A lowered salt intake does not compromise iodine status in South Africa, a country with mandatory salt iodization


Objective: Universal salt iodization is an effective strategy to optimize population-level iodine. At the same time as salt-lowering initiatives are encouraged globally, there is concern about compromised iodine intakes. This study investigated whether salt intakes at recommended levels resulted in a suboptimal iodine status in a country where salt is the vehicle for iodine fortification. Methods: Three 24-h urine samples were collected for the assessment of urinary sodium and one sample was taken for urinary iodine concentrations (UICs) in a convenience sample of 262 adult men and women in Cape Town, South Africa. Median UIC was compared across categories of sodium excretion equivalent to salt intakes lower than 5, 5 to 9, and greater than or equal to 9 g/d. Results: The median UIC was 120 μg/L (interquartile range 75.3–196.3), indicating iodine sufficiency. Less one-fourth (23.2%) of subjects had urinary sodium excretion values within the desirable range (salt <5 g/d), 50.7% had high values (5–9 g/d), and 22.8% had very high values (>9 g/d). No association between urinary iodine and mean 3 × 24-h urinary sodium concentration was found (r = 0.087, P = 0.198) and UIC status did not differ according to urinary sodium categories (P = 0.804).

Conclusion: In a country with mandatory universal salt iodization, consumers with salt intakes within the recommended range (<5 g/d) are iodine replete, and median UIC does not differ across categories of salt intake. This indicates that much of the dietary salt is provided from non-iodinated sources, presumably added to processed foods.

Introduction

Iodine deficiency disorders include endemic goiter, hypothyroidism, brain damage, cretinism, congenital abnormalities, poor pregnancy outcomes, and impaired cognitive and physical development [1]. To prevent iodine deficiency disorders, the World Health Organization (WHO) has endorsed universal salt iodization, where all salt for human and animal consumption is iodized. Approximately 70% of the world’s population is estimated to use iodized salt in a total of 130 countries [2]. In South Africa, mandatory iodization of table salt at 40 to 60 ppm was introduced in 1995 [3] and subsequently revised to a level of 35 to 65 ppm in 2007. The iodization program has effectively eliminated iodine deficiency in the country, but there are some loopholes in the program, such as the domestic use of non-iodized agricultural salt in the northern provinces [4].

There is concern that iodine deficiency may re-emerge as a result of public health strategies to lower salt intakes in populations. A large body of evidence from epidemiologic and experimental studies has shown a consistent relation between sodium intake and blood pressure [5–8]. A high-salt intake increases the risk of stroke and total cardiovascular disease [9,10] and gastric cancer in some populations [11]. In children, sodium intake contributes to the development of hypertension later in life [12].

After the human immunodeficiency virus, ischemic heart disease and stroke are the leading causes of death in South Africa [13] and hypertension is estimated to be present in 60% to 78% of men and 50% to 71% of women 45 y and older [14] A shift in
dietary patterns from a reliance on traditional staples, such as a maize meal, to processed foods that are high in salt partly explains the increase in hypertension in recent decades [15,16]. The modification of salt intake and weight reduction may decrease the cardiovascular risk related to hypertension in urban, developing communities of African descent [17].

Sodium intakes around the world are well in excess of physiologic need (i.e., 10–20 mmol/d), with most adult populations having intakes higher than 100 mmol/d or even higher than 200 mmol/d, particularly in Asian countries [18]. The WHO has set a worldwide sodium target of no higher than 5 g/d (sodium <2000 mg or ¼/− 90 mmol/d) [19], whereas other agencies have recommended a maximum of 6 g/d [20–22]. Voluntary sodium-decreasing targets for categories of foods have been set in the UK [23] and these have formed the basis for similar target-setting processes in Australia, USA, and Canada. South Africa is the first country to adopt a mandatory regulation for maximum sodium levels in bread, margarine and spreads, savory snacks, processed meats, soup powders, and stock cubes [24]. These food categories have been shown to be major contributors to salt intake in that population [25]. It is estimated that decreasing the sodium content of bread by 50%, in addition to other proposed decreases in margarine, soups, and gravies, would decrease the salt intake by 0.85 g/d, resulting in 7000 fewer deaths from cardiovascular disease and 4000 fewer non-fatal strokes in the country per year and save R300 million (~US$40 million) each year in health care costs associated with non-fatal strokes alone [26].

Although the salt-decreasing efforts in South Africa are to be applauded, their impact on the iodine status of the population needs to be assessed. The present study was undertaken to investigate whether salt intakes that meet recommended levels (≤5 g/d) result in an increased suboptimal urinary iodine status in a country where salt is the vehicle for iodine fortification.

### Materials and methods

Men and women from three different ethnic groups (black, mixed ancestry, and white; 20–65 y old) were recruited from their place of work, the Cape Town City Council offices, South Africa. Equal numbers of hypertensive (blood pressure ≥140/90 mmHg and/or on antihypertensive medication) and normotensive (blood pressure ≤140/90 mmHg) men and women were planned (n = 150/group, 50 from each ethnic group). Approval for the study was granted by the research and ethics committee of the University of Cape Town, and written informed consent was obtained from all participants. The detailed methodology is described elsewhere [25].

Three 24-h urine samples were collected for the assessment of urinary sodium using flame photometry and one sample was taken from the first 24-h collection for an analysis of urinary iodine concentrations (UICs). Three tablets (450 mg/d) of non-metabolizable para-aminobenzoic acid (PABA; Laboratories for Applied Biology, London, UK) were given to the subjects, to be taken with meals during the collection period, and the urinary excretion of PABA was measured caloriometrically as a marker of completeness of urine collection [27]. Urinary sodium concentration was measured using flame photometry. Urine collections were excluded from the analyses for that day of collection if the volume was no larger than 500 mL (n = 9 samples) or if urinary creatinine values were lower than 0.2 mmol/L and PABA was no higher than 97% or 2) urinary creatinine values were equal to 0.2 to 0.3 mmol/L <1 g/L and PABA was no higher than 75% (n = 23) [28].

The UIC was determined using a modification of the Sandell–Kolthoff method using ammonium persulfate digestion and microplate reading [29,30] in the iodine laboratory of the Medical Research Council, which meets the international using ammonium persulfate digestion and microplate reading [29,30] in the

### Results

Three hundred twenty-five volunteers participated in the study. Three complete urine collections were obtained in 44.3%, two in 27.8%, and one in 16% of subjects. Twelve percent of subjects had no usable urinary data. For the total sample (N = 325), as previously reported [31], urinary sodium excretion was significantly higher in white subjects than in mixed–ancestry or black subjects (mean 164.8 mmol/d, standard deviation 91.0; 147.5 mmol/d, 73.5; and 135.3 mmol/d, 50.1, respectively; P <0.05). This equates to daily salt (NaCl) intakes of 9.5, 8.5, and 7.8 g in white, mixed-ancestry, and black subjects, respectively. Twenty-three percent of subjects had urinary sodium concentrations lower than 100 mmol/d, and this proportion did not differ among ethnic groups.

The UIC were available for 261 men and women; of these, useable data for 24-h urinary sodium excretion were available for 222 participants. There were no significant differences in dietary or urinary variables or in body mass index between the iodine subsample (n = 261) and the larger sample (data not shown). The remaining analyses report on these two subsets. The MUIC indicated sufficient at 120 μg/L (interquartile range 75–196). Thirty-nine percent of participants (n = 102) had some degree of suboptimal iodine status (UIC <100 μg/L), whereas 12.3% had a UIC lower than 50 μg/L (Table 1). The MUIC did not differ among ethnic groups (Table 2). Fifteen percent of the sample (n = 40) had a UIC at least 200 μg/L, and 9% (n = 23) had values that were excessive (MUIC ≥300 μg/L).

In the subset of 222 subjects, 23.2% had 24-h urinary sodium excretion values within the desirable range (<100 mmol/d), 50.7% had high values (100–170 mmol/d), and 22.8% had very high values (>170 mmol/d).

No association between urinary iodine and 24-h urinary sodium excretion concentrations within the desirable range (<100 mmol/d), 50.7% had high values (100–170 mmol/d), and 22.8% had very high values (>170 mmol/d).

No association between urinary iodine and 24-h urinary sodium excretion was found (r = 0.087, P = 0.198), and the UIC status did not differ according to the urinary sodium categories of interest (P = 0.804, chi-square test). The percentages of subjects with a UIC indicative of sufficiency in the three urinary sodium excretion categories were 63%, 58%, and 62% for lower than 90, 90 to 150, and higher than 150 mmol/d, respectively (P = 0.804, chi-square test) (Table 3). Similar results were found for urinary sodium excretion categories equivalent to salt intakes no higher than 6, 6 to 10, and higher than 10 g/d (data not shown). Of the 27 subjects with a UIC lower than 50 μg/L, only one had urinary sodium levels lower than 90 mmol/d; most had urinary sodium levels higher than 150 mmol/d (P = 0.140, Fisher exact test).

### Table 1

<table>
<thead>
<tr>
<th>UIC categories</th>
<th>n</th>
<th>In sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20 μg/L</td>
<td>8</td>
<td>3.1%</td>
</tr>
<tr>
<td>20–50 μg/L</td>
<td>24</td>
<td>9.2%</td>
</tr>
<tr>
<td>50–100 μg/L</td>
<td>70</td>
<td>26.8%</td>
</tr>
<tr>
<td>&gt;100 μg/L</td>
<td>159</td>
<td>60.9%</td>
</tr>
<tr>
<td>Total</td>
<td>261</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

UIC, urinary iodine concentration

8.6, and higher than 8.6 g, respectively. Analysis was also performed using different categories of urinary sodium reference values (<100 mmol/d, salt 6 g/d; 100–170 mmol/d, salt 6–10 g/d; >170 mmol/d, salt >10 g/d).

All descriptive and inferential statistical analysis was carried out using SPSS 17.0 (SPSS, Inc., Chicago, IL, USA). Differences in the proportions of participants in various UIC categories, by ethnic group, were assessed using chi-square tests. Chi-square tests and non-parametric bivariate Spearman correlations were used to identify relations between categorical data. Fisher exact tests were also used to delineate relations between 2× 2 categorical variables.

Please cite this article in press as: Charlton KE, et al., A lowered salt intake does not compromise iodine status in South Africa, a country with mandatory salt iodization, Nutrition (2012), http://dx.doi.org/10.1016/j.nut.2012.09.010
rural differences exist with respect to sources of dietary salt, with more than 70% of total non-discretionary salt being provided by the bread and cereals food group in rural black South Africans compared with 49% to 54% in urban dwellers [25]. Information on the salt intake of South African children is not available; however, bread and margarine are among the 10 most frequently consumed foods in children 1 to 9 y old [35].

Information on whether iodinated salt is used as an ingredient in the manufacturing of processed foods is limited to one study [36] that investigated the iodine content of salt used in bread, margarine, and salty snack flavorings. Despite 11 of the 12 manufacturers surveyed reporting that they used non-iodized salt in their products, substantial amounts of iodine were found in the salt used by a third of these manufacturers’ products, with a mean content of 39 to 69 ppm, and these were items that were mostly distributed countrywide. An appreciable percentage of the food companies used iodized salt unknowingly in the manufacturing of frequently consumed processed foods, and this may have a considerable impact on the daily iodine intake of consumers.

The salt intake estimations in our study include added (discretionary) and non-discretionary salt intakes. Previous reports from the total sample that included urinary excretion and dietary estimates of salt [31] used a crude method to determine the discretionary salt intake. The discrepancy between intrindividually reported dietary sodium intake and 24-h urinary sodium excretion suggested that the salt added to food at the table and in cooking made up 46%, 33%, and 42% of total sodium intake (equating to a daily added salt amount of 4.08, 4.15, and 4.76 g) in black, mixed-ancestry, and white subjects, respectively. Using these figures, and assuming an average salt iodization level of 50 ppm, it is estimated that iodine provided from table salt would be 204, 208, and 238 mg/d, which exceeds the recommended daily allowance of 150 mg/d [37]. Halving this amount would still provide over two-thirds of the recommended daily allowance, with the remainder of iodine being contributed from other iodine-rich dietary sources such as seafood and dairy products. Previous reports from South Africa have shown the iodine content of table salt to be variable over time. Within 1 y of the introduction of universal salt iodization, the iodine concentrations in retailer salt samples doubled from 14 to 33 ppm and further increased to 42 ppm over the next 2 y [38], but relapsed to 33 ppm after another 2 y.

Ongoing monitoring and surveillance of iodine status is required as the salt intakes of populations decrease so the amount of iodine added as a fortificant to iodized salt can be increased, as necessary, without risk of excess [39]. Implementation of universal salt iodization without adequate monitoring has resulted in iodine intakes that are considered to be more than adequate in 27 countries (MUIC >200 µg/L) and excessive in seven countries (MUIC >300 µg/L) [40]. High iodine intakes are associated with iodine-induced hyperthyroidism and autoimmune thyroid disease [39,41], although there is wide variation in the tolerable upper intake levels among countries, ranging from 600 µg/d for adults and pregnant women in Europe [42] to 1100 µg/d in the USA [37].

The recommended method of assessing the success or failure of fortification programs in correcting iodine deficiency is by determining the MUICs at a population level in children 6 to 12 y every 5 y [32]. However, vulnerable sectors of the population may require particular scrutiny. For example, Switzerland has one of the world’s most effectively functioning salt iodization programs [43], yet a lack of iodine in the diets of very young children has recently been identified [44]. This is because most

### Table 2

<table>
<thead>
<tr>
<th>Iodine status</th>
<th>Ethnic group</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black (n = 84)</td>
<td>Colored (n = 85)</td>
</tr>
<tr>
<td>Median UIC (µg/L)</td>
<td>144 (75–246)</td>
<td>131 (82–187)</td>
</tr>
<tr>
<td>Suboptimal iodine status (&lt;100 µg/L)</td>
<td>31</td>
<td>27</td>
</tr>
<tr>
<td>Subjects within ethnic group</td>
<td>36.9%</td>
<td>31.8%</td>
</tr>
<tr>
<td>Total Iodine replete (≥100 µg/L)</td>
<td>11.9%</td>
<td>10.3%</td>
</tr>
<tr>
<td>Subjects within ethnic group</td>
<td>53</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>32.2%</td>
<td>32.6%</td>
</tr>
</tbody>
</table>

UCL, urinary iodine concentration

Values are presented as median (interquartile range), number, or percentage. P = 0.081 for difference in iodine status according to ethnic group (chi-square test).

### Discussion

South African adults have an optimal iodine status (i.e., MUIC 100–199 µg/L; <20% with UIC levels <50 µg/L [32]) which indicates a well-functioning salt iodization program, as has been reported in a national study of women and children 6 to 9 y old in the country [4]. Mandatory iodization of table salt, at a level of 40 to 60 ppm, replaced voluntary iodization in December 1995, using potassium iodate as the fortificant [3] rather than potassium iodide that is used in North America and Europe. Iodine is highly bioavailable in these forms. Salt used in the manufacturing of processed foods and salt packaged in bags of at least 20 kg are exempted from mandatory iodization [3]. The South African regulation to the act regarding iodine in salt was revised in 2007 and specifies that iodine should be added to food-grade salt at a concentration of 35 to 65 ppm. In 2005, 77% of households in the country used adequately iodized salt, described as salt containing more than 15 ppm of iodine [4].

Concerted efforts are being made in many countries to lower salt consumption [33]. Because the primary food vehicle for iodine fortification is salt, there is concern that decreasing salt consumption will increase the risk of iodine deficiency. Dietary modeling conducted in the Netherlands estimated the effect of 12%, 25%, and 50% decreases in salt from processed foods and table salt [34]. Only at a 50% salt decrease would iodine intake become inadequate for a small percentage of the population, which confirms the lack of conflict between population-wide strategies of decreasing salt and adequate iodized salt consumption.

It has been reported previously that South Africans, regardless of ethnic group, consume salt in excess of the recommended 5 g/d [31]. We demonstrate here, for the first time, that iodine status was not compromised in adults who had salt intakes in line with the recommendations, and the reasons for a lack of association between urinary sodium and urinary iodine excretion are postulated below.

Most salt in the diets of South Africans, as in most other countries, is consumed in processed foods. In adults, bread is the major source of dietary salt intake, providing 25% to 41% of non-discretionary salt intake in various groups, although meat products, such as processed meats and commercial meat pies, in addition to margarine, are also important sources. Urban versus
commercably available weaning foods are not fortified with iodine, and do not contain salt, and nutritional guidelines discourage the addition of salt to foods prepared in the home for children younger than 1 y.

A strength of our methodology is the use of three repeated 24-h urinary collections for the assessment of habitual salt intake. Assuming a standard deviation for a 24-h urinary sodium excretion of about 60 mmol/d (1.38 g/d), a minimum sample of 100 participants is required to ensure sufficient power for a single 24-h urinary sodium collection to be generalizable to the study population. Because of large day-to-day variabilities in urinary sodium excretion, precision is improved by obtaining more than one 24-h urine collection per individual.

Limitations to the study include the use of a single casual urine sample to assess the median urinary iodine excretion; however, this is the universally accepted reference method. Few individuals had sodium excretion values in the reference category of interest (<5 g/d); thus, estimates of MUIC in this group may be unreliable. However, similar interquartile ranges between the lowest sodium excretion category and the other two with larger numbers of subjects suggest a similar variability in UIC distribution. Therefore, generalizability of the findings from a convenient sample of adults in paid employment from a major South African city to other geographic areas cannot be made. Environmental determinants of iodine status, such as iodine in drinking water, may vary across the country. The presence of endemic goiter in the absence of iodine deficiency disorders in some towns in the Northern Cape has been attributed to high concentrations of fluoride in the water supply, thought to be behaving as goitrogens.

The complex interaction of the effects on health of competing public health priorities highlights a need for nationally representative data that provide meaningful information. For the impact of a salt decrease on iodine status, this includes collection of indicators such as the UIC in various age groups, the determination of tap water concentrations, the use of iodized salt in processed foods, and the contribution of food sources of iodine.

In conclusion, our findings indicate that those adults who have urinary sodium excretion values equivalent to salt intakes of 5 g/d or less do not have a compromised iodine intake. The lack of an increased MUIC across three levels of salt intake indicates that much of the dietary salt is provided by non-iodinated sources, probably from the contribution of processed foods. Strategies to lower salt in the food supply and through discretionary use require careful attention to the contribution of iodine from various dietary sources to ensure that iodine status is not compromised. Ongoing monitoring and surveillance at the national level will be required to assess the impact of changes to the salt content of foods and the resultant contribution of iodized salt from processed foods.

Acknowledgments

The authors thank Emmerentia Strydom of the Nutritional Intervention Research Unit of the Medical Research Council for meticulously conducting the urinary iodine analyses. Joanna Russell is thanked for editorial assistance.

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Please cite this article in press as: Charlton KE, et al., A lowered salt intake does not compromise iodine status in South Africa, a country with mandatory salt iodization, Nutrition (2012), http://dx.doi.org/10.1016/j.nut.2012.09.010