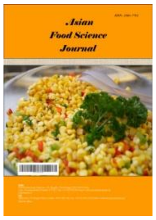

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Salt Iodization and Urinary Iodine Concentration Levels among Primary School Children in Mt. Elgon Sub-County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. Author SNO originated the concept, collected data, analyzed data, and wrote the first manuscript draft. Authors AOM and BNKM performed critical proposal and manuscript reviews. Author PN collected data, analyzed data, and performed critical proposal and manuscript reviews. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Iodine plays a key role in thyroid hormone production and functioning. Inadequate iodine intake results in iodine deficiency (ID) which impairs the normal functioning of the thyroid. The deficiency is responsible for damage to brain development, growth retardation, cretinism, and thyroid dysfunction. Millions of people have been condemned to a life of few prospects and continued underdevelopment due to ID. The study was conducted to assess iodine status among primary school children in the Mt. Elgon region and the impact of salt iodization on this status.
Study Design: A school-based cross-sectional descriptive study to assess iodine status among primary school children was employed in the study.
Study Area and Duration: The study was carried out in Kenya, Bungoma County, Mount Elgon Sub-County. The study period was between 27th November 2018 and 26th November 2019.

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Methodology: Healthy primary school children aged 6 to 12 years who met the inclusion criteria were included in the study. Spot urine samples were collected in schools, while water samples were collected from different water sources. Salt was collected from households (HH) and at distribution outlets. The Sandell Kolthoff reaction was used to analyse urine and water samples while salt was analysed using iodometric titration.

Results: The median urinary iodine concentration (UIC) was 200.7 µg/l. Out of which 0.55% were severely deficient, 5.25% moderately deficient, 18.23% with a mild deficiency, 25.69% had adequate iodine levels, 22.38% had more than adequate, and 27.90% had excess iodine levels. Household and salt samples from different distribution outlets that conformed to set standards of iodization were 49.4% and 63.64%, respectively. Iodine was not detected in all the water samples collected.

Conclusion: The study population was found to have adequate iodine based on the median UIC of 200.7 µg/l. However, there was a coexistence of both deficiency and excessive UIC and salt iodization within the population. No iodine was detected in the water samples in the region.

Keywords: Iodine deficiency; primary school children; urine iodine concentration; iodometric titration.

1. INTRODUCTION

Iodine is required by the body for the production and functioning of thyroid hormones in the thyroid gland [1,2]. Chronic iodine intake below the recommended levels results in iodine deficiency (ID) a condition referred to as hypothyroidism [1] while constant intakes above recommended levels may cause hyperthyroidism [3]. Collectively, the consequences associated with ID are commonly referred to as iodine deficiency disorders (IDD) [2]. During early childhood, ID interferes with brain development causing a loss in intelligent quotient [4]. Besides, delayed physical development, growth retardation, cretinism, and thyroid dysfunction [2,5]. Hyperthyroidism also impairs thyroid function and is associated with detrimental health effects such as iodine-induced hypothyroidism and autoimmune thyroid disease [3].

Globally salt iodization is the most widely used strategy for control and elimination of ID [2]. The population median urinary iodine concentration (UIC) is the recommended biomarker to assess the iodine status of populations [2]. For a national or regional population assessment, WHO recommends the use of UIC, since most of the iodine absorbed in the body is released through urine excretion [6]. Furthermore, UIC accurately reflects current iodine status as opposed to goitre prevalence which lags behind iodine status changes [7]. School children are the most preferred group for iodine assessment due to the easy accessibility and high vulnerability [2].

It is estimated that more than 1.5 billion people are at risk of iodine deficiency disorders globally [8]. Over the past two decades, salt iodization has resulted in marked improved iodine status in over 150 countries [3]. In Kenya, the salt iodization programme is deemed successful as the household use of the salt is more than 90% [9].

The study aimed to assess the iodine status of primary school children (6-12 years) in the Mt. Elgon region, the iodine levels in water sources in the region, and the HH salt and salt iodine levels at distribution outlets (wholesale, retail, and kiosk).

2. METHODOLOGY

The study design and population involved a school-based cross-sectional descriptive study. The research was conducted between March and April 2019 in Mt. Elgon Sub-county, Bungoma County Kenya. Mt. Elgon is located on the North-Western Kenya and Eastern Uganda International boundaries within the Lake Victoria and Lake Turkana basins. Furthermore, it is the fourth highest mountain in Africa and has a forest cover of 107,821 hectares [10]. Mt. Elgon Sub-county occupies an area of 936.75 Km^2 with Mt. Elgon forest covering 609.6 Km^2. The population in the area is rural-based and land use is dominantly for agriculture. The area experiences two rainy seasons, long and short (March to July, and August to October, respectively) [10].

The study population involved healthy school-aged-children who did not have a known chronic illness aged 6-12 years who had resided in the region for more than one year. The children had not been sick within the previous month. Before participation, parents/guardians voluntarily consented to children's participation after which the primary school children gave assent.

A sample size of 385 participants was required for the study as calculated using the sample proportion method [11].

For the sampling procedures, a list of all schools in Mt. Elgon Sub-County was obtained from the Ministry of Education, Bungoma County. Each division in the sub-county was treated as a cluster. In each cluster, schools were selected purposively (preference being mixed-gender schools). An equal number of boys and girls were selected. Thus, within each class/grade stratification sampling was performed forming boys' and girls' strata. In each stratum, random sampling was done to obtain an equal number of boys and girls from each class/grade. Students selected for the study provided salt samples from their households. Salt samples from distribution levels were obtained purposively from wholesalers, retailers, and kiosks. Water samples were obtained purposively from different water sources (piped tap water, borehole, streams, wells, river, and springs) in each division.

Sample collection involved requesting 10 ml urine specimens from study participants and storing them in acid-washed 15ml polypropylene plastic tubes. Moreover, each of the children included in the study was requested to bring a tablespoon full of household salt samples that they used at home. Packets of 200 grams of all brands of salts available in the region were purchased from kiosks, retail shops, and wholesale shops in different areas of the region. Water samples (10 ml) from different divisions of the region were collected in 15 ml polypropylene plastic tubes from boreholes, streams, rivers, shallow, and deep wells as well as piped water (taps). Different cool boxes and freezers were used for different samples during storage and transportation. Furthermore, the samples were handled using gloves and strict caution was observed to prevent their contact with dust or any other possible contaminant. After the spot urine sample collection, the samples were stored in a portable cool box whose temperature ranged between -4 to 4 °C. They were then transported within 2 hours into a portable -20°C freezer for storage. After the fieldwork, they were transported to Kenya Medical Research Institute (KEMRI) Centre for Public Health (CPHR) laboratories for storage at -20°C.

The analysis entailed determining the urine and water samples' iodine content using the Sandell-Kolthoff reaction that is based on the reaction of iodine with ammonium persulfate [2]. The salt iodine level was determined using the iodometric titration method [2]. The urine, water, and salt iodine determination methods are WHO/UNICEF/ICCIDD approved methods [2]. The samples were analyzed in duplicate and urine samples of known values used as internal reference materials. Also, samples of known values obtained from the Center for Disease Control EQUIP Programme (Ensuring the Quality of Iodine Procedures) were used as external reference materials for quality assurance. The standard operating procedures recommended by WHO/UNICEF/ICCIDD were adhered to during the analysis [2].

Before recruitment, parents/guardians of potential participants were explained to in simple lay language the purpose, procedures, risks, benefits, and timelines of the study. Data collected was handled with the utmost confidentiality and strictly used for the study purposes only. The integrity, dignity, and privacy of the study participants were maintained at all-time throughout the study. The study participants were informed about their rights to voluntary participation.

There was no risk of harm in the study participation except time consumption as the process took about 20 minutes. The potential impact of the assessment is that it helped in estimating the iodine nutrition situation and the salt iodization proficiency within the region.

2.1 Statistical Analysis

The data obtained were analyzed using Microsoft Office, Professional Plus Excel 2016 Software and presented using descriptive statistics.

Urinary iodine concentration findings were reported as median values as recommended by WHO/UNICEF/IGN [12]. The median UIC were interpreted as indicated < 20 µg/l (severe iodine deficiency), 20-49 µg/l (moderate deficiency), 50–99 µg/l (mild deficiency), 100–199 µg/l (adequate iodine nutrition), 200–299 µg/l (more than adequate), ≥ 300 µg/l (risk of hyperthyroidism) as shown in Table 1 [2].

Table 1. Epidemiological Iodine nutrition assessment criteria based on median urinary iodine concentrations of primary school children (≥ 6 years)

Median Urinary Iodine Intake Primary School Children		
Median Urinary Iodine (µg/l)	**Iodine Intake**	**Iodine Status**
< 20	Insufficient	Severe iodine deficiency
20 – 49	Insufficient	Moderate deficiency
50 – 99	Insufficient	Mild deficiency
100 – 199	Adequate	Adequate iodine nutrition
200 – 299	More than adequate	More than adequate
> 300	Excess	Risk of hyperthyroidism

Source: WHO/UNICEF/ICCIDD (2007)

The salt iodine concentration findings were reported as a mean and standard deviation classification based on the Kenya Bureau of Standards recommendations [13]. Mean potassium iodate (KIO_3) concentration <50 mg/Kg inadequate, 50-84 adequate, and >84 excessive. The findings were categorized into overall UIC primary school children, UIC male and female, salt iodine concentration in household and distribution outlets.

3. RESULTS

3.1 Demographic Characteristics

Of the 362 SAC recruited for the study, 186 (51.38%) were boys and 176 (48.61%) were girls. For the boys, the highest proportion (31.2%) was aged 6-7 years, while for the girls it was 8-9 years (33.5%) as shown in Table 2. Of the 336 salt samples provided by the children, 172 were from boys while 164 were from girls. Further, the water samples from different water sources obtained within the region were 53. The salt samples from distribution outlets were 11.

3.2 Urinary Iodine Concentration

As shown in Table 3. The median of the iodine concentration in the urine samples of the children was 200.7 µg/l. Of this, 0.55% of the samples had <20 µg/l urinary iodine concentration, 5.25% between 20-40 µg/l, and 18.23% between 50-99 µg/l ranges, classified as severe, moderate, and mild deficiency, respectively based on the WHO classification [2]. The proportion whose levels were adequate and more than adequate was observed in 25.69% between 100-199 µg/l and 22.38% between 200-299 µg/l respectively. Urinary iodine concentration above 300 µg/l, which is classified as excess, was observed in 27.90% of the children.

Boys had a higher median urinary iodine concentration of 211.3 as compared to girls who had a concentration of 188.0 as shown in Table 4.

Table 2. Number of Samples Collected and Age Distribution between Genders

Age (years)	Number Males	Number Females	Males Percentage	Female Percentage
6_7	58	42	31.2	23.9
8_9	51	59	27.4	33.5
10_11	51	47	27.4	26.7
12	26	28	14.0	15.9
	Total = 186	Total = 176		

Table 3. Urinary iodine concentration of the children

Iodine (µg/l)	Frequency	Percentage	Iodine Status
< 20	2	0.55	Severe iodine deficiency
20 – 49	19	5.25	Moderate deficiency
50 – 99	66	18.23	Mild deficiency
100 – 199	93	25.69	Adequate iodine
200 – 299	81	22.38	More than adequate
> 300	101	27.90	Risk of hyperthyroidism
	N =362	Median 200.7 (µg/l)	

Table 4. Urinary iodine concentration of the children (boys and girls)

Girls		Boys			
Iodine (μg/l)	Frequency	(%)	Frequency	(%)	Iodine Status
< 20	0	0.00	2	1.08	Severe deficiency
20 – 49	10	5.68	9	4.84	Moderate deficiency
50 – 99	37	21.02	29	15.59	Mild deficiency
100 – 199	47	26.70	46	24.73	Adequate iodine
200 – 299	42	23.86	39	20.97	More than adequate
> 300	40	22.73	61	32.80	Risk of hyperthyroidism
Median Girls = 188.0 (μg/l)		Median Boys = 211.3(μg/l)			

3.3 Household Salt Potassium Iodate Concentration

Of the 336 HH salt samples analyzed, 31.25% had less than 50 mg/Kg, 49.40% had between 50-84 mg/Kg while 19.35% had more than 84 mg/Kg potassium iodate as summarized in Table 5. This classification is based on the Kenya Bureau of Standards mandatory salt iodine standard that was set for optimum fortified iodine levels at 30-50 mg iodine/kg salt, which is equivalent to 50-84 mg/kg potassium iodate [13]. Potassium iodate is the exclusive form of fortified iodine in the country [13].

3.4 Distribution Levels Iodine Content

Of the salt samples from the distribution level, a mean iodine concentration of 65.34 mg/Kg was obtained. Using the Kenyan Government classification 27.27% were below 50 mg/Kg thus considered inadequate while 63.64% were within 50-84 mg/Kg, considered adequate. The remaining 9.09% was iodized above the recommended threshold of 84 mg/Kg, which is considered excess as shown in Table 6.

3.5 Water Iodine Concentration

Iodine was not detected in all the water samples collected.

4. DISCUSSION

The overall median UIC of SAC was 200.7 μg/l which indicates adequate iodine nutrition status in the population-based on WHO/UNICEF/ICCIDD classification [14]. Adequate iodine level was observed in 25.69% and 22.38% were at risk of excess. Only 24.03% of the population was found to be deficient. These findings in general illustrate iodine nutrition sufficiency within the sampled primary school children. These results compare well to the Kenya National Micronutrient Survey (KNMS) of 2011 whose SAC median UIC was 208.0 μg/l [7]. However, the results obtained in the study does not mean iodine nutrition sufficiency within the Mt. Elgon region population because different groups have different iodine needs: preschool children 0-59 months 90 μg, school children 6-12 years 120 μg, and adolescents and adults 150 μg [2]. Pregnant and lactating women also have a different criterion, which is higher compared to the rest 150-249 μg this is due to the increased renal clearance during gestation and most important fetus dependence on maternal iodine for thyroid hormone synthesis [15].

Iodine deficiency (severe, moderate, or mild) was observed in 24.03% of the children. On the other hand, 28.4% of the children had excessive iodine levels (>300 μg/l). Both these situations are associated with an increased risk of thyroid disorder [16]. For instance, hyperthyroidism can result in autoimmune thyroid disease. [17]. It is important to note that these findings illustrate a co-existence of both insufficiency and excess median UIC within the same population. Such a situation was also observed in a study in Makueni Kenya [3].

Universal salt iodization (USI) is the most successful strategy for iodine deficiency elimination [18]. In Kenya, salt iodization is mandatory. The standard for iodization is set at 50 - 84 mg/Kg of KIO_3 [13]. According to the Kenya Demographic Household Survey Report of 2014, Kenya has almost achieved the USI goal of having more than (90% of the HH using iodized salt [9]). The salt iodization levels in this study were found to be at an average of 64.0 mg/Kg of KIO_3 (SD 27.6) which is within the recommended iodization level. This compares well with the mean salt iodization level of 62 mg/Kg of KIO_3 (SD 23.3) reported from the KDHS of 2014. However, only 49.40% of the samples were iodized according to the applicable Government standards (50-84 mg/Kg). The KNMS study of 2011 findings also compare well where 48.3% of household salt collected were found to be adequately iodized in accordance to the Kenyan set standard [7].

Table 5. Iodine concentration in household salt samples

Household Salt Potassium Iodate Concentration			
Potassium Iodate (mg/Kg)	**Frequency (n=336)**	**Percentage (%)**	**Iodization Status**
< 50	105	31.25	Inadequate
50 – 84	166	49.40	Adequate
> 84	65	19.35	Excessive
Mean 64.0 mg/Kg ±27.6 (SD)			

Table 6. Iodine concentration in salt samples from distribution outlets

Distribution Levels Salt Potassium Iodate Concentration			
Potassium Iodate (mg/Kg)	**Frequency (n=11)**	**Percentage (%)**	**Iodization Status**
< 50	3	27.27	Inadequate
50 – 84	7	63.64	Adequate
> 84	1	9.09	Excessive
Mean 65.34 mg/Kg ±18.2 (SD)			

All the salt samples from the distribution chain outlets were labelled as iodized. However, only 63.64% of the samples were adequately iodized 27.27% were insufficiently iodized while 9.09% was excessively iodized based on the standards. Insufficient and excessive salt iodization may impairs the normal functioning of the thyroid [19].

Iodine was not detected in any of the sampled water samples. This implies that the excess urinary iodine concentrations observed in some of the children cannot be attributed to the water that they use.

5. CONCLUSION

The study demonstrates adequate iodine nutrition among the study population with adequate salt iodization in the household and distribution levels. However, there was a coexistence of both insufficiency and excessive median UIC, which increases the risk of thyroid disorders. There was also a coexistence of inadequate and excessive salt iodization in the sampled salt samples, which influence iodine nutrition of the population. Despite the challenges in salt iodization level the study result, indicate good progress in IDD elimination through salt iodization. It was noted that iodized salt was one of the main sources of iodine to the population and water had no implication on the population iodine status.

There is need to put more focus on constant and continuous monitoring of salt fortification and implementation of mechanisms that will ensure iodization is in accordance to the set standard as variations might be the cause of coexistence of insufficient and excess median UIC. Besides, capacity building to facilitate continuous consumable salt and urine iodine concentration monitoring.

CONSENT

All authors declare that written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office/chief editor/editorial board members of this journal.

The parents/guardians who permitted their children's participation gave informed consent by signing an informed consent document. Those who were unable to sign used a thumbprint mark to consent. The children whose parents gave consent were asked for their assent to participate in the study.

ETHICAL APPROVAL

Jomo Kenyatta University Institutional Ethical Review Committee gave ethical approval to the study protocol (REF: JKU/2/4/896A). The National Council for Science, Technology, and Innovation (NACOSTI) granted permission for the study to be conducted in the Mt. Elgon region (REF: NACOSTI/P/18/78691). Additionally, the county and sub-county administration granted permission for the study implementation in the region REF: BCE/DE/19/Vol.1/238 and MT.ELG/TRN/31134 respectively.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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