Original Article

Study of biochemical prevalence indicators for the assessment of iodine deficiency disorders in adults at field conditions in Gujarat (India)

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The main objective of this study was to assess the severity of iodine deficiency disorders (IDD) in the adult populations of the Baroda and Dang districts from Gujarat, western India using biochemical prevalence indicators of IDD. The other aim of this study was to establish a biochemical baseline for adequate iodine intake as a result of program evolution in the face of multiple confounding factors, like malnutrition and goitrogens responsible for goiter. A total of 959 adults (16–85 years) were studied from two districts (Baroda and Dang) and data was collected on dietary habits, anthropometric and biochemical parameters such as height, weight, urinary iodine (UI) and blood thyroid stimulating hormone (TSH). Drinking water and cooking salt were analyzed for iodine content. All subjects, irrespective of sex and district, showed median UI = 73 μg/L and mean blood TSH ± SD = 1.59 ± 2.4 mU/L. Seven per cent of the studied population had blood TSH values > 5 mU/L. Females in Baroda and males from Dang district were more affected by iodine deficiency as shown by a lower median UI. Mean TSH was significantly higher in women from both districts as compared to men ($P = 0.001$). The blood spots TSH values > 5 mU/L were seen in 20% of women from Dang. The normative accepted WHO values for UI and TSH for the severity of IDD as a significant health problem are not available for target population of adults. Urinary iodine normative limits and cut-offs are established for school-aged children. Blood spot TSH upper limit and cut-off values are available for neonate populations. The IDD has not been eliminated so far, as more than 20% of both male and female subjects had UI < 50 μg/L. Males were more malnourished than females in both districts ($P < 0.05$). Pearl millet from Baroda contained flavonoids like apigenin, vitexin and glycosyl-vitexin. Dang district water lacked in iodine content. Iodine deficiency disorder is a public health problem in Gujarat, with the Baroda district a new pocket of IDD. High amounts of dietary flavonoids in Baroda and Dang, malnutrition and an additional lack of iodine in Dang water account for IDD.

Key words: blood spot TSH, goitrogens, Gujarat; (Western India), iodine deficiency disorders, urinary iodine.

Introduction

Iodine deficiency disorders (IDD) are a public health problem in 130 out of 191 countries worldwide, potentially affecting about 5 billion people according to recent information on global IDD status. Based on estimates of an average total goiter rate of about 38%, at least 2 billion people are directly affected by iodine deficiency.[1]

Iodine is an essential element for thyroid function, necessary for the normal growth, development and functioning of the brain and body. Iodine deficiency was once considered a minor problem, causing goiter, an unsightly, but seemingly benign cosmetic blemish. However, it is now known that iodine deficiency is the most common preventable cause of irreversible mental handicap in the world today, constituting a threat to the social and economic development of many countries of the world, including some in Europe.[2]

The effects of IDD vary according to the person's status. On individuals the effects include goiter, hypothyroidism and loss of energy. In pregnant women they range from miscarriages, stillbirths and mentally retarded children. In children, the effects include impaired mental and physical development, mental retardation, physical deformities and cretinism. Overall, on society, the effects of IDD are lower productivity and a higher demand on social services.

The IDD is seen as an iceberg of effects in a population, with the visible effects (cretinism) accounting for as much as 1–10% of the ramifications. At least 90% of the consequences of IDD remain hidden. The solution is relatively simple. A teaspoon of iodine is all a person requires in a lifetime, but because iodine cannot be stored for long periods by the body, tiny amounts are needed regularly. In areas of endemic iodine deficiency, where soil and therefore crops and grazing animals do not provide sufficient dietary iodine to the populace, food fortification and supplementation have proven highly successful and sustainable interventions. Iodized salt programs and iodized oil supplements are the most common tools in the fight against IDD.[3]

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Iodine deficiency disorder is assessed by clinical and biochemical indicators. Urinary iodine is the main impact indicator of current iodine intake, whereas neonatal thyroid stimulating hormone (TSH) screening is a valuable indicator for the assessment of IDD. However, TSH screening is not available in most developing countries with iodine deficiency.[2] A previous study has shown the dissonance of biochemical and clinical parameters in the similar target population of schoolchildren as a result of the multiple confounding factors leading to the development of goiter.[4]

Criteria for sustainable elimination of IDD[5] include:

(a) Sustained normal iodine nutrition, confirmed by a median urinary iodine (UI) concentration of at least 100 µ/gL, with less than 20% of the population below 50 µg/L, and based on monitoring data within the last two years before evaluation, and

(b) If iodized salt is the vehicle for iodine elimination, the availability of adequately iodized salt for consumption must be guaranteed, as demonstrated by more than 90% of households consuming effectively iodized salt.

To date, no major survey that uses only biochemical prevalence indicators for IDD has been carried out in Gujarat State.

The main objectives of the present study were:

1. To assess the severity of IDD in adult populations of Baroda and Dang districts from Gujarat, Western India, using biochemical prevalence indicators of IDD.

2. To establish a biochemical baseline for adequate iodine intake as a result of the iodine supplementation program in the face of multiple confounding factors, such as malnutrition and goitrogens responsible for development of goiter.

Subjects and methods

The population of the Gujarat State is about 42 million with 56% of the population engaged in agriculture and allied activities. It consists of both urban and rural segments, but some of the districts like Dang have predominantly tribal populations. The majority of the rural and tribal populations belong to the low socioeconomic strata of the society. Their diet is mainly vegetarian and consists of cereals, pulses and vegetables. The staple evening meal of the Baroda population is pearl millet pancakes. Various epidemiological surveys for IDD in Gujarat have reported high prevalence rates of goiter by palpation, with tribal belts being the most severely affected. The Baroda district has never been investigated for IDD. The rural children live in villages that are not too far from the city. The Dang district has been investigated in the past and goiter prevalence by palpation was found to be 40%.[6] The sale of non-iodized salt has been banned in the district since 1994.

Population studied

Nine hundred and fifty-nine adults aged 16–85 years were selected randomly by home surveys and school visits. Figure 1 shows their age and sex distribution. There were 504 males and 455 females (M : F ratio = 1.1 : 1). There were 604 rural subjects (327 males and 277 females) that belonged to two villages of the Baroda district and stayed in their homes. Tribals (*n* = 355) from the Dang district included 178 males and 177 females, 148 resided at home and 207 were boarding school residents (Table 1). Data on age, sex, height and weight were recorded and the body surface area (BSA) were calculated by using the formula:[7]

$$\text{BSA (m}^2\text{)} = \text{weight (kg)}^{0.425} \times \text{height (cm)}^{0.725} \times 71.84 \times 10^4.$$

Random urine samples for UI and blood spots for TSH determination were collected from all subjects.

Urinary iodine

Since casual urine samples were collected, it was desirable to measure about 300 from a population group to allow for varying degrees of subject hydration and other biological variation between individuals (a sample of 200 specimens would give a relative precision of 20%, e.g., 50 ± 10% below 100 µg/L).[5] For UI analysis a modified acid-digestion method (method E) was used, based on the reaction between cerium IV and arsenic III (Sandell–Kolthoff Reaction) using a Technicon Autoanalyser II (Technicon Instruments, NY, USA).[8] The method has several potential sources of error and does not separate out the interfering substances (IS).[9] The IS were removed from the urine samples to obtain accurate true UI value. The results were expressed as micrograms of iodine per litre of urine (µg/L). The present method showed a good correlation with UI measurement by the ion coupled plasma mass spectrometer (ICPMS; Varian, Frenchs Forest, Australia) and method A.

Interfering substances

The urine samples were diluted according to the requirement from the peak and UI was measured as above. The arsenic acid was added to a 200 µL of diluted sample or neat sample (one having low total UI). It was kept for 1 h and then ceric ammonium sulfate solution was added and the mixture was kept in the dark for 24 h. This was read in the autoanalyser again and the calculations were done to arrive at the true UI and the amount of IS. The standard curve was plotted and the standards of different concentrations of iodine were also run throughout.

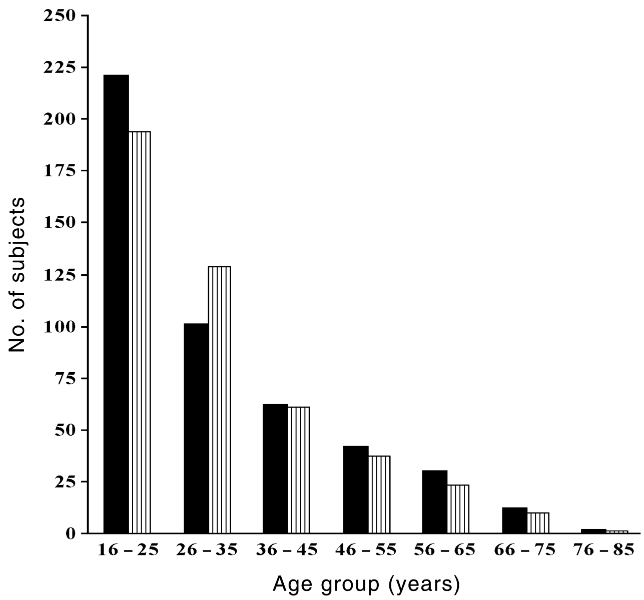

Figure 1. Age and sex distribution of the adult population of Gujarat. (■), men; (▥), women.

Blood spot thyroid stimulating hormone

The TSH levels of the blood spots were measured using commercially available Bioclone neonatal TSH ELISA (Bioclone, Marrickville, Australia) kits for the quantitative determination of TSH. This test is an enzyme-linked immunoassay incorporating a biotinylated anti-TSH polyclonal antibody (antibody reagent) and an anti-TSH monoclonal antibody bound to the microwells. It is an amplified method, utilizing the biotin-streptavidin linkage to increase the signal generated. The polyclonal-monoclonal pair gives rapid incubation times and enhanced specificity. The TSH is first eluted from the blood spot and at the same time the eluted TSH binds to the anti-TSH antibody on the microwell. During the next incubation, a 'sandwich' is formed between added biotinylated antibody, the antibody on the microwell and the eluted sample TSH antigen. The plate is washed to remove unbound material. Streptavidin-peroxidase (amplification reagent) is then added and binds to the biotinylated antibody at many sites. The plate is washed again to remove unbound streptavidin-peroxidase, then 3,3´,5,5´-tetramethylbenzidine (TMB) substrate solution is added. The substrate solution reacts with the enzyme to produce colour in direct proportion to the amount of antigen in the sample. From photometric absorbance readings a standard curve is constructed and the TSH in patient samples can be quantified.

Interpretation, presentation of results and availability of reference data

Biochemical parameters (UI and blood TSH) are measured on a continuous scale, but their results do not have normal Gaussian distribution. The use of means and standard deviations alone may be inappropriate (unless logarithmic transformation of means and standard deviations to get normal distribution is performed), hence the presentation of median or other percentiles is ideal.

Interpretation of IDD status depends on the availability of reference data as these help in establishing cut-off values and prevalence levels for use in identifying public health problems. However, the data for biochemical indicators in adults are not available. It is recommended that the full distribution of results are presented using cut-off points to delineate the upper and lower tail of distribution.[5]

Statistical methods

Proportion, mean, standard deviation, median and interquartile ranges have been used to describe the data as appropriate. Statistical analyses were performed using SPSS version 6.1.2 (SPSS, Chicago, USA).

Results

Urinary iodine levels

The median total UI (that includes IS) for all adults was 160 µg/L and the more accurate true UI (after removal of IS) was 73 µg/L. Thus, large amounts of IS were detected in urine, presumably due to goitrogens (Table 2). Total UI was significantly lower in females ($P < 0.001$), but true UI was not different ($P = 0.29$). In Baroda, women had significantly lower total and true UI ($P < 0.001$), whereas in Dang, men had lower values for both UI levels ($P < 0.001$). The IS were greater in Baroda men and Dang women ($P < 0.001$, Table 3). Classification of the study group into subgroups, based on UI values as recommended by WHO, is shown in Fig. 2 (a,b). In Dang, 52% of women and 75% of men are iodine deficient (UI < 100 µg/L), while 31% of women and 46% of men had moderate (UI < 50 µg/L) iodine deficiency (Fig. 2a). In the Baroda district, 69% of women and 59% of men are iodine deficient (UI < 100 µg/L), while 30% of women and 24% of men had moderate (UI < 50 µg/L) iodine deficiency (Fig. 2b). Thus, IDD is far from being eliminated in both the districts of Gujarat that manufacture 70% of iodinated salt for India.

Table 1. Distribution of the study group based on geography, residence and sex ($n = 959$)

	District								
	Baroda ($n = 604$)		Dang ($n = 355$)						
Village	Muval	Tentalav	Vaghai	Dediapada	Rutambhara	Baripada	Saputara	Rambhas	Total
Study group									
Male	232	95	107	2	0	40	24	4	177
Female	208	69	75	12	91	0	0	0	178
Home	440	164	124	0	0	0	24	0	148
Boarding	–	–	58	14	91	40	0	4	207
Total	440	164	182	14	91	40	24	4	355

Table 2. Data analysis for adult population of Gujarat State

Parameters	Range	Mean ± SD	Median (IQ)	97th percentile
Age (years)	16–85	31.4 ± 15	28 (18–40)	65
Height (cm)	122–180	155.2 ± 9.2	154.9 (149–162)	173
Weight (kg)	21–92	45.8 ± 9.7	45 (40–50)	68.5
BMI (kg/m^2)	10.9–39.6	19.0 ± 3.7	18.3 (16.7–20.6)	27.5
Total UI (µg/L)	0–1256	209.7 ± 175	160 (90–270)	670
True UI (µg/L)	0–450	88.5 ± 63.5	73 (40–120)	225
IS (µg/L)	0–920	121.3 ± 131	74 (37–159)	500
TSH (mU/L)	0–32.98	1.59 ± 2.4	0.79 (0.11–2.36)	6.9
BSA (m^2)	0.89–1.9	1.41 ± 0.16	1.39 (1.30–1.51)	1.6

Median (IQ) = median with an interquartile range in parentheses; BMI, body mass index; UI, urinary iodine; IS, interfering substances; TSH, thyroid stimulating hormone; BSA, body surface area.

Table 3. Anthropometric measurements and biochemical prevalence indicators in men and women from Baroda and Dang

Parameters	Range	Mean ± SD	Median (IQ)	Range	Mean ± SD	Median (IQ)	*P*
Baroda (*n* = 604)		Women (*n* = 277)			Men (*n* = 327)		
Age (years)	16–85	37.5 ± 15	35 (26–48)	16–83	36.6 ± 15	33 (25–47)	*NS*
Height (cm)	130–147	151 ± 5.8	151 (147–154)	127–180	163 ± 6.6	163 (158–167)	0.001
Weight (kg)	29–92	46 ± 11	45 (39–51)	25–81	49 ± 9	48 (43–55)	0.001
BMI (kg/m^2)	11.5–39	20.4 ± 4.9	19 (17–23)	10.9–33.0	18.6 ± 3.3	18 (16–20)	0.001
Total UI (μg/L)	0–654	163 ± 105	128 (91–220)	0–720	211 ± 123	192 (116–276)	0.001
True UI (μg/L)	0–378	80 ± 57	65 (40–110)	0–425	94 ± 58	84 (51–126)	0.003
IS (μg/L)	0–435	83 ± 66	64 (40–110)	0–510	118 ± 88	96 (56–162)	0.001
TSH (mU/L)	0–24.4	1.5 ± 2.1	0.9 (0.13–2.4)	0–8.8	1.24 ± 1.4	0.8 (0.15–2.0)	0.08
BSA (m^2)	1.02–1.9	1.4 ± 0.2	1.3 (1.2–1.5)	0.9–1.9	1.5 ± 0.1	1.5 (1.4–1.6)	0.001
Dang (*n* = 321)		Women (*n* = 181)			Men (*n* = 140)		
Age (years)	16–50	21.6 ± 7	18 (17–28)	16–56	19.3 ± 6	17 (17–19)	0.003
Height (cm)	122–172	147 ± 7.5	147 (143–152)	130–176	157 ± 8.4	158 (152–163)	0.001
Weight (kg)	21–60	40 ± 5	40 (36–44)	26–62	44 ± 6.4	44 (40–48)	0.001
BMI (kg/m^2)	11.3–27	18.5 ± 2.6	18.4 (17–20)	12–25	17.9 ± 2.2	17.6 (16.5–19)	0.03
Total UI (μg/L)	0–1256	327 ± 279	222 (79–560)	0–720	143 ± 129	94 (53–196)	0.001
True UI (μ/L)	0–450	107 ± 83	90 (40–163)	0–250	68 ± 49	55 (28–100)	0.001
IS (μg/L)	0–920	220 ± 213	135 (28–377)	0–470	75 ± 98	32 (17–78)	0.001
TSH (mU/L)	0–33	2.7 ± 3.8	1.1 (0.2–4.1)	0–8	1.1 ± 1.6	0.36 (0–1.6)	0.001
BSA (m^2)	0.9–1.6	1.3 ± 0.1	1.3 (1.2–1.4)	1.0–1.7	1.4 ± 0.13	1.4 (1.3–1.7)	0.001

Median (IQ) = median with an interquartile range in parentheses; BMI, body mass index; UI, urinary iodine; IS, interfering substances; TSH, thyroid stimulating hormone; BSA, body surface area; *NS*, not significant.

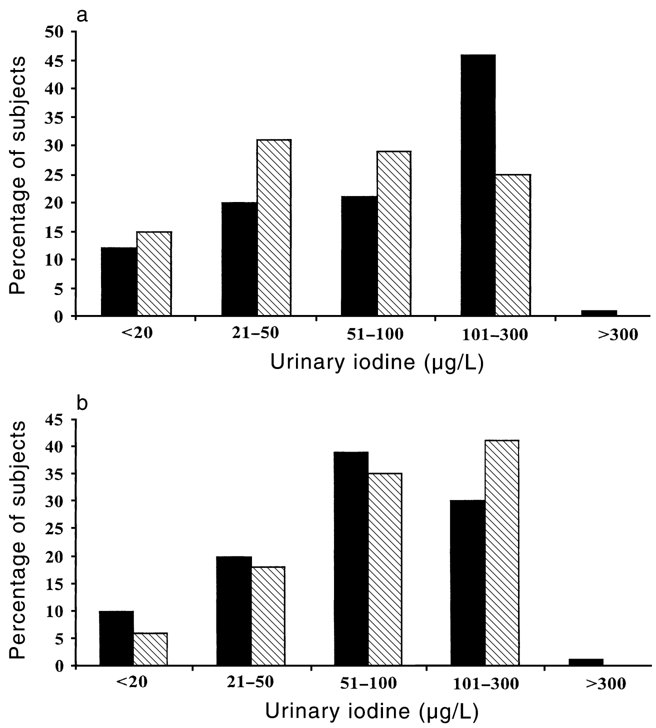

Figure 2. (a) Dang and (b) Baroda. Frequency distribution of urinary iodine in μg/L: < 20 μg/L iodine deficiency (severe), 21–50 μg/L iodine deficiency (moderate), 51–100 μg/L iodine deficiency (mild), 101–300 μg/L (adequate iodine intake), > 300 μg/L (more than adequate iodine intake). (▨), men; (■), women.

Tribals from Dang ($n = 355$) had statistically significant lower UI concentrations and IS levels in urine ($P < 0.001$) as compared to Baroda.

All the villages of the Dang district, except Rutambhara, had low levels of total and true UI. In fact, the median true UI was < 50 μg/L in four villages of Dang. Resident girls of Rutambhara boarding school had very high total urinary iodine levels (92 –1256 μg/L) and true UI 15–450, the majority of which was contributed by large amounts of IS (36–816 μg/L) with median true urinary iodine of only 150 μg/L (Table 4).

There were no significant differences in the total UI between the two villages Muval and Tentalav of the Baroda district, whereas true UI was higher in Tentalav ($P < 0.05$) (Table 5).

Blood spot thyroid stimulating hormone levels

The mean ± SD value of TSH for all subjects, irrespective of sex or district, was 1.59 ± 2.40 mU/L. Seven per cent of the subjects had whole blood TSH values > 5 mU/L. Linear regression analysis showed a very weak ($r = 0.07$), but statistically significant ($P = 0.02$) correlation between UI and blood spot TSH levels. In Dang, the mean TSH levels were significantly higher in females than males ($P < 0.001$), whereas in Baroda there was no significant sex difference ($P = 0.08$). Dang district subjects had significantly higher mean TSH concentration ($P < 0.001$) than their counterparts in the Baroda district. The frequency distribution of blood spot TSH levels for men and women of Dang and Baroda is shown in Fig. 3a and b, respectively. Blood spot TSH values > 5 mU/L were seen in 20% women and 3% men from Dang and in 3% women and 4% men in Baroda. The normative values for TSH as a prevalence indicator to describe the severity of IDD, as a significant public health problem, is not published so far by any recognized international body including WHO/UNICEF/ICCIDD.[3] The upper limit of 5 mU/L for blood spot TSH is only for the target population of neonates. If we consider an upper limit of 3 mU/L for an adult population, then 35% women and 16% men from the Dang district and 18% women and 14% men from the Baroda district show increased TSH levels.

Distribution of per cent population having TSH > 5 mU/L from different villages is shown in Table 6. The highest proportion of subjects in this category was from Rutambhara and lowest in Rambhas, Baripada and Saputara in the Dang district.

Variation by village in each district

There were no significant differences in the variables like age, weight, total urinary iodine, body mass index (BMI) and BSA between the two villages of Muval and Tentalav of the Baroda district. However, height, true UI, IS were higher in Muval and TSH was higher in Tentalav ($P < 0.05$) (Table 5).

Dang district villages (Vaghai, Saputara, Dediapada, Rambhas, Rutambhara, Baripada, Dungarda) showed differences in distribution of all the parameters (Table 6).

Using the least significant difference method of multiple comparisons, we found the following pattern for various parameters used in this study:

Height: Dediapada < (Rutambhara, Saputara) < (Vaghai, Baripada) < Muval < (Tentalav, Rambhas).

Weight: (Dediapada, Saputara, Rutambhara, Vaghai) < (Muval, Tentalav, Baripada, Rambhas).

BMI: All comparable in terms of pair-wise multiple comparisons.

Total UI: Baripada < (Rambhas, Dediapada, Saputara, Vaghai, Tentalav, Muval) < Rutambhara.

True UI: Baripada < (Rambhas, Dediapada, Vaghai, Tentalav) < (Muval and Saputara) < Rutambhara.

IS: Baripada < (Dediapada, Saputara, Rambhas, Vaghai, Tentalav) < Muval < Rutambhara.

Table 4. Biochemical and anthropometrical parameters in villages of the Dang district

	Village					
	Vaghai	Saputara	Dediapada	Baripada	Rambhas	Rutambhara
BMI (kg/m^2)	17.2 (16.2–19)	18.2 (16.7–20)	18.5 (15.1–20.8)	19.7 (18.5–22.7)	20.2 (19.1–21.5)	19.0 (18.1–20.3)
BSA (m^2)	1.35 (1.28–1.44)	1.31 (1.18–1.43)	1.21 (1.1–1.29)	1.52 (1.32–1.6)	1.56 (1.55–1.61)	1.3 (1.23–1.45)
Total UI (μg/L)	88 (48–192)	146 (76–170)	74.5 (64–100)	34 (18.5–70.5)	81 (32–128)	560 (370–700)
True UI (μg/L)	47 (26–80)	104 (33–148)	55.5 (30–72)	24 (10.5–58)	28 (24–64)	150 (108–200)
IS (μg/L)	29 (16–96)	33 (21–42)	25.5 (18–40)	10 (7–13.5)	33 (8–68)	262 (175–470)
TSH (mU/L)	1.35 (1.28–1.44)	0.64 (0.26–0.98)	4.13 (3.84–4.29)	3.56 (3.24–3.56)	0.23 (0–0.33)	1.62 (0.4–4.98)

Median with interquartile range in parentheses. BMI, body mass index; UI, urinary iodine; IS, interfering substances; TSH, thyroid stimulating hormone; BSA, body surface area.

Table 5. Results of biochemical parameters and derived indices for nutritional status in subjects from two villages of Baroda district

Parameters	Range	Mean ± SD	Median	Interquartile range
Muval				
BMI (kg/m^2)	11.1–39.6	19.5 ± 4.2	18.6	16.7–21.6
Total UI (μg/L)	0–720	197.9 ± 118	177	108–258
True UI (μg/L)	0–425	90.6 ± 58.6	80	50–120
IS (μg/L)	0–510	107.3 ± 82.4	84	49–140
TSH (mU/L)	0–24.4	1.26 ± 1.79	0.79	0.10–2.0
BSA (m^2)	0.94–1.9	1.44 ± 0.16	1.44	1.33–1.54
Tentalav				
BMI (kg/m^2)	10.9–33.8	19.4 ± 4.2	18.6	16.7–21.5
Total UI (μg/L)	0–600	167.8 ± 115	128.5	87.5–234
True UI (μg/L)	0–240	80.2 ± 55.2	72	36–108
IS (μg/L)	0–440	87.6 ± 75.6	63.5	37.5–118
TSH (mU/L)	0–8.82	1.58 ± 1.62	1.0	0.33–2.64
BSA (m^2)	1.04–1.84	1.47 ± 0.16	1.47	1.37–1.58

BMI, body mass index; UI, urinary iodine; IS, interfering substances; TSH, thyroid stimulating hormone; BSA, body surface area.

Table 6. Percentage of subjects having TSH > 5 mU/L and mean TSH with SD values from the villages of both districts

District	Village	% of subjects TSH > 5 mU/L	Mean ± SD TSH (mU/L)
Baroda	Muval	3	1.26 ± 1.79
	Tentalav	4.5	1.58 ± 1.62
Dang	Rutambhara	24.5	2.7 ± 2.7
	Baripada	0	3.46 ± 1.33
	Saputara	0	0.79 ± 0.74
	Vaghai	8.5	1.7 ± 3.5
	Dediapada	3	3.84 ± 1.27
	Rambhas	0	0.22 ± 0.30

TSH, thyroid stimulating hormone.

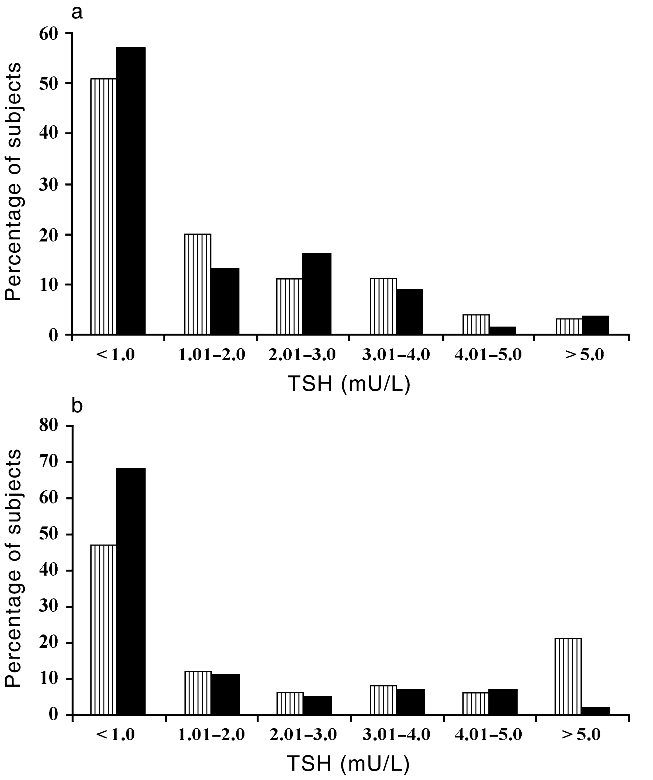

Figure 3. (a) Baroda and (b) Dang. Frequency distribution of thyroid stimulating hormone (TSH) (mU/L) in described ranges. (■), men; (▥), women.

TSH: Rambhas < (Saputara, Muval, Tentalav, Vaghai) < (Rutambhara, Baripada, Dediapada).

BSA: Dediapada < (Rutambhara, Saputara, Vaghai) < (Muval, Baripada and Tentalav) < Rambhas.

(Note: Groups of villages in parentheses are comparable and ' <' indicates statistically significantly less ($P < 0.05$) than the village or group of villages next to it).

Iodine content of drinking water in Dang was nil but adequate in the Baroda district. This is reflected in lower median UI levels in the Dang district.

Pearl millet is rich in dietary goitrogens mainly as flavonoids like apigenin, vitexin and glycosyl vitexin. The quantity of vitexin and apigenin was higher in pearl millet from Tentalav.[4]

Discussion

We used biochemical prevalence indicators and epidemiological criteria to assess the severity of IDD in the state of Gujarat, aiming at a large target population of adults older than 15 years. Using criteria recommended by WHO[4] for defining the severity and prevalence of IDD as a public health problem with the target population of schoolchildren for UI and neonates for TSH as indicators, Gujarat state, on the whole, has mild IDD based on urinary iodine and blood TSH levels in adults. It should be understood that 'mild' is a relative term; it does not imply that this category of IDD is of little consequence.[5] These findings are even more concerning given that an iodine deficiency control program has been implemented in this region of India. These findings indicate that further iodine prophylaxis measures and greater monitoring of the effectiveness of such a program need to be undertaken in this region. Iodine supplementation programs have been implemented for many years with a ban on the use of non-iodized salt in the Dang district. Nevertheless, IDD has not been eliminated from Gujarat, although the state produces 70% of the iodized salt for India.[2] The reason for this could be the use of iodized salt past expiry date, despite the fact that it should be used within six months of purchase.[1] It is likely that either the public is not aware of this fact or more likely that the manufacturer does not write the date of expiry.

The lower UI values in females reflected lower intake of iodine in females compared to males. The increased proportion of women of childbearing age in the iodine deficiency range is particularly important because iodine deficiency in fetuses and infants can lead to irreversible intellectual deficits with greater impact on a population.[10] Dang females showed high amounts of IS in the urine thought to be goitrogens and they interfere with synthesis of thyroid hormones and as a result of this there was increase in TSH in these subjects. We shall identify these goitrogens in urine samples in the future. The blood spot TSH measurements were > 5 mU/L in 10% women and 3.5% men, therefore proving beyond doubt that females are affected more by iodine deficiency. (We used 5 mU/L as a cut-off point, which is 20% higher than the normal range of TSH in the Institute of Clinical Pathology and Medical Research, Westmead Hospital). In the Rutambhara village of the Dang district, 24% of the females had TSH > 5.0 mU/l, with a borderline low median UI and probably a sufficient intake of iodine. We attribute these findings to a very high amount of goitrogens intake due to spices, organic disulfides in onions and garlic consumption.

There was significant difference in the biochemical indices (UI and TSH) of iodine deficiency and all the anthropometric indices in both districts from Gujarat. The Dang district was more severely affected by iodine deficiency and nutritional status than the Baroda district. This can be explained as follows:

1. The Dang district is a remote mountainous area likely to be leached and as there is no natural correction, iodine deficiency may have existed in the soil for a long time. An indication of the iodine content of the soil can be given by iodine levels in the local drinking water, and all the villages of the Dang district lacked iodine in drinking water. Drinking water is a very important source of iodine for the entire population as the climate is very hot.
2. Higher consumption of flavonoids in pearl millet, along with unknown goitrogens is probably the explanation for these differences.[4]
3. Nutritional factors may also be responsible, as malnutrition has been reported to contribute to goiter development.[11] The higher secondary school subjects (16–19 years) in the government-run boarding school and the adults from various household surveys receive a low-calorie diet as per the budget of schools and their low socioeconomic status. This factor affected their growth as shown by mean and median BMI. Malnutrition decreases the production of thyroid hormones and this increases the blood TSH levels.[12]

5. There is a ban on the sale of non-iodized salt in the district, but the tribal population manages to obtain and consume non-iodized salt because of their beliefs.

Girls from the Rutambhara boarding school had a very high range of UI levels and IS which can be explained on the basis of diversity of consumption of spices (chillies), onions, garlic, oils like kharsani and peanut, along with vegetables of the brassica family.

Among the two villages of the Baroda district, there was not much difference in the mean values of all the biochemical parameters, but 4.5% of the subjects from Tentalav had blood TSH levels > 5 mU/L. Malnutrition was more common in the Tentalav village.

The reason for IDD in the Baroda district is consumption of flavonoids in their staple diet of pearl millet.[4] The Tentalav village population is affected more because of consumption of large amounts of apigenin and vitexin in pearl millet, with malnutrition being an additional factor.

The differences of IDD severity, based on biochemical parameters between different villages of the Dang district, can be explained by the fact that the children selected from boarding schools consumed iodized salt, whereas those from households did not. This history of iodized salt intake had no bearing on IDD prevalence as median UI was below 50 µg/L in most of the villages (Table 6). The household tribal subjects did not use iodized salt, as they believe that it alters the taste.

A relatively greater intake of flavonoids like apigenin, vitexin and glycosylvitexin in Tentalav subjects than in Muval subjects, is reflected in higher median values for TSH.[4]

Biochemical indicators of IDD in this population may be underestimating the severity of the problem, in part, explained by the concomitant impact of goitrogens and malnutrition in the pathogenesis of goiter.

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