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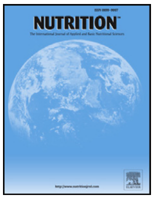

Applied nutritional investigation

Salt-reduction strategies may compromise salt iodization programs: Learnings from South Africa and Ghana

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ABSTRACT

Objectives: Universal salt iodization has been adopted by many countries to address iodine deficiency. More recently, salt-reduction strategies have been widely implemented to meet global salt intake targets of <5 g/d. Compatibility of the two policies has yet to be demonstrated. This study compares urinary iodine excretion (UIE) according to 24-h urinary sodium excretion, between South Africa (SA) and Ghana; both countries have implemented universal salt iodization, but in Ghana no salt-reduction legislation has been implemented.

Methods: Participants from the World Health Organization's Study on Global Ageing and Adult Health Wave 3, with survey and valid 24-h urinary data (Ghana, $n = 495$; SA, $n = 707$), comprised the sample. Median 24-h UIE was compared across salt intake categories of <5, 5–9 and >9 g/d.

Results: In Ghana, median sodium excretion indicated a salt intake of 10.7 g/d (interquartile range [IQR] = 7.6), and median UIE was 182.4 μg/L (IQR = 162.5). In SA, both values were lower: median salt = 5.6 g/d (IQR = 5.0), median UIE = 100.2 μg/L (IQR = 129.6). UIE differed significantly across salt intake categories ($P < 0.001$) in both countries, with positive correlations observed in both—Ghana: $r = 0.1501$, $P < 0.0011$; South Africa: $r = 0.4050$, $P < 0.0001$. Participants with salt intakes <9 g/d in SA did not meet the World Health Organization's recommended iodine intake of 150 μg/d, but this was not the case in Ghana.

Conclusions: Monitoring and surveillance of iodine status is recommended in countries that have introduced salt-reduction strategies, in order to prevent reemergence of iodine deficiency.

Introduction

Iodine deficiency disorders remain a major global health issue, affecting nearly 2 billion people worldwide and placing them at risk of irreversible brain damage and cognitive impairment. Iodine deficiency causes thyroid dysfunction and is implicated in psychomotor and developmental problems in its mild forms, and cretinism in its most severe form [1]. Populations residing in areas affected by severe iodine deficiency may exhibit learning

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K.C. and P.K. designed the study; R.B. and A.E.S. managed data collection; L.Z. and J.B. conducted iodine analyses in South Africa; N.M., B.C., I.R., and E.M. managed the data and conducted the statistical analyses; E.M., K.C., and J.R. wrote the first draft. K.C. takes responsibility of the content of this article. All authors read and approved the final manuscript.

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difficulties, particularly in children born to women who were iodine deficient while pregnant [2]. The World Health Organization (WHO) in 1991 attempted to address iodine deficiency as a public health concern by recommending universal salt iodization (USI). Many countries have since made excellent progress toward achieving the target of eliminating iodine deficiency disorders [3].

Ghana launched its USI program in 1995 in response to a nationwide survey conducted the year before, which reported that iodine deficiency disorders were endemic in almost half of the 110 districts of the country [4]. Household access to iodized salt fluctuated in the 20 y that followed adoption of USI [4–6]. Recent studies among Ghanaian school-age children (6–12 y) and pregnant women have reported a median urinary iodine concentration (UIC) of 202 μg/L and 155 μg/L, respectively, indicating adequate iodine intake [7,8].

Similarly, in South Africa (SA), low access to iodized salt by much of the population [9] led to implementation of a mandatory salt iodization program in 1995 [10]. Following an intensive mass education and health-promotion program related to iodine intake, improved coverage and usage of iodized salt was recorded in the 2005 national survey, with a 15% increase in the number of households using iodized salt and a median UIC of 215 μg/L and 177 μg/L for schoolchildren and adult women, respectively. However, since that time, no further national surveys have been conducted to assess iodine status in SA [11]. South Africa's mandatory salt-reduction legislation introduced in 2016, in response to WHO's voluntary target of <5 g/d, may have implications for the adequacy of iodine intake because of reductions in iodized salt used in processed foods and associated changes in salt use behaviors [12–14], but this has yet to be investigated.

Given that both Ghana and SA have national salt iodization programs but only SA has implemented mandatory salt-reduction legislation, a comparison of salt and iodine intake between these two countries provides an opportunity to investigate the impact of salt legislation on iodine intakes in South Africans, using Ghana as a comparator country. Additionally, an updated evaluation of the effectiveness of the salt iodization programs in both countries will be provided. The aim of this study is to compare urinary iodine excretion across urinary sodium (Na) excretion categories in adult populations from both Ghana and SA.

Materials and methods

This study utilized nationally representative data sets of adults, largely 50 y and older, who were randomly selected to participate in the World Health Organization's Study on Global Ageing and Adult Health (WHO-SAGE) Wave 3 in Ghana and SA. WHO-SAGE is a longitudinal multicountry survey developed to compile comprehensive information on the health and well-being of adult populations and respond to their needs through policy, planning, and research. It has been conducted in six low- and middle-income countries—China, Ghana, India, Russia, Mexico, and SA—since 2002 [15], with the third wave of the study implemented in 2018-19 in SA and Ghana, respectively. A nested salt substudy was included in Wave 3 in both countries, which included collection of 24-h urine samples for the analysis of Na and iodine concentrations [16].

A total of 6973 participants were recruited for the main WHO-SAGE cohort (Ghana: $n = 4449$; SA: $n = 2524$), of whom 5756 with valid survey data (Ghana: $n = 3548$; SA: $n = 2208$) were selected. In selecting the main sample to align with the aims of WHO-SAGE, stratified sampling was conducted to select participants ages 50 y and older, with approximately 30% of adults ages 18 to 49 y as a comparative cohort in each country. In the sample selection, all WHO-SAGE Wave 2 (2015/2016) households were eligible for inclusion in Wave 3 (2018-19) data collection. The sampling method used in SAGE Ghana followed a similar design, based on the 2003 World Health Survey/SAGE Wave 0 [17] with primary sampling units stratified by region, location, and proportional allocation by size [18]. In SA, participants were selected from probability-sampled enumeration areas using a multistage cluster-sampling strategy, with stratification by province, residence, and race. In both countries, replacements for sample attrition used a systematic sampling approach to randomly select new households as previously described [16]. In selecting the nested subsample for this study, participants from randomly selected enumeration areas that provided 24-h urine samples were included. A sample size of 1200 in each country was targeted for the nested salt substudy from the complete WHO SAGE Wave 3 cohort. Overall, a total 2310 participants provided 24-h urine samples (Ghana: $n = 1121$; SA: $n = 1189$), of which 1202 samples (Ghana: $n = 495$; SA: $n = 707$) were deemed to be valid using the criteria of urine volume ≥ 300 mL/d and creatinine concentration of ≥3 mmol/d [19] and availability of corresponding survey (Fig. 1).

In Ghana, teams consisting of three to five interviewers visited participants across the country, taking approximately eight months to complete data collection (August 2018–April 2019). In SA, 20 survey teams collected data from participants nationwide over a period of six months (October 2018–March 2019). In both countries, data were collected in the homes and workplaces of participants, using computer-assisted personal interviews. Surveys that included sociodemographic variables and anthropometric and blood pressure measurements were conducted in the home language of participants. All survey teams were trained with support from the WHO-SAGE team, using standardized training and survey materials [15]. Participants provided 24-h urine samples in 5-L urine bottles containing 1 g thymol, after the collection procedure was thoroughly explained. Thymol has the property of preserving urinary creatinine, Na, and potassium concentrations for up to 5 d [20]. In collecting urine, participants were instructed to void the "first urine" but include the "last urine" and note the time of collection; keep the bottles to themselves and collect only their urine; collect all urine passed within the 24-h period; and keep the urine in a cool place [21]. The 24-h urine sample was collected, thoroughly mixed, and volumes recorded, with three aliquots of 5 mL kept in cold boxes and transported to the Noguchi Memorial Institute for Medical Research, University of Ghana, in Ghana and Global Clinical and Viral Laboratories and the North-West University Centre of Excellence for Nutrition, in SA, for quantitative analysis of Na and iodine. Urine samples were stored at −20°C and batch analyzed using the Sandell–Kolthoff method with ammonium persulfate digestion and microplate for iodine analysis and the ion-selective electrode method for Na analysis [21,22]. Sodium (mmol/L) in the 24-h urine sample was converted to salt intake (g/d) using the formula Na mmol/L × 24-h volume (L) × 23.1 (the molecular weight of Na)/390 (390 mg Na/1 g NaCl).

Participants were categorized with low (<5 g/d), medium (5–9 g/d), or high (>9 g/d) salt intake, and iodine metrics were investigated between these categories. To convert urinary excretion values to estimated daily iodine intake (μg/d), urinary iodine excretion (UIE; μg/24 h) was divided by 0.92, based on the assumption that approximately 92% of dietary iodine is excreted in urine. A median UIC < 100 μg/L indicates population-level deficiency [23]. Participants' weight and height were measured with calibrated scales and a stadiometer, respectively. Hypertension status was determined by a measured blood pressure ≥ 140/90 mm Hg or self-reported treatment in the last 2 wk. For salt-use behavior questions, responses such as "always" and "often" were combined into "frequent use," whereas "sometimes," "rarely," and "never" were combined as "infrequent use." The study complied with the Declaration of Helsinki, and ethical approval was obtained from the WHO Ethics Committee (RPC 149), the University of Ghana Medical School Ethics and Protocol Review Committee (MS-Et/M.03-P 3.1/2005-2006), the North-West University Human Research Ethics Committee (Potchefstroom, South Africa), and the University of the Witwatersrand Human Research Ethics Committee (Johannesburg, South Africa).

Estimated iodine intake values and UIE analyses were compared across three categories of 24-h urinary Na values, equivalent to salt intakes of <5, 5–9, and >9 g/d. Normality of the data was checked by visual inspection of histograms and the Shapiro–Wilk test. Categorical variables were evaluated using absolute numbers (percentages), χ^2 and Fisher's exact tests, whereas Mann–Whitney U and Kruskal–Wallis tests explored differences between groups for nonparametric data. Spearman rank-order correlations were used to assess association between iodine concentrations and estimated salt intake, body mass index, and weight. The Pearson correlation coefficient was calculated between log-transformed UIE and estimated salt intake. Data were analyzed using Stata software, Release 16 (Stata Corp LLC, 2019; College Station, TX, USA).

Results

Of the 2310 participants who provided urine samples, 1202 (52%) had both valid urine and survey data and were included in the analysis. The sociodemographic characteristics of the subsample are compared with those of the main survey sample in Supplementary Table 1. Whereas the SA subsample had significantly older participants than the larger main survey, the Ghana subsample had a significantly higher proportion of younger participants than the main survey. Waist-to-height ratio and diabetes prevalence were significantly higher in the subsamples than in main survey samples in both countries. In Ghana, median UIE was 182.4 μg/d (interquartile range [IQR] = 162.5), equivalent to a median UIC of

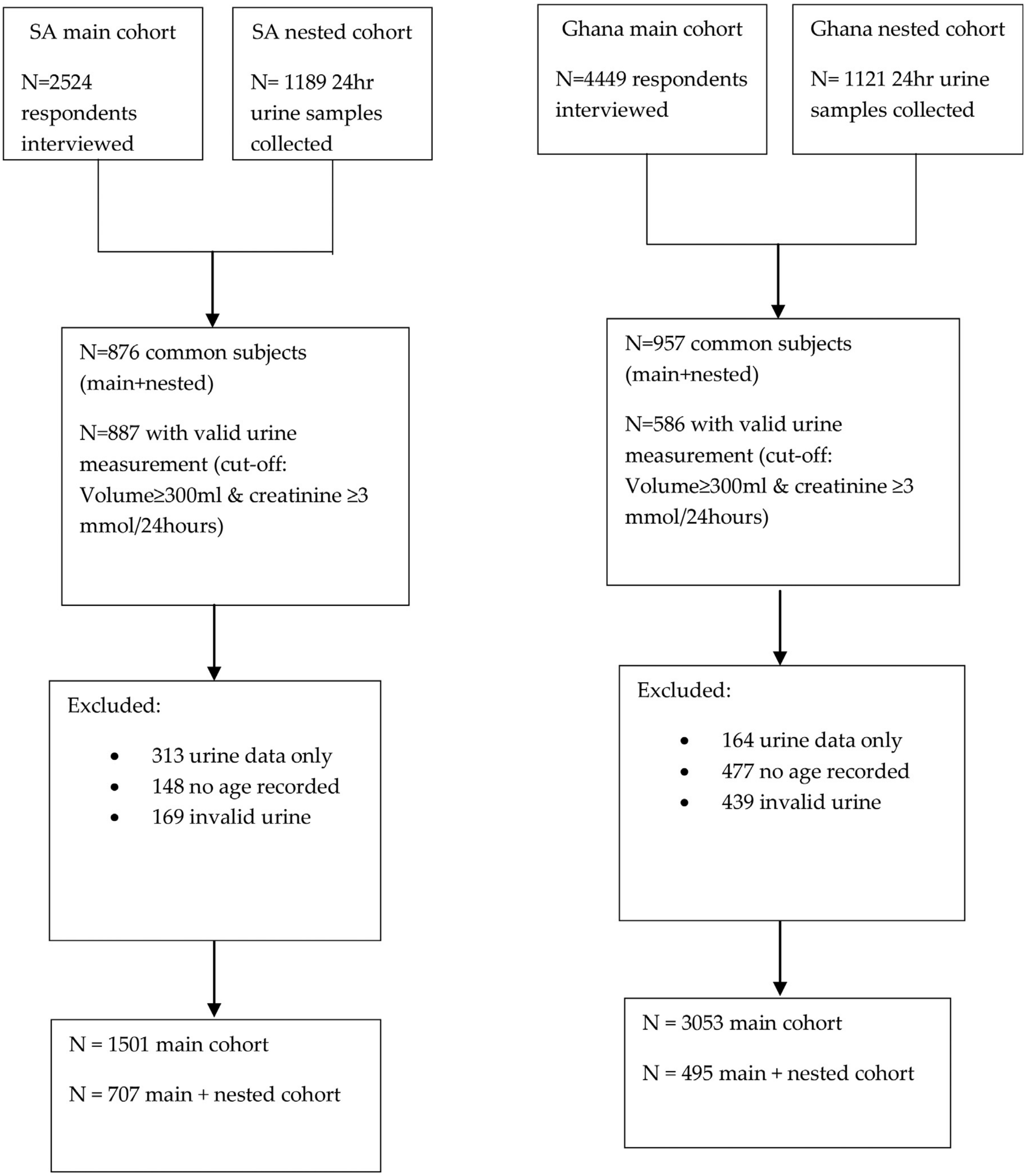

Fig. 1. Flow diagram of recruitment in South Africa (SA) and Ghana. “Main cohort” represents the interview data; “nested cohort” refers to the urine data.

137.3 μg/L, and median salt intake was 10.7 g/d (IQR = 7.6). In SA, median UIE was considerably lower, at 100.2 μg/d (IQR = 129.6), equivalent to a median UIC of 90.2 μg/L, and accompanied by a lower median salt intake of 5.6 g/d (IQR = 5.0). No significant differences in UIE were found for sex or age category (18–49, 50+) in either country. In the lowest salt category (<5 g/d), UIE indicated suboptimal iodine intake among the SA subsample (72.4 μg/L, IQR = 75.6), but in Ghana it was adequate (UIE = 135.2 μg/L, IQR = 102.7; Tables 1 and 2). UIE significantly increased with increasing salt intake in both SA and Ghana (Fig. 2), with low to moderate correlations observed between UIE and salt intake in each country—South Africa: $r = 0.1501$, $P = 0.0011$ (Table 3); Ghana: $r = 0.405$, $P < 0.0001$ (Table 4). In Ghana, the lower UIC across salt intake categories appears to contradict the increasing UIE values. This can be explained by differences in 24-h urinary volume, such that those with volumes below 1 L/d will have UIC less than UIE. Three quarters (73.3%) of participants with salt intake $<$ 5g/d had urinary volumes less than 1 L/d, compared with 45% at 5–9 g/d and 9.8% at $>$ 9g/d.

In the South African sample, there was no association between UIE and anthropometric measures (body mass index, weight, waist and hip circumferences; Table 3), whereas in Ghanaian women UIE was positively correlated with all these measures, controlling for salt intake (Table 4). This may reflect higher intake of food sources of iodine in larger women, presumably related to higher energy intake overall, but lack of

Table 1
Urinary iodine, estimated iodine intake, and sodium excretion values by salt intake equivalent categories, WHO-SAGE Wave 3, South Africa

Variable	All (n = 707)	Salt < 5 g/d (n = 313)	Salt 5–9 g/d (n = 233)	Salt > 9 g/d (n = 161)	P
Sodium (mg/d)	2171 (1959)	1271 (647)	2564 (716)	4551 (1571)	0.0001
Salt (g/d)	5.6 (5.0)	3.3 (1.7)	6.6 (1.8)	11.7 (4.0)	0.0001
UIC (μg/L)	90.2 (107.2)	79.3 (96.8)	95.3 (100.7)	112.5 (126.6)	0.0001
UIC < 50 μg/L, n (%)	165 (23.7)	93 (30.3)	40 (17.4)	32 (20.0)	0.001
24-h UIE (μg/d)	100.2 (129.6)	72.4 (75.6)	117.3 (124.2)	170.8 (200.7)	0.0001
Estimated iodine intake (μg/d)*	108.9 (140.8)	78.7 (82.1)	127.5 (135.0)	185.7 (218.1)	0.0001
Daily iodine intake below EAR for iodine (95 μg/d), n (%)	302 (43.3)	186 (60.6)	79 (34.4)	37 (23.1)	<0.0001
Frequently add salt to food at table, n (%)	108 (15.3)	46 (14.7)	39 (16.7)	23 (14.3)	0.745
Frequently add salt to food during cooking, n (%)	460 (65.1)	199 (63.6)	158 (67.8)	103 (64.0)	0.559
Believe they consume too much salt, n (%)	59 (8.6)	30 (9.9)	19 (8.4)	10 (6.3)	0.417
Believe a high-salt diet is bad for health, n (%)	506 (81.6)	230 (81.9)	165 (80.5)	111 (82.8)	0.853
Regularly control salt intake, n (%)	255 (42.7)	114 (42.9)	83 (42.6)	58 (42.7)	0.998

EAR, estimated average requirement; UIC, urinary iodine concentration; UIE, urinary iodine excretion.
Data are presented as median (interquartile range) unless otherwise indicated. Continuous variables compared using independent-samples Kruskal–Wallis test.
*Daily iodine intake assumed as 24-h UIE (μg/d)/0.92 to account for biovariability.

Table 2
Urinary iodine, estimated iodine intake, and sodium excretion values by salt intake equivalent categories, WHO-SAGE Wave 3, Ghana

Variable	All (n = 492)	Salt < 5g/d (n = 45)	Salt 5–9 g/d (n = 140)	Salt > 9 g/d (n = 307)	P
Sodium (mg/d)	4164 (2981)	1573 (436)	2777 (748)	5448 (3647)	0.0001
Salt (g/d)	10.7 (7.6)	4.0 (1.1)	7.1 (1.9)	14.0 (9.3)	0.0001
UIC (μg/L)	137.3 (136.9)	184.9 (204.6)	164.5 (131.4)	118.9 (130.3)	0.0001
UIC < 50 μg/L, n (%)	42 (8.9)	0	3 (2.2)	39 (13.2)	<0.0001
24-h UIE (μg/d)	182.4 (162.5)	135.2 (102.7)	172.5 (143.2)	200.6 (180.4)	0.0002
Estimated iodine intake (μg/d)*	198.3 (176.6)	146.9 (111.6)	187.4 (155.7)	218.1 (196.1)	0.0002
Daily iodine intake below EAR for iodine (95 μg/d), n (%)	55 (11.6)	9 (21.4)	20 (14.9)	26 (8.8)	0.025
Frequently add salt to food at table, n (%)	58 (11.7)	4 (8.9)	13 (9.3)	41 (13.4)	0.381
Frequently add salt to food during cooking, n (%)	399 (80.6)	40 (88.9)	119 (85.0)	237 (77.2)	0.051
Believe they consume too much salt, n (%)	48 (9.7)	7 (15.6)	8 (5.7)	33 (10.8)	0.096
Believe a high-salt diet is bad for health, n (%)	378 (78.3)	34 (77.3)	107 (79.3)	236 (78.4)	0.958
Regularly control salt intake, n (%)	235 (48.9)	15 (33.3)	75 (55.1)	143 (48.1)	0.038

EAR, estimated average requirement; UIC, urinary iodine concentration; UIE, urinary iodine excretion.
Data are presented as median (interquartile range) unless otherwise indicated. Continuous variables compared using indendent-samples Kruskal–Wallis test.
*Daily iodine intake assumed as 24-h UIE (μg/d)/0.92 to account for biovariability.

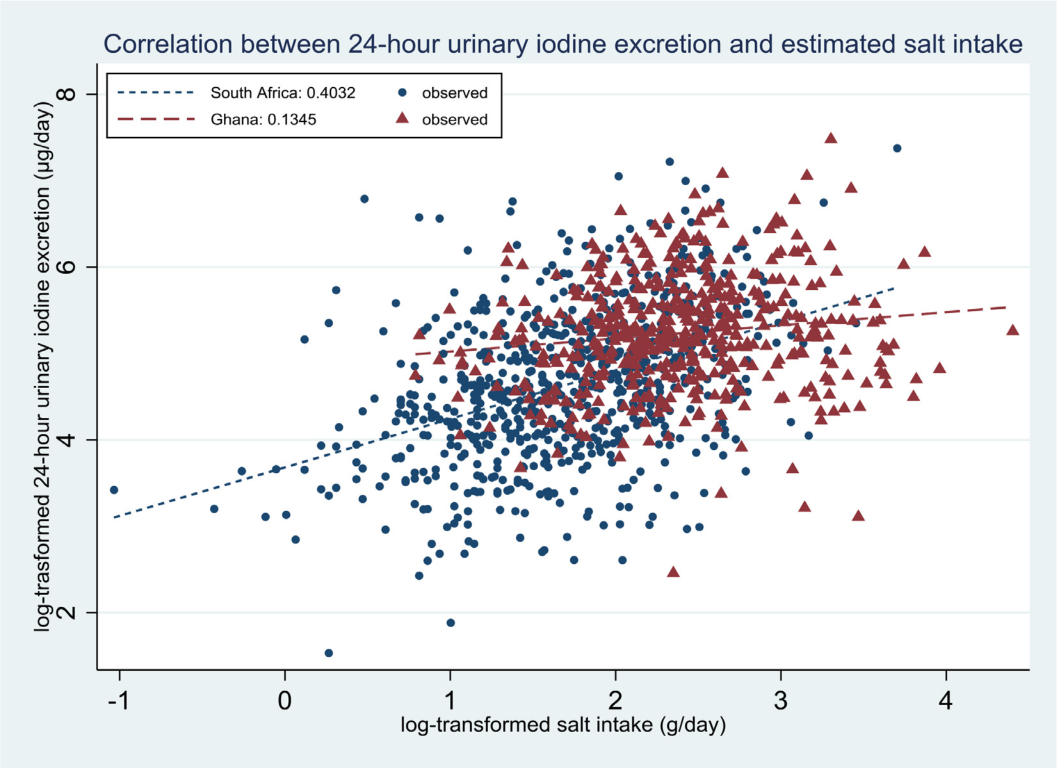

Fig. 2. Correlation between urinary iodine excretion (UIE, μg/d) and estimated salt intake (g/d).

Table 3
Spearman rank-order and partial correlations with 24-h urinary iodine concentration, WHO-SAGE Wave 3, South Africa

Variable	Correlation	All (n = 697)	Men (n = 216)	Women (n = 481)
Salt intake (g/d)	r	0.4050	0.4166	0.3999
	P	<0.0001	<0.0001	<0.0001
BMI (kg/m^2)	r	0.0210	0.1227	−0.0081
	P	0.5944	0.0859	0.8641
Weight (kg)	R	0.0425	0.1684	0.0103
	P	0.2736	0.0161	0.8263
Waist circumference (cm)	R	0.0460	0.0156	0.0561
	P	0.2481	0.8304	0.2416
Hip circumference (cm)	r	−0.0319	−0.0008	−0.0439
	P	0.4429	0.9914	0.3882

BMI, body mass index.
Correlations between iodine and body size controlled for salt intake.

Table 4
Spearman rank-order and partial correlations with 24-h urinary iodine concentration, WHO-SAGE Wave 3, Ghana

Variable	Correlation	All (n = 471)	Men (n = 162)	Women (n = 309)
Salt intake (g/d)	r	0.1501	0.1494	0.1460
	P	0.0011	0.0678	0.0102
BMI (kg/m^2)	r	0.1051	−0.0266	0.1768
	P	0.0254	0.7421	0.0023
Weight (kg)	r	0.1191	0.0136	0.1704
	P	0.0107	0.8655	0.0030
Waist circumference (cm)	r	0.1595	0.1353	0.1873
	P	0.0006	0.0922	0.0012
Hip circumference (cm)	r	0.1466	0.0709	0.2030
	P	0.0019	0.3790	0.0005

BMI, body mass index.
Correlations between iodine and body size controlled for salt intake.

dietary data prevents further explanation, and this remains speculation at best.

Discussion

Our study found that in a sample of South African adults surveyed after introduction of a salt-reduction policy, those with low salt intake (<5 g/d) had inadequate iodine intake (using 24-h UIE as a biomarker of intake), but this was not observed in a sample of Ghanaian adults. Conversely, only South Africans with salt intake above 5 g/d had optimal estimated iodine intake, but Ghanaians had optimal intake across all salt intake categories. Our data do not support previous reports of frequent use of non-iodized or inadequately iodized salt in Ghana [24]. This study, being the first report of salt and iodine intake levels in SA following implementation of mandatory salt targets for processed foods in June 2016, highlights a risk of inadequate iodine consumption in South Africans who meet the recommended salt intake of 5 g/d or less.

Data from a substudy of WHO-SAGE SA Wave 2 [14] that were collected immediately before implementation of the salt legislation in 2016—by which time some manufacturers may have already reformulated their products [25]—support our current finding. The impact of the SA salt legislation on consumption of iodine has not been thoroughly investigated to date [26], and with more stringent salt restrictions that came into effect in June 2019 [27], potential adverse consequences on population iodine intake must be carefully monitored. Fortification levels of iodine in salt may need to be revised accordingly. Based on the current policy madating iodization of table salt, the results could be interpreted to mean that those in the highest category of salt intake may have been using more table salt (iodized), thus contributing to higher iodine intake, but the lack of dietary data limits further assertion. It has previously been reported that despite manufacturers not being required by law to use iodized salt in processed foods (only table salt falls under the legislation), commercial use of iodized salt in the production of processed food is common. Significant amounts of iodine have been detected in a third of foods surveyed, and these were common brands of bread, margarine, and salty snack flavorings [28]. If food manufacturers have previously used iodized salt in food processing, then salt-reduction legislation may inadvertently reduce population iodine intake [26] even if there are no changes in discretionary use of salt.

In Ghana, overall iodine intake was higher than in South Africa across all salt intake categories. Our data are in contrast to previous reports that only a third of households nationwide in Ghana have access to sufficiently iodized cooking or table salt [24,29]. The 2014 Ghana Demographic and Health Survey indicated that 36.6% of women and children lived in environments with no iodized salt [30], and that only four in 10 households consumed salt with adequate iodine [31]. Additionally, traditional street eateries (informal eating places outside the home called “chop bars”) that are popular in Ghana [32] commonly use non-iodized salt in their meal preparation [33]. Low availability and unaffordability of adequately iodized salt, accompanied by low consumer awareness of the importance of using iodized salt [24,31,34,35], have been identified as major setbacks for the effectiveness of the USI program. Findings from the Ghana Iodine Survey indicated that half of all households in the southern salt-producing areas and approximately half of households in the middle region of Ghana were accessing salt with no added iodine, thus violating Public Health Amendment Law 2012 Act 851 [24,36]. Only 8.6% of households nationally were using salt with iodine levels in the WHO recommended range of 15–40 ppm, suggesting that production methods for salt iodization may have been compromised [24,37]. Chemical analysis of Ghana’s 11 most popular brands of iodized salt indicated that only three met the recommended 50-ppm iodine concentration at retail [38]. Both household and market surveys have also reported that low availability and high cost of adequately iodized salt are deterrents to accessing the commodity [35]. In the current study, despite known inadequacies in the salt iodization program in Ghana, median UIE was considerably higher in that country than in SA. Other sources of dietary iodine in Ghanaian cuisine warrant further consideration, as well as the use of iodized salt in commercial food processing. This would inform strategies for salt reduction in the country without compromising iodine intake.

Our study found that median salt intake was considerably lower in the SA sample compared to Ghanaians, as expected, because of South African legislation setting maximum permitted salt levels in processed foods [26] and other national health-promotion programs to reduce discretionary salt intake, such as Salt Watch [39]. The high morbidity and mortality associated with non-communicable diseases [40] has resulted in many countries embarking on salt-reduction interventions to reduce hypertension and cardiovascular disease [41], but such strategies do not exist in Ghana.

Our analysis is supported by data from WHO-SAGE SA Wave 2 [14] that raised concern that salt-reduction strategies may adversely affect iodine consumption. However, other studies provide conflicting evidence [42,43]. A previous study in South African adults in 2004 reported no difference in median urinary UIC across salt intake categories [13]. The reasons are unclear, but at the time it was assumed that the predominant use of non-iodized salt in the production of processed food products resulted in a lack of difference in iodine across a range of salt intakes. Additionally, national data collected in 2002 showed that 37.3% of households in SA used non-iodized salt at home [44].

Our findings highlight a need for health authorities in Ghana and SA to continually monitor both salt and iodine intake in order to adjust salt iodization levels as required to ensure the compatibility of salt iodization and salt-reduction strategies [45]. Monitoring of salt iodization at any point along the food supply chain (production, packaging, storage, retail outlets, and homes) is key to ensuring its efficacy. Greater advocacy efforts are required to result in implementation of healthy food environment policies geared toward the prevention of nutrition-related non-communicable diseases in Ghana. An analysis of 41 food environment policies investigated in the country rated 75% of all good-practice indicators as low [46].

It is also timely for SA to reconsider iodine levels in table salt [47,48], to meet the needs of those with the lowest salt intake while at the same time avoiding excessive iodine supply to areas where salt intake is high. In both countries, coordination and collaboration between government agencies and sectors are needed to harmonize food policies to enhance their effectiveness. A multisectoral approach backed by a strong political or social interest from government will be most appropriate.

Strengths of this study include the comparison of salt and iodine intake in two low- to middle-income countries, both with mandatory salt iodization programs but only one with a mandatory salt-reduction policy; a large, nationally representative sample of participants aged 50+ y; and the use of the gold-standard method (24-h urine collection) for measuring salt intake. Limitations include loss of sample size due to incomplete survey or urine collection, and gender disparity, with more women than men likely to provide urine samples in both countries. Data-collection procedures may have created a selection bias for greater participation by those who were home or had flexible employment requirements. A lack of dietary intake data limits our ability to identify which sources of food contributed to total salt or iodine intake in both countries. Additionally, this study excluded pregnant women and children; therefore, further study is warranted among those iodine-sensitive groups.

Conclusions

SA's salt-reduction strategies, including legislation regarding maximum permitted levels of salt in processed foods, may be compromising population-level iodine intake. In a comparator country, Ghana, that has not introduced salt-reduction policies, population salt intake is considerably higher, and despite reported evidence of a poorly functioning salt iodization program, iodine intake is adequate across all levels of salt intake. Our findings highlight an urgent need to continually monitor the effectiveness of salt iodization programs, especially in countries where salt-reduction efforts are being undertaken to meet WHO's global voluntary target of population intake of below 5 g/d.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2020.111065.

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