

Determination of discretionary salt intake in rural Guatemala and Benin to determine the iodine fortification of salt required to control iodine deficiency disorders: studies using lithium-labeled salt^{1,2}

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ABSTRACT The use of discretionary salt, which is salt added during cooking and at the table, as a suitable vehicle for iodine intake was assessed by measuring salt consumption using the lithium-marker technique in rural areas of Guatemala and Benin. In both countries, we studied boys aged 6–12 y and their mothers. Subjects used lithium-labeled salt after all unlabeled salt was removed from their households. In Guatemala, 24-h urine samples for 9 mother-son pairs were collected at baseline and on days 7, 8, and 9 during the use of lithium-labeled salt. Total maternal salt intake averaged 5.2 ± 1.7 g/d ($\bar{x} \pm$ SD), of which $77 \pm 24\%$ came from discretionary sources, whereas Guatemalan boys consumed 1.8 ± 0.6 g salt/d, of which $72 \pm 12\%$ came from discretionary sources. In Benin, urine collection from 13 mother-son pairs took place at baseline and on days 5 and 7. Beninese mothers had a total salt intake of 9.0 ± 2.9 g/d and their sons had an intake of 5.7 ± 2.8 g/d; discretionary salt contributed $52 \pm 14\%$ and $50 \pm 13\%$, respectively, of total salt consumed. Therefore, fortification of household salt appears to be an appropriate method of controlling iodine deficiency in both countries, although fortification of other salt sources could be considered in Benin. *Am J Clin Nutr* 1998;68:636–41.

KEY WORDS Iodine fortification program, salt consumption, lithium-marker technique, Guatemala, Benin, boys, women, iodine deficiency disorders

INTRODUCTION

Iodine deficiency disorders (IDD) constitute one of the major public health problems in the developing world, with more than one billion people at risk. Retarded physical and mental development are important health consequences of lack of iodine in the diet (1). For adult women, the recommended daily iodine intake is 150 μ g (200 μ g during pregnancy); it is 120 μ g for children 7–12 y of age (2). The natural iodine content of food depends on the iodine content of the soil in which it is grown. For people living in an iodine-deficient area, it is impossible to improve their iodine status by selecting foods grown locally.

In the countries involved in this study, Guatemala and Benin, iodine deficiency is still a problem. Although Guatemala has had a salt fortification program for decades, a goiter rate of 20% was

found in schoolchildren in 1988 (3). Benin has had no program for fortifying salt until lately, and in recent studies goiter rates of 45–60% were found, which indicates that IDD is a severe public health problem in Benin (4).

Fortification of salt has proven to be an effective measure to combat iodine deficiency. Salt is a basic ingredient of almost every meal worldwide, so a very large target group can be reached. There are various technologies for fortifying salt with iodine; all are quite simple and inexpensive (5). To determine the amount of iodine supplementation required for cooking and table salt, we need to know how much salt is consumed from these discretionary sources.

Several attempts have been made to assess the dietary intake of salt in individuals in different countries. These estimates are usually based on individual responses to questionnaires, national food consumption statistics, or figures for household salt purchase (5). In some developing countries, calculations of potential consumption of iodized salt are based on food balance sheet data, that is, total consumption of salt divided by the population. All these methods are suspected of being inaccurate because they do not account for salt losses during cooking or on the table, or for the use of salt for other purposes, such as for animal feed and deicing (6).

A relatively new method for measuring the actual consumption of salt by an individual is the lithium-marker technique (6–12). The principle of this method, first introduced by Sanchez-Castillo et al (6), is the labeling of household salt with a known amount of lithium. A metabolic study showed that 93% of the lithium in labeled salt is excreted in urine, 1.7% in feces, and 1.7% in sweat (7). Because of the high proportion of lithium excreted in urine, the amount of which stabilizes after 6 d, it is

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possible to calculate the consumption of labeled household salt. Leclerq et al (13) simplified the original design by showing that, at a constant intake, the excretion of lithium measured over 3 d after stabilization provides a good estimation of intake.

The recently released Guatemalan Micronutrient Survey (14) estimated that the average daily discretionary salt intake per capita is 11 g in rural areas. In this study, salt consumption was estimated by using information on the amount of salt purchased for consumption by the whole family, the number of family members, and the time in which the amount purchased was consumed. No research on salt consumption has been done in Benin as far as we know. The iodine content of salt mandated by their respective governments is 30–100 µg/g in Guatemala and 30–50 µg/g in Benin. The present studies were designed to determine the average amount of salt consumed by individuals in these 2 different developing countries by using the lithium-marker technique. Labeling with lithium instead of iodine has the advantage that lithium is not taken up by the body and that there is no or relatively little interference from other sources. Because there is some consumption of iodized salt by the populations in both Guatemala and Benin now, information was obtained about the potential contribution of discretionary salt to the iodine supply in Guatemala and Benin.

SUBJECTS AND METHODS

Subjects

In Guatemala, 9 boys aged 6–9 y and their mothers participated in the study, which was carried out in January and February 1996. All subjects lived in Buena Vista, a hamlet of San Pedro Sacatepéquez, where the ambient temperature is 12–25°C during the first 2 mo of the year. Although it is only ≈20 km from the capital, the area is still very rural. The subjects were selected nonrandomly by seeking families with a son in the target age range and asking them to participate after the study was explained to them. In Benin, subject selection was based on the population of an ongoing study of schoolchildren in the rural village of Pénessoulou, Sous-Préfecture of Bassila, in the province of Atacora. After an information meeting for parents was held, 13 boys (aged 8–12 y) and their mothers were selected. The fieldwork here also took place in January and February 1996, and the ambient temperature during these months was 10–32°C. The parents' consent was obtained after they had been given a full explanation of the study in their own language, which is Spanish or Cakchiquel in Guatemala and Anii in Benin. The Guatemalan study was approved by the CeSSIAM Ethical Committee on Studies with Human Subjects and the Beninese study by the Medical Ethics Committee of the University of Benin in Cotonou.

Preparation of labeled salt

The lithium-labeled salt given to the subjects was prepared by AKZO-Nobel (Hengelo, Netherlands), according to the method described by Sanchez-Castillo et al (8). Lithium carbonate was mixed with sodium chloride in the proportion of 92 g Li₂CO₃/kg salt. Portions of this mixture were placed in alumina crucibles (Alsint Haldenwanger, Berlin) and heated in a furnace at 900°C. After cooling, the labeled salt was milled into fractions of different size. Two kilograms of this premix was mixed with 18 kg unlabeled household salt. Of this 20 kg, one-half was used in

Guatemala and the other half in Benin. The grain size of the salt used in Guatemala was set at 300–800 µm because the salt there is commonly quite coarse, whereas for Benin the grain size was 150–630 µm.

After the salt was packed in plastic bags of 250 g each, the lithium content was determined at the Wageningen Agricultural University in 10-g samples taken from every fourth bag. The mean content in the Guatemalan samples was 1575 mg Li/kg salt (CV: 3.7%) and in the Beninese samples was 1579 mg Li/kg salt (CV: 19.6%). Unfortunately, the CV of the lithium content of the salt in Benin was large, probably due to settling out of the lithium in the stored salt.

Experimental design

The experimental period lasted 10 d for each family in Guatemala and 7 d for those in Benin. On day 0, 1 d before the start of the intervention, the subjects collected their urine for 24 h. Because water and some vegetables may be a source of lithium (7), basal excretion of lithium as well as that of sodium and chloride was measured in the day 0 urine sample. During the experimental days, the families used the lithium-labeled salt instead of their usual household salt. In both countries, all pre-existing salt in the households was purchased so that no unlabeled salt was available in the households during the study. In Guatemala, 24-h urine samples were collected on days 7, 8, and 9 for measurement of urinary lithium, sodium, and chloride excretion while using the labeled salt. In Benin, this was done on days 5 and 7.

Urine collections

Labeled plastic bottles were distributed to the mothers and children for collection and storage of urine. Smaller bottles were also used to collect urine at school (with the help of the teachers), in the fields, or at the market. Thymol was used as a preservative (≈1 g per bottle) in Benin. Urine collections were planned so that they did not take place during the menstrual period of the women. On the day the collection began, the first urine voided on rising was not collected, but all subsequent urine voided over the next 24 h, ending with the first urine voided on the following day, was collected. The total volume of the urine was calculated from its weight measured on a digital balance, assuming that the density of urine is 1.000 kg/m³. Then, the urine was transferred in duplicate into screw-top, plastic test tubes. The aliquots were placed in a freezer within 24 h of collection. All urine samples were sent to the laboratory of the Division of Human Nutrition and Epidemiology of Wageningen Agricultural University and stored at –18°C until analyzed.

Analysis of urine samples

Urinary sodium and lithium were measured with an atomic absorption spectrophotometer (model 2380; Perkin-Elmer, Norwalk, CT). Chloride was measured by using a colorimetric method with a Chloor-o-counter (type 77; Marius, Utrecht, Netherlands). All measurements were carried out in duplicate.

Calculations

Because of the possible intake of sodium as sodium monoglutamate or as other nonchloride sodium sources in food, total salt intake was calculated from the urinary output of chloride, assuming that forms of dietary chloride not bound to sodium were negligible. The lithium output derived from the labeled salt was cal-

culated from the mean on days 7–9 (Guatemala) or days 5 and 7 (Benin), corrected for the background lithium excretion on day 0. Leclercq et al (13) reported that $95 \pm 6\%$ ($\bar{x} \pm SD$) of lithium consumed is excreted in urine. Discretionary salt consumption was calculated by dividing the excretion of lithium for each day urine was collected from each subject by the proportion of lithium in the salt. Individuals' means were calculated for all days of complete urine collection. Finally, the means for groups of mothers and for children were calculated. Discretionary salt consumption was expressed as a percentage of total salt intake.

Statistics

All statistical analyses were carried out by using SAS, version 6.09 (15). All variables were checked for normality by using tests for skewness, kurtosis, and Shapiro-Wilk, stem-leaf, and normal probability plots. Because all variables were found to be reasonably normally distributed, the differences between groups and days were compared by using Student's *t* test.

RESULTS

The mean ages of the Guatemalan mothers and children were 37.4 and 8.1 y, respectively, and of the Beninese mothers and children were 38.0 and 9.7 y, respectively. Beninese mothers had a mean ($\pm SD$) height of 1.58 ± 0.03 m and a mean weight of 58.5 ± 10.9 kg. Their sons had a height of 1.26 ± 0.06 m and a weight of 24.1 ± 3.0 kg. Anthropometric data for the Guatemalan subjects were not available.

In Guatemala, 56 of the 72 urine collections (78%) were complete. The 16 collections reported as incomplete were distributed over 11 subjects. In Benin, all 78 collections (100%) were complete. The collections were classified as complete on the basis of self-reported criteria. The urinary volume, ion excretion, and data on salt intake are shown in **Table 1**. Mothers had a total salt intake of 5.2 ± 1.7 g/d in Guatemala and of 9.0 ± 2.9 g/d in Benin, based on chloride excretion. Discretionary salt contributed $77 \pm 24\%$ of the total salt ingested by Guatemalan mothers and $52 \pm 14\%$ of that by Beninese mothers. Guatemalan children consumed 1.8 ± 0.6 g salt/d, of which $72 \pm 12\%$ came from a discretionary source; Beninese children consumed 5.7 ± 2.8 g

salt/d, of which $50 \pm 13\%$ came from a discretionary source. In both countries, total salt intake and discretionary salt intake were lower in the children than in the mothers ($P < 0.01$). No significant differences were found for mean sodium and chloride excretion during the experimental days compared with baseline values, except for the Guatemalan boys, in whom absolute excretion of both sodium and chloride was 40% lower ($P < 0.05$) during the experimental days (Table 1). Also, urine volume was significantly ($P < 0.01$) lower in the Guatemalan boys during days 7–9 than during the baseline collection. The molar concentrations of sodium and chloride were not different between days.

No significant differences in salt intake between Beninese mothers and their sons were found when their body weights were taken into account. Total salt intake on a body weight basis for Beninese women was 0.16 ± 0.05 g/kg body wt and for their sons was 0.23 ± 0.10 g/kg body wt. In both countries, no significant differences between mothers and children were found in the proportion of salt intake that was discretionary. In Guatemala, the difference in mean urine volume between mothers and children was significant ($P < 0.001$). Because salt intake is not always normally distributed, it may be better expressed by median values, which are also included in Table 1. Because the data are normally distributed, the mean and median values are similar.

DISCUSSION

In the work of Sanchez-Castillo and James (12), the use of the lithium-marker technique was aimed at providing advice to individuals at risk of hypertension. Such people need to know how to reduce salt intake, especially which sources of salt in food should be reduced. In the present study, we extended the application of this technique to the estimation of adequate fortification levels for iodine in commercial salt supplies to control IDD in a developing country.

Moreover, in contrast with the situation in the United Kingdom (10), where only 15% of the sodium excreted came from salt used for cooking and added at the table (discretionary salt), the corresponding figures for the specific populations studied in Guatemala and Benin were 75% and 50%, respectively. Although the precision of our study was low because of the small

TABLE 1

Daily ion excretion and total and discretionary salt intakes in mothers and their sons in Guatemala and Benin¹

	Guatemala				Benin			
	Day 0		Days 7–9 ²		Day 0		Days 5 and 7 ³	
	Mothers (n = 8)	Sons (n = 7)	Mothers (n = 9)	Sons (n = 9)	Mothers (n = 13)	Sons (n = 13)	Mothers (n = 13)	Sons (n = 13)
Salt excretion and intake								
Urine excretion (L/d)	1.18 ± 0.37	0.71 ± 0.09	1.10 ± 0.24	$0.56 \pm 0.24^{4,5}$	1.13 ± 0.40	0.82 ± 0.28	1.20 ± 0.36	0.74 ± 0.21
Ion excretion (mmol/d)								
Sodium	89 ± 28	53 ± 20	93 ± 31	33 ± 12^6	146 ± 46	97 ± 40	143 ± 48	118 ± 43
Chloride	89 ± 36	51 ± 16	88 ± 29	31 ± 11^6	148 ± 51	102 ± 38	140 ± 51	124 ± 38
Lithium	0.00 ± 0.01	0.00 ± 0.01	0.89 ± 0.43	0.28 ± 0.12	0.00 ± 0.02	0.00 ± 0.02	1.01 ± 0.49	0.86 ± 0.40
Estimated salt intake								
Total (g/d)	—	—	5.2 ± 1.7 (5.3)	1.8 ± 0.6^7 (1.8)	—	—	9.0 ± 2.9 (8.0)	5.7 ± 2.8^7 (5.1)
Discretionary (g/d)	—	—	3.9 ± 2.0 (3.4)	1.3 ± 0.6^7 (1.3)	—	—	4.7 ± 1.9 (3.9)	2.9 ± 1.9^7 (2.3)
Discretionary (%)	—	—	77 ± 24 (64)	72 ± 12 (72)	—	—	52 ± 14 (48)	50 ± 13 (45)

¹ $\bar{x} \pm SD$; medians in parentheses.

²Calculated over 3 d.

³Calculated over 2 d.

^{4,6}Significantly different from day 0: ⁴ $P < 0.01$, ⁶ $P < 0.05$.

^{5,7}Significantly different from mothers: ⁵ $P < 0.001$, ⁷ $P < 0.01$.

number of subjects studied, our estimates are 3–5 times higher than the proportion of discretionary salt consumed in the United Kingdom (10). Our estimates almost certainly reflect real differences from the United Kingdom and a difference between the subjects in Guatemala and Benin. We speculate that the practices contributing to the relatively lower contribution of discretionary salt per se in Benin is the use of condiment cubes (Maggi cubes; Nestlé SA, Vevey, Switzerland, and similar products from other manufacturers). These are used in sauces eaten with staple foods and are rich sources of salt.

Including the present study, there are now 4 studies on the salt intake of populations determined by using a lithium-labeled salt technique (Table 2). The first 3 studies were conducted in European countries (United Kingdom and Italy) with temperate climates; adults were included in all studies but children were included in only the Italian study. In the studies in Guatemala and Benin, we added data from 2 groups of mothers and their male offspring for tropical latitudes. As shown in Table 2, the Beninese women in our study consumed more salt than European women, whereas Guatemalan mothers consumed less. Salt intakes from all sources for Beninese children were equivalent to those for adult Guatemalan women. The lowest average daily salt intakes (≈ 2 g/d) yet documented by this method are those of the children from Guatemalan households.

Physiologic adaptation expressed through cultural factors may account for most of the 2-fold difference in total salt intake between the Beninese and Guatemalan populations. Indeed, both countries are in the tropical latitudes, but the indigenous population of Buena Vista lives in the highlands, where the ambient temperature is 12–25°C in the first 2 mo of the year and humidity is low. The Beninese community of Pénessoulou is close to sea level in a climate that is both humid and hot, with ambient temperatures in January and February of 10–32°C. It may be that higher salt intakes are physiologically appropriate to compensate for higher salt losses in sweat in the hotter African setting.

Another notable finding is that the estimates of discretionary salt consumption were much lower by this urinary excretion method than by other methods for assessing salt intake (14, 17). The question arises as to how much of this difference can be explained by incompleteness of urine collections. Without the benefit of external markers, such as *para*-aminobenzoic acid (18), or intrinsic markers, such as creatinine from endogenous

muscle turnover, it is difficult to verify the completeness of urine collections. We opted to address the issue of collection losses by relying on self-reported criteria. Because all urine collections that were reported as incomplete were left out of the calculations and the measured 24-h volumes of urine (Table 1) were not different between the women, we believe that the differences between the lithium-marker technique and other methods of estimating discretionary salt intake were not the result of a major error in the lithium-marker technique.

Of the groups studied, only the Guatemalan boys showed a decrease in absolute excretion of sodium and chloride during the experimental days, coupled with a decreased urine volume and steady sodium and chloride concentrations. This may have been caused by incomplete collections of urine during the experimental days, which would have led to an underestimation of the salt consumption by this group of $\approx 40\%$. However, even if corrected by this proportion, their salt consumption would still have been quite low. In addition, the estimate of the proportion of discretionary salt consumed is not affected by incomplete collection of urine, as shown by Leclercq et al (13).

Overall, subjects did not change their salt intake habits, although the lithium-labeled salt was less coarse than the salt they were used to. Although we are aware of the limits of this study, the results are nevertheless striking. The daily, discretionary salt intake per capita in Guatemala estimated from data on household salt purchases is 11 g (14), whereas we found it to be 4 g for adult women with the urinary lithium-marker technique. Even if we underestimated the salt consumption by 50% because of incomplete urine collections, salt consumption would still be much lower than expected from estimates made by using other methods.

In Table 3, we compared the mandatory iodine content of salt in Guatemala and Benin with the content recommended by the World Health Organization (5). As an exercise, we assigned the amounts of iodine that would be needed in the salt of the respective areas to meet the recommended daily intakes of 150 μg for adult women and 120 μg for children in the age range of the children in this study. Several assumptions and caveats are worth mentioning. The first is that there are no systematic errors and that the estimates of total salt intake based on chloride excretion and of discretionary salt intake are accurate. Although the same original mix was used in both countries, the amount of

TABLE 2
Comparison of published estimates of daily salt intakes assessed by the lithium-labeling method

Reference	Subjects	n	Salt intake		Site
			Total g	Discretionary g [%]	
Sanchez-Castillo et al (9), 1987	Men	33	10.6 \pm 0.55	1.22 [11]	United Kingdom
Sanchez-Castillo et al (9), 1987	Women	50	7.4 \pm 0.29	0.91 [12]	United Kingdom
Leclercq et al (13), 1990	Men	7	9.35 \pm 1.75	2.63 \pm 1.17 [32 \pm 12]	Italy
Leclercq et al (16), 1991	Men	71	11.2 \pm 3.4	4.0 \pm 2.3 [36 \pm 17]	Italy
Leclercq et al (13), 1990	Women	7	7.66 \pm 2.81	2.16 \pm 0.82 [32 \pm 15]	Italy
Leclercq et al (16), 1991	Women	78	9.4 \pm 3.3	3.8 \pm 2.4 [39 \pm 18]	Italy
Leclercq et al (13), 1990	Children (8–12 y)	5	6.14 \pm 2.10	1.64 \pm 0.82 [24 \pm 11]	Italy
Leclercq et al (16), 1991	Children (8–12 y)	121	7.7 \pm 2.5	2.5 \pm 1.3 [34 \pm 15]	Italy
Present study	Women	13	9.0 \pm 2.9	4.7 \pm 1.9 [52 \pm 14]	Benin
Present study	Women	9	5.2 \pm 1.7	3.9 \pm 2.0 [77 \pm 24]	Guatemala
Present study	Boys (8–12 y)	13	5.7 \pm 2.8	2.9 \pm 1.9 [50 \pm 13]	Benin
Present study	Boys (6–9 y)	9	1.8 \pm 0.6	1.3 \pm 0.6 [72 \pm 12]	Guatemala

TABLE 3

Comparison of the iodine content of salt mandated by the government with that recommended by the WHO, and the desirable content based on salt consumption in Guatemala and Benin

	Guatemala	Benin
Mandatory iodine content of salt (mg/kg)	30–100	30–50
WHO recommendation (mg/kg)	40–60 ¹	20–30 ²
Desirable iodine content of salt, based on median salt intake of women (mg/kg)	44	38
Desirable iodine content of salt, based on median salt intake of children (mg/kg)	92	52


¹Assuming a daily salt consumption of 5 g/person, the recommendation for retail sacks varies from 40 mg/kg for a cool, dry climate to 60 mg/kg for a warm, moist climate; Guatemala has both climates.

²Assuming a daily salt consumption of 10 g/person, the recommendation varies from 20 mg/kg for a cool, dry climate to 30 mg/kg for a warm, moist climate; Benin also has both climates.

lithium in the salt in Benin was more variable (CV: 19.6%). This might have been a cause of error in the outcome of the calculations for Benin. Losses of lithium in sweat in England during wintertime were small as determined by Sanchez-Castillo et al (7), but it is likely that Guatemalan and Beninese people sweat more because of exertion and the hotter climate. However, analysis of the sweat of physically active people after they ingested lithium showed that sweat is not an important route of lithium excretion (19).

Beyond the specifics of the accuracy of methods would be the issue of how prudent it is to generalize our particular values beyond the 2 isolated rural populations in their respective nations. In this regard, there is the premise that rural populations are more vulnerable to IDD than are urban ones. It would thus be important that the 2 areas chosen—Buena Vista in Guatemala and Pénessoulou in Benin—have dietary total and discretionary salt use patterns that are typical of the rural societies of the respective nations. Finally, beyond the representative nature of the populations is the issue of the small sample sizes that our limited supply of lithium-labeled salt permitted us to study. Was the total of 26 person-days of excretion covered by the Beninese design for each age group and the 27 person-days of excretion per age group in Guatemala sufficiently representative to reflect the usual, year-round pattern for the respective localities? On a person-to-person basis, there is the same concern for the ability of 2 d of observations in Benin and 3 d in Guatemala to reflect “usual” intakes for individuals throughout the year.

Assuming that the aforementioned assumptions and premises are valid, recommended fortification levels of iodine for the 3.4 and 3.9 g/d median discretionary salt intakes for the women of Guatemala and Benin to achieve an intake of 150 µg I/d would be 44 and 38 µg/g, respectively (Table 3). On the basis of the central tendency hypothesis, the iodization levels necessary to protect children would be 92 and 52 µg/g salt in the respective nations. The currently mandated supplementation levels in both nations would be sufficient to meet these estimates of iodine fortification, but the amount recommended by the WHO would not be protective.

In conclusion, fortification of household salt is a promising approach to overcoming IDD in the rural areas of both countries. Nothing in the present study challenges this tenet. However, we conclude that the actual salt consumption varies considerably between countries and may be much lower than expected from existing research. It is obvious that actual salt intake has a direct effect on the iodine intake of a population. Therefore, we think it is necessary to examine salt intake patterns carefully within the framework of iodine fortification programs. 

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