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# Iodine status of pregnant women and children age 6 to 12 years feeding from the same food basket in Mopani district, Limpopo province, South Africa

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**Objectives:** The aim of the study was to assess the iodine status of pregnant women and children age 6 to 12 years feeding from the same food basket in Mopani District.

**Design:** A cross-sectional study was conducted.

**Setting:** The setting was primary health care clinics and households from five municipalities of Mopani District in Limpopo province.

**Subjects:** A total of 565 conveniently selected pregnant women and 116 children aged 6 to 12 years were recruited, of which 116 were mother–child pairs.

**Methods:** The demographic information, iodine nutrition knowledge and salt consumption patterns were obtained using a validated questionnaire. Spot urine, household drinking water and salt samples were collected and analysed for iodine using standard procedures. A professional nurse, using filter paper to determine thyroid stimulating hormone (TSH) levels, collected spot finger–stick blood samples from pregnant women.

**Results:** The findings showed that only 52.5% of household salt had an iodine concentration level of more than and equal to 15 ppm. The median iodine concentration of household drinking water was 46.2 µg/l (interquartile range [IQR] 10.8–73.4 µg/l). The TSH levels of the majority of pregnant women were normal and the maternal overall median urinary iodine concentration (UIC) was 164 µg/l (IQR 92–291 µg/l), indicating maternal iodine sufficiency. However, median UIC in the first and third trimesters was below 150 µg/l, indicating iodine insufficiency. The UIC level of children in the study was 386 µg/l (IQR 200–525 µg/l), signifying iodine excess.

**Conclusion:** Iodine status of pregnant women in this study was sufficient, with UIC for children excessively high, more than two times higher than the iodine status of pregnant women. The reasons for the excessive UIC in school-age children need to be elucidated.

**Keywords:** iodine deficiency and excess, pregnant women, school age children, urinary and household salt and drinking water iodine concentration

## Introduction

Iodine is an essential trace mineral required for the synthesis and production of thyroid hormones, which regulate many important functions in the body, including enzyme activity and protein synthesis.<sup>1</sup> Iodine deficiency (ID) occurs when iodine intake falls below required levels to maintain adequate thyroid hormone production.<sup>2</sup> The consequences of ID include stillbirth, mental retardation, poor growth, foetal brain malformations, miscarriages and cognitive problems.<sup>3</sup> The developing foetus and children aged 0 to 24 months are susceptible to irreversible damage to the brain and the central nervous system caused by ID.<sup>4–7</sup> Pregnant women have a higher recommended daily iodine intake than other populations in order to support the developing foetus.<sup>8</sup> According to the WHO, population-based prevalence surveys of iodine status should be performed by measurement of urinary iodine concentration from spot urine samples.<sup>9</sup>

Studies by Zimmermann *et al.*<sup>10</sup> in Limpopo and that of Mabapa *et al.*,<sup>11</sup> also done in the Limpopo province (Vuwani and Mutale Areas), South Africa, used the results from school-age children (SAC) as a proxy for iodine status in the general population. SAC iodine status, however, has been used as a proxy for iodine status in pregnant women. Recently, this approach has been challenged as children tend to consume disproportionately more iodine

from milk and milk products and other food items, and SAC are not the primary beneficiaries of iodine interventions.<sup>12</sup> The primary target groups are pregnant and lactating women, whose iodine requirement increases dramatically to maintain the thyroid function of the developing foetus and then the infant.<sup>13</sup> In 2011, a review of population-based surveys in SAC and pregnant women concluded that adequate iodine nutrition of SAC might not reflect adequate iodine nutrition status during pregnancy.<sup>3</sup> De Benoist *et al.*<sup>3</sup> proposed that more surveys of iodine status of pregnant women are required. To our knowledge, the iodine status of pregnant women has not been studied before in South Africa.<sup>14</sup> The aim of this study was to evaluate the iodine nutrition status of pregnant women and school-age children feeding from the same basket in Mopani district, Limpopo province, South Africa.

## Methods

### Design and study population

The study was conducted in Mopani District, the second biggest of five districts in Limpopo province, South Africa. The district has an estimated population of 1 092 507 and the languages spoken by the majority of people are Xitsonga (48.55%) and Northern Sotho (46.36%). The estimated female population is

(54.5%) while the male population is 45.5%.<sup>15</sup> The pregnant women and SAC were from five different municipalities within Mopani district, i.e. Ba-Phalaborwa, Maruleng, Greater Tzaneen, Greater Letaba and Greater Giyani.

The target population was pregnant women and their children aged 6 to 12 years in this district. A total of 565 pregnant women attending antenatal care, of which 116 were mother–child pairs, were conveniently selected from 41 primary health care clinics. The primary health care facilities were randomly selected from the list of 91 clinics obtained from the department of health district office. The study population was from both rural and peri-urban areas with varying levels of education. Pregnant women who were multiparas were included in the study. Children aged 6 – 12 years were recruited from women who had this age group in their homes. Since many (62%) women did not have children in that age group, only 116 mother–child pairs were recruited. Pregnant women with known thyroid disease before pregnancy, pre-existing diabetes mellitus or women who smoked during pregnancy were excluded from the study.

The participating women gave written informed consent for themselves and their children. Children gave verbal assent. The University of Venda (UNIVEN) Ethics Committee approved the study and an ethics certificate (SHS/01/NUT/003) was issued. The Limpopo Provincial Health Department granted permission for the study to be conducted. Furthermore, cooperation was sought from the Mopani District Health Department, which gave clearance for the researcher to access the clinics. The study protocol complied with the Declaration of Helsinki (2008) and the laws and regulations of South Africa.

#### **Data collection**

Data were collected at the clinic sites and from the households between March 2012 and February 2013. At the clinic, a validated questionnaire was administered to solicit data on demographic parameters, salt consumption patterns and iodine nutrition knowledge. The pregnant women supplied information about themselves and the children. Women also provided spot urine samples for determining UIC and spot finger–stick blood samples for determining thyroid-stimulating hormone (TSH) levels. A professional nurse, using filter paper grade IDBS-226 (Ahlstrom, Sweden) obtained from Zurich, Switzerland, collected 404 spot finger–stick blood samples from pregnant women. Spot urine samples were collected from women who were in various stages of pregnancy using a 40 ml specimen container, that is, during the first, second or third trimesters. Spot urine samples were collected between 08h00 and 17h00.

The pregnant women gave permission for the researcher to visit their households. During the household visits, urine samples were collected from the 116 children using a 40 ml specimen container. Three teaspoons of salt used for food preparation were collected in a small plastic bag with zip lock from 449 households and 565 drinking-water samples from communal taps, taps in the households and yards, and boreholes were collected using 40 ml specimen containers with screw caps. The water sources for the five municipalities are not same. There are 19 different dams in total, which are the main suppliers of household water inside the house or as communal taps. For this study, water was, therefore, collected from the household container in their kitchen or the household's storage place. All water samples were grouped together irrespective of the original source, and analysed together, not according to source.

The samples were transported on ice from the field to UNIVEN where they were stored at –70 °C until analysis. Of the 565 urine samples from pregnant women, only 521 were analysed (44 spilled during shipping) and of the 116 urine samples collected from children, only 84 were analysed as 32 spilled during shipment from UNIVEN in Limpopo to the Medical Research Council in Cape Town where the analysis was done.

#### **Laboratory analysis**

The Sandell–Kolthoff method with microplate reading of the end point was used for iodine analyses in urine and water samples, whereas the iodometric titration method was used for salt analyses at the iodine laboratory of the Nutritional Intervention Research Unit, Medical Research Council, Cape Town, Western Cape.

Dried blood spots on filter paper were analysed for whole blood thyrotropin (TSH) and serum T4 with an automated time-resolved fluoro-immunoassay. The analyses were done at the Swiss Federal Institute of Technology laboratory in Zurich. American Thyroid Association cut-off reference values were used. A total of 388 blood samples were analysed, as the remaining 16 samples were inadequate for analysis.

#### **Data analysis**

Data were analysed using SPSS® 21.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics of frequencies, means, medians, standard deviation and standard error for all variables were calculated. Pearson correlation tests were done to determine the statistical relationship between different variables. The strength of the correlation was determined by the Pearson correlation coefficient ( $r$ ). A strong correlation was  $r > 0.70$  or  $r < -0.70$ , moderate correlation was  $r > 0.30$  to  $0.70$  or  $r < -0.30$  to  $-0.70$  and weak correlation was  $r = 0.00$  to  $0.30$  or  $r = 0.00$  to  $-0.30$ .  $P$ -values were used to determine the statistical significance of correlations between variables. Correlations were significant at  $p < 0.05$  and  $p < 0.01$ .

#### **Results**

Table 1 indicates the actual sample sizes of various groups and variables measured in the study.

Most (54.7%) of the pregnant women were single, 44.8% were married and 0.5% were widowed. Of the 565 pregnant women, 43.2% indicated that they had only one child, 29.7% had two children, 14.5% had three children, 7.8% had four children, 4.6% had more than four children and 0.2% did not respond to this question. The majority of women (52.2%) were in the third trimester, 37.7% were in the second trimester and 10.1% were in the first trimester of their pregnancies.

#### **Household salt consumption and knowledge of iodine nutrition**

The results indicate that 98.9% of women consumed salt. More than 50% of these participants added salt before cooking, whereas 43.5% added salt during cooking. About 40% of women used fine salt, 47.1% used coarse salt, and 12% used both fine and coarse salt (Table 2).

The majority of women (88.3%) indicated that they did not know about iodised salt and 90.6% indicated that they did not know what iodine is. Only 5.3% correctly indicated that iodised salt is the main source of dietary iodine in South Africa and 0.2% indicated that fish/seafood and vegetables are other major sources of dietary iodine.

**Table 1:** Actual samples of various groups and variables measured in the study

Study groups and variable measured	Actual sample number (n)					
	Greater Giyani	Ba-Phalaborwa	Greater Tzaneen	Maruleng	Greater-Letaba	Mopani District
Pregnant women (demographic and dietary information)	298	27	85	62	93	565
Household salt samples	274	24	76	55	70	499
Drinking water samples	219	21	45	36	57	378
Urine samples of pregnant women	279	25	80	55	82	521
Pregnant women blood sample	184	19	40	55	90	388
Children aged 6–12 years	54	10	21	14	17	116
Urine samples of children	44	10	11	8	11	84

**Table 2:** Consumption of salt.

Characteristics	Number and percentage, n (%)					
	Greater Giyani	Ba-Phalaborwa	Greater Tzaneen	Maruleng	Greater Letaba	Mopani District
Salt consumption:						
Eat salt	298 (100%)	26 (96.7%)	82 (96.5%)	62 (100%)	91 (97.8%)	559 (98.9%)
Do not eat salt	–	1 (3.7%)	3 (3.5%)	–	2 (2.2%)	6 (1.1%)
Addition of salt when cooking:						
Before cooking	155 (52.0%)	9 (33.3%)	40 (47.1%)	35 (56.5%)	62 (66.7%)	301 (53.3%)
During cooking	131 (44.0%)	18 (66.7%)	41 (48.2%)	26 (41.9%)	30 (32.3%)	246 (43.5%)
After cooking	10 (3.4%)	–	1 (1.2)	1 (1.6%)	–	12 (2.1%)
Did not respond	2 (0.7%)	–	3 (3.5%)	–	–	5 (0.9%)
Type of salt used when cooking:						
Fine salt	93 (31.2%)	15 (55.6%)	41 (48.2%)	43 (54.8%)	41 (44.1%)	233 (41.2%)
Coarse salt	158 (53.0%)	8 (29.6%)	31 (36.5%)	22 (35.5%)	47 (50.5%)	266 (47.1%)
Both	45 (15.1%)	2 (7.4%)	11 (12.9%)	6 (9.7%)	4 (4.3%)	68 (12.0%)
Did not respond	2 (0.6%)	2 (7.4%)	2 (2.4%)	–	1 (1.1%)	7 (1.2%)

### Household salt and drinking water iodine concentration

Approximately 29.3% of households' salt had an iodine concentration of less than 5 ppm, which indicates non-iodisation. Around 18.2% of households' salt had an iodine concentration between 5 and 14.9 ppm, indicating under-iodisation and 52.5% of households consumed salt with an iodine concentration of more than 15 ppm. Almost half (47.5%) of the households consumed salt with iodine less than 15 ppm. The mean iodine concentration of household salt was 25 ppm, an acceptable level of iodine concentration (Table 3).

About 18% of household drinking water samples had an iodine concentration of less than 5 µg/l. The majority (41.3%) of household drinking water had an iodine concentration greater

than 60 µg/l and 10.6% of household drinking water had an iodine concentration of 20–39.9 µg/l. The median iodine concentration of drinking water from the five areas in Mopani District was 46.2 µg/l (IQR 10.8–73.4 µg/l). The sources of drinking water included communal taps, taps inside the household and yards and boreholes.

### Iodine status of pregnant women

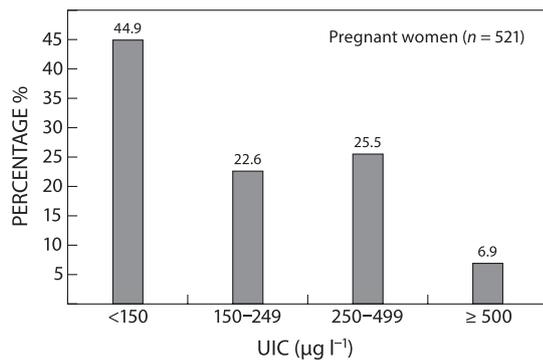
Iodine status of pregnant women was determined using UIC and TSH levels. The UIC distribution is presented in Figure 1 according to the WHO/UNICEF/ICCIDD reference criteria.

The maternal median UIC level in the first trimester was 145 µg/l, which is less than the recommended value of 150–249 µg/l, and

**Table 3:** Household salt iodine concentration

Salt iodine concentration (ppm)	Greater Giyani	Ba-Phalaborwa	Greater Tzaneen	Maruleng	Greater Letaba	Mopani District
Non-iodised (< 5 ppm)	59 (21.5%)	6 (25.0%)	33 (43.4%)	21 (38.2%)	27 (38.6%)	146 (29.3%)
Under-iodised (5–14.9 ppm)	62 (22.6%)	–	10 (13.2%)	12 (21.8%)	7 (10.0%)	91 (18.2%)
Acceptable (15–64.9 ppm)	131 (47.8%)	18 (75.0%)	31 (40.8%)	20 (36.4%)	33 (47.1%)	233 (46.7%)
More than required (≥ 65–79.9 ppm)	12 (4.4%)	–	–	1 (1.8%)	2 (2.9%)	15 (3.0%)
Excessive (≥ 80 ppm)	10 (3.6%)	–	2 (2.6%)	1 (1.8%)	1 (1.4%)	14 (2.8%)
Mean (ppm)	29	33	22	18	23	25

Note: ppm = mg of iodine per kg of salt.



**Figure 1:** Distribution of urinary iodine concentration (UIC) (µg/l) of pregnant women ( $n = 521$ ).

**Table 4:** Maternal median urine iodine concentration (UIC) by pregnancy stages in Mopani District

Stage of pregnancy	n	%	Maternal UIC (µg/l)
First trimester	57	10.1	145
Second trimester	213	37.7	201
Third trimester	295	52.2	132
Total	565	100	164 (IQR 92–291)

pregnant women in the third trimester had a median UIC level of less than 150 µg/l. (Table 4).

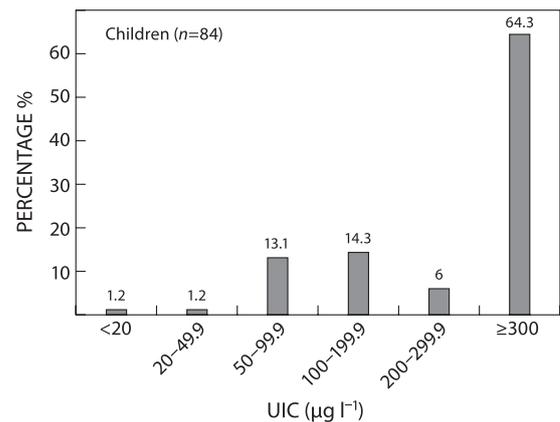
The maternal median UIC level was 164 µg/l (IQR 92–291 µg/l), indicating maternal iodine sufficiency, with 44.9% of pregnant women having UIC levels lower than 150 µg/l, potentially making them vulnerable to iodine deficiency. The median UIC in all the areas showed iodine sufficiency except in Greater Tzaneen with a median UIC of 111 µg/l (Table 5).

#### TSH levels of pregnant women

TSH levels of pregnant women were measured per trimester and almost all participants had normal TSH levels. During the first trimester, TSH values ranged from 0.3 to 1.3 mIU/l (normal range 0.1 – 2.5 mIU/l). TSH levels of the pregnant women were within the normal range of 0.2–3.0 mIU/l during the second semester. A value of 5.6 mIU/l was observed during the third trimester, which was the only value above the normal range of 0.3–3.0 mIU/l as stipulated by the American Thyroid Association.<sup>16</sup>

#### The UIC levels of children

The UIC levels of children aged 6–12 years are illustrated in Figure 2.



**Figure 2:** Distribution of urinary iodine concentration (UIC) (µg/l) of children ( $n = 84$ ).

Almost two-thirds (64.3%) of children had UIC levels greater and equal to 300 µg/l, which is considered excessive, except for Greater Tzaneen, where 45.5% of SAC urinary iodine was in the sufficient range; the other four areas had excessive UICs. The median UIC level of children in the study was 386 µg/l (IQR 200–525 µg/l) (Table 6).

#### Relationships among household salt and water iodine concentration, child UIC and maternal UIC and TSH

Correlations were done to determine the statistical relationship between different variables. The results indicated that there was a very weak negative significant correlation between maternal UIC and TSH ( $r = -0.13$ ,  $n = 352$ ,  $p < 0.05$ ). The median UIC in pregnant women was 164 µg/l (IQR 92–291 µg/l) and median UIC in children was 386 µg/l (IQR 200–525 µg/l) and were significantly different ( $p < 0.01$ ). There was a weak significant correlation between median UIC in pregnant women and median UIC in their children ( $r = 0.30$ ,  $n = 76$ ,  $p < 0.01$ ).

When the association between iodine concentration in household salt and both maternal UIC and that of children was determined, the results showed that there was a significant weak relationship between iodine concentration in household salt and maternal UIC ( $r = 0.26$ ,  $n = 462$ ,  $p < 0.01$ ). However, there was no significant relationship between iodine concentration in household salt and UIC in children ( $r = 0.17$ ,  $n = 83$ ,  $p = 0.12$ ).

Iodine concentration in drinking water was significantly correlated with maternal UIC; there was a weak positive significant relationship between these two variables ( $r = 0.30$ ,  $n = 349$ ,  $p < 0.01$ ). There was no significant relationship between iodine concentration in drinking water and UIC in children ( $r = 0.11$ ,  $n = 72$ ,  $p = 0.36$ ).

**Table 5:** Maternal median urinary iodine concentration (UIC) by iodine status in Mopani District

Iodine status (µg/l)	Greater Giyani	Ba-Phalaborwa	Greater Tzaneen	Maruleng	Greater Letaba	Mopani District
Iodine insufficient(< 150)	103 (36.9%)	12 (48.0%)	51 (63.8%)	27 (49.1%)	41 (50.0%)	234 (44.9%)
Iodine sufficient(150–249)	60 (21.5%)	7 (28.0%)	17 (21.3%)	17 (30.9%)	17 (20.7%)	118 (22.6%)
Above requirement(250–499)	89 (31.9%)	6 (22.2%)	10 (12.5%)	8 (14.5%)	20 (24.4%)	133 (25.5%)
Excessive (≥ 500)	27 (9.7%)	–	2 (2.5%)	3 (5.5%)	4 (4.9%)	36 (6.9%)
Median UIC (µg/l)	204 (IQR 107–349)	162 (IQR 103–261)	118 (IQR 61–196)	150 (IQR 64–206)	152 (IQR 94–268)	164 (IQR 92–291)

**Table 6:** Urine iodine concentration (UIC) of children

Iodine status ( $\mu\text{g/l}$ )	G-Giyani	Ba-Phalaborwa	G-Tzaneen	Maruleng	G-Letaba	Mopani District
Severe iodine deficient (< 20)	1 (0.3%)	–	–	–	–	1 (1.2%)
Moderate iodine deficient (20–49.9)	1 (0.3%)	–	–	–	–	1 (1.2%)
Mild iodine deficient (50–99.9)	4 (9.1%)	2 (20.0%)	2 (18.2%)	3 (37.5%)	–	11 (13.1%)
Iodine sufficient (100–199.9)	5 (11.45%)	–	5 (45.5%)	1 (12.5%)	1 (9.1%)	12 (14.3%)
Above requirement (200–299.9)	3 (6.8%)	1 (10.0%)	–	–	1 (9.1%)	5 (6.0%)
Excessive ( $\geq 300$ )	30 (68.2%)	7 (70.0%)	4 (36.4%)	4 (50.0%)	9 (81.8%)	54 (64.3%)
Median UIC( $\mu\text{g/l}$ )	394 (IQR 257–524)	528 (IQR 210–731)	187 (IQR 151–326)	321 (IQR 89–500)	502 (IQR 359–926)	386 (IQR 200–525 $\mu\text{g/l}$ )

## Discussion

This is the first study in South Africa that measured both UIC and TSH in a reasonable number of pregnant women. The majority were in the second and third trimester. The low first trimester numbers could be because most women delay antenatal health care visits or they may not be aware that they are pregnant.

In the current study, 52.5% of households used adequately iodised salt with an iodine concentration of  $\geq 15$  ppm, which is lower than the international goal of 90% of households using adequately iodised salt.<sup>17</sup> Of concern is that almost 48% of the households are using inadequately or non-iodised salt. The majority of women had inadequate knowledge on iodine nutrition and its benefits. Almost all households (98.9%) indicated that they consume salt as the main source of iodine and that they added salt either before or during cooking. A study in India<sup>18</sup> reported the effect of cooking methods on iodine losses. It showed the loss of iodine during cooking depends on the method and cooking time or when salt is added during the process. It concluded that it is advisable to sprinkle salt after cooking (where it is possible) rather than adding salt while cooking. The consumption of salt and how it is added to food should be included as part of nutrition education on iodine. Despite the success of the mandatory iodisation programme at the national level in South Africa, there are some areas, particularly in the Limpopo province, where the implementation is poor or there is poor knowledge and practices. This could be attributed to many factors, including lack of knowledge on iodine nutrition or the reported use of cheap non-iodised agricultural salt bought at local *spaza* shops (informal convenience stores) and from small-scale salt traders.

Iodine in drinking water may serve as an indication of the amount of iodine occurring naturally in the environment.<sup>17</sup> However, the limited contribution of iodine in water to the total daily iodine intake would usually not be considered in meeting the requirements of children and women.<sup>17</sup> In this study, however, the median iodine concentration in water was 46.2  $\mu\text{g/l}$  (IQR 10.8–73.4  $\mu\text{g/l}$ ) and almost half of the household drinking water samples (41%) had iodine concentrations greater than 60  $\mu\text{g/l}$ . This confirms other findings that the median iodine concentration of drinking water in Limpopo (64.837.3  $\mu\text{g/l}$ ; IQR 14.9–91.4  $\mu\text{g/l}$ ) is higher than in other provinces, except for the Northern Cape (196.6151.6  $\mu\text{g/l}$ ; IQR 132.3–238.9  $\mu\text{g/l}$ ).<sup>17</sup> This may have contributed significantly to the iodine intake of children and women in Mopani district. The data clearly showed that drinking water can be a potential source of iodine intake in vulnerable groups in the population, although many studies on iodine

nutrition tend to overlook this important potential source of dietary iodine. Borehole water and river or spring water contributed to the household storage water, and was the most probable reason for the high iodine content.

The mean iodine concentration of household salt in this study was 25 ppm, indicating adequate levels of iodine concentration. This is similar to the 2001 South African national mean iodine concentration of 27 ppm<sup>19</sup> but differs from the National Food Consumption Survey Fortification Baseline (NFCS-FB-1) carried out in 2005, where the national mean iodine concentration in household salt was 39.7 ppm.<sup>17</sup> Mabapa *et al.*<sup>11</sup> reported a mean household salt iodine concentration of  $11.59 \pm 36.70$  and the mean iodine salt concentration for the salt found in retailers for Vuwani was  $29.93 \pm 29.61$  and for Mutale in the neighbouring Vhembe district  $23.29 \pm 21.48$ .

According to the WHO/UNICEF/ICCIDD criteria, the median UIC during gestation should be 150–249  $\mu\text{g/l}$ .<sup>9</sup> The overall median UIC attained in the current study (164  $\mu\text{g/l}$ ) is within the normal range and indicates iodine sufficiency in the pregnant population. The results are similar to the NFCS-FB-1 of non-pregnant women in South Africa (median UIC of 176.8  $\mu\text{g/l}$ ), which reported adequate iodine nutrition.<sup>17</sup> In Cambodia, Karakochuk *et al.*<sup>20</sup> also found adequate iodine status in pregnant women. The results of our study, however, showed that there was variation in median UICs when measured in different trimesters. The median UICs in the first and third trimesters were below 150  $\mu\text{g/l}$ , indicating inadequate iodine nutrition, whereas the UIC in the second trimester was 201  $\mu\text{g/l}$ , indicating adequate iodine nutrition. The overall median UIC during pregnancy may therefore not give an accurate reflection of the iodine status of pregnant women. The possible causes of the variation in UIC in different trimesters are not clear in the current study, nor have other researchers explained these variations.<sup>21</sup> TSH is also an indicator of the iodine status of pregnant women. According to Pearce,<sup>22</sup> if adequate iodine is not available to produce thyroid hormones during pregnancy, TSH rises and consequently maternal and foetal goitre may develop. Despite one outlier in TSH levels in the third trimester, adequate iodine nutrition can be inferred by the normal TSH levels in all three trimesters of pregnancy in this study.

The UIC in SAC was in the excessive category as specified by the WHO/UNICEF/ICCIDD criteria, with the median UIC of 386  $\mu\text{g/l}$  observed in two-thirds (64.3%) of children. According to the WHO/UNICEF/ICCIDD, UIC levels greater than 300  $\mu\text{g/l}$  could be excessive and may have adverse effects. The excessive median

UIC is reason for concern, especially since the long-term effects of such a high median UIC have not been studied. The median UIC in the current study is considerably higher than the national median UIC of 214.8 µg/l for 6–9-year-olds as reported by the NFCS-FB-1.<sup>17</sup> The median UIC of pregnant women in the study was lower than the UIC in SAC. The study findings are in agreement with other studies,<sup>3,23</sup> where UIC among pregnant women was lower than in SAC. The study results show a significant difference from the study by Mabapa *et al.*<sup>11</sup> in the neighbouring Vhembe district, where SAC had median UIC levels of 75 µg/l and 101.17 µg/l in the Vuwani and Mutale areas, as well as that by Zimmermann *et al.*<sup>10</sup> who found a median UIC of 74 µg/l, indicating mild iodine deficiency. In addition, the very low percentage of children who are below 50 µg/l for UIC (2.4%) is in contrast to what was reported by Zimmermann *et al.*<sup>10</sup> in 2007 and Mabapa *et al.*<sup>11</sup> in 2014, where 31% and 59%, respectively, were below 50 µg/l. The difference could be due to many factors including the use of appropriately iodised salt and the iodine concentration of water. Although these districts are neighbours the sources of water were different, with only Giyani Municipality sharing water from Nandoni Dam, from 2017, but not at the time of this study. Furthermore, the salt content and/or types of foods accessible to the children from the *spaza* shops could have been different.

Our study has several limitations. The study was cross-sectional, using pregnant women at different stages of pregnancy, and did not follow the same cohort from the first trimester to the last trimester. The number of SAC included in the study was small and generalisability within this group would be limited. The study did not determine the nutritional status of the children or dietary intakes, and no goitre rate estimation was done. All these parameters would be required to account for confounders of iodine status in both the women and children. Furthermore, the retailer salt was not analysed. The water source was household kitchen or home storage, thus the original source (dam, borehole, well, river or spring) was not determined. In addition, the five municipalities are served by 19 dams in the district.

## Conclusion

In conclusion, the median UIC of 164 µg/l obtained in this study of pregnant women indicates a sufficient iodine intake in Mopani district. The median UIC (386 µg/l) of school-aged children, however, is twice that of pregnant women and indicates excessive iodine intake for the sub-sample of mother–child pairs. Children tend to consume disproportionately more iodine from various food items at school and from *spaza* shops. More studies looking at the analysis of food eaten by SAC should be conducted to determine various iodine sources that these children are exposed to, including iodine from drinking water. The pregnant women in this study were unaware of iodised salt and its dietary sources. Almost half the household salt used was found to be insufficiently iodised as per national programme requirements in South Africa. Further studies that focus on monitoring of iodine status in pregnant women and SAC are required.

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