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Iodine nutritional status of children on the island of Tanna, Republic of Vanuatu

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Abstract

Objective: To evaluate the iodine nutritional status of children living on the island of Tanna, Republic of Vanuatu.
Design: Cross-sectional study. Urine and household salt samples were collected for iodine measurement. Thyroid volumes were measured by ultrasound. A food consumption frequency survey was carried out, particularly in relation to salt, iodine-rich foods and foods that containing thiocyanate, a potentially goitrogenic substance. Urinary thiocyanate levels were also measured.
Setting: Island rural communities in Tanna, Vanuatu.
Subjects: One hundred and fifty-three schoolchildren between 8 and 10 years of age from four locations on the island participated.
Results: The median urinary iodine excretion (UIE) among the children was 49 mg/l, indicating moderate iodine deficiency. This was corroborated by 27 % of boys and 33 % of girls having thyroid glands greater than the international standard for their age, and 36 % of boys and 45 % of girls having thyroid glands greater than the international standard for their body surface area based on ultrasonography. There was a highly statistically significant inverse correlation between thyroid volume and UIE for boys and girls ($r = -0{\cdot}444$, $P = 0{\cdot}001$ and $r = -0{\cdot}319$, $P = 0{\cdot}005$, respectively). There was no correlation between thiocyanate and UIE or thyroid volume. Only 34 % of children reported to consume fish (tinned or fresh) on a weekly basis.
Conclusions: Against the common perception, the study has demonstrated that the children on the island of Tanna were in a state of moderate iodine deficiency. More data need to be collected from other Pacific Island countries in order to provide evidence for formulating public policy in prevention and control of iodine deficiency disorders in these nations.

Keywords
Iodine nutrition
Urinary iodine
Thyroid volume
Schoolchildren
Tanna Island

Iodine is an essential trace element for the synthesis of thyroid hormone. Normal human growth and development is dependent upon an adequate supply of thyroid hormone. The causal association between iodine deficiency and endemic goitre has been well recognised for almost a century. While endemic goitre is the most visible consequence of iodine deficiency, the most significant and devastating consequences are the result of damage to the developing brain[1]. The potential impact of iodine deficiency on the intellectual development of children living in iodine-deficient areas is of particular concern, especially when all of the adverse effects of iodine deficiency can be prevented by an adequate dietary intake of iodine.

Iodine deficiency has not been perceived as a major public health problem in the Pacific Island Countries under the notion that the people who live on islands regularly eat seafood, a rich natural source of iodine, as part of their normal diet. In the Pacific, iodine deficiency disorders (IDD) have been documented in the highlands of Papua New Guinea[2,3] and in Fiji[4,5], but there are no data available for any other Pacific Island Country or Territory, including Vanuatu. There have been anecdotal reports of goitre on the island of Tanna in Vanuatu in recent years, but the iodine nutritional status of the people, the prevalence of goitre and its possible cause have not been investigated. While the most common

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cause of IDD is inadequate iodine intake, known goitrogenic substances such as thiocyanate and its precursors (cyanogenic glycosides, isothiocyanates and glucosinolates) are found in a number of foods, including cassava[6–10], vegetables of the Brassica family[7,8,11] and sweet potatoes[8], which are part of the Ni-Vanuatu diet. Because thiocyanate increases renal excretion of iodide and blocks the uptake of iodine by the thyroid gland, it could be a contributing factor to the development of goitre[12]. The enzymes responsible for producing the goitrogenic effect of isothiocyanates can be inactivated by food processing (soaking, washing, boiling, cooking, etc.) through heat and leaching into water[11,13]. In rural Vanuatu such as Tanna Island, while rice, wheat flour and processed food are imported, the majority of fruit and vegetables consumed are produced locally. The iodine content of the soil and foods grown in Tanna has not been documented. Fish, seafood and seaweed are part of the Ni-Vanuatu diet, with the intake of fresh seafood likely to depend on proximity to the ocean. While seafood is a natural source of iodine, the amount of iodine in seafood can vary considerably. The intake of other dietary sources of iodine such as dairy foods, meat and dietary supplements is thought to be low. Salt is not produced locally in Vanuatu, and both iodised and non-iodised salt are imported. Vanuatu does not have legislation to prohibit the importation of non-iodised salt, or to control iodine levels[14]. The consumption of iodised salt in Tanna and Vanuatu is unknown.

The aims of the present study were to determine iodine nutritional status and the prevalence of goitre in schoolchildren on the island of Tanna and the potential contribution of dietary sources of goitrogens.

Methods

Sample selection

Some 26 000 people are estimated to live on the island of Tanna, with an estimated 1800 being children aged 8–10 years. Due to time and financial constraints, it was not possible to examine a randomly selected, representative sample of schoolchildren. Instead we aimed to recruit 100–150 children aged 8–10 years, representing a sample of at least 5 % of this age group.

Sampling sites were identified in consultation with the Vanuatu Ministry of Health. Sites were determined based on geographical localities across the island, the presence of a health facility (hospital, health clinic or dispensary) and number of primary schools in the surrounding areas from which children could be sampled (based on a list of primary schools provided by the Ministry of Education). Four locations across Tanna were selected: one inland to the north (Jet dispensary in Middlebush); two coastal (Lenakel in the west and Kitow dispensary at White Sands in the east); and one site in the south near the active volcano (Ikurumanu).

Field work

In the weeks preceding the survey, staff from Lenakel Hospital visited selected schools in the four locations to explain the purpose of the study, to outline the examinations involved and what would be required of participants to school principals, teachers and children. Parents, preferably mothers, were requested to attend data collection to provide verbal consent, to observe examinations and withdraw children from any aspect of the study if they had any concerns, and to assist with the completion of the dietary questionnaire. On the day of the survey in each locality, children, principals and/or teachers and parents from selected schools were transported to the health facility where the survey was conducted. Children were registered, weighed and measured using the standard anthropometrical assessment method. Children were also asked to bring a small sample of salt used in their households. Forty-six salt samples were collected in total. Some children did not bring samples and some samples were brought in by teachers, who claimed that all children's families in the same village use the same salt as there is only one supplier/shop in the village from where all families purchase salt. Thyroid volumes of the children were measured by ultrasound using a portable ultrasound machine (SonoSite 180, Bothell, WA, USA) with a 7·5 MHz 6-cm linear transducer. All ultrasound measurements were performed by one sonographer (C.J.E.) with the students placed in a supine position with the neck fully extended. The volume of each thyroid lobe (cm) was calculated using the following formula: volume of each lobe = length × width × thickness × 0·479. A spot urine sample was collected for measuring urinary iodine concentrations.

A dietary questionnaire designed to obtain information on the frequency of consumption of good dietary sources of iodine, as well as foods thought to contain thiocyanate in the Ni-Vanuatu diet, was used in the survey. The questionnaire was developed in consultation with the Vanuatu national nutritionist (T.M.), with input from the International Council for the Control of Iodine Deficiency Disorders (ICCIDD) and the UNICEF Pacific regional nutritionist, using the Iodine Survey of Tasmanian School Children[15] as a basis. The foods included in the survey were: salt, fish, seaweed, cassava (manioc), sweet potato (kumala) and vegetables of the Brassica family (cabbage, Chinese cabbage, cauliflower and broccoli). Dairy foods, red meat, chicken and eggs and dietary supplements were not included due to low consumption of these foods by Ni-Vanuatu. Frequency of use categories were specified as the number of times consumed daily, weekly, monthly, rarely or never. Preparation methods for potentially goitrogenic foods were also included in the survey. Questionnaires were completed by interviewing the students, with their mothers or their teachers present, by two authors who speak fluent Bislama (N.M., T.M.). Household salt samples were collected and tested for iodine

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using a semi-quantitative testing kit (China Endemic Diseases Research Centre, Harbin Medical University).

Urinary iodine excretion and urinary thiocyanate levels

Urine samples were stored at −20°C in Lenakel Hospital before transportation to the Institute of Clinical Pathology and Medical Research (Sydney, Australia), where they were stored at −20°C until assayed. The urinary iodine measurement was performed by ammonium persulfate digestion[16] prior to Sandell–Koltoff reaction in a microtitre plate format[17]. Urinary thiocyanate (SCN) level was measured by Kit D1, a method developed by the Australian National University (Canberra, Australia)[18].

Statistical analysis

Statistical analysis was performed using the SPSS for Windows statistical software package version 15 (SPSS Inc., Chicago, IL, USA). Age- and body surface area (BSA)-specific 50th and 97th percentiles for thyroid volume were calculated for boys and girls. The body surface area was calculated by the formula: BSA = weight $(kg)^{0\cdot425} \times$ height $(cm)^{0\cdot725} \times 71\cdot84 \times 10^{-4}$. The thyroid volume and urinary iodine excretion (UIE) data were log-transformed to approximate normality prior to analysis. ANOVA was used to compare the distributions of age, weight, height, BSA and log thyroid volume. Spearman's rank correlation (r) was used to quantify the association between thyroid volume, UIE and SCN. Two-tailed tests with a significance level of 5 % were used throughout. The χ^2 test was used to analyse the association between dietary variables and urinary iodine levels.

Results

One hundred and fifty-three children from fourteen schools participated in the study, representing approximately 8–9 % of this population age group on the island (Table 1). The mean age of the study children was 8·9 (SD 1·1) years. The median UIE was 49 μg/l. Seventy-two per cent of the children had UIE < 100 μg/l (95 % CI 65·0, 79·2 %) and 51 % had UIE < 50 μg/l (95 % CI 42·7, 58·6 %). Figure 1 shows the frequency distribution of median UIE levels, categorised according to the WHO criteria for severity of IDD. It illustrates that the UIE levels were skewed towards the left, with 19 % below 20 μg/l (n 29) and 32 % between 20 and 49 μg/l (n 49).

The median urinary SCN was 4 mg/l. There was no correlation between SCN and thyroid volume ($r = -0\cdot148$, $P = 0\cdot083$) nor between SCN and UIE ($r = 0\cdot092$, $P = 0\cdot281$).

The log thyroid volume data were compared with the international normative data for the 50th and 97th percentiles, by BSA and age, for both boys and girls[19] (Table 2). Thirty-six per cent of boys and 45 % of girls had thyroid glands greater than the international standard 97th percentile for their BSA, and 27 % of boys and 33 % of girls had thyroid glands greater than the international standard 97th percentile for their age. Figure 2 illustrates the distribution of thyroid volume by BSA together with the 50th and 97th percentile international normative values[19]. Children from Tanna, being moderately iodine-deficient, had much larger thyroid glands compared with the international reference values in iodine-sufficient schoolchildren when adjusted by BSA or by age. There was a highly statistically significant inverse correlation between thyroid volume and UIE (Fig. 3) for boys ($r = -0\cdot444$, $P = 0\cdot001$; n 77) and girls ($r = -0\cdot319$, $P = 0\cdot005$; n 76). There was no statistically significant difference in these measures between boys and girls.

The dietary survey revealed (Table 3) that a majority (90 %) of children reported eating food with salt added during cooking on a daily basis. Forty-six salt samples

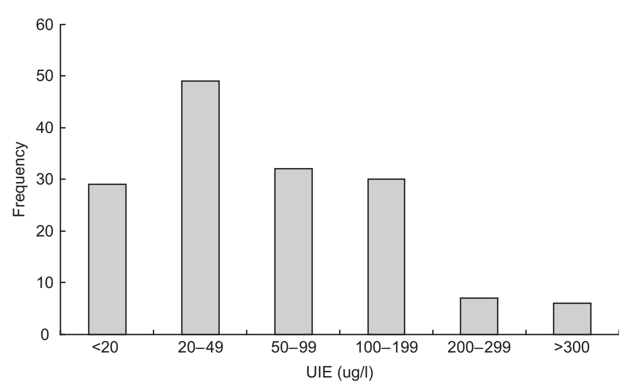

Fig. 1 Frequency distribution of urinary iodine excretion (UIE) levels in 8–10-year-old schoolchildren (n 153) on the island of Tanna, Republic of Vanuatu. Iodine replete, UIE ≥ 100 μg/l; mild iodine deficiency, UIE = 50–99 μg/l; moderate iodine deficiency, UIE = 20–49 μg/l; severe iodine deficiency, UIE < 20 μg/l

Table 1 Summary of anthropometric data, urinary iodine excretion (UIE) and urinary thiocyanate (SCN) levels of 8–10-year-old schoolchildren (n 153) on the island of Tanna, Republic of Vanuatu

	Age (years)		Weight (kg)		Height (cm)		BSA (m^2)		UIE (μg/l)		SCN (mg/l)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Median	IQR	Median	IQR
Boys (n 77)	8·8	1·2	26·9	4·6	131·0	7·7	1·0	0·1	55·0	26·0–123·5	6·0	2·0–10·0
Girls (n 76)	8·9	1·0	28·7	5·1	133·5	8·1	1·0	0·1	45·0	30·0–100·8	3·5	1·0–6·0
All (n 153)	8·9	1·1	27·8	4·9	132·2	8·0	1·0	0·1	49·0	30·0–107·0	4·0	1·0–6·5

BSA, body surface area; IQR, interquartile range.

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Table 2 Percentage with thyroid volume (ml) greater than the international standard 50th and 97th percentile values (P50 and P97)[19] among 8–10-year-old schoolchildren (n 153) on the island of Tanna, Republic of Vanuatu

Based on BSA				Based on age			
Boys		Girls		Boys		Girls	
%	95 % CI	%	95 % CI	%	95 % CI	%	95 % CI
Percentage >international standard P50							
84·4	76·3, 92·5	92·1	86·0, 98·2	84·4	76·3, 92·5	84·2	76·0, 92·4
Percentage >international standard P97							
36·4	25·7, 47·1	44·7	33·5, 55·9	27·3	17·3, 37·3	32·9	22·3, 43·5

BSA, body surface area.

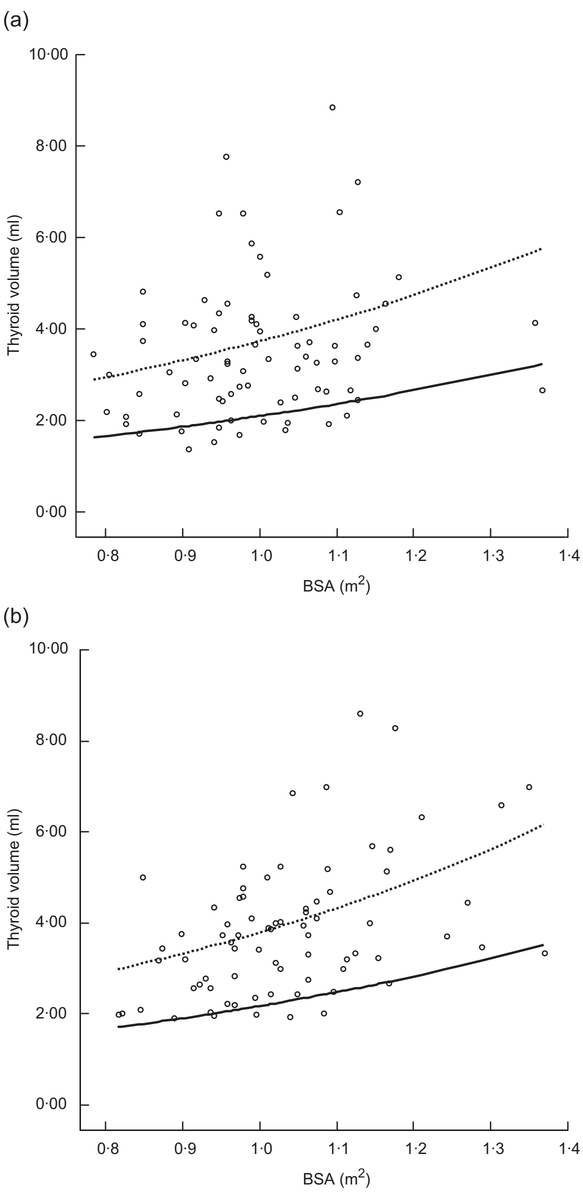

Fig. 2 Distribution of thyroid volume according to body surface area (BSA) in 8–10-year-old schoolchildren (n 153) on the island of Tanna, Republic of Vanuatu: (a) boys and (b) girls. P50 (50th percentile; ——) and P97 (97th percentile; - - - -) curves are based on the international normative data[19]

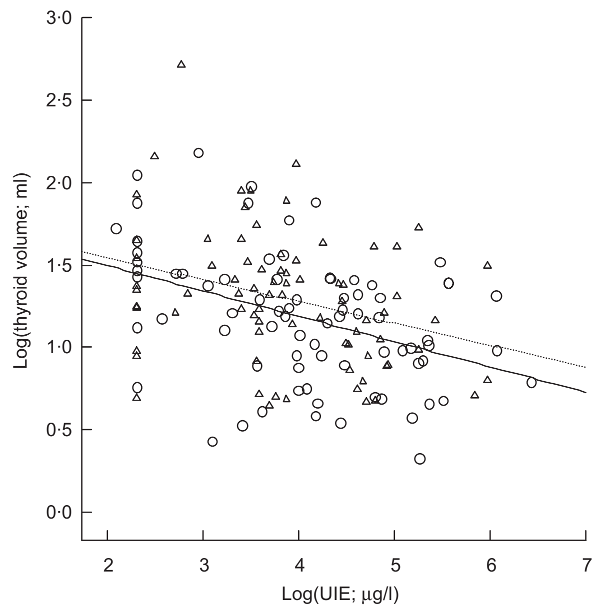

Fig. 3 The correlation between log urinary iodine excretion (UIE) and log thyroid volume among 8–10-year-old schoolchildren (n 153; - - △ - -, girls; —○—, boys) on the island of Tanna, Republic of Vanuatu

were brought in from households; among them twenty were iodised (43·5 %) at 20–50 ppm based on the intensity of the colour change.

Over one-third of children (39 %) reported eating fish on at least a weekly basis and a further 44 % on a monthly basis; however, 70 % reported eating mainly tinned fish. Fish was reported to be eaten more often in the coastal locations of Lenakel and White Sands, where 57 % of children reported to consume fish at least weekly, compared with 37 % in Middlebush and Ikurumanu. Eating fish at least monthly was associated with urinary iodine sufficiency (UIE > 100 μg/l, $P = 0·011$; $P = 0·045$ after adjusting for location, age and sex). Some children reported consuming seaweed, but not on a regular basis.

Almost three-quarters (72 %) of the children reported eating cassava (manioc) on a daily basis. The frequency of consumption was slightly higher in sample sites outside Lenakel, where 79 % of children reported eating cassava

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Table 3 Reported frequency of food consumption among 8–10-year-old schoolchildren (*n* 153) on the island of Tanna, Republic of Vanuatu

	Daily		Weekly		Monthly		Rarely/never	
Food item (no. of responses)	*n*	%	*n*	%	*n*	%	*n*	%
Salt								
Added to food during cooking (*n* 110)	129	90·2	7	4·9	4	2·8	3	2·1
Added to food on plate after cooking (*n* 132)	27	20·5	30	22·7	7	5·3	68	51·5
Iodine-rich foods								
Fish (*n* 142)	7	4·9	48	33·8	62	43·7	25	17·6
Seaweed (*n* 143)	1	0·7	10	7·0	56	39·2	76	53·1
Foods potentially goitrogenic								
Cassava (manioc) (*n* 143)	103	72·0	16	11·2	22	15·4	2	1·4
Sweet potato (kumala) (*n* 131)	38	29	38	29	44	33·6	11	8·4
English cabbage (*n* 138)	24	17·4	44	31·9	45	32·6	25	18·1
Chinese cabbage (*n* 142)	22	15·5	30	21·1	5	36·6	38	26·8

daily. Sweet potato (kumala) was in season at the time of the study, and was consumed by 29 % of the children on a daily basis and a further 29 % at least weekly. The most common cruciferous vegetables consumed were English and Chinese cabbage. These foods were also in season at the time of the survey, and were grown in the family's garden or purchased at local markets. A small proportion of children ate these foods on a daily basis (17 % and 15 %, respectively).

Discussion

The present study assessed 8–9 % of children in the age group of 8–10 years living on the island of Tanna; they were found to be iodine-deficient. Iodine deficiency is likely to be an important public health problem for the island. According to the WHO/UNICEF/ICCIDD criteria[20], the children from Tanna Island are moderately iodine-deficient. This is further corroborated by the enlarged thyroid glands of these children. As shown in Fig. 3, the lower UIE levels were associated with greater thyroid volumes. By definition this makes Tanna an endemic goitre area. While the distribution of UIE levels was skewed to the left as shown in Fig. 1, there were 8 % with UIE > 200 μg/l (*n* 13). This may reflect the intermittent consumption of iodised salt or other iodine-containing foods including iodised salt. From the forty-six individual salt samples we collected, twenty were iodised. Owing to the small number of samples we were not able to meaningfully evaluate the correlation between the home salt samples and UIE levels. Children or their mothers had no knowledge of what type of salt they consumed. They simply purchased what was available in the shops. We visited a few shops near the survey sites. Salt came in 25-kilogram bags and was then divided into small portions and packaged in clear plastic bags in the shop for sale. The shopkeepers did not have any knowledge about what type of salt they would get as it depended on what was brought to the island by importers. It is likely that the children were exposed to iodised salt on an arbitrary and irregular basis.

The dietary questionnaire revealed that up to 72 % children reported consuming cassava on a daily basis. The chronic consumption of cassava has been shown to exacerbate the effect of iodine deficiency on the development of endemic goitre and endemic cretinism[21]. However, the effects of thiocyanate on the development of goitre are very complex and are determined by the level of iodine intake in the diet, the cyanoside content in fresh cassava roots and leaves, the preparation methods of cassava-based foods and finally the quantity and frequency of consumption of these foods[6]. Furthermore, the varieties of cassava grown in the Pacific tend to be sweeter and contain less cyanogenic glycoside than the bitter species grown in other regions of the world[22]. In the present study, the urinary SCN levels in children from Tanna Island were relatively low. In addition, we could not demonstrate any association between urinary SCN and UIE or thyroid volume, making it unlikely that thiocyanate is a contributory factor in the development of goitre in this population. Iodine deficiency, therefore, is considered to be the main cause of goitre in these children.

Only less than 40 % of the children reported eating fish on a weekly basis; and among them only 30 % ate fresh fish. This clearly indicates that even residents living on this island do not eat enough fresh fish to ensure an adequate daily iodine intake. On the other hand, over 90 % of children reported having salt added to food while cooking on a daily basis. Salt fortification with iodine is therefore a logical solution for providing adequate iodine nutrition to the people of Tanna, and the other islands of Vanuatu.

Many countries in the world have adopted universal salt iodisation as the main intervention strategy for the prevention and control of IDD[23]. This requires governments to develop public policy to ensure that all edible salt is iodised. Efforts should also be made to raise public awareness, informing the general public of the benefits of consuming iodised salt without necessarily encouraging an increase in salt intake that may have adverse cardiovascular effects on the population in the longer term.

In conclusion, the study has demonstrated that the children on the island of Tanna were in a state of moderate

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iodine deficiency. It challenges the general perception that iodine deficiency is not a significant public health concern in Pacific Island Countries, with vast expanses of coastline and presumed easy access to seafood. More data need to be collected from other small island nations in order to make a better assessment of the magnitude and severity of the problem, to provide evidence for formulating public policy in IDD prevention and control in these nations. Finally, the study raises concern about other less visible consequences of moderately severe iodine deficiency in this population. It is a well-established fact that moderate to severe iodine deficiency in a population causes intellectual impairment, hearing and learning defects, as well as other neurodevelopmental disorders. It is a matter of great concern that endemic goitre is most likely not the only consequence of iodine deficiency in the residents of Tanna and that the adverse effects of IDD may be far more common in Pacific Island Countries than we ever imagined. This serious public health issue needs to be recognised and addressed as a matter of urgency.

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