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Association between 24-hour urinary sodium and iodine in a Beninese population

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ABSTRACT

Aims: To evaluate the association between sodium concentration in 24-hour urine and iodine status in an urban and rural population of Benin. **Patients and Methods:** A two-center descriptive, and cross-sectional observational study was conducted. Three hundred and fifty-four apparently healthy subjects (men and women) aged 25 to 64 were selected. Adequate iodine intake was defined as an iodine/creatinine urinary ratio (I/Cr) between 32.7 and 70.0 µg/g, and deficiency and excess such as < 32.7 µg/g and ≥ 70.0 µg / g respectively. Urinary sodium / creatinine (Na/Cr) ratios were classified as low (< 96.0 mmol /g), intermediate (96.0 – 171.8 mmol/g), high (≥ 171.8 mmol/g). **Results:** The median urinary iodine concentration was 66.8 µg/L (IQI, 42 to 98) and the median urinary I/Cr ratio was 46.8 µg /g (IQI, 32.7 to 70.0). Iodine deficiency (< 100 µg /L) and iodine excess (> 300 µg /L) were observed in 75.1% and 2.5% of subjects, respectively. There was a statistically significant association between uncorrected UNaC and iodine status in the study population (p < 0.001). Paradoxically, no statistically significant association was found between the ratio I/Cr and Na/Cr in urine (p = 0.05). The distributions of UIC, UNaC and I/Cr, urinary Na /Cr ratios varied according to age group and sex. **Conclusion:** No significant association was recorded between iodine status and UNaC in the Beninese study population. The recommended optimal iodine intake for eliminating disorders related to iodine deficiency has not yet been achieved in the study population; at least 50% of participants had inadequate UIC even after correction.

Keywords: Iodine; Benin; sodium; urine creatinine; nutrition.

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1 Introduction

Iodine is an essential element for the synthesis of thyroid hormones [1]. This mineral is absorbed by the stomach, the duodenum, and by the thyroid then excreted in the urine. The iodine deficiency and excess are associated with thyroid dysfunction and diseases (endemic goiter, dramatic neurological consequences, etc.) [2]. Systematic iodization of salt (sodium chloride) constitutes the least expensive and most effective strategy for preventing and controlling iodine deficiency disorders [3]. The World Health Organization (WHO) recommends an iodine content of 15 to 40 ppm for dietary salt [4]. However, this initiative risks losing its effectiveness with the recommendations to limit sodium intake in order to combat hypertension [5]. Since sodium chloride is the primary vehicle for iodine fortification, successful campaigns to reduce salt consumption may also lead to reduced iodine consumption [6]. According to

Mizéhoun-Adissoda et al.'s study, sodium intake in Beninese population is higher than the WHO recommended target of 5 g/day [4]. Previous studies carried out in Benin, whether national surveys or ad hoc studies, have generally focused on the availability of iodine in salt at household level, in markets or at local production site [4]. These studies showed that the availability of iodine in salt was insufficient to meet international and national recommendations. If salt is the main source of iodine, there could be an association between sodium intake and iodine status in Benin. However, to the best of our knowledge, no study has yet examined the association between iodine levels and salt consumption in Benin. The primary objective of the current study was to evaluate the relationship between 24 – hour urine sodium and iodine concentrations in an urban and rural population in Benin. The secondary objective was to evaluate the association between urinary iodine and sodium levels in different age groups.

2 Patients and Methods

2.1 Study area

Both The study took place in the urban area of Bohicon and the rural area of Tanvè (Benin, West Africa). The municipality of Bohicon, located in the department of Zou, has ten districts, two of which are urban districts (Bohicon 1 and Bohicon 2). According to the 2013 General Population and Housing Census [7], the population was estimated at 170,604, of which 53% were women. Tanvè is an administrative division under the jurisdiction of the municipality of Agbangnizoun, with a population estimated at 11,546 in 2013 [8]. These two areas were selected because of their ethnic similarity (predominance of Fon: 93% and 98% in Bohicon and Tanvè, respectively); and the similarity of their eating habits to diets based on cereals, tubers, legumes, fish. Meat and dairy products are less available in this area [4].

2.2 Study design

This was an observational, cross-sectional, two-center study (Bohicon and Tanvè).

2.3 Participants

2.3.1 Inclusion criteria

Subjects aged 25 – 64 (male and female) were included; living in urban Bohicon or rural Tanvè for at least six months; present at the time of selection: between November 2012 and September 2013 and signed informed consent. Was not included, any person who presented visible goiter; or person with speech and comprehension disorders, with a mental illness; or pregnancy or menstruation and any use of diuretics.

2.3.2 Exclusion criteria

Creatinine over 24 hours < 10 mg / kg body weight for women and < 15 for men or diuresis < 500 mL. Glucosuria measured with semi-quantitative strips (Multistix® 8SG, Siemens, Germany) positive.

2.4 Judgment criteria

2.4.1 Primary judgment criterion

Urinary iodine, sodium and creatinine concentrations, (more precisely the iodine/creatinine (I/Cr) and sodium/creatinine (Na/Cr) ratio).

2.4.2 Secondary judgment criterion

Urinary iodine, sodium and creatinine concentrations (more specifically the iodine/creatinine (I/Cr) and sodium / creatinine ratios) in age groups (< 30, [30 - 40[, [40 - 50[, [50 - 60[and ≥ 60 years)

2.5 Number of subjects required

A cluster sampling technique with a probability proportional to size was used [9-11], based on information provided by the National Institute of Statistics and Economic Analysis [12]. Thirty clusters were selected in each of the two areas. In each household, an apparently healthy man or woman was selected in turn and according to the predefined age groups.

2.6 Collection of urine samples

In order to optimize the 24-hour urine collection and taking into account the constraints of a full collection, the following steps were considered:

- Avoiding periods when eating habits are likely to change;
- Tracked by a nurse from the team at the health center nearest to the district where the participant resides;
- Medical justification of absence from work for employees.

Each participant received one or two plastic containers (5 L) for collecting 24 hours urine. These containers were kept closed. The start and end of the collection were recorded. Participants reported whether they had missed any urine, particularly during bowel movement (from a few drops to a significant amount). After the collection was completed, the urine was homogenized and 2 mL samples were collected. These samples were immediately frozen at -20°C and sent in December 2013 to the biochemistry and molecular genetics laboratory at Limoges University Hospital in France, while respecting the cold chain.

2.7 Analysis of urine samples

Urinary Na concentration was determined using the ion selective electrode method [13]. Urinary creatinine was measured by the Jaffé kinetic method. All analyzes were carried out using a Cobas automatic analyzer (Roche, Basel Switzerland), with the C8000 module for Na and the C701 module for creatinine. Creatinine excretion was used to assess the completeness of 24 – hour urine collection [14, 15]. Glucosuria was measured using semi-quantitative strips (Multistix® 8SG, Siemens, Germany). Because small amounts of salt are also excreted through sweat and feces, the estimated sodium dietary intake from urinary Na excretion was corrected by coefficients of 0.9 [16, 17].

Iodine was measured by ICP-MS (Perkin Elmer Sciex Elan 6100 DRC ICP Mass Spectrometer, Courtaboeuf, France) in the Laboratory of Pharmacology and Toxicology at Limoges University Hospital in France. The laboratory is accredited by The French Accreditation Committee - International Organization for Standardization (COFRAC ISO) 15189 for this dosage [4]. For iodine measurements, 200 mL of urine were collected from each 24-h sample. The samples and their controls, composed of lyophilized human urine enriched with iodine, were diluted 20-fold by adding an aqueous solution containing 0.1 mg/L NH4 OH, 0.1 g/L EDTA, 5 mg/L n-butanol, and 0.1% Triton x 100. For each sample and control, five readings (replicates) were performed and the average was considered. The WHO and Iodine Global Network criteria were used to determine iodine intake status. An appropriate level of consumption in a population was characterized by the combination of the following: a median urinary iodine concentration (UIC) ≥100 mg/L and < 20% of the study population with UIC < 50 mg/L [18].

2.8 Anthropometric measurements and blood pressure

Body weight was measured using an electronic scale to the nearest 0.1 kg (E753, SECA, Hamburg, Germany). Height was measured in the standing position with a measuring rod (SECA 0.1 cm). Body mass index (BMI) was calculated as weight (kg)/height^2 (m^2). Waist circumference (WC) was measured at a 0.1 cm precision using an inelastic tape and the World Health Organization (WHO)'s standard procedure. Abdominal obesity was defined as WC ≥102 cm in men, ≥ 88 cm for women [19]. Blood pressure (BP) was measured three times at 5-minutes intervals on day 0 (D_0) and day 1 (D_1). Measurements were performed on the left arm with the patient seated after a rest of ≥ 5 min, using an electronic oscillometric monitor (M6 Comfort, Omron, Japan). The M6 monitor cuff of is adequate for both normal and large arms. Mean blood pressure at D_0 and D_1 were calculated and the average of values was used in this study [4].

2.9 Ethics

The study protocol was approved by the Ethics Committee of the Faculty of Health Sciences, University of Abomey-Calavi (Benin).

2.10 Data and statistical analysis

A previous study showed that the urinary I/Cr ratio has a significant diagnostic value for assessing iodine intake [20]. It is the same for sodium, in order to correct for the effects of urinary dilution, we used the adjusted value as the urinary sodium/creatinine ratio (Na/Cr).

Analyses follow the 2007 STROBE recommendations. The statistical analyses were carried out using Stata 14.0 (StataCorp, College Station, TX, USA).

Quantitative variables were described by mean ± standard deviation, 95% confidence intervals, median and interquartile range. Categorical variables were described by effectives and percentages.

A chi-square test was used to investigate the association between urinary I/Cr and Na/Cr ratios (Adjusted Iodine and Sodium Concentrations). A Fisher's exact test was used to investigate the association between crude UNaC and iodine status (crude) as an exploratory measure. In addition, multivariate linear regression analysis after adjustment for age and sex was conducted as an exploratory measure.

Urinary iodine, sodium, and creatinine concentrations (especially iodine/creatinine (I/Cr) and sodium/creatinine Na/Cr ratios) by age group were expressed as mean ± standard deviation and confidence interval at 95%. The threshold of significance for each comparison was 5% in a two-sided situation.

3 Results

3.1 General characteristics of the study population

General characteristics of the studied population are summarized in Table 1. Of the 402 urine samples collected, 48 results were excluded because creatinine was too low (n = 30), use of diuretics (n = 1), glucosuria (n = 7), or laboratory analysis issues (n =10). Thus, this study was based on 354/402 participants, 182 (51.4%) of whom were women. One hundred and eighty-four (52.0%) lived in rural areas.

Among this population, 245 (69.2%) had low socioeconomic status and 234 (66.1%) had an education level of primary school or less. Ninety-four participants (26.5%) had high blood pressure and only 46 (13.0%) were receiving treatment for this condition (Table 1).

Table 1. Qualitative characteristics of the studied population

Variables	Number	%
Sex	354	
Men	172	48.6
Women	182	51.4
Age by gender	354	
Men		
<30	30	17.4
[30-40[	45	26.2
[40-50[	49	28.5
[50-60[	41	23.8
≥60	7	4.1
Women		
<30	36	19.8
[30-40[	46	25.3
[40-50[	49	26.9
[50-60[	35	19.2
≥60	16	8.8
Area	354	
Rural	184	52.0
Urban	170	48.0
Socio-economic status (SES)	354	
Low	245	69.2
High	109	30.8
Education level	354	
≤Primary	234	66.1
>Primary	120	33.9
Marital status	354	
Married	310	87.6
Unmarried	44	12.4
High blood pressure (mm Hg)	354	
Normal	260	73.5
Raised	94	26.5
Treatment _HBP	354	
No	308	87.0
Yes	46	13.0
Smoking	354	
Never	305	86.2
Former	37	10.4
Rarely	2	0.6
Regularly	10	2.8
Adding salt at the table	353	
Never	281	79.6
Sometimes	55	15.6
Often	9	2.5
Always	8	2.3
Adding salt while cooking meals	353	
Never	3	0.8
Sometimes	3	0.8
Most meals	20	5.7
Every meal	323	91.5
I do not know	4	1.1

The mean age of our study population was 43.0 ± 11.4 years, with a median of 43 years (IQR, 33 – 53 years), 18.6% were younger than 30 years, 25.7% between 30 and 40 years, 27.7% between 40 and 50 years, 21.5% between 50 and 60 years, and 6.5% were 60 years or older. Mean BMI was 24.3 ± 5.0 kg/m^2. One hundred and twenty-four (35.0%) participants were obese (BMI ≥ 25 kg/m^2).

The median urinary sodium concentration (UNaC), based on 24-hour urine collection, was 186.9 mmol/L (IQR, 122.5 - 257.7), of which 25.2% had a high UNa concentration. The median urinary Na/Cr ratio was 130.4 (IQR 96.0 - 171.8) (Table 2).

3.2 Association between crude values of UIC and urinary sodium

There was a significant relationship between crudes UIC and UNaC ($p < 0.001$) (Table 3). In the low urinary sodium group, 20.4%, 4.5%, and 0% of subjects had iodine deficiency, iodine sufficiency, and iodine excess, respectively.

In the high urinary sodium concentration group, 14.8%, 9.7% and 0.8% of subjects had iodine deficiency, adequate and excessive iodine intake, respectively.

Regardless of the sodium concentration group (low, intermediate or high), the proportion of iodine deficient subjects is greater than the proportions of patients with adequate and excessive iodine concentration.

3.3 Association between urinary I/Cr and Na/Cr ratios

No significant association was recorded between urinary I/Cr and urinary Na/Cr ratios ($p = 0.05$) (Table 4). In the low urinary Na/Cr ratio group, 5.4%, 13.6%, and 6.0% of subjects had iodine deficiency, adequate iodine intake, and excessive iodine intake, respectively, whereas in the high urinary Na/Cr ratio group, 4.0%, 13.3%, and 7.9% of subjects had iodine deficiency, adequate iodine intake, and excessive iodine intake, respectively. Regardless of the sodium concentration group (low, intermediate, or high), the proportion of subjects with adequate iodine concentration was greater than the proportions of subjects with deficient and excessive iodine concentration.

Table 2. Description of the quantitative and categorical characteristics of the studied population

Variables	n (%)	Means ± SD	CI 95 %	Q25%	Median	Q75%
Age (year)	**354**	43.0 ± 11.4	[41.8 – 44.2]	33	43	53
<30	66 (18.6)					
[30-40[	91 (25.7)					
[40-50[	98 (27.7)					
[50-60[	76 (21.5)					
≥60	23 (6.5)					
Body mass index (kg/m²)	**354**	24.3 ± 5.0	[23.8 – 24.8]	20.7	23.3	27
<25	230 (65.0)					
≥25	124 (35.0)					
24h Creatinine (g/L)	354	1.5 ± 0.7	[1.4 – 1.6]	1.1	1.4	1.8
Urinary sodium (mmol/L)	**353**	200.5 ± 97.5	[190.3 – 210.7]	122.5	186.9	257.7
Low (<122.5)	88 (24.9)					
Intermediate (122.5-257.7)	176 (49.9)					
High (≥257.7)	89 (25.2)					
Urinary iodine concentration (µg/L)						
Deficient (<100)	265 (75.1)					
Adequate (100-300)	79 (22.4)					
Excessive (≥300)	9 (2.5)					
Urinary Na/Cr ratio (mmol/g)	**353**	139.1 ± 60.98	[132.7 – 145.5]	96.0	130.4	171.8
Low (<96.0)	88 (24.9)					
Intermediate (96.0-171.8)	176 (49.9)					
High (≥171.8)	89 (25.2)					
Urinary I/Cr ratio (µg/g)	**353**	56.3 ± 38.1	[52.3-60.3]	32.7	46.8	70.0
Deficient (<32.7	88 (24.9)					
Adequate (32.7-70.0)	176 (49.9)					
Excessive (≥70.0)	89 (25.2)					

CI: Confidence Interval; I/Cr: Iodine/Creatinine; Na /Cr: Sodium /Creatinine; Q: Quartile; SD: Standard deviation.

Table 3. Urinary Iodine and Sodium Concentrations in Study Subjects

UIC. µg/L	UnaC. Mmol/L			Total	p-value
	Low (<80)	Intermediate (80-150)	High (≥150)		
Deficient (<100)	20.4	39.8	14.8	**75.0**	**< 0.001**
Adequate (100-300)	4.5	8.2	9.7	**22.4**	
Excessive (≥300)	0.0	1.7	0.9	**2. 5**	
Total	**24.9**	**49.7**	**25.4**	**100.0**	

Values are presented as a proportion of weighted subjects (%). UIC: Urinary iodine concentration; UNaC: Urinary sodium concentration.

Table 4. Urinary I/Cr and Na/Cr ratios in study subjects

Urinary I/Cr ratio. in µg/g	Urinary Na/Cr ratio. mmol/g			Total	p-value
	Low (< 47)	Intermediate (47-114)	High (≥114)		
Deficient (< 32.71)	5.4	15.6	4.0	25.00	0.05
Adequate (32.71-70.02)	13.6	22.7	13.4	49.7	
Excessive (≥ 70.02	6.0	11.4	7.9	25.3	
Total	**25.0**	49.7	25.3	100.00	

Values are presented as proportion of weighted subjects (%). I/Cr: Iodine/Creatinine; Na/Cr: Sodium / Creatinine.

3.4 Association between UNaC and iodine status in different age groups in Beninese population

Sodium and Iodine concentration in 24 hours urine (mmol per day) in different age groups according to sex.

3.4.1 Urinary sodium concentration (UNaC)

The 24 – hour weighted average UNaC was 200.5 ± 97.5 mmol/day (202.0 mmol/day for men and 199.1 mmol/day for women) (Table 5). Men aged 50 to 60 years presented the highest 24 – hour UNaC (215.3 mmol/day). After this age, there was a significant decrease in UNaC. In women the highest average concentration (237.7 ± 97.7 mmol/day) was observed in the youngest (< 30 years). This mean concentration gradually decreases with age.

3.4.2 Urinary Iodine Concentration (UIC)

The 24-hour weighted average UIC was 84.3 ± 67.8 µg/L (94.1 µg/L/day for men and 75.0 µg/L/day for women) (Table 5). Men aged 50 to 60 years displayed the highest 24-hour UIC (102.7 µg/day). In women, the highest mean 24-hour UIC was observed in those under 30 years of age. After this age, there is a decrease in this concentration, but not progressively with increasing age (Table 5).

3.4.3 Urinary Iodine Concentration (UIC)

The largest proportion of low urinary Na/Cr ratio (< 96.0 mmol/g) was observed in participants aged 40 to 50 years (29/88) and the largest proportion of high urinary Na/Cr ratio (>171.8 mmol/g) was observed in participants aged 30 to 40 years (24/89) (Table 6).

A low urinary Na/Cr ratio was observed in 2.5%, 6.5%, 8.2%, 5.9%, and 1.7% of the subjects aged less than 30 years, [30 to 40 y [, [40 to 50 y [, [50 to 60 y [, and more than 60 y, respectively (p = 0.37) (Table 6) while high urinary Na/Cr ratios were observed in 6.5%, 26.8%, 5.4%, 4.8%, and 1.7% of the subjects, respectively.

Urinary I/Cr ratio, in µg/g

Iodine deficiency (< 32.7 µg/g) was higher in subjects aged 30 to 50 y, whereas iodine excess (>70.0 µg/g) was higher in those aged 40 to 50 years (Table 6).

Iodine deficiency was observed in 5.1%, 6.2%, 6.2%, 5.7%, and 1.7% of the subjects aged less than 30 y, [30 to 40 y[, [40 to 50 y[, [50 to 60 y[, and more than 60 y, respectively (p = 0.81) (Table 6), whereas iodine excess was observed in 5.4%, 5.1%, 7.4%, 5.1%, and 2.3% of the subjects in these same age groups, respectively.

Table 5. Urinary sodium and iodine concentration in different age groups

	Age (year) <30	30-40	40-50	50-60	≥60	Total
Sodium						
Total						
Means ±SD	220.7 ± 96.5	205.3 ± 103.9	193.8 ± 97.6	199.8 ± 94.7	155.2 ± 67.5	**200.5 ± 97.5**
CI 95 %	[196.9 – 244.4]	[183.7 – 226.9]	[174.1 – 213.4]	[178.1 – 221.4]	[126.0 – 184.4]	**[190.3 – 210.7]**
Men						
Means ±SD	200.2 ± 92.5	205.3 ± 113.4	197.5 ± 90.9	215.3 ± 104.7	142.8 ± 52.5	**202.0 ± 99.7**
CI 95 %	[165.7 – 234.7]	[171.2 – 239.4]	[171.4 – 223.6]	[182.3 – 248.3]	[94.2 – 191.4]	**[187.0 – 217.0]**
Women						
Means ±SD	237.7 ± 97.7	205.3 ± 94.9	189.9 ± 104.9	181.6 ± 79.0	160.6 ± 73.9	**199.1 ± 95.6**
CI 95 %	[204.7 – 270.8]	[177.1 – 233.5]	[159.5 – 220.4]	[154.4 – 208.7]	[121.2 – 200.1]	**[185.1 – 213.2]**
Iodine						
Total						
Means ±SD	95.4 ± 91.5	79.2 ± 56.7	81.0 ± 49.4	88.8 ± 80.7	72.0 ± 46.4	**84.3 ± 67.8**
CI 95 %	[72.9 – 117.9]	[67.4 – 91.0]	[71.0 – 90.9]	[70.3 – 107.2]	[52.0 – 92.1]	**[77.2 – 91.4]**
Men						
Means ±SD	87.5 ± 59.1	92.8 ± 67.1	91.9 ± 53.4	102.7 ± 81.7	95.3 ± 66.7	**94.1 ± 65.6**
CI 95 %	[65.5 – 109.6]	[72.7 – 113.0]	[76.5 – 107.2]	[76.9 – 128.5]	[34.6 – 157.0]	**[84.2 – 103.9]**
Women						
Means ±SD	102.0 ± 112.0	65.9 ± 40.7	69.8 ± 42.5	72.4 ± 77.4	61.9 ± 32.0	**75.0 ± 68.8**
CI 95 %	[64.0 – 139.9]	[53.8 – 78.0]	[57.5 – 82.2]	[45.8 – 99.0]	[44.8 – 78.9]	**[64.9 – 85.1]**

Values are expressed as weighted mean and standard deviation. CI: confidence interval; SD: standard deviation.

Table 6. Urinary I/Cr and Na/Cr ratios by age group

	Age (year)					Total	p-value
	<30	30-40	40-50	50-60	≥60		
Urinary Na/Cr ratio. mmol/g							**0.37**
Low (<96.0	9(2.6)	23(6.5)	29(8.2)	21(5.9)	6(1.7)	**88(24.9)**	
Intermediate (96.0-171.8)	34(9.6)	44(12.5)	49(13.9)	38(10.8)	11(3.1)	**176(49.9)**	
High (≥171.8)	23(6.5)	24(26.8)	19(5.4)	17(4.8)	6(1.7)	**89(25.2)**	
Total	**66(18.7)**	**91(25.8)**	**97(27.5)**	**76(21.5)**	**23(6.5)**	**353(100.0)**	
Urinary I / Cr ratio. in µg/g							**0.81**
Deficient (<32.7)	18(5.1)	22(6.2)	22(6.2)	20(5.7)	6(1.7)	**88(24.9)**	
Adequate (32.7-70.0)	29(8.2)	51(14.4)	49(13.9)	38(10.8)	9(2.5)	**176(49.9)**	
Excessive (≥ 70.0)	19(5.4)	18(5.1)	26(7.4)	18(5.1)	8(2.3)	**89(25.2)**	
Total	**66(18.7)**	**91(25.7)**	**97(27.5)**	**76(21.6)**	**23(6.5)**	**353(100.0)**	

Values are expressed as weighted mean and standard deviation. CI: confidence interval; SD: standard deviation.

4 Discussion

In the present study, the median UNaC based on 24-hour urine collection was 186.9 mmol/L (IQR, 122.5 – 257.7), of which 25.3% had a high UNaC. Interestingly, previous study[4] has shown that sodium intake in the Beninese population was higher than that recommended by WHO, suggesting excessive salt additions to the diet.

The median urinary iodine concentration (UIC) was 66.8µg/L (IQR, 42-98). Unlike other studies [20, 21-24], at least 75% of participants in our study were iodine deficient (< 100 µg/L). Iodine intakes in the study population of Bohicon and Tanvè [4] were therefore inadequate, reflecting a deficiency.

In a Korean study [22], approximately half of the study population had excessive iodine intake. According to Kim et al. 1998 [25], seaweed was the main source of dietary iodine (more than 60%) in Korea among adults.

Our results could be partly explained by traditional dietary habits and practices using overly salty foods and spices and by insufficient intakes of potentially iodine-source foods such as milk or marine products.

Our study showed that regardless of the sodium concentration (low, intermediate or high) the proportion of iodine deficient subjects is higher than the proportions of subjects with adequate and excessive iodine concentration.

Indeed, for reasonable (intermediate) salt intake nearly 40% of the participants had insufficient iodine intake compared to around 20% and 15% for low and high UNaC respectively. However, those with higher salt intake were found to have sufficient intake [26].

Since the primary dietary vehicle for iodine fortification is salt, there is concern that reducing its consumption will increase the risk of iodine deficiency. Thus, there is a risk that sodium reduction strategies will negatively impact iodine intakes and lead to a risk of inadequate iodine intakes unless the high levels of iodine in salt are revised accordingly [26]. This fact is reinforced by the results of the current study. Indeed, we observed that when moving from an intermediate level of salt consumption to a low level, only 4.5% of the participants had an adequate iodine concentration. These results corroborate the significant association between crude UNaC and iodine status (crude concentration) in the Beninese population ($p < 0.001$).

A Korean study revealed that the I/Cr ratio has significant diagnostic value in assessing iodine intake [20]. In our investigation, after adjustment, through creatinine excretion there was no significant association between UNaC and iodine status. However, it should be noticed that we are at the limit of significance ($p = 0.05$). After application of the urinary Na/Cr and I/Cr ratios, whatever the group of sodium concentration (low, intermediate or high), the proportion of subjects with an adequate iodine concentration is higher than the proportions of subjects with a deficient or excessive iodine concentration. This fact could possibly be explained by a high consumption (nearly 85% of the participants) of a considerable source of iodine including fish which are among the seafood products richest in iodine. Indeed, dairy products from animals fed iodine-rich supplements could also be good sources of iodine [27].

In the current study, the distributions of UIC and UNaC, as well as the urinary I/Cr, Na/Cr ratios varied by age groups and sex. The highest rate of 24-hour UNaC and UIC was observed in men aged (50 to 60 years) and younger women (< 30 y). The low urinary Na/Cr ratio was observed in participants aged 40 to 50 years, and the high urinary Na/Cr ratio was observed in participants aged 30 to 40 years. Low urinary I/Cr ratio was higher in subjects aged 30 to 50 years, whereas the high urinary I/Cr ratio was observed in those aged 40 to 50 years.

In this study, we determined the corresponding urinary Iodine/Creatinine ratio values using the WHO UIC standards for iodine nutritional status.

A similar study found a significant association between sodium intake and iodine status in a Korean population with high UIC, UNaC, and urinary I/Cr and Na/Cr ratios recorded in elderly (≥ 60 y) and young adolescents (aged 10 to 18 y). Low UIC, UNaC, and urinary I/Cr and Na/Cr ratios were found in young adults (aged 19 to 29 y). These patterns of sodium intake in young adults and older adults were consistent with their UICs and urinary I/Cr ratios, which reflect iodine intake [20]. Differences in dietary habits between young adults and the elderly may be responsible for this variation and physiological status [4]. Another study provided evidence that the association between salt restriction and iodine deficiency may be true for women but not for men in this population [27].

In the present study, the iodine intake of the Beninese population was lower than that reported in previous studies [20, 22]. The median UIC value was 66.8µg/L (IQR, 42 - 98) and a mean UIC of 138 µg/L for Nigeria [4]. Studies carried out in the West African sub-region reported, for Côte d'Ivoire, a median UIC of 166 µg/L and a median UIC of 443 µg/day in Abidjan (the capital of Côte d'Ivoire), suggesting that iodine intake was adequate in these populations and even possibly excessive in Abidjan [28].

One of the strengths of the current study is the use of the gold standard method for assessing salt intake, namely 24-hour urine collections. It is reported that in epidemiological studies on salt from 24 – hour urine, at least 30% of the collections are not usable, while in our study only 22% are not. The considerable number (354/402) of participants with 24-hour urine samples collected for all 354 participants constitutes also a strong point. We underlined an almost equal representation between men (51.4%) and women, but also between rural (52.0%) and urban areas.

Despite the important results, this study presents several limitations. Firstly, this was a cross-sectional study. The creatinine values used to validate the completeness of 24-hour urine in the absence of a reference are not specific to black subjects, and may have introduced bias into the ratios.

Nevertheless, to the best of our knowledge, this is the first national study evaluating the possible association between iodine status and sodium consumption in the Beninese population.

5 Conclusion

No statistically significant association was recorded between iodine status and urinary sodium concentration in the Beninese population studied. Despite ongoing public health efforts, the optimal iodine intake recommended for the elimination of disorders due to iodine deficiency has yet to be attained, even in the face of excessive salt consumption within the population.

Our study findings indicate the necessity to enhance the national salt iodization program to effectively eliminate iodine deficiency disorders. Additionally, alternative sources of iodine should be recommended to individuals who need to reduce their dietary salt intake for health-related reasons.

Highlights

- Successful campaigns to reduce salt consumption may also result in reduced iodine consumption
- Optimal iodine intake has not yet been achieved in Beninese despite excessive salt consumption.
- No significant association between iodine and sodium concentration in the Beninese population
- Salt iodization program should be strengthened to eliminate iodine deficiency disorders.
- Alternative sources of iodine should be suggested to those who need to reduce dietary salt.

List of abbreviations:

BMI: Body mass index
CI: Confidence interval
HBP: High Blood Pressure
I/Cr: Ratio iodine/creatinine
ICCIDD: International Council for Control of Iodine Deficiency Disorders
ID: Iodine deficiency
IQI: Interquartile interval
Na/Cr: Ratio sodium/creatinine
NHANES: National Health and Nutrition Examination Survey
SES: socio-economic status
UIC: Urinary iodine concentration
UNaC: Urinary sodium concentration
WHO: World Health Organization

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