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Abstract

Universal salt iodization (USI) was adopted in Madagascar in 1995 within the framework of a worldwide policy to eliminate iodine deficiency disorders. Despite early USI adoption, there are no representative data on the iodine status of the Malagasy population. The aims of this study were to determine the iodine status of the Malagasy population and to assess the use of adequately iodized salt among households.

We randomly sampled women of reproductive age (WRA) using a national, two-stage, stratified cross-sectional survey in 2014. Casual urine from WRA and salt samples from the household containing WRA were collected to measure urinary iodine concentration (UIC) and to assess household salt iodine content.

Data from 1721 WRA in 1128 households were collected and analyzed. The national median UIC was 46 μg/L (interquartile range (IQR): 13-98 μg/L), indicating a moderate iodine deficiency. The median

UIC was 53 µg/L (IQR: 9-89 µg/L) in pregnant women and 46 µg/L (IQR: 13-98 µg/L) in non-pregnant women. The national median iodine concentration of household salt was 10 mg/kg (IQR: 6.3-15.8 mg/kg) and 26.2% (95% CI: 22.1-31.0%) of households containing WRA used adequately iodized salt (≥15 mg/kg). Women living in households with adequately iodized salt had higher median UIC (72 µg/L vs. 50 µg/L). Iodine status was significantly lower among women from low socio-economic households.

Madagascar's USI program needs to be revitalized. Implementing strategies to provide adequately iodized salt and enhancing iodized salt legislation to prevent severe complications resulting from iodine deficiency in the Malagasy population are essential.

Key words: iodine status; Madagascar; universal salt iodization program; salt iodine content; national survey

Introduction

Nutrition is an important determinant of health and human development and undernutrition accounts for 45% of all child deaths worldwide (Black et al., 2013). Inadequate food intake has always played an essential role in malnutrition (Bhutta, 2008), encompassing both macronutrients and micronutrients. Globally, the three most common forms of malnutrition resulting from micronutrient deficiency are iron, vitamin A, and iodine deficiency, which together affect at least one-third of the world's population, mainly those from low-income countries (Allen, de Benoist, Dary, & Hurrell, 2011).

Iodine is an essential trace element that is required for normal thyroid function. It is therefore critical to the production and regulation of thyroxin and triiodothyronine, two important growth hormones. Clinical and subclinical manifestations of iodine deficiency are called iodine-deficiency disorders (IDD). Iodine deficiency *in utero* and in early childhood impairs brain development and leads to reduced intellectual potential (Bath, Steer, Golding, Emmett, & Rayman, 2013; Zimmermann & Boelaert, 2015; Zimmermann et al., 2006). The World Health Organization (WHO) recommends universal salt iodization (USI), which is iodization of all salt for human and animal consumption, as the preferred strategy for controlling IDD. USI is a relatively inexpensive and easy to implement, and it has been one of the most successful nutritional interventions in the past 30 years (Allen et al., 2011). The iodine status of a population is determined based on the urinary iodine concentration (UIC) from spot urine samples collected in a representative sample, with the median UIC compared against global reference values (WHO, UNICEF, & ICCIDD, 2007). The UIC of a group is considered to be a valid biomarker of the iodine nutrition status of a population because the daily excretion of iodine closely reflects the population's iodine intake (Ristic-Medic et al., 2009; Zimmermann, Jooste, & Pandav, 2008) .

Madagascar adopted the USI policy in September 1995 (Decree No. 95-587 of 05/09/1995) making salt iodization mandatory in the country since then. The Malagasy legislation on salt iodization prescribes that the crystal salt sold in bulk packaging (25-kg to 60-kg sacks) must have a minimum of 50 parts per million (ppm or mg/kg) iodine, and for salt sold in consumer packs (250 g) the iodine concentration must be at least 30ppm. A national committee for IDD was established in the 1990s under the leadership of the Ministry of Public Health, including relevant ministries such as Commerce, Agriculture, Scientific Research, Interior, and Justice; multilateral partners such as UNICEF, WHO, USAID, and World Bank; and salt producers. In July 2013, the committee for the elimination of iodine deficiencies was re-activated under the coordination of the National Nutrition Office. Surveillance was performed by seven governmental sentinel salt laboratories and one central department of health laboratory in Antananarivo (Jooste, 2014).

In Madagascar, salt production is sufficient to meet the domestic consumption demand. There are three main sources of salt: one large scale producer located in the North of the country who produces most of the local salt (40–50%) using industrial iodization processes; about 8 medium scales enterprises located in the mid-western region, which supplies 30–35% of the salt in Madagascar; and over a 100 small producers in the south who supply 20–25% of the salt. Salt from the last two sources might not be adequately iodized (Jooste, 2014).

Despite the national legislation, political instability in Madagascar has hampered enforcement of this legislation and there is no functioning system for licensing of salt producers. UIC surveillance efforts ceased in the 2000s.

The present study was conducted on women of reproductive age (WRA) to assess the iodine status of the Malagasy population and the availability of iodized salt at household level with WRA, with the ultimate aim to inform USI policy and program in Madagascar and beyond.

Methods

Study design and sampling

We conducted a nationally representative survey from November 2015 to January 2016 using a stratified two-stage cluster sampling method. . The target population was WRA (15–49 years), who resided and were present in the selected households at the time of the survey. If a selected household had more than one WRA, they were all invited to participate in the study. Women who had their menstrual periods at the time of the survey were not included. Because the availability of iodized salt at household level could have an impact on iodine intake and iodine status, the country was divided into three strata according to the proportion of households with adequately iodized salt in the last Demographic and Health Survey (DHS) (INSTAT, 2010), which used rapid test kits to assess the iodine level in the household salt. Stratum 1 included areas where less than 20 % of households had access to adequately iodized salt; stratum 2 included areas where 20% to 60% of households had access to adequately iodized salt ; and stratum 3 included areas where the proportion of households with adequately iodized salt is more than60% (Figure 1).

A two-stage cluster sampling was performed. In the first stage, 30 villages were selected from within each stratum (90 villages in total) with a probability that was proportionate to size. In the second stage, households were selected in each village by systematic random sampling using a list of households obtained from the village chief. Within a household, all

WRA were enrolled. . The sample size for this survey was estimated based on a precision of 5% at the national and strata levels, an expected prevalence of iodine deficiency of 20%, and a design effect of two. The sample size was at least 1476 (492 in each stratum). Accounting for 15% non-compliance, the expected sample size was a total of 1736 WRA (578 in each stratum, 19-20 in each village). Based on an average household size estimated at 4.7 persons (INSTAT, 2010) and considering that WRA represent 24% of the population in Madagascar (UNFPA, 2014), around 17 households per village needed to be visited to have 19-20 WRA per village. However, if the expected number of 19-20 WRA per village was reached with fewer than 17 households visited, survey workers were instructed to move to the next selected village.

For each woman who met the inclusion criteria, questionnaires were administered to collect data on individual characteristics (e.g. date of birth, level of education, occupation), household characteristics (e.g. number of inhabitants, household assets), as well as data on cooking salt (e.g. availability of salt, type of salt, place of purchase, storage conditions) All data were collected using tablets and daily quality checks were performed by supervisors.

Analysis

Urine sampling and analysis

A casual urine sample (20 mL) was collected from each participant in a clean and sterile, pre-labeled and tightly capped vial.. For women who could not remember her last menstrual period, an additional 5-mL urine sample was collected for a pregnancy test as it has been shown that UIC varies with physiological status ((WHO et al., 2007). All samples were stored at room temperature in the field for a maximum of five days and were then sent to the

Laboratory of Food Hygiene and Environment at the Institut Pasteur de Madagascar (IPM) where they were stored at −20°C until they were analyzed.

At the IPM laboratory, the UIC was measured using a modified microplate method. This method involves the digestion of the sample using ammonium persulfate (Dunn et al., 1993) followed by the colorimetric determination through the Sandell–Kolthoff reaction using 96-well plates and an absorbance reader at 405 nm.

Salt analysis

Salt samples (30–50 g) were collected from the salt used for meal preparation from each household that had WRA who were included in the survey. If the household used several types of salt (e.g. fine, coarse), samples of each salt type were collected. These cooking salts were packed in small sachets and sent to the Nutrition Laboratory of the Ministry of Public Health, Madagascar for determination of their iodine content.

The iodine content was quantified using the iodometric titration method (Mannar & Dunn, 1995).

External quality control

External quality control was performed for both UIC and salt iodine content. For salt iodine content, the external control was done by the Laboratory of Human Nutrition at the Swiss Federal Institute of Technology Zurich using 150 randomly selected salt samples (50 per stratum). The control for UIC was done by the American Center for Disease Control (CDC) through its program named Ensuring the Quality of Urinary Iodine Procedures (EQUIP) (CDC, 2017) and by the Laboratory of Human Nutrition at the Swiss Federal Institute of Technology Zurich , using 150 randomly selected urine samples. . For UIC, we obtained a correlation coefficient of 0.76 between the two methods, the inter-laboratory coefficient of variation at UIC around 100 µg/L and 200 µg/L were 20%.

Case definitions

We used the WHO criteria on median UIC in µg/L to classify iodine status according to the physiological status of the women (WHO et al., 2007). The population of non-pregnant and non-lactating women was classified using the median UIC as follows : <20 µg/L (severe deficiency), 20–49 µg/L (moderate deficiency), 50–99 µg/L (mild deficiency), 100–199 µg/L (adequate), 200–299 µg/L (above requirements), and ≥300 µg/L (excessive). Deficiency in pregnant women was classified according to the median UIC as follows : <150 µg/L (inadequate), 150–249 µg/L (adequate), 250–499 µg/L (more than adequate), and ≥500 µg/L (excessive). For the population of lactating women, an UIC <100 µg/L was considered to be deficient and an UIC ≥100 µg/L was considered to be adequate. At the subject level, because of a lack of internationally recognized UIC cut-offs in individuals, we used the same cut-off as that of the population level to categorize subjects with UIC less than the required values. For pregnant women, we used an UIC threshold of 150 µg/L, for the other group (lactating women, non-lactating and non-pregnant women), the UIC cut-off was 100 µg/L.

Adequately iodized salt was defined as salt with an iodine concentration ≥15 mg/kg. If the household provided more than one type of salt sample, the sample with the higher value of iodine content was used for the statistical analysis.

Data management and statistical analysis

Data were collected on tablets and were entered directly into an Access database during the interview. Data analysis was performed using R software (Team, 2008). Data on household characteristics and assets were used to derive an index of household wealth (Filmer & Pritchett, 2001). We defined five wealth quintiles with the first quintile representing the poorest segment and the fifth quintile representing the wealthiest segment of the sampled household.

It has been shown that UIC is not normally distributed (Kolmogorov-Smirnov test). Therefore non-parametric tests were performed. UIC and salt iodine content were expressed as the median and/or percentage using the categorizations defined above. Median and interquartile range (IQR) values of UIC were calculated based on women's physiological status (pregnant, lactating, or non-lactating and non-pregnant), strata (stratum 1, 2 and 3), household wealth index, and access to adequately iodized salt.

All analyses took into account the sampling design (stratification, clustering, unequal probabilities of selection) using the *survey* R package. Median of iodine concentration was compared by groups using the non-parametric Mann-Whitney U test for two groups and the Kruskal-Wallis test for more than two groups.

Multivariate logistic regression analysis was performed to identify risk factors associated with UIC value <100 µg/L (<150 µg/L for pregnant women).

Bivariate analysis was used to identify the explanatory variables that were included in the multivariate analysis. Explanatory variables with a p value < 0.2 were included in the multivariate analysis. A backward logistic regression was performed to obtain the final model and the variables associated with an UIC value <100 µg/L.

Ethical clearance

The survey protocol was approved by the Ethics Committee of the Ministry of Public Health of Madagascar (N°097-MSANP/CE - 06/10/2014). Written informed consent was received for each participant, and for minors, informed consent was obtained from their parent or guardian. To compensate for the salt taken as a sample for this study, participating households were provided with 250 g of iodized salt.

Results

Sample characteristics

Of the 1760 WRA who participated in the survey, 27 had no urine samples and were excluded. Among the remaining 1733 women, 12 had a non-valid UIC result (IUC ≥1000 µg/L) and were excluded from the global estimation of iodine urinary concentrations. In total, 1721 women from 1287 households were included in the final analysis including 316 households (24.5 %) with more than 1 WRA (Figure 2).

The median age of women was 26 years (IQR, 19–35 years). The overall sample population that completed the survey was composed of 62.4% non-pregnant non-lactating women, 10.7% pregnant women, and 26.9% lactating women. Approximately 19.4% of the women surveyed never received a school education, 51.2% completed at least 1 year in elementary school, 21.0% had at least 1 year in secondary education, and 8.4% had a high school level or higher education.

The proportion of women who had income-generating activities was 82.7%, while 17.3% did not have income-generating activities. Table 1 shows the socio-demographic characteristics, physiological status and place of residence for women who were included in the survey.

Urinary Iodine Concentration

UIC in the overall study population

The median UIC of all women included in the survey was 46 µg/L (IQR, 13–98 µg/L) denoting a moderate iodine deficiency. When considering only household from which only one woman was randomly selected, the median UIC was 47µg/L (IQR, 11-103 µg/L). The median UIC was 47 µg/L (IQR, 16–93 µg/L) in non-pregnant non- lactating women, 40 µg/L (IQR, 4–104 µg/L) in lactating women, and 53 µg/L (IQR, 9–89 µg/L) in pregnant women. The proportion of women with UIC <100 µg/L was 76.2% (95%CI, 71.7–80.0) in non-pregnant non-lactating women and 73.3% (95%CI, 66.0–80.0) in lactating women. In pregnant women, the proportion with UIC < 150 µg/L was 81.6% (95%CI, 71.0–89.0).

There was a statistically significant difference in the median UIC values between stratum 1 and stratum 2 ($p<0.001$), and between stratum 2 and stratum 3 ($p<0.001$). Median UIC was 26 µg/L (IQR,4–59 µg/L) in stratum 2, 51 µg/L (IQR, 11–107 µg/L) in stratum 1, and 52 µg/L (IQR, 19–110 µg/L) in stratum 3.

UIC by physiological status

Table 2 shows the median UIC by stratum and physiological status of the women. Our results suggest that depending on the women's physiological status (pregnant, lactating, non-pregnant and non-lactating), the median UIC varies significantly within each of the stratum and that, regardless of the physiological status of women, the lowest median UIC values were found in stratum 2.

Median UIC varied significantly with household wealth quintile (p<0.001). The median UIC was 21 µg/L (IQR, 1–46 µg/L) for the households in the poorest quintile compared to 62 µg/L (IQR, 25–119 µg/L) for the households in the wealthiest quintile.

Although not statistically significant, our study shows that the median UIC level consistently decreased with increasing level of education among women. Median UIC was 52 µg/L (IQR, 24–114 µg/L) for women who never received a school education, 46 µg/L (IQR, 9–109 µg/L) for those who had at least 1 year in elementary school, 45 µg/L (IQR, 10–78 µg/L) for those who had at least 1 year in secondary, and 40 µg/L (IQR, 14–67 µg/L) for women who had a high school education (Table 3).

Iodine content of salt used in households containing WRA

The 1733 women who provided urine samples belonged to 1291 households, and among these households, 88.2% (n = 1140) provided salt samples. The analysis of salt in households with WRA (salt iodine content, other salt characteristics) was conducted with data from 1140 households. For the analysis between urinary iodine concentration and adequacy of salt iodine content, we used data from 1128 households containing both WRA with at least one valid UIC and providing at least one salt sample (Figure 2).

In the overall sample, the median iodine concentration of salt in household containing WRA was 10 mg/kg (IQR, 6.3–15.8 mg/kg). The distribution of salt iodine content varied between stratum ($p=10^{-15}$), with a median of 7.9 mg/kg in stratum 1 (IQR, 5.8–13.2 mg/kg), 35.3

mg/kg (IQR, 16.0–68.0 mg/kg) in stratum 2, and 69.0 mg/kg (IQR, 28.0–123.8 mg/kg) in stratum 3. The proportion of households with WRA with adequately iodized salt (≥15 mg/kg) was 26.2% (CI 95%, 22.1–31.0%). When disaggregated by stratum, the proportion of households with adequately iodized salt was 15.5% in stratum 1, 18.0% in stratum 2, and 38.1% in stratum 3 ($p<0.001$; Table 4).

Coarse salt was used in 87.1% of households, fine salt in 12.8% of households, and rock salt in 0.1% of households. Most households (92.8%) reported purchasing their salt usually from the local market or from the local grocery stores and the remaining 7.2% of households purchased their table salt from a street vendor or got it from their neighbor. More than half of the households (59.7%) kept their salt in covered containers, 39.1% kept it in its original packaging, and 1.2% kept it wrapped in a paper. The results on salt iodine content show a statistically significant difference in the proportion of households with adequately iodized salt by stratum household socio-economic status, place of purchase, and storage method of table salt (Table 4).

Association between median urinary iodine concentration and adequacy of salt iodine content

The study results showed significant differences in the median UIC according to access to adequately iodized salt ($p=0.002$). The median UIC of women from households that used adequately iodized salt was 72 µg/L (IQR, 32–149µg/L), vs. 50 µg/L (IQR, 16–105 µg/L) for women in households with inadequately.

At the stratum level, we found significant differences in median UIC based on access to adequately iodized salt (p=0.02) in stratum 3 only. In stratum 3, the median UIC of women from households with adequately iodized salt was 89 µg/L (IQR, 41–149 µg/L), and those from households using inadequately iodized salt was 55 µg/L (IQR, 19–118 µg/L).

Association between subject-level iodine status and living environment, socio-demographic factors, and salt iodine content adequacy

The multivariate analysis shows that household wealth quintiles and salt iodine adequacy were associated with an occurrence of UIC <100 µg/L for non-pregnant women and <150 µg/L for pregnant women. The odds of women from household using inadequately iodized salt having UIC< 100 µg/L was 1.7 (OR, 1.7; 95%CI, 1.1–2.6) higher compared to those with access to adequately iodized salt. The odds of women from the poorer and the poorest households having UIC< 100 µg/L were 8.6 (OR, 8.6; 95%CI, 2.1–36.7) and 4.3 (OR, 4.3; 95%CI, 1.9–10.0) higher, respectively, compared to women from the wealthiest households.

Discussion

This study is the first to report national representative data on iodine status in Madagascar. It assesses the adequacy of the Madagascar national salt iodization program, over nearly two decades after the promulgation of salt iodization legislation by the Malagasy Government in 1995, which was in line with UNICEF and WHO recommendations for the adoption of USI as the main strategy to eliminate IDD (WHO et al., 2007). Our results are concerning because the median UIC at the national level was 46 µg/L among women of reproductive age, which is indicative of moderate iodine deficiency. The median UIC for the pregnant women (53µg/L) was three-times less than the reference value, which is 150 µg/L.

This denotes an urgent public health problem because it presents a subsequent risk of impaired fetal development (Bath et al., 2013; Bougma, Aboud, Harding, & Marquis, 2013). Our study highlighted that the poor iodine status of Malagasy population is partly explained by the low availability and use of adequately iodized salt at household level. . The proportion of households with WRA using adequately iodized salt was 26.2% (95% CI, 22.1–31.0%), indicating a low coverage of adequately iodized salt in these households.

This national survey on iodine status in Madagascar was conducted 18 years after the introduction of the national USI policy. Our results suggest that the Malagasy population has a moderate iodine deficiency and that three-quarters (76%; 95%CI, 72.4–79.0%) of the population had an UIC <100 μg/L (<150 μg/L for pregnant women). From the IGN network website, it appears that five countries (Mozambique, Ukraine, Samoa, Vanuatu and Madagascar) have updated data on UIC. Of these countries, Madagascar has the lowest median UIC (IGN, 2017). The finding of insufficient iodine intake among 81.6% (95% CI, 71.0–89.0) of pregnant women also has serious implications. A recent study in the United Kingdom found that mild-to-moderate iodine deficiency during pregnancy is associated with an increased risk of sub-optimal scores for the verbal intelligence quotient (IQ) at 8 years of age, and reading accuracy, comprehension, and reading score at 9 years of age (Bath et al., 2013). Additionally, in moderate-to-severely iodine-deficient areas, controlled studies have demonstrated that iodine supplementation before or during early pregnancy generally increase developmental scores in young children by 10–20% (Zimmermann, 2012).

We found that only one-quarter (26.2%) of households with WRA had access to adequately iodized salt, and that the median salt iodine concentration was 10 mg/kg, which is below the recommended level of 15mg/kg National legislation defining the national norms for salt iodization exists in Madagascar. However, our results indicate to that the USI program is not effective and that it needs to be revitalized.

As found in other studies (Ategbo, Sankar, Schultink, van der Haar, & Pandav, 2008; Ghattas et al., 2015; Rohner et al., 2016), the iodine status in Madagascar appears to be partly associated with the salt iodine content at the household level.

Implications for USI program in and beyond Madagascar

The analyses at individual level noted that women from households with inadequately iodized salt and those from poor households are more likely to have an UIC <100 µg/L. The association of UIC with household wealth might be linked to the place where household cooking salt is purchased. We found that the place where salt is purchased differs according to the household wealth index, and 56.8% of those who purchased their salt in grocery stores were from the two wealthiest categories. A higher household wealth index score might represent more diverse food choices. Additionally, we found an inequity in access to adequately iodized salt, with 41% of the wealthiest households having adequately iodized salt vs. 7 % for the poorest households. Other studies associate this inequity to salt availability and affordability (Knowles et al., 2017). Our study showed that there were disparities in salt iodine concentration between strata. Stratum 1 and 2 located respectively in the south and mid-western region, had lower proportion of household with adequately iodized salt (respectively 15.5% and 18%) compared to stratum 3. Stratum 1 and 2 are mainly supplied by medium and small producers with low capacity to iodized salt while stratum 3 is supplied by the large scale salt producer located in the northern part of the country. Our results highlight the importance of assuring the universal coverage of adequately iodized salt in all categories of the population because this might result in much greater equity in iodine status at the population level. In addition, our results call for urgent implementation of a strategy to support medium and small scale producers improve their capacity to increase production of adequately iodized salt. Such strategy may technical assistance with expertise in iodization best practices, building capacity on iodization technology, establishment of a clear quality control mechanism primarily focusing on parameters at the salt production point.

Households' practices such as salt storage method and place of purchase were associated with the presence of adequately iodized salt in the households .We found that salt samples kept in their original packaging had on average less iodine than those kept in covered containers, . Salt stored in its original packaging might be exposed to sunlight, dust, moisture, or heat, which may result in loss of iodine (Kapil, Prakash, & Nayar, 1998; Waszkowiak & Szymandera, 2008). It is important to ensure that good-quality iodized salt is available in retail shops especially grocery stores given that the majority of household gets their salt from those stores.

USI program monitoring

For decades, Madagascar, just like many other countries, relied almost solely on Rapid Test Kit (RTK) results collected through nationwide surveys such as DHS to assess the USI program. In Madagascar, the last DHS (INSTAT, 2010) used RTK and reported 50 % household coverage of adequately iodized salt. Our study indicates that RTK results are not reliable. Therefore, surveys like ours, which include more reliable indicators are required in Madagascar and in other countries to adequately and reliably monitor the USI programs

Study strength and limitations

One of the strengths of this study is that the iodine status was assessed in WRA a more vulnerable group than school aged children usually sampled in USI surveys. In addition, our study included both the impact and monitoring of UIS indicators (WHO et al., 2007), and we were able to assess the association between the quality of household salt and the iodine status of WRA within these households.

Another limitation is that we used the UIC median cut-offs to classify women having UIC< 100 µg/L group. UIC obtained from a single spot measurement is associated with large intra-individual variation, making it unsuitable for use at the individual level (Konig, Andersson, Hotz, Aeberli, & Zimmermann, 2011). However, the use of a large sample size (100 to 500 per subgroups) may compensate for the bias related to the use of only one casual urine sample (Andersen, Karmisholt, Pedersen, & Laurberg, 2008).

During the external quality control, we found a moderate correlation between the UIC measured with the in-country technique and the reference. Similarly, a low concordance was observed for the measurement of the salt iodine concentration. The reference laboratory used a much more sensitive method for the analysis of iodine in salt and this probably contributed to the observed difference. Nevertheless, in all cases, the values are low and the public health decisions were the same.

One of the limitations of this study was that we did not collect salt samples from all households but only from household containing WRA thus our results about salt iodine content are not representative of all households.

Iodine deficiency during pregnancy has detrimental consequences on the fetus. Pregnant women therefore represent the most vulnerable group to iodine deficiency. The number of pregnant women (n = 170) included in our study was less than the minimum required sample size of 300 (WHO et al., 2007). Because of the limited sample size, our results on UIC among pregnant women should be interpreted with caution.

In conclusion, the median UIC in our study suggests that the population in Madagascar faces moderate iodine deficiency, which is linked to a low percentage of households with access to adequately iodized salt as supported by the association between salt iodine adequacy and UIC at individual level. From program standpoint the low proportion of household containing WRA with access to adequately iodized salt indicates that the country has not yet achieved USI and that effort needs to revitalize the program. It is important to ensure the supply of quality iodized salt for all households by developing the regulatory capacity in salt producers. To maintain an effective USI program over the long term, it is important to set up a system that coordinates and monitors the production of a quality iodized salt. Communications should be performed and should be considered as an integral part of the production and the development of regulatory strategies. Communications should be focused on the benefit of consuming iodized salt and the recommended method of salt storage.

Key messages

- The national median UIC was 46 µg/L, indicating a moderate iodine deficiency.
- This moderate iodine deficiency seemed to be linked to a low percentage of households with adequately iodized salt, with only 26% of households with women reproductive age using adequately iodized salt.
- The USI program in Madagascar needs to be revitalized. It is essential to provide adequately iodized salt to prevent severe complications resulting from iodine deficiency in the Malagasy population.

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Table 1. Socio-demographic characteristics and physiological status of women included in the iodine status survey (n=1721)

Characteristics	**n**	**Proportion (%)**[a]	**95% CI** [a]
Strata*			
Stratum 1	559	31.9	28.7-35.0
Stratum 2	569	16.8	14.9-19.0
Stratum 3	593	51.3	47.7-55.0
Physiological status			
Pregnant women	170	10.7	8.5-13.0
Lactating women	438	26.9	23.8-30.0
Non-pregnant non-lactating women	1113	62.4	58.8-66.0
Education level			
No formal schooling	250	19.4	16.6-23.0
Primary schooling	747	51.2	47.6-55.0
Secondary schooling	483	21.0	18.5-24.0
High school level	241	8.4	6.9-10.0
Occupation			
With income-generating activities	1267	82.7	80.2-85.0
No income-generating activities	454	17.3	15.0-20.0

[a], *weighted proportions and 95% CI accounting for sampling design*
**stratum 1 is the stratum with a low proportion of households that had adequately iodized salt; stratum 2 is the stratum with a medium proportion of households with adequately iodized salt; stratum 3 is the stratum with a high proportion of households using adequately iodized salt*

Table 2. Median urinary iodine concentration by strata for each category of Malagasy of women of reproductive age

Strata	n	Median UIC (IQR) in µg/L[a]	p-value*
	Pregnant women n=170		0.039
Stratum 1	51	72 (17–141)	
Stratum 2	57	31 (0–62)	
Stratum 3	62	53 (16–80)	
	Lactating women n= 438		0.017
Stratum 1	161	34 (3–158)	
Stratum 2	145	21 (4–59)	
Stratum 3	132	48 (13–102)	
	Non pregnant non-lactating women n=1113		<0.001
Stratum 1	347	51 (16–87)	
Stratum 2	367	26 (6–58)	
Stratum 3	399	52 (24–116)	

*[a], weighted median; IQR, interquartile range; *, Kruskal-Wallis p-value*

Table 3. Bivariate relationships between median urinary iodine concentrations (UIC) and age, education level, occupation status, and wealth quintiles

		Urinary Iodine Concentration			
		N	Median (µg/L)*	IQR (µg/L)	p **
Age					0.531
	<27 years	889	47	11–115	
	≥ 27 years	832	44	15–85	
Education level					0.060
	No formal schooling	250	52	24–114	
	Primary schooling	747	46	9–109	
	Secondary schooling	483	45	10–78	
	High school level	241	40	14–67	
Occupation status					0.060
	Income-generating activities	1267	54	17–119	
	Non-generating activities	454	56	22–92	
Wealth quintiles					<0.001
	Wealthiest	445	62	25–119	
	Wealthier	484	48	18–85	
	Middle	283	40	7–106	
	Poorer	204	68	29–133	
	Poorest	305	21	1-46	

*IQR, interquartile range; *, weighted median; NS, not statistically significant;**:Kruskal-Wallis or Mann-Whitney Wilcoxon p-value*

Table 4. Bivariate relationships between the prevalence of salt iodization adequacy and wealth quintiles, the strata, the place of purchase, and the variety and the storage method of table salt (n=1140)

		Prevalence of salt iodization adequacy			
		N	Adequately iodized salt[a] (%)	95% CI[b]	p
Strata					<0.001
	Stratum 1	420	15.6	10.6-22.0	
	Stratum 2	408	18.0	14.2-23.0	
	Stratum 3	312	38.1	31.0-46.0	
Wealth quintiles					<0.001
	Wealthiest	311	41.0	32.8-50.0	
	Wealthier	337	22.5	15.8-31.0	
	Middle	162	16.2	10.8-24.0	
	Poorer	131	14.0	7.4-25.0	
	Poorest	199	7.1	4.1-12.0	
Variety of salt used by the household					0.422[c]
	Coarse	902	25.5	21.2-31.0	
	Fine	235	30.3	20.6-42.0	
	Rock	3	0	-	
Storage method					<0.001[d]
	Covered containers	601	33.8	28.0-40.0	
	Original	516	15.3	10.8-21.0	

	packaging				
	Paper	23	0	-	
Place of purchase					<0.001
	Grocery store	1088	28.0	23.6-33.0	
	Other (street vendor, neighbor)	52	3.0	0.8-11.0	

[a], *adequately iodized was defined as containing ≥15 mg/kg of iodine; %, percentages weighted for unequal probability of selection;* [b], *confidence interval, calculated taking into account the complex sampling design;* [c], *Chi-square p-value not taking into account of the category of rock salt;* [d], *Chi-square p-value not taking into account of the category of paper as a storage method for the household salt.*

Table 5. Binary logistic regression analysis for the variables associated with UIC <100 µg/L for non-pregnant women and <150 µg/L for pregnant women. Variables with no statistical significance in the model (p>0.05) were excluded (n=1128).

		N	UIC<100 µg/L** (%)	Crude OR (95% CI)	Adjusted OR* (95% CI)
Household wealth quintiles					
	Wealthiest	311	82.6	1	1
	Wealthier	325	82.1	0.9 (0.6–1.4)	0.9 (0.6–1.4)
	Middle	162	88.9	1.7 (0.9–3.0)	1.8 (1.0–3.2)
	Poorer	131	98.5	13.5 (3.2–56.4)	8.6 (2.1–36.7)
	Poorest	199	96.5	5.7 (2.5–12.9)	4.3 (1.9–10.0)
Access to iodized salt					
	Adequately iodized salt (≥15 mg/kg)	227	79.3	1	1
	Insufficiently iodized salt (<15 mg/kg)	901	98.8	2.3 (1.5–3.4)	1.7 (1.1–2.6)

*OR, odds-ratio; 95% CI, confidence interval at 95%; *, adjusted with strata;**: UIC <100 µg/L for non-pregnant women and <150 µg/L for pregnant women. Covariates used to build the model were age (<27years, ≥ 27 years), adequacy of household salt iodine content (adequately iodized, insufficiently iodized), education level (no formal schooling, primary schooling, secondary schooling, high school level), and household wealth quintiles (poorest, poorer, middle, wealthier, wealthiest).*

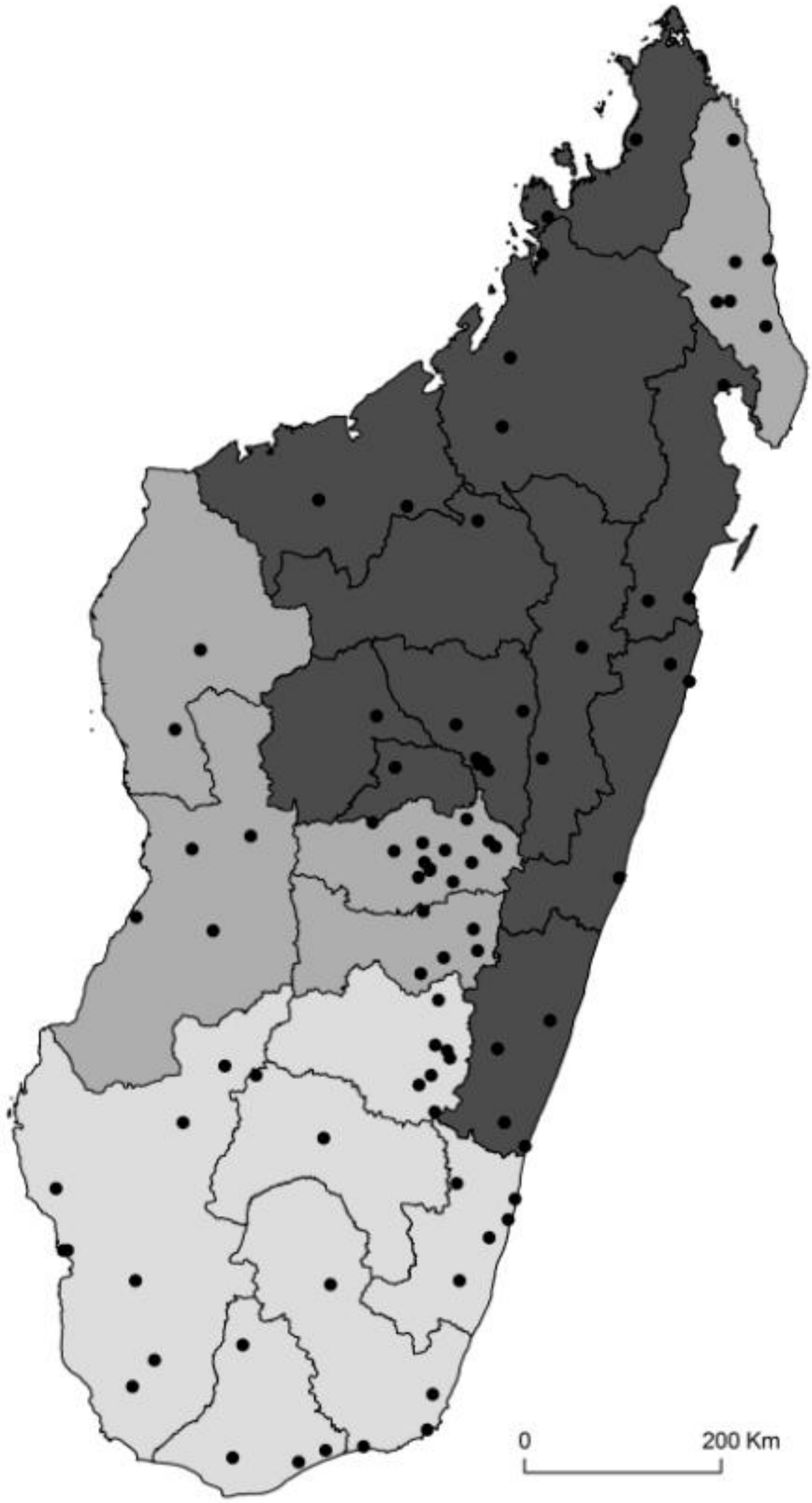
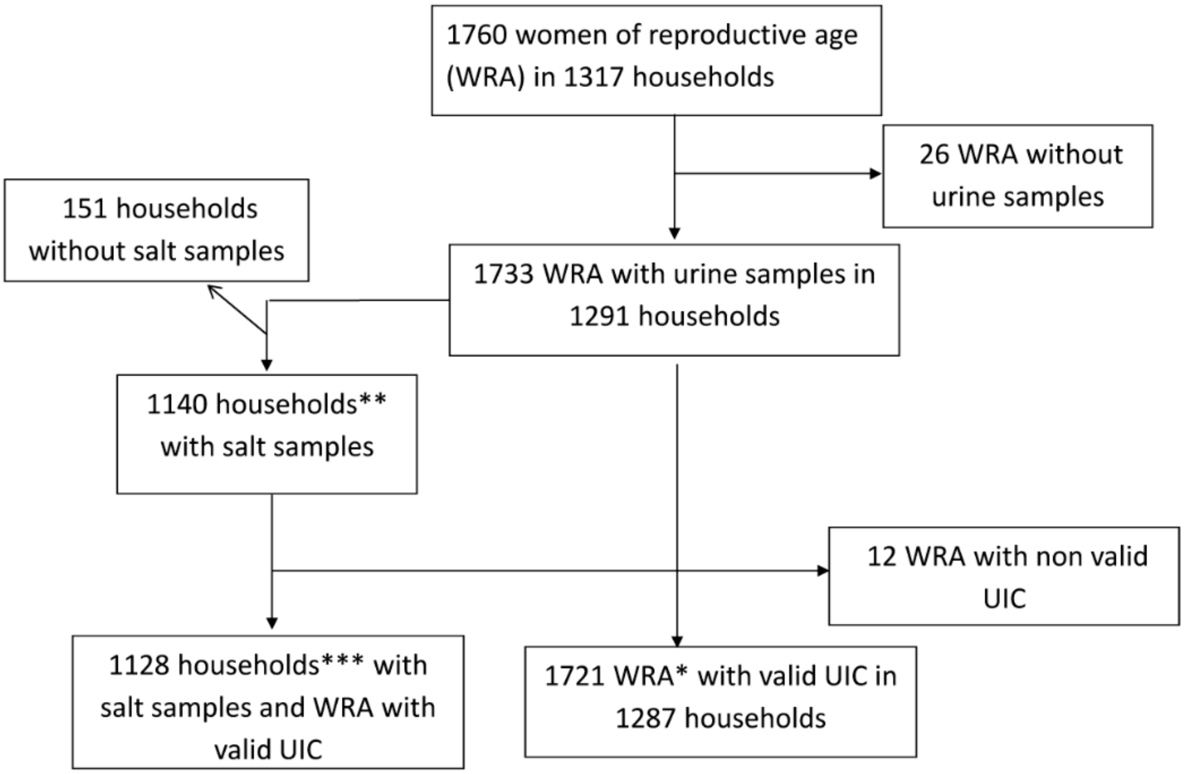


Figure 1. Geographic location of strata and villages included in the national survey of iodine status, Madagascar, 2014



* : assessment of UIC was performed with 1721 WRA
** : analysis of salt iodine content and their characteristics in households containing WRA was performed with data from 1140 households with salt samples
***: analysis of relationship between UIC and adequacy of salt iodine content was performed with data from 1128 households

Figure 2. Flow chart of WRA and households included in the assessment of UIC and salt iodine content