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Iodine status and fish intake of Sudanese schoolchildren living in the Red Sea and White Nile regions

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Abstract

Objective: To investigate iodine status and fish consumption of schoolchildren living in the Red Sea and White Nile regions of Sudan.

Design: Cross-sectional study to determine urinary iodine concentration, visible goitre rate, iodine content of salt and fish consumption.

Setting: Port Sudan (Red Sea) and Jabal Awliya (White Nile), Sudan.

Subjects: Two hundred eighty (*n* 280) children aged 6–12 years (142 boys, 138 girls).

Results: The median urinary iodine concentration in children from Port Sudan and Jabal Awliya was 553 and 160 μg/l, respectively. Goitre was detected in 17·1 % of children from Port Sudan but only in 1·4 % from Jabal Awliya, The salt samples from Port Sudan contained 150–360 mg iodine (KOI_3)/kg salt, whereas those from Jabal Awliya had levels below the detection limit. Despite consuming salt devoid of iodine, children from Jabal Awliya had optimal iodine status. It is plausible that consumption of Nile fish from Jabal Awliya Reservoir, which is a good source of iodine and favoured by the locals, might have provided sufficient iodine. In contrast, children from Port Sudan were at higher risk of iodine-induced hyperthyroidism resulting from consumption of excessively iodised salt.

Conclusions: The findings of the study clearly demonstrated that (i) Sudan still has a problem with iodine nutrition and quality control and monitoring of salt iodisation and (ii) including fish in the diet could provide a sufficient amount of iodine for schoolchildren.

Keywords
Iodine
Iodised salt
Fish
Children
Sudan

Iodine deficiency is one of the leading causes of poor mental and psychomotor development in children[(1)]. Although iodine deficiency has been eradicated in many countries, it remains a serious public health problem in Africa including Sudan[(2)]. Sudan, which has a long history of iodine deficiency with widespread endemic goitre, initiated the national Iodine Deficiency Disorders Control Programme in 1989 in an effort to control iodine-deficiency disorders. After a trial of several interventional measures such as distribution of potassium iodide tablets, filtration of iodine into well water[(3)] and iodine fortification of sugar and oil[(4)], universal salt iodisation was adapted as a long-term preventive strategy to combat iodine deficiency in 1994[(5)]. At present, the Sudanese government has set the specification for iodine content of salt at 25–35 mg/kg. However, production as well as use of iodised salt remains low[(6)]. Moreover, a Ministerial Declaration issued in July 2003 which called for iodisation of all salt produced in Sudan failed to be implemented. Worryingly, a recent survey found that the prevalence of goitre in children aged 6–12 years has increased from 22·0 % in 1997[(7)] to 38·8 % in 2006[(8)].

Iodine is found in the soil and the sea, hence dietary iodine availability is determined primarily by the iodine content of soil and the amount of seafood consumed[(9)]. Although iodine can be obtained from drinking water and beverages, iodine from food contributes most to human intake[(10)]. Saltwater fish and seaweed are good sources of iodine, however the content in fish varies considerably from species to species and also within species[(11–13)]. For instance, the reported iodine concentration in cod ranges between 12 and 652 μg/100 g and in mackerel from 17 to 240 μg/100 g. Despite iodine-deficiency disorder being one of the most serious public health problems in Sudan, data on iodine contents of food items including fish consumed by households are scare. Sudan harbours varieties of river and sea fish resources from the Nile River (Blue, White and Main), the Red Sea and man-made

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lakes. It is reported that over 100 fish species prevail in the Nile River and reservoirs, and 236 species of bony fish in the Red Sea[14]. The most common species of fish favoured by Sudanese are *Lates niloticus* (Nile perch), *Bagrus bayad* (species of catfish), *Oreochromis niloticus* (Nile tilapia), *Synodontis schall* (species of catfish) and *Tetraodon lineatus* (Nile puffer, *fahaka* pufferfish). Most fish is consumed fresh locally or transported refrigerated to other cities, but some is sun-dried and wet-salted for local consumption and export.

In the present study our first aim was to assess the iodine status of Sudanese schoolchildren aged 6–12 years living in Port Sudan (Red Sea region) and Jabal Awliya (White Nile region). Port Sudan, the capital city of Red Sea State, is the major salt production site for domestic use. Jabal Awliya, on the other hand, is a small city near the White Nile located in an area known for fresh fish from Jabal Awliya Reservoir and the iodine status of children in this area has not been assessed previously. Our second aim was to determine the iodine content of cooking salts consumed by the children and their families, and the third was to evaluate fish consumption by the children and their families as well as their teachers.

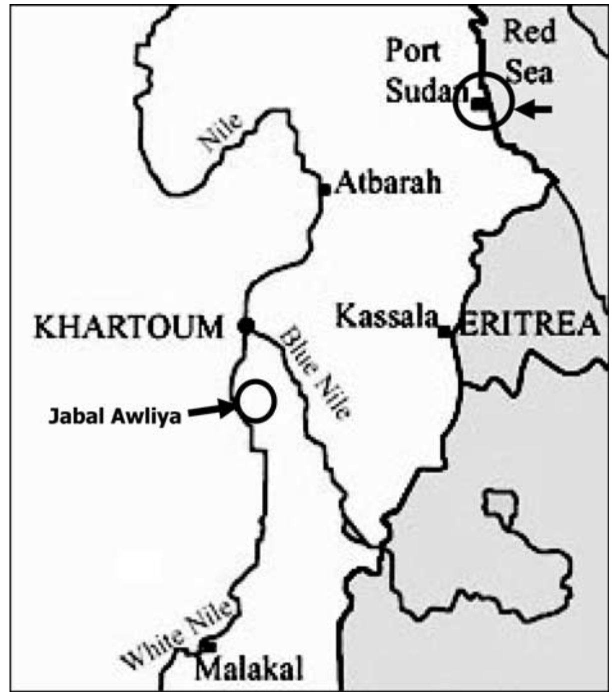

Fig. 1 Location of Port Sudan and Jabal Awliya

Methods

Survey location and participants

The present cross-sectional study was performed in two areas in the Sudan, (i) Port Sudan locality in Red Sea State and (ii) Jabal Awliya in Khartoum State, from January to November 2006. The location of the survey areas is illustrated in the map of Sudan in Fig. 1. The study protocol was designed in accordance to the WHO/UNICEF/International Council for the Control of Iodine Deficiency Disorders (ICCIDD) monitoring guideline, 3rd edition[2]. The Ministry of Education of the Sudan granted ethical approval for the survey and written consent was obtained from the parents or guardians of the participating children prior to the survey. Moreover, a letter which explained how to (i) complete the fish intake questionnaires and (ii) collect salt samples used for cooking was sent to all parents and/or guardians of the participating children.

A probability-proportional-to-size sampling method was used to obtain a representative sample of 140 schoolchildren aged 6–12 years from each locality. The total number of schools in the region was divided by the required number of clusters to determine the sampling interval (k). The starting point for selection of the first cluster or school was determined by selecting a random number between 1 and k. Then the remaining schools were selected by systematic random sampling using the calculated sampling interval. According to the list provided by the Ministry of Education, there were 178 primary schools in Port Sudan and 172 in Jabal Awliya. Of these schools, six schools (three for boys and three for girls) were randomly selected in each region. In Sudan, children 6–12 years old go to single-sex school. In the second stage, one or two classes were randomly selected from each school depending on the number of students per class. A total of 280 children were recruited from Port Sudan (n 140) and Jabal Awliya (n 140). The mean age was 9·8 years and the ratio of the number of boys to girls was 0·9 to 1·0 in both localities.

Urine sample collection and analysis

A urine sample was collected from each child in a sterile pre-labelled capped cup and 2–3 ml of urine was transferred into pre-labelled vials (three aliquots) by one of the survey team members. The first aliquot samples were kept as reference in the central laboratory in Sudan. The remaining two aliquot samples were airmailed frozen in an insulated shipping container on dry ice to the International Iodine Network Laboratory, Nutrition Intervention Unit at the Medical Research Centre in Cape Town, South Africa for analysis. Urinary iodine concentration (UIC) was determined after ammonium persulfate digestion of the urine samples, followed by the Sandell–Kolthoff reaction and microplate reading of the end point[15]. In brief, urine samples were left to reach room temperature and then mixed to suspend sediment. Duplicates of 250 μl of urine sample, working standards ranging from 0 to 300 μg iodine/l and internal urine controls were prepared. Then 1 ml of ammonium persulfate was added to each tube and heated for 60 min at 91–95 °C. Once tubes were cooled to room temperature, 2·5 ml of arsenious acid solution was

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added and vortexed. Finally, 300 μl of ceric ammonium sulfate solution was added to each tube at 15 to 30 s intervals between successive tubes, mixing each with a vortex after addition. The absorbance at 405 or 420 nm was read 30 min after the addition of ceric ammonium sulfate to the first tube.

Frequency of fish eating questionnaire

Children were trained and instructed to deliver the fish eating frequency questionnaire form to their parents, answer the questions and bring it back to school. The form contained a question which asked 'Do you eat fish at least once a week?' and they were to tick boxes either 'Yes' or 'No'. This was done under our supervision and of the headmaster and school health supervisor. It is very common in Sudan that teachers in city schools are originally from another part of the country. Hence, teachers in participating schools were also asked to complete the questionnaire to assess whether relocation to the city changed their dietary habits.

Salt specimen collection and testing

Each child was asked to bring sample of salt (about 2 tablespoons) from home on the day of the survey. The presence of iodine in the salt samples was tested initially using a Rapid Test Kit[16] and then the quantity was determined by titration with a solution of sodium thiosulfate using starch as the indicator[17].

Assessment of goitre

Presence of goitre was assessed by palpation of the neck. A medical officer of the team received training in the recognition of visible goitre and carried out all assessments. The size and consistency of the thyroid gland were carefully noted. When necessary, the children were asked to swallow (e.g. some water) when being examined as the thyroid moves up on swallowing. The size of each lobe of the thyroid was then compared to the size of the tip (terminal phalanx) of the thumb of the individual being examined.

Statistical analysis

The statistical software package SPSS for Windows version 16·0 (SPSS Inc., Chicago, IL, USA) was used in data analysis. Non-parametric tests (Mann–Whitney *U* and Kruskal–Wallis *H*) were used to compare the UIC of children from Port Sudan and Jabal Awliya and the differences among different schools within each region. *P* values below 5 % were considered significant.

Results

Urinary iodine concentration

The mean and median UIC of the children from surveyed schools in Port Sudan and Jabal Awylia are given in Table 1.

The mean UIC of the children from the six schools in Port Sudan was 588 (SD 327) μg/l (median 553 μg/l). The UIC was highest in children from Daim Arab for Boys, whereas children from Alingaz for Girls had the lowest UIC among surveyed Port Sudan schools ($P = 0{\cdot}002$). There was no difference in mean UIC of children from Al-Wihda Sharig for Boys, Alfarouq for Boys, Um Alqura for Girls and Alingaz 'A' for Girls. Although the mean UIC was greater in boys (637 (SD 323) μg/l) than girls (538 (SD 325) μg/l), this difference was not significant ($P = 0{\cdot}057$) due to large variation (Fig. 2). When the UIC of the children was categorised

Table 1 Urinary iodine concentration (UIC) and goitre rate of Sudanese schoolchildren aged 6–12 years (*n* 280) according to region and school, January to November 2006

Region	School name	*n*	UIC (μg/l) Mean	SD	Median	With goitre *n*
Port Sudan	Al-Wihda Sharig for Boys	23	609	313	702	3
	Daim Arab for Boys	24	771*	322	783	6
	Alfarouq for Boys	24	530	299	511	5
	Um Alqura for Girls	23	671	254	727	0
	Alingaz for Girls	23	400*	264	313	3
	Alingaz 'A' for Girls	23	543	393	153	7
	Total	140	588	327	553	24
	Goitre rate (%)					17·1
Jabal Awliya	Al Tadreeb for Boys	23	160	58	153	0
	Mousaab ibn Omeer for Boys	24	173	98	148	0
	Alshahed Mousbah for Boys	24	246†	128	231	1
	Um Ayman for Girls	23	104†,‡	60	95	0
	Rabha Alkinaniah for Girls	22	179	87	167	0
	Al Humaira for Girls	24	189‡	74	185	1
	Total	140	176§	96	160§	2
	Goitre rate (%)					1·4

**P* = 0·002.
†*P* = 0·002.
‡*P* = 0·005.
§*P* < 0·0001 compared with the total mean UIC of children from Port Sudan.

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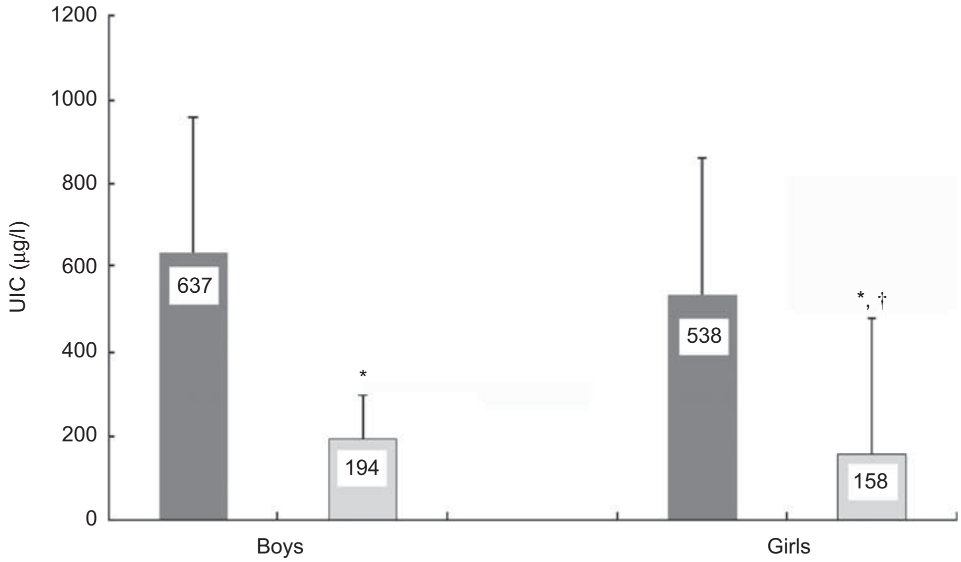

Fig. 2 Comparison of urinary iodine concentration (UIC) of Sudanese schoolchildren aged 6–12 years (*n* 280) according to sex and region (■, Port Sudan; □, Jabal Awliya), January to November 2006. Values are means with their standard deviations represented by vertical bars. *Mean value was significantly different from that of boys or girls from Port Sudan ($P<0{\cdot}01$); †mean value was significantly different from that of boys from Jabal Awliya ($P<0{\cdot}05$)

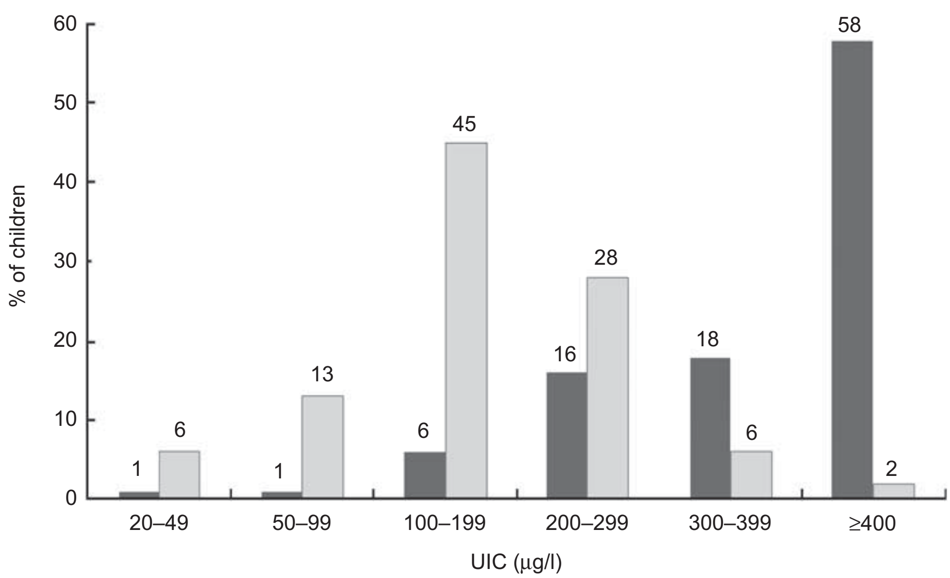

Fig. 3 Distribution of urinary iodine concentration (UIC) in Sudanese schoolchildren aged 6–12 years (*n* 280) according to region (■, Port Sudan; □, Jabal Awliya) and WHO criteria (20–49 µg/l, insufficient (moderate iodine deficiency); 50–99 µg/l, insufficient (mild iodine deficiency); 100–199 µg/l, adequate (optimal); 200–299 µg/l, above requirements (risk of more than adequate iodine intake); ≥300 µg/l, excessive (risk of adverse health consequences such as iodine-induced hyperthyroidism, autoimmune thyroid disease)), January to November 2006

according to the WHO/UNICEF criteria for assessing iodine[2], 1 % of samples were below 50 µg/l (insufficient – moderate iodine deficiency), 6 % were in the range 100–199 µg/l (adequate – optimal) and 92 % were ≥200 µg/l (above requirements – more than adequate; Fig. 3).

In contrast, the mean UIC of the children from Jabal Awliya was 175 (SD 96) µg/l (median 159 µg/l). In this region, the UIC was highest in children from Alshahed Mousbah for Boys and lowest in Um Ayman for Girls. When the mean UIC was compared between schools, the girls from Um Ayman for Girls had significantly lower UIC compared with boys from Alshahed Mousbah for Boys ($P=0{\cdot}002$) and girls from Al Humaira for Girls ($P=0{\cdot}005$). When boys and girls were compared, the

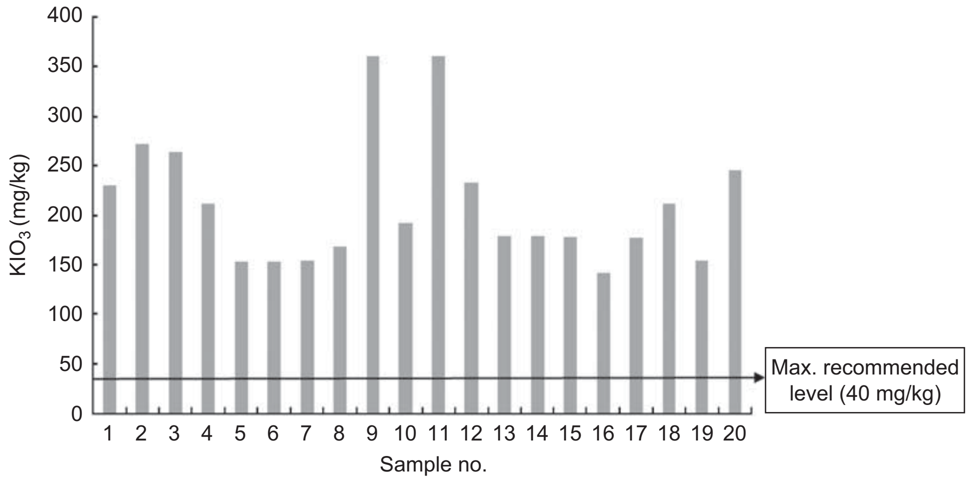

Fig. 4 Iodine content (KIO_3 mg/kg) of salt samples from Port Sudan, January to November 2006

Table 2 Frequency of fish intake among Sudanese schoolchildren aged 6–12 years (*n* 280) and teachers according to region and school, January to November 2006

		No. of children		No. of teachers	
Region	School name	Interviewed (*n*)	Consuming fish weekly (*n*)	Interviewed (*n*)	Consuming fish weekly (*n*)
Port Sudan	Al-Wihda Sharig for Boys	23	0	14	3
	Daim Arab for Boys	24	0	11	0
	Alfarouq for Boys	24	1	12	1
	Um Alqura for Girls	23	0	10	2
	Alingaz for Girls	23	1	11	3
	Alingaz 'A' for Girls	23	0	13	2
	Total	140	2	71	11
	Rate (%)		1·4		15·5
Jabal Awliya	Al Tadreeb for Boys	23	17	14	13
	Mousaab ibn Omeer for Boys	24	19	11	9
	Alshahed Mousbah for Boys	24	17	12	11
	Um Ayman for Girls	23	18	10	10
	Rabha Alkinaniah for Girls	22	16	11	8
	Al Humaira for Girls	24	21	13	12
	Total	140	108	71	63
	Rate (%)		77·1		88·7

mean UIC was 22·9 % lower in girls (158 (SD 82) μg/l) than boys (194 (SD 105) μg/l; $P = 0{\cdot}031$; Fig. 2). As shown in Fig. 3, 45 % of children from Jabal Awliya had adequate iodine level (100–199 μg/l; Fig. 3). However, 19 % of children were at risk of iodine deficiency (6 % moderate deficiency, 20–49 μg/l; 13 % mild deficiency, 50–99 μg/l) while 36 % were exposed to iodine toxicity (≥200 μg/l).

When the children from Port Sudan and Jabal Awylia were compared, the mean UIC of children from Port Sudan was 3·3 times higher than that of children from Jabal Awylia ($P < 0{\cdot}0001$).

Iodine content of salt

All 140 children in each region brought salt samples from home. The rapid test showed that all 140 salt samples in Port Sudan contained iodine. Therefore, the quantification of iodine was carried out on twenty random salt samples. The quantity of potassium iodate varied between 141 and 361 mg/kg in salt consumed by children living in Port Sudan (Fig. 4). On the contrary, there was no trace of iodine in the salt samples obtained from children from Jabal Awliya.

Goitre rate

Visible goitre was presented in 17·1 % of children from Port Sudan whereas its rate was only 1·4 % in children from Jabal Awylia (Table 1).

Consumption of fish

In Port Sudan, 1·4 % of children and 15·5 % of teachers reported that they ate fish at least once weekly (Table 2). In contrast, a significantly higher number of children (77·1 %) and teachers (88·7 %) from Jabal Awliya reported weekly consumption of fish.

Discussion

There was a striking difference in mean UIC and prevalence of goitre in children, and iodine content in salt, between Port Sudan and Jabal Awliya. According to WHO/UNICEF/ICCIDD criteria[2], iodine deficiency (UIC ≤ 99 μg/l) was present in 2 % and 19 % of children from Port Sudan and Jabal Awliya, respectively. However, more children from Port Sudan had goitre compared with those from Jabal Awliya. The prevalence of goitre in children from Port Sudan in our survey was somewhat lower (17·1 % *v.* 34·9 %) than in the nationwide survey which was conducted in the same year as our study[8]. It is plausible that the relatively smaller number of children we surveyed compared with theirs (*n* 140 *v.* *n* 654) might have underestimated the true prevalence of goitre. Nevertheless, the fact remains that both we and Medani *et al.*[8] found that children from Port Sudan had extremely high UIC. Medani *et al.*'s survey, which was carried out in eleven cities of nine States, found that children from Port Sudan had the highest UIC (464 μg/l) while those from the remaining cities had UIC less than 100 μg/l. It is worth noting that although 45 % of children from Jabal Awliya had optimum level of iodine, 36 % of them were still exposed to high iodine. This is of concern because children who are exposed to excessive iodine intake could be at greater risk of adverse health effects including iodine-induced hyperthyroidism or autoimmune thyroid disease[2,18]. Iodine intake in the range of 400–300 μg/l from iodine-rich drinking water has previously been associated with thyroid abnormalities in Chinese children[19].

We speculate that one of the possible causes of the high UIC in children from Port Sudan could be consumption of over-iodised salt. The estimated amount of iodine in salt from Port Sudan was about nine times greater than the safe level recommended by WHO (15–40 mg/kg)[2]. Excessive intake of iodine due to consumption of salt with high iodine content was also reported in long-term refugees in Darfur refugee camp in the Western Sudan[20]. More than 90 % of salt in Sudan is produced by solar evaporation of Red Sea brine by private producers in Port Sudan[21]. The recommended iodine content in salt for human consumption by WHO/ICCIDD is 15–40 mg/kg[2]. At present, the Sudanese government has set the specification for iodine content of salt at 25–35 mg/kg. However, not only the production of iodised salt is limited but also there is no monitoring mechanism in place to monitor the iodine content of all types of salt intended for human consumption[16]. With poor quality control at the production level and the high degree of fluctuation in iodine fortification, there is now a risk that the population, who was severely deficient in iodine previously, is now consuming an excess amount of iodine. Although it is accepted that the risks posed by deficiency greatly outweigh those associated with excess, it still is a concern that avoidable morbidity and mortality may occur[22].

One of the interesting findings was that fish in the diet was more common in children and teachers from Jabal Awliya. It is conceivable that the low goitre rate in children of Jabal Awliya despite their use of salt devoid of iodine could be due to high consumption of fish, which is a natural food source for iodine[23]. Jabal Awliya is located along the White Nile and accommodates one of the largest water reservoirs in Sudan. It is an excellent breeding ground for all types of fish and fresh fish from this man-made lake are popular with the locals. A study by Gür *et al.*[24] also speculated that fish in the diet might have contributed to the low prevalence of iodine deficiency in schoolchildren living in Istanbul.

Some progress has been made since international efforts to eliminate iodine-deficiency disorders were initiated; however, there is no supportive policy environment yet for successful universal salt iodisation in Sudan. In the absence of a monitoring and surveillance system, the population will be exposed to suffer from the double burden of both iodine deficiency and excessive iodine intake. Monitoring and surveillance of iodine level by measuring UIC is vital to guide the operation of the entire iodine-deficiency disorders control programme.

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