidal uptake of iodine (Stanbury and Dunn, 2001). Other goitrogens such as sinigrin (allylthioglucoside), glucobrassin, and progoitrin were isolated and characterized from various Brassica species (cabbage, kale, broccoli, cauliflower, Brussels sprouts). Millet diets have also been documented to be rich in vitexin, a C-glycosylflavone directly implicated in inhibiting thyroid peroxidase-catalysed protein iodination (Hathcock and Rader, 1999). The role of goitrogens in inducing iodine deficiency and reducing excretion of iodine in urine has been reported in Congo and Sudan (Elnour *et al.*, 2000).

In 2003, the International Council for the Control of Iodine Deficiency Disorders (ICCIDD) estimated that 329.8 million people (40.1%) in Africa are iodine deficient (ICCIDD, 2003). In 2004, ICCIDD reported progress towards elimination of iodine deficiency in Africa, with variable degrees of success, whereby, in some countries iodine deficiency has been virtually eliminated, while in others severe problems remain in implementing national salt iodization programmes. The improvement has been attributed almost entirely to the increased utilization of iodized salt (Wright, 2004). However, a 2007 report by UNICEF on global progress toward universal salt iodization, found a slowed progress over the past decade (ICCIDD, 2007). Slightly more than half (60%) of households in the Eastern and Southern African regions, 67% of Sub-Saharan Africa region, and 43% of households in Tanzania had access to iodized salt (ICCIDD, 2007).

Tanzania is moderately affected by iodine deficiency. However, there are areas of severe endemicity (TFNC, 1999). In 1996, 41% of the Tanzanians were considered to be at risk of iodine deficiency disorders (IDD), with total goitre rate (TGR) of 37% (with rates up to 60% in the mountainous areas) and 160,000 cretins (WHO, 1997). A national survey conducted in 1998 to evaluate the achievements and constraints faced by the National IDD Control Programme, reported a significant reduction in TGR in more than half of the selected goitre endemic districts, as compared to previous years (TFNC, 1999). The exceptions were observed in some of the districts, namely Ludewa and Arumeru, where TGR was almost the same as before the implementation of IDD control measures (TFNC, 1999). It is clear that iodine deficiency remains a significant public health problem in the country.

Although iodine deficiency is the main factor in the aetiology of endemic goitre, the additional role of dietary intake of goitrogens is often disregarded. This study was conducted because of the consequences posed by iodine deficiency and the need to investigate factors associated with iodine nutrition in a goitre-endemic area of the country. It assessed iodine status of school-children and investigated on associated factors, such as knowledge and practices regarding iodine nutrition, including consumption of iodine-rich and goitrogen-containing foods and iodine levels in salt at the household level.

Materials and Methods

Study area

A cross-sectional study was carried out in January 2003 in Arumeru district of Arusha Region, Tanzania. The 2002 national census conducted by the government of United Republic of Tanzania (URT) reported that Arusha region has a total population of 1,292,973 people, with average household size of 4.5 people. The region is divided into 5 districts. Arumeru district has the highest number of inhabitants in the region, with a population of 516,814 people (URT, 2003). From this district, Enaboishu division was purposively selected because of a high number of households and varied socio-economic status. From this division, Kimunyaki ward was selected by simple random sampling. The ward has a population of 18,967 inhabitants and 4,291 households (URT, 2003).

Subjects and sampling

The study population consisted of 100 parents and their school-aged (8-10 years) children. A random list of households with school-children aged 8 to 10 years was prepared in order to construct a sampling frame. From this list, one hundred households were selected by simple random sampling. A sub-sample of 50 households was selected for additional measurements by systematic sampling (every second household). Ethical approval to conduct the study was obtained from the Sokoine University of Agriculture, Morogoro. A verbal consent was obtained from the selected parents.

Data collection

Primary data were collected using a pre-tested structured questionnaire that sought information on socio-demographic and socio-economic characteristics of the parents; and knowledge and practices regarding iodine nutrition. Knowledge regarding iodine nutrition included questions on whether respondents have heard of iodine and IDD, knew sources of iodine, consequences of lacking iodine and causes of goitre. On the other hand, practices regarding iodine nutrition assessed consumption pattern of selected iodine-rich foods and goitrogen-containing foods and iodine content of salt used in the homes. Optimal practices were considered to be reflected in optimal levels of urinary iodine concentration (UIC), thus UIC of selected school-children was also determined.

Collection of salt and urine samples

A sub-sample of 50 households was selected by systematic sampling from the main sample of 100 interviewed households. From this sub-sample, salt samples used in the homes were collected in a screw-cap plastic bottle. In addition, fasting morning urine samples were obtained from one randomly selected schoolchild (8-10 years) per household. Fifty children were provided with screw-cap plastic bottles and urine samples were collected under supervision of the researchers. Samples were put in ice-packed cool box and transported to the Department of Pathology, Faculty of Veterinary Medicine, Sokoine University of Agriculture, where they were stored at $-20^{o}C$ for seven days before analysis.

Chemical analysis of salt and urine samples

Salt samples were analysed quantitatively for iodine by using iodometric titration method (Mannar and Dunn, 1995). The method involved the use of sulphuric acid to liberate iodine from the iodated salt and potassium iodate to solubilize the free iodine. The salt solution was titrated with freshly prepared standardized sodium thiosulphate solution where starch solution was used as end-point indicator. The amount of sodium thiosulphate solution used was recorded and converted to parts per million (ppm). After analysis, the salt samples were classified according to their iodine levels (Coppens *et al.*, 1999).

Iodine concentration in the urine samples was determined using Sandell–Kolthoff reaction (Dunn *et al.*, 1993; WHO, 1994) in which urine was digested first with ammonium persulphate. The concentration of iodine was then determined from its catalytic reduction of ceric ammonium sulphate in the presence of arsenious acid. A spectrophotometer (UV-VIS) was used to examine the reduction of ceric ammonium sulphate. A standard iodine solution was used in order to extrapolate the concentrations of iodine. After determination, the concentration of iodine was recorded in micrograms (μg) of iodine per litre of urine.

Statistical analysis

The Statistical Package for Social Sciences (SPSS) Software (Version 9.0; SPSS Inc., Chicago, USA) was used to summarize and analyze the data. Descriptive statistics for all the variables were computed. Differences between selected groups of children were determined by t-test. Associations between variables were tested using Chi-square test. A value of $P<0.05$ was considered statistically significant.

Results Household and parents characteristics

Selected parents and household characteristics are presented in Table 1. Majority (82.5%) of the households were headed by males and most (73.8%) of the respondents were farmers. Sixty-three percent of respondents had not completed primary education and 14% had never attended school. Mountain springs were reported to be a source of drinking water by 80% of respondents. Almost all (94.8%) of the household farms were located on the highlands away from the dwellings. The mean household size was 4.5 ± 2.77 persons, with a range of 1 to 15 persons.

Parents knowledge on iodine nutrition

Results of assessment of knowledge regarding iodine nutrition are presented in Table 1. Majority of the respondents (74%) had heard of IDD and iodine (76%) from different multiple sources. These sources included radio programmes (58.1%), health personnel (44.6%), school teachers (19%), and newspapers (9.5%). Other sources that were mentioned by few (6.8%) respondents included posters and television. Less than half (40%) knew the different food sources of iodine. Among the mentioned sources were fish, meat, milk, beans, all grains, fruits and vegetables. Salt was not among the mentioned sources. More than half of the respondents (71%) were aware of the presence of iodated salt sold in village markets. Fifty-eight percent of the respondents knew the consequences of lacking iodine in the body of which goitre, mental retardation and dwarfism were mentioned. Less than half (44%) of the respondents knew that goitre was caused by iodine deficiency. Almost all respondents (93%) had seen a person with goitre in their community, and 17.5% had a household member with goitre.

Table 1. Household Characteristics and Parents' Knowledge on iodine nutrition (n=100)

Characteristic	Proportion (%)
Household Characteristics	
Household head	
Male	82.5
Female	17.5
Education level of household head	
Never gone to school	14
Not completed primary education	63
Completed primary education	14
Completed secondary education	9
Occupation of household head	
Farming	73.8
Small business	13.6
Employed	2.6
Sources of drinking water	
River	20
Mountain springs	80
Location of household farm	
Lowland	5.8
Highland	94.2
Knowledge of iodine and IDD	
Heard of IDD	
Yes	74
No	26
Heard of a mineral called iodine	
Yes	76
No	24
Know sources of iodine from foods	
Yes	40
No	60
Know consequences of lacking iodine	
Yes	58
No	42
Know causes of goitre	
Yes	44
No	56

Household practices

More than half of the school-children were reported to have consumed selected iodine-rich foods (Table 2) seven days prior to the survey. Cereal grains, milk, fresh-water fish, fruits and vegetables were the most frequently consumed foods by majority of the children. In most of the study households, cereal grains constituted the main staples while milk (consumed mostly as fermented), fresh-water fish, and vegetables were consumed as the main relish. Although more than half (50-59%) of the children reported to have consumed marine fish, chicken, legumes, and potatoes, these foods were mostly consumed once per week. More than half of the school-children were reported to have consumed selected goitrogen-containing foods (Table 2) seven days prior to the survey. These were cassava, kale and cabbage. During the study, kale and cabbage were the most common vegetables locally grown by most households and also highly available in the local markets. Cabbage was the most frequently (twice or more per week) consumed vegetable, while cassava and kale were mostly consumed once per week. Frequency of consuming millet and sorghum was low, and those who consumed the grains were very few.

Table 2. Frequency of consuming selected iodine-rich foods and goitrogen-containing foods by the children (n=100)

Food item	Proportion consuming the food item (%)	Proportion (%) at different frequencies of consumption per week		
		Once	2 – 3 times	> 3 times
Iodine-rich foods				
Fresh–water fish	98	33	59	6
Marine fish	53	51	2	0
Beef	98	7	79	12
Chicken	59	56	1	2
Milk	98	0	5	93
Eggs	76	56	18	2
Cereal grains	99	0	3	96
Legumes	56	45	10	1
Potatoes	50	43	6	1
Fruits	100	1	11	89
Vegetables	98	1	16	81
Goitrogen-containing foods				
Cassava	71	59	10	2
Millet	3	2	1	0
Sorghum	1	1	0	0
Kale	88	54	32	2
Cabbage	93	23	48	22

Iodine content in salt and urinary iodine status

Forms of salt found to be used by the households were fine (crystalline) salt (97%) and coarse salt (3%). Fine salt was sold in polyethylene packets while coarse salt was sold in open air. These were purchased from shops and markets. After purchase, packaged fine salt would be emptied in plastic containers, then covered and stored in the coolest part of the kitchen. Coarse salt was also stored in covered plastic containers. Majority of those who used fine salt cited availability, presence of iodine and ease in dissolving as reasons for their salt preference; while those who preferred coarse salt cited availability as a reason for preference. The most determining factors for household's choice of salt were price (90%), availability (6%) and taste (4%). Fourteen percent of the households reported occasional use of "magadi," a common ingredient containing bicarbonate of soda, to soften beans, maize and vegetables during boiling. It was reported further that, magadi has a salty taste such that, there will be no need of adding salt in the food.

The mean age of the school-children was 8.98 ± 0.75 years. Table 3 shows the levels of iodine in household salt. Ninety-six percent of the salt samples contained 15 ppm or more of iodine. Median urinary iodine concentration (UIC) of the school-children was 49.17 µg/L (range: 16.27 µg/L - 206.05 µg/L). Mean UIC was 61.43 ± 44.35 µg/L. Table 3 presents a classification of children according to IDD status using urinary iodine concentration. Very few (10%) of the children had normal urinary iodine levels of 100 µg/L and above. Less than half (40%) of the school-children had mild iodine deficiency and 42% had moderate iodine deficiency. Severe iodine deficiency was found in 8% of the children.

A high proportion of children with moderate iodine deficiency were also found to have consumed kale (90.5%), cabbage (100%) and cassava (66.7%). Although use of bicarbonate of soda or 'magadi' as a salt substitute displaces consumption of iodated salt, there was no significant difference in UIC between children from households that used bicarbonate of soda and those that did not use bicarbonate of soda (p=0.633).

Table 3. Iodine status in the salt samples and urine from the children

Iodine status	Range	Frequency	Proportion (%)
Salt	(ppm)		
Non-iodated	<5	0	0
Insufficiently iodated	5-14	2	4
Adequately iodated	15–45	18	36
Over-iodated	>45	30	60
Total		**50**	**100**
Urinary iodine concentration	(μg/L)		
Severe deficiency	<20	4	8
Moderate deficiency	20–49	21	42
Mild deficiency	50–99	20	40
Optimal	100–199	4	8
More than adequate	≥200	1	2
Total		**50**	**100**

Discussion

Overall, a high proportion of residents of Kimunyaki ward in Arumeru District had heard of iodine and IDD. Surprisingly, knowledge regarding sources of iodine, consequences of lacking iodine and causes of goitre were lacking. Similar observations were made by Tanzania Food and Nutrition Centre (TFNC) in the national survey conducted in 1998 (TFNC, 1999). Less than half of the respondents in this study could link goitre to iodine deficiency and lack of iodine in the body to IDD. Production and distribution of information, education and communication (IEC) materials on iodine is sporadic and coverage is often low. In addition, broadcasting information about iodine through radio programmes is irregular. These have contributed to limited knowledge on iodine. A high proportion of household heads had not completed primary education, thus very few would have benefited from lessons on IDD in schools. Indeed, few respondents cited schools as their source of information on iodine. Although radio was the most cited (58.1%) source of information, the ability of rural households to access radio programmes and ensure systematic follow-up is limited due to lack of electricity and recurrent cost of batteries.

The observed high proportion (Table 3) of household salt samples been adequately iodated (15 ppm and above) is in agreement with the national level of 84% reported in the 2004 survey (URT, 2005) and the range of 62% - 98% reported in the 1998 survey (TFNC, 1999). Moreover, the 1998 survey found that 92% of household salt samples in Arumeru were adequately iodated. A minimum concentration of 18.7 ppm at the household level has been recommended for the country (WHO, 1997). This implies that almost all salt used for household consumption in the study is adequately iodated as 96% of the salt samples contained iodine levels higher or equal to 18.7 ppm. There was no specific distribution pattern for iodated salt in the country, although it is common to find imported salt in the border districts. Since there were no local production sites for salt in the study area and all salt consumed came from outside the area, then the adequacy of iodine in salt samples could be explained by the adequacy of processing during salt production and iodation, and good storage practices.

The observed high proportion of households using finely crystallised salt implies that they are more likely to benefit from high quality salt than their counterparts who used coarse salt. Fine salt that is well refined, packaged and stored has been documented to adequately retain iodine than coarse salt (Dunn and Van der Haar, 1990). In the 1998 survey, iodine levels in coarse salt samples obtained from Arumeru district were found to be lower than those found in fine salt (TFNC, 1999). A study conducted in South Africa documented that loss of iodine from fine salt was lower than that of coarse salt (Jooste, 2003). This has been related to the effect of large particle size, inadequate iodization method and high level of impurities in maintaining iodine stability in coarse salt (Jooste and Locatelli–Rossi, 2003).

The median (49.17 μg/L) urinary iodine concentration [UIC] of the school-children in this study was lower than 328 μg/L, a value reported in the 1998 survey for Arumeru District (TFNC, 1999). Urinary iodine concentration is a marker of very recent dietary intake (UN ACC/SCN, 2000). Moderate iodine deficiency has been defined as median UIC of 20-49 μg/L among school-children (WHO, 1994). Using this criterion, it is observed in this study that the district is faced with moderate iodine deficiency. The benchmark set by the United Nations for monitoring progress towards elimination of IDD as a public health problem is that less than 50% of the target group should have urinary iodine below 100 μg/L and less than 20% should have levels below 50 μg/L (UN ACC/SCN, 2000; Coppens *et al.*, 1999). In this study, 90% of the children had UIC below 100 μg/L, while 32% had UIC below 50 μg/L. The low levels of urinary iodine concentration found in this study increases the risk of impaired cognitive performance among school-children. Children from iodine deficient areas have been known to have lower intelligence quotients (IQ) and poor school performance than children from iodine–sufficient populations (Bleichrodt and Born, 1994).

The high prevalence of IDD among the school-children in this study could be explained by several factors, namely, location of household farms in the mountains with sharp slopes, low consumption of iodine-rich foods in relation to increased iodine requirements, and high consumption of goitrogen–containing foods. It is important to note that household farms were located on higher grounds characterized by constant high rainfall. Constant rainfall and floodwater have been known to erode away the iodine–rich surface soils such that crops grown on would also lack iodine (Johnson and Fordyce, 2003).

The observed low frequency of consumption of known sources of iodine among the school-children in this study compared with high frequency of consuming goitrogen-containing foods could be the reason for iodine deficiency. Goitrogens that are naturally found in foods compete with iodine uptake by thyroid gland (Hetzel and Clugston, 1999). Kale, cabbage, cassava, millet, and sorghum are goitrogen-containing foods commonly consumed by the households. Consumption of cassava and sorghum has been associated with development of endemic goitre in Central Africa and Sudan, respectively (Elnour *et al.*, 2000). In this regard, high concentration of goitrogens than that of iodine could have limited adequate iodine uptake and subsequent use of iodine in synthesis of thyroxine hormones.

To meet iodine requirements, school-children (7-12 years) need 120 μg of iodine daily, and this would normally be met by consumption of adequate diet and iodated salt (WHO, 1996). During the school-age period, the children failed to meet their iodine needs from the habitual diets because of increased requirements. Their diets were characterized by low iodine content of habitual foods and high content of goitrogens resulting in inadequate iodine intake. Although use of bicarbonate of soda or 'magadi' as a salt substitute displaces consumption of iodated salt, this practice was used by few households and it had no influence on children UIC, thus less likely to have a great influence on iodine deficiency.

Conclusion

It can be concluded that iodine deficiency is a problem in Arumeru district. The deficiency is attributed to low consumption of iodine-rich foods and high intake of goitrogens coupled with limited knowledge on iodine nutrition by the inhabitants.

It is recommended that the National IDD Control Programme need to conduct periodic re-advocacy on iodine nutrition for continuous political commitment. The Programme should strengthen partnership with stakeholders such as district councils, salt processing industries and distributors, non-governmental organizations, and media organizations. Agricultural and health officials at the district level should design communication strategies that are broad enough to deliver specific and tailored messages that provide the public with required knowledge on iodine nutrition to foster attitude and behaviour change. Extensive studies to determine salt and iodine intake, processing and storage of foods rich in iodine and foods that contain goitrogens are needed to ascertain the extent to which dietary factors contribute to IDD in this population and other endemic areas in the country.

Acknowledgement

The authors acknowledge all parents in Kimunyaki Ward, Arumeru for the patience in responding to the questions and allowing their school-children to be tested for urinary iodine concentration. The Government of Tanzania is acknowledged for provision of funds to conduct the study.

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