

Iodine Status of Rural School Children in Vhembe District of Limpopo Province, South Africa

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ABSTRACT

Iodine is essential for the synthesis of thyroid hormone. Iodine deficiency develops due to imbalance between dietary iodine intake and thyroid requirements. Iodine deficiency disorders (IDD) includes a wide spectrum of abnormalities in the physical and cognitive development of human. To determine the prevalence of iodine deficiency in Vhembe district, Limpopo Province South Africa, to establish whether the mandatory salt iodization provides sufficient iodine to the study population. Two rural municipalities in Vhembe district (Mutale and Vuwani). A cross sectional school based survey. 664 primary school children aged 6-14 years. Biochemical analyses were performed for the iodine concentration in urine and salt samples. Ultrasonography was used to determine thyroid size in a subsample of 251 school children. The median urinary iodine was 82.2µg/L for Vhembe district and significant differences were found between Mutale and Vuwani (p=0.001). The coverage of iodized salt was 18.2% in Vhembe district and there was a high usage of coarse salt in both sub-districts (50% in Mutale and 46.2% in Vuwani). A total of 42 (5%) subjects with grade 1 goiter were observed in Mutale and 8 (0.97%) subjects in Vuwani. Mild iodine deficiency exists in Vhembe district with almost a third of the study population falling within the severe category.

Key words: Goiter, Urinary iodine, Iodine deficiency disorder.

INTRODUCTION

Iodine is used in the synthesis of thyroid hormone. This is its only known function in human metabolism. The two thyroid hormones, thyroxine (T4) and triiodothyronine (T3) stimulate cell oxidation and regulate basal metabolic rate (BMR), apparently increasing oxygen uptake and reaction rates of enzymes systems handling glucose (Williams, 1994). Iodine is rapidly absorbed from the gut and of the 15-20 mg of iodine in the body 70-80% is in the thyroid gland, which weighs only 15-25g (Zimmermann, Jooste and Pandav, 2008). Iodine is taken up by the cells of the thyroid gland involving an iodine pump in a process which is stimulated by

the thyroid stimulating hormone (TSH or thyrotropin) released by the pituitary gland.

Iodine deficiency develops due to imbalance between dietary iodine intake and thyroid requirements. If the environment is adequate in iodine content, humans have no difficulty in obtaining the required small amount of iodine through water and food (WHO, 1990). More than 20 million are estimated to have some degree of preventable brain damage (Hetzl, 2000). In Pakistan, it has been estimated that 50 million people are affected from iodine deficiency while the prevalence of goiter ranges from 55% to as high as 80-90% in the plain and hilly areas, respectively (WHO, 1993).

Iodine deficiency disorders (IDD) includes wide spectrum of abnormalities in human physical and cognitive development. Goiter is common in all ages, but most significant are the effects on brain development during pregnancy and the first 2 years of infancy which are periods of rapid brain growth (Hetzel, 2000). Iodine deficiency is the single most common cause of preventable mental retardation and brain damage in the world (Hetzel, 1983). It also causes goiters and decreases the production of thyroid hormones vital to growth and mental development. Children with iodine deficiency can grow up stunted, apathetic, mentally retarded and incapable of normal movement, speech or hearing. Iodine deficiency disorders (IDD) may occur at virtually any age and include abnormalities such as goiter, abortions, stillbirth, hypothyroidism, cretinism, impaired mental function and retarded physical growth (DeLange, 1994; Hetzel, 1983).

The severe form of iodine deficiency results in endemic cretinism characterized in its fully developed form by mental defect, deaf mutism and spastic diplegia. The extent of brain damage that occurs due to iodine deficiency in a given population varies considerably, a meta analysis studies on evaluating the impact of iodine deficiency on intelligent quotient (IQ) of children revealed that iodine deficiency causes a mean loss of 13.5 IQ points in children (Hetzel, 2000).

A population is defined to have a public health problem if more than 5% of children aged 6-12 years are found to have an enlarged thyroid. It is imperative to maintain the urinary median at more than 100 μ g/L to prevent iodine deficiency and at the same time not to exceed 200 μ g/L to prevent hyperthyroidism. Regular monitoring of salt and iodine levels will ensure a satisfactory maintenance of normal iodine nutrition (Hetzel, 2000).

Both historical data and the fact that endemic goiter exists in all our neighboring countries point towards the likelihood that endemic goiter also exists in certain geographical areas in South Africa. In 2001, 18 cases of visible goiter were observed in Sambandou village in Limpopo during the visit by the Provincial Department of Health, UNICEF and MRC. The number of reported cases by clinics and

hospitals in Vhembe were found to be increasing. Other clinics, for example Matavhela from the same area, have also reported cases. The information was provided by the local health clinic in the village. The magnitude of iodine deficiency disorders was not known. For any kind of intervention programme baseline information is prerequisite. Therefore, the study was undertaken to estimate the prevalence of iodine deficiency in the district.

Methodology

Study area

The study was conducted in primary schools of 2 sub-districts (Vuwani and Mutale) of Vhembe district in 2003. Eleven schools were randomly selected from Mutale sub-district and 13 schools were selected from Vuwani bringing the total number of schools to 24. Children aged 6-14 years from the two sub-districts were used as subjects in the study. The children were randomly selected using the class-list provided by the headmaster. A total amount of 829 schoolchildren participated in the study however 165 children were excluded from the study due to missing values for either urine, salt or age.

Biochemical assessment

Identical sampling and data collection procedures were used in the 2 sub-districts, which were conducted in different months. Salt samples (n=54) purchased from 24 retailer shops each situated in the vicinity of a school where the study was conducted were analysed for iodine content. Schoolchildren were given small plastic bags with a zip lock seal to take home for collecting 5 teaspoons of salt (fine or coarse) that was used for preparing food at their homes. These plastic bags were given to the child on the day of urine collection and the children had to return them to the teacher or principal the following day. The researcher went back to the school to collect the salt samples. The salt samples (n=725) were collected and only 664 samples analysed by means of idiometric titration method (WHO, 1993) at the iodine laboratory of the Nutritional Intervention Research Unit (NIRU) of the Medical Research Council (MRC) in Cape Town. The remaining 165 leaked during shipment to MRC. The coefficients of variation (CVs) were 0.68 at 20 ppm and 1.05 at 60 ppm for this method.

About 810 urine samples were collected from subjects using 40mL specimen containers with screw caps. The samples were kept in a cooler box with freezer blocks. The urine samples were aliquoted in 2.2-3mL safe lock Eppendorf micro tubules and packed in storage bags. The samples were kept refrigerated at -20 degrees Celsius until analysis. About 664 urine samples were analysed for iodine content by means of manual acid digestion and spectrophotometric detection of iodine by ceric ammonium reduction in the Sandell-Kolhoff reaction (Dunn *et al.*, 1993; WHO/UNICEF/ICCIDD, 1994). The remaining 146 spilled during shipment to MRC.

Clinical assessment

The thyroid gland of each child was visually inspected and palpated and was graded according to the criteria of the World Health Organization, the United Children's Fund, and the International Council for Control of Iodine Deficiency Disorders (Dunn *et al.*, 1993), as not palpable (grade 0) or palpable not visible (grade 1), or palpable and visible (grade 2). This was done by a professional nurse. Thyroid sizes were assessed by ultrasonography on a sub sample of children consisting of 251 subjects (Vuwani=84; Mutale=167) due to budgetary and logistical reasons. Furthermore, ultrasonography estimation of thyroid size has been advocated as being more precise than palpation (Dunn *et al.*, 1993; WHO/UNICEF/ICCIDD, 1994). However, such examinations are cumbersome and costly to carry out in remote parts of low-income countries.

Anthropometric measurements

The children were weighed without shoes and wearing light clothes. The subjects stood still in the middle of the scale's platform without touching anything and with the body weight equally distributed on both feet. The weights were taken by a registered dietician using Tanita bathroom solar scale (model 1631). The scale is accurate within 0.1 kg.

Height was taken without shoes and socks (feet bare) flat on the floor, heels close together and against the wall. Heels, shoulder blades, and buttocks were also against the wall. The shoulders were in a relaxed position, arms at the sides and the head in the Frankfort horizontal plane (look straight ahead). The height was taken twice by a registered trained

dietician to increase reliability and the average was calculated. This was done using a portable height meter fitted with a metal tape measure and which measures to the nearest millimetre.

Ethical Approval

Permission to conduct the study was obtained from the Department of Education (Vhembe district) and from the Ethics Committee of the University of Venda. A written consent was obtained from parents or guardians of the children before data collection began.

Statistical analysis

The data collected was entered in Windows Excel spread sheet and SPSS. The Z-scores were computed using WHO anthroplus software. Descriptive statistics were computed (means, standard deviations, medians, interquartile ranges and frequencies). Chi-square (χ^2) tests were used to compare differences between categorical data. Mann-Whitney tests were used to compare differences between groups as data that were not normally distributed. A p-value <0.05 was considered as statistically significant.

RESULTS

Nutritional status

Our findings showed that 7.4% (Vuwani 6.7% and Mutale 8.1%) of the children were stunted and 2.1% (Vuwani 1.5% and Mutale 2.8%) were underweight. Furthermore 19% were at risk for underweight (Vuwani 17% and Mutale 20.8%). In addition overweight was observed in 3.9% of the children (Vuwani 5% and Mutale 2.8%) while obesity was present in 1.2% of the children (1.2% in both sub-districts).

Looking at the measured variables, differences were observed in weight values of the children from Vuwani sub-district being heavier. With regard to Body mass index for age Z-score (BAZ) children from Mutale recorded lower mean Z-scores (Table 1).

Iodine content in household salt

No differences were observed with regard to the iodine content of household salts between the two districts but urine iodine excretion was higher in

Mutale ($p=0.001$) (Table 2). Salt samples from the two districts showed no differences in iodine content but further analysis revealed that iodine content of fine salt was higher than that of coarse salt (41.54 ± 25.35 ppm vs. 10.28 ± 13.33 ppm; $p<0.0001$). Only 18.2% of the household samples were adequately iodised (> 15 ppm of iodine per kg salt).

There were no differences in the overall salt iodine concentrations between the two sub-districts, but in males it was observed that there were differences in the inadequate iodised salt category with Mutale having lower percentage of adequate iodised salt samples (26.5%) than Vuwani sub-

district (38.8%) ($X^2=7.13$; $p=0.028$) and in females there were no differences observed. Table 3 show children as categorized by gender within various salt categories. When sub-districts were not taken into consideration there were no differences in both salt iodine and urinary iodine between the two genders.

Iodine content in retailer salt:

Salt samples purchased from 24 retailer shops, each situated in the vicinity of a school where the study was conducted were analysed for the iodine content. The shops had different types of

Table 1: Mean and SD of measured variables in the study population

Variables	Total (N=664)		Vuwani (N=342)		Mutale (N=322)		P –values
	Mean	SD	Mean	SD	Mean	SD	
Age (years)	8.92	1.07	8.97	1.04	8.86 ±	1.11	0.407
Weight (kg)	25.7	4.55	26.07	4.25	25.31 ±	4.84	0.002
Height (cm)	127.78	7.17	128.19	6.92	127.35 ±	7.41	0.133
¹ HAZ	-0.70	1.07	-0.69	0.93	-0.70 ±	0.99	0.415
² BAZ	-0.36	0.83	-0.29	0.82	-0.45 ±	0.82	0.009
Salt (ppm)	11.59	36.70	12.23	46.36	10.92 ±	22.31	0.896
³ Urine (µg/L)	82.22	1002	75.02	(999)	101.17	(150)	0.001

¹HAZ- height-for-age Z-score; ²BAZ- Body Mass Index-for-age Z-score;

³Median and interquartile ranges

Table 2: Percentage coverage of household salt with > 15 ppm

Status	Vuwani (N=342)	Mutale (N=322)
No iodine (0 ppm)	166 (48.5%)	171 (53.1%)
Inadequate (<15 ppm)	120 (35.1%)	86 (26.7%)
Adequate (15-40 ppm)	56 (16.4%)	65 (20.2%)

salt from different salt producing companies. The mean iodine salt concentration for the salt found in retailers for Vuwani was 29.93 ± 29.61 and for Mutale 23.29 ± 21.48 . However, half (51.9%) was fine and 48.1% was coarse salt. There were no differences observed in the mean iodine concentration of both sub-districts. Table 4 shows iodine concentration in retailer salt.

With respect to urinary iodine, Vuwani recorded higher percentages of mild urinary iodine (44.2%) as compared to Mutale sub-district

Table 3: Percentage coverage of household salt > 15 ppm by gender

Status	Total (N=664)	Female (N=363)	Male (N=301)
No iodine (0ppm)	337 (50.8%)	181(49.9%)	156 (51.8%)
Inadequate (<15ppm)	206 (31%)	108 (29.8%)	98 (32.6%)
Adequate (15 – 40 ppm)	121 (18.2%)	74 (20.4%)	47 (15.6%)

(23.9%) ($X^2=49.96$; $p < 0.0001$). With respect to gender differences males from Vuwani recorded higher values of mild urinary iodine (38.7%) than those in Mutale sub-district (23.2%) ($X^2=22.98$; $p < 0.0001$). The same was observed in females where the observed values were 48.4% and 24.65% respectively ($X^2=28.80$; $p < 0.0001$). Tables 5 and 6 indicate percentages of children within various urinary iodine categories by sub-district and gender respectively.

Thyroid volume by ultrasonography:

Goiter diagnosis by ultrasonography was also done but only in a sub-sample of 251 schoolchildren (Vuwani=84; Mutale=167). The results indicated that 8 cases of goitre were found in Vuwani and 42 cases were from Mutale. These cases had

thyroid volumes greater than 97th percentile (P97) according to the reference values for thyroid volume by ultrasound in iodine sufficient schoolchildren (Zimmermann *et al.*, 2004).

In the total study population urinary iodine correlated with WAZ ($r=0.100$; $p=0.016$) and HAZ ($r=0.108$; $p=0.005$). But subdividing the population into districts revealed correlations only in Vuwani district where urinary iodine correlated with WAZ ($r=0.170$; $P=0.004$) HAZ ($r=0.125$; $P=0.021$) and BAZ ($r=0.152$; $P=0.005$).

DISCUSSION

Limpopo province is amongst the worst affected provinces in South Africa with regard to

Table 4: Iodine content and texture in retailer salt

	Total (N=54)		Vuwani (N=26)		Mutale (N=28)		P-values
Salt (ppm)*	26.49	25.68	29.93	29.61	23.29	21.48	0.436
Texture#							
Coarse	26	48.1%	12	46.2%	14	50%	—
Fine	28	51.9%	14	53.8%	14	50%	—

*Mean and SD #N and Percentages.

Table 5: distribution of iodine concentrations in various categories

Status	Vuwani (N=342)	Mutale (N=322)
<20 µg/L	10 (2.9%)	14 (4.3%)
20-49µg/L	69 (20.2%)	70 (21.7%)
50-99µg/L	151(44.2%)	77 (23.9%)
100-199µg/L	83 (24.3%)	81 (25.2%)
200-299µg/L	18 (5.3%)	36 (11.2%)
>300µg/L	11 (3.2%)	44 (13.7%)

nutritional status with the prevalence of stunting at 23% in two national surveys and severe stunting having increased from 6.9% to 8.3% from 1999 to 2005 while underweight over the years was 9.3% (Labadarios, 1999; Kruger, 2007). The results from the current study revealed that underweight children residing in Mutale had significantly lower BAZ- scores as compared to those in Vuwani. School age is a very crucial period of life. There is a transition from childhood to adolescent where rapid growth occurs. At this stage of development

Table 6: Percentage of children within various urine iodine categories by gender

Status	Total (N=664)	Female (N=363)	Male (N=301)
Severe (<20µg/L)	24 (3.6%)	11 (3%)	13 (4.3%)
Moderate (20-49 µg/L)	139 (20.9%)	71 (19.6%)	68 (22.6%)
Mild (50-99µg/L)	228 (44.3%)	135 (37.2%)	93 (30.9%)
Optimum (100-199µg/L)	164 (24.7%)	84 (23.1%)	80 (26.6%)
More than adequate (200-299µg/L)	54 (8.1%)	33 (9.1%)	21 (7%)
Excess ($e \geq 300 \mu g/L$)	55 (8.3%)	29 (8%)	26 (8.6%)

micronutrients deficiencies may occur and hinder physical growth. Mild iodine deficiency has been examined at population level and it has been found to retard growth (Joshi and Nair, 2011). The mechanism whereby mild iodine deficiency can retard growth and iodine repletion can produce a growth response is absolutely clear with the role of thyroxin in growth and development. Both thyroid and growth hormones are essential for normal growth and development (Shapiro, Samuels and Yaffe, 1978; Robson *et al.*, 2002). Thyroid hormone also directly affects epiphyseal growth, bone maturation, and stature (Nilsson *et al.*, 1994). Thyroxin has been shown to stimulate growth hormone and insulin like growth factors (Mason *et al.*, 2002). Hypothyroidism is a well recognised cause of short stature in children, and in hypothyroid Colombian children with minimal thyroid dysfunction, T₄ administration increased growth (Hernandez-cassis, Cure-Cure, and Lopez-Jamarillo, 1995).

It has been shown that urinary iodine is related to growth and BMI in both children and adults (Knudsen *et al.*, 2005). The present findings of the positive association only in Vuwani district could be related to the district having a higher number of children with low urinary iodine content.

When looking at differences between fine and coarse salt it was found that fine salt had higher iodine content as compared to coarse salt. This is bound to be as coarse salt is mainly used for agricultural purposes. At household level only 18.2% of the households were found to use salt that was adequately iodised which is way below the international coverage of 90% (http://whqlibdoc.who.int/hq/1996/WHO_NUT_96.pdf). This is due to the fact that the agricultural salt is not iodised and it is used by the majority of the people in Vhembe district. It is also cheap and easily accessible.

Household use of agricultural non iodised salt in countries with mandatory iodisation results in shortcomings of iodisation programmes. UNICEF investigation also found that only 14% of agricultural salt in sub-Saharan Africa is iodised (Dangerfield, 2000). The price differences between iodized and non-iodized salt also aggravates shortcomings in national salt iodisation. Given a choice, price-sensitive buyers are more likely to purchase non-

iodised salt if it is cheaper than the iodised product. Some options that may overcome the impact of a price differential include educating children and adults in the community, skilful use of rapid test kit to demonstrate the presence of the required iodine in salt, marketing strategies that promote the use of iodised salt, and mandatory iodisation of all table salt.

The iodisation process seems to be generally less effective in coarse salt than in fine salt, possibly because of differences in particle size, impurities or iodised methods (Jooste, 2003). The main aim of determining the iodine content of salt stocked by retailers is to give a reflection of the iodine concentration to which consumers are exposed at household level.

Urinary iodine

School-age children are a convenient test for goitre prevalence because of their accessibility. They reflect the current status of iodine nutrition in the community except for pregnant and lactating women and are a major priority group for prompt correction of iodine deficiency (Benade, 1997). Urine samples were analysed for iodine concentration in the current study. The urinary iodine concentration is a good marker of dietary iodine as 80-95% of the daily intake is excreted in the urine (DeLange, 1994). For this reason, urinary iodine concentration values were used for population estimates. The higher urinary iodine content observed in Vuwani shows that the nutritional iodine status was better than that of Mutale for both genders and this is supported by findings that Vuwani retailers tended to sell more of fine salt than Mutale as well as the finding that the retailer iodine salt content in Vuwani had more iodine content. Though both of these observations were not significant, one can probably assume that the trend could lead to the observed differences.

Thyroid palpation

Thyroid palpation in schoolchildren is a cost effective way to assess the iodine status of a population if the palpation system is precise and easy to apply (Peterson *et al.*, 2000). The results in the current study indicated that 8 grade 1 goitre cases were diagnosed in Mutale and 3 in Vuwani, this in itself supporting the fact that Vuwani had a better iodine status than Mutale.

CONCLUSION

The present study revealed that there was mild iodine deficiency in Vhembe district and immediate measures should be taken to eradicate iodine deficiency and its disorders. The study also found that the use of adequately iodized salt was low. Even though government has made it mandatory to iodize commercial salt efforts must be made for the regular iodization of coarse salt which is mainly meant for agricultural use since it was consumed by many people in the district.

The hypothalamic-pituitary–thyroid (HPT) axis is responsible for regulating daily function of many biological systems in mammals and other vertebrates, and is an essential regulator of early brain development. Adequate levels of iodine

are critical for normal functionality of the thyroid gland (DeLange, 1994). Significant parallels exist between detriments seen in humans suffering from developmental ID, maternal hypothyroxenemia, congenital hypothyroidism and animal models of Thyroid hormones (TH) insufficiency induced by a variety of means. In humans, immediate identification of hormone insufficiency in pregnancy and in the newborn is essential to provide adequate treatment to reduce the severity of neurological insult. Despite early detection and treatment, subtle cognitive deficits may remain and serve to underscore the importance of TH to brain development and function (Gilbert *et al*, 2011). Thus it highly likely that the children in this study will suffer from cognitive deficits if taking the low iodine content of the commercial and household salts if taken as a surrogate measure of their iodine intake.

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