

# Iodine Status of Breastfed Infants and their Mothers after Sixteen Years of Universal Dietary Salt Iodization Program in Dosso, Niger

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**Abstract:** *Introduction:* Universal dietary salt iodization (UDSI) was implemented in Niger in 1996. However, since 2000 there was a slowdown in progress against iodine deficiency.

*Objective:* The objective was to assess iodine nutritional status of infants and their lactating mothers living in Dosso, the state capital of a severe iodine deficiency region in Niger.

*Methods:* The study was centered on 238 full-term infants and their mothers. Some of the data collected were: arm circumference (AC), head circumference (HC) of infant; familial thyroid disease history; the infant feeding method; age of the mother and child; parity, occupation and educational level of the mother.

*Results:* In infants, the urinary iodine concentration (UIC) ranged from 20 to 1600 µg/l with a median of 220 µg/L and 17.23 % had iodine deficiency (UIC<100µg/L). In mothers, the UIC was within 10 and 820 µg/L with a median of 68 µg/L and 69.75 % had iodine deficiency. No significant statistical correlation was found between infant UIC and their age, type of feeding and gender as well as educational level, occupational group, parity and age of their mothers (p>0.05). Spearman's correlation test indicated weak significant correlation between maternal and infant UIC (r = 0,167, p = 0, 01).

*Conclusion:* Iodine status was suboptimal in 70% of mothers and 17% (mild to moderate) of breastfed infants, thus indicating an urgent need to provide iodine supplement for lactating women in Dosso.

**Keywords:** Urinary iodine concentration, infants, lactating women, Iodine nutrition, Niger.

## INTRODUCTION

Iodine is an essential trace element for human health whose deficiency is responsible for various pathologies commonly called iodine deficiency disorders (IDD) [1-4]. The first national survey on IDD conducted in 1994, in schools showed that Niger was among the countries south of Sahara affected by iodine deficiency [5]. This survey was centered on 8933 schoolchildren aged 10-15yrs. The total goiter rate was 35.8%, ranging from 21% in Niamey to 44% at Dosso and Tahoua. Visible goitre was 5.7% and the highest rates were found in Dosso (10%), Tahoua (9%) and Maradi (8%) regions. Urinary iodine from 795 pupils gave a median urinary iodine concentration (UIC) of 34µg/L, ranging from 10 to 940µg/L. About 90% of the pupils tested had UIC below 100µg/L [5]. In 1996, universal dietary salt iodization (UDSI) was adopted by Niger as a strategy for prevention, control, and elimination of iodine deficiency[6]. Thus, the

production, importation, distribution and marketing of dietary iodized salt were made mandatory by an inter-ministerial act in October 1995 which came into force on 1 April 1996 [6]. A system of quality control of dietary iodized salt was introduced, reinforced by devices at the customs offices, distribution channels and sales.

A 1998 survey two years after introduction of iodized salt assessed 944 pupils from 237 primary schools in eight regions of the country. The use of iodized salt led to an increase in iodine content of urine. Thus, the median UIC increased from 34 µg/L in 1994 to 270 µg/L in 1998, with range of 116 to 796 µg/L. The percentage of schoolchildren with normal urinary iodine excretion increased from 10 to 77.3%. The total goiter rate decreased from 35.8% to 20.4% and the visible goiter from 5.7% to 1.4%. The 1998 study obtained 894 dietary salt samples from retailers, and found 64% with iodine content > 25 ppm against 7% before the UDSI program [5, 7]. However, from the year 2000 there was a lack of control of iodized dietary salt quality. According to the second Multiple Indicator Survey, 44% of households were consuming dietary iodized salt in 2000, which indicates a decrease of 20% over 1998 [8]. In 2001 the ThyroMobil visited selected sites; the median UIC was 54

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$\mu\text{g/L}$ , in sharp contrast to the 1998 data [5]. In 2006, of the 1000 dietary salt samples collected from retailers in the eight regions of Niger, 78.7% had iodine content below 25 ppm [9, 10]. In 2010, 229 samples of imported dietary salt were collected at the customs office at the entrance of the Niamey urban community; 67.2% had iodine content below 30 ppm and 52.4% had iodine content of less than 15 ppm [11]. During the same survey, 250 samples were collected from retailers, 98.2% had iodine content below 30 ppm and 87.6% had iodine content less than 15 ppm [11]. The same year, 32.6% of infants consulted in the Niamey Urban Community primary health centres had UIC below 100  $\mu\text{g/L}$  [12].

Above observations thus confirm a slowdown in progress against iodine deficiency in Niger since the good results of 1998. It is therefore urgent to assess the impact of reducing the coverage of iodized salt on people's health at least for vulnerable groups. Indeed, data from several countries indicated that lack of a well monitored dietary salt iodization (DSI) program is accompanied by recurrence of iodine deficiency [13]. The aim of our study was to assess iodine status of mothers and their infants in a context where national controls are not effective at ensuring universal availability of adequate dietary iodized salt. The study was conducted in Dosso town because this region is one of the most affected by IDD [5]; it is also bounded by two international borders that make it even more difficult to control the importation, distribution and marketing of iodized salt. This study was centred on neonates and infants aged 1-17 months and their lactating mothers because up till today no data were available on these groups whereas this period is still critical for brain damage resulting from iodine deficiency. Moreover, for infants under six months of age, breast milk is the major source of iodine for thyroid hormones biosynthesis, followed by infant fortified iodine formula [14-16].

## SUBJECTS AND METHODS

This cross-sectional study took place in the three Integrated Health Centers (IHC) of the state capital of Dosso in Niger. The study was centered on 238 full-term infants and their lactating mothers seen in infant consultation in the three (IHC). Participation in the study was voluntary and exclusion criteria were: refusal of the mother to participate in the study, children who were not breast-fed, children who have not been brought by their mothers, children whose urine could not be collected, children exposed to disinfectants, antiseptics or contrast agents containing iodine. The protocol is in accordance with the Helsinki Declaration of 1975 as revised in 2008 and informed consent was obtained from each participant recruited. The study was endorsed by the National Ethics Committee and the

Academic Scientific Council of Abdou Moumouni University. Some of the data collected were: age, gender, arm circumference (AC), head circumference (HC), the infant feeding method, family history of thyroid disease, parity, maternal occupational group and level of education (not enrolled, primary, secondary + higher).

The ratio AC/HC assessed the nutritional status of children between one month and 5 years [17]. The measurement of urinary iodine concentrations (UIC) was used as a criterion for the assessment of nutritional status in iodine. Casual urine samples were used for assessment of UIC [1]. The urine samples were analysed using the method of Wawschinek as modified by Dunn *et al* [18]. The statistical analysis was carried out using SPSS 17.0 program (Chicago, IL, USA). Kholmogorov-Smirnov test was used to assess normality of UIC. Mann-Whitney U test was used for differences between two groups; Kruskal-Wallis were used for comparison of all groups.  $P < 0.05$  was considered significant.

## RESULTS

The 238 infants were aged 1-17 months (mean  $\pm$  SD:  $5.97 \pm 3.36$  months) out of which 124 (52.10%) were less than 6 months. One hundred and twenty five infants (52.52%) were male and one hundred and thirteen infants were female (47.48%). One hundred and twenty three infants (51.68%) were exclusively breastfed and one hundred and fifteen infants (48.32%) mixed-fed. The 238 mothers were aged 16 to 53 years (mean  $\pm$  SD  $27.95 \pm 7.05$  years). Forty two (17.65%) mothers were aged between 16 and 20, fifty six (23.53%) between 21 and 25, sixty-seven (28.15%) between 26 and 30 and seventy-three (30, 67%) aged over 30 years. One hundred and forty two (59.66%) mothers were not enrolled, fifty seven (23.95%) had a primary level of education and thirty nine (16.39%) a secondary or higher education. Two hundred and six (86.55%) mothers were housewives and thirty two (13.45%) had an income generating activity (teachers, retailers resellers, cashiers, tailors).

The Nutritional status of infants according to AC/HC ratio expressed in Table 1 showed that malnutrition was a major public health problem in these infants. About 60% of them suffered from mild to moderate malnutrition and 1.2% was severely malnourished. No significant relationship was found between iodine status and AC/HC ratio ( $P = 0.08$ ).

The median UIC of the infants was 220  $\mu\text{g/L}$  which is higher than the median UIC criterion ( $\geq 100 \mu\text{g/L}$ ) recommended by WHO/UNICEF/ ICCIDD [1]. The percentage of children with UIC below 50  $\mu\text{g/L}$  was far lower than the 20% tolerated in a given population and no child suffered

**Table 1. Nutritional Status of Infants According to AC/HC Ratio**

AC/HC Ratio	Nutritional Status	Percent (n) of Infants
< 0.25	Severe	1.26% (3)
0.25-0.28	Moderate	15.55% (37)
0.29-0.31	Mild	44.12% (105)
> 0.31	Normal	39,07% (93)

**Table 2. Urinary Iodine Concentration (UIC) and Percent below Cut-off Points that Indicated Suboptimal Status of Iodine Nutrition for All Infants and their Lactating Mothers**

Parameters	All Infants	All Lactating Mothers
N	238	238
Mean Age (Month / year)	5.97 ± 3.36	27.95 ± 7.05
Median UIC (µg/L)	220	68
20 <sup>th</sup> Percentile UIC (µg/L)	107.20	40
Percent with UIC UIC < 50 µg/L	3.78 (9)	36.13% (86)
Percent with UIC UIC < 100 µg/L	17.23 (41)	69.75% (166)
Percent with UIC UIC < 150 µg/L	34.03 (81)	83.19% (198)

Figures in parentheses are the number of infants or lactating mothers

**Table 3. Distribution (Percent) of Urinary Iodine Concentration (UIC) of All Infants and Lactating Mothers According to Range of UIC and Status of Iodine Nutrition**

Rang UIC (µg/L)	Status of Iodine Nutrition	All Infants	All Lactating Mothers
< 20	Severe	0	2.10% (5)
20-49	Moderate	3,78 (9)	34.03% (81)
50-99	Mild	13,45 (32)	33.61% (80)
100-199	Normal	27,73 (66)	18.91% (45)
200-299	Risk of IIH*	15,55 (37)	7.98% (19)
>300	Risk of IIH*	39,50 (94)	3.36% (8)

\* IIH: Iodine-Induced Hyperthyroidism

Figures in parentheses are the number of infants or lactating mothers

from severe deficiency (Table 2 and 3). However mild to moderate Iodine deficiency still affected 17% of the children (Table 2).

Median UIC of the lactating mothers (68 µg/L) was below the 100 µg/L defined as optimal [1]. About 70% of the lactating mothers had mild to moderate iodine deficiency and two 2% had severe iodine deficiency (Table 2 and 3). In addition, the percent of lactating mothers with UIC less than 100 µg/L was four times higher compared to their infants.

The Kholmogorov-Smirnov test indicated that the UIC were not normally distributed. No relationship was found between infant nutritional iodine status and age ( $p = 0.135$ ), type of feeding ( $p = 0.624$ ) and gender ( $P = 0.232$ ) of the infants as well as educational level ( $p = 0.274$ ), occupational group ( $p = 0.684$ ), parity ( $p = 0.663$ ) and age ( $p = 0.163$ ) of the mothers. On the other hand significant relationship was found between maternal iodine status and their school level ( $p = 0,006$ ) and the infant age ( $p = 0,008$ ). Spearman's correlation test indicated very weak ( $r = 0,167$ ,  $p = 0, 01$ ) significant correlation between the UIC in lactating mothers and their infants.

The lactating mothers and their infants were grouped according to the infant feeding method: exclusive breastfeeding and breastfeeding mixed with baby foods / locally prepared gruels. Four sub-groups were constituted: exclusively breastfed Infants (EBF-Infants), mixed-fed-Infants (MF-Infants), exclusively breastfeeding mothers (EBF-Mothers) and mixed-feeding mothers (MF- Mothers). The mean age of

EBF-Infants was  $3.63 \pm 1.46$  months and the median age was 3 months. The mean age of MF-Infants was  $8.49 \pm 2.99$  months and the median age was 8 months. The EBF-Infants were significantly younger ( $p=0,000$ ) than the MF-Infants.

The UIC and iodine nutrition status for EBF-Infants and MF-Infants are presented in Tables 4 and 5. Percent of MF-Infants with UIC below the cut-off points for optimal status of iodine nutrition was relatively lower compared to that of EBF-Infants, but no difference was observed in their median UIC.

Approximately two thirds of MF-Mothers and three quarters of EBF-Mothers were deficient in iodine. Severe iodine deficiency was observed in 4% EBF-Mothers. The Spearman's correlation test indicated weak ( $p = 0,032$ ,  $r = 0,194$ ) significant linear relationship between the UIC of EBF-Infants and EBF-Mothers. A weak non-significant linear relationship ( $r = 0,145$ ,  $p = 0,125$ ) was found between the UIC of the MF-Infants and MF-Mothers.

## DISCUSSION

According to WHO, for lactating women and children <2 years of age a median UIC of 100 µg/l can be used to define adequate iodine intake, but no other categories of iodine intake are defined [1,19]. In the present study, the median UIC of the breastfed infants was higher than the recommended adequate minimum UIC of 100 µg/L. In addition, less than 5% of the infants had UIC below 50 µg/L

**Table 4. Urinary Iodine Concentration (UIC) and Percent below Cut-off Points that Indicated Suboptimal Status of Iodine Nutrition Status for Exclusively Breastfed Infants (EBF-Infants), Mixed-fed-Infants (MF-Infants), Exclusively Breastfeeding Mothers-(EBF-Mothers) and Mixed-feeding Mothers (MF- Mothers)**

Parameters	EBF-Infants	MF-Infants	EBF-Mothers	MF-Mothers
N	123	115	123	115
Mean age (Month/year)	3.63 ± 1.46	8.49 ± 2.98	27.22 ± 6.25	28.72 ± 7.69
Median UIC (µg/L)	220	220	60	68
20 <sup>th</sup> Percentile UIC (µg/L)	100	120	40	40
Percent with UIC: < 50 µg/L	2.44 (3)	5.22 (6)	36.58 (45)	36.65 % (41)
Percent with UIC: < 100 µg/L	18.70 (23)	15.65 (18)	76.42 (94)	63.61 % (72)
Percent with UIC: < 150 µg/L	39.58 (45)	31.30 (36)	87.80 (108)	78.26% (90)

Figures in parentheses are the number of infants or lactating mothers

**Table 5. Distribution (Percent) of Urinary Iodine Concentration (UIC) of Exclusively Breastfed-infants (EBF-Infants), Mixed-Fed-infants (MF-Infants), Exclusively Breastfeeding-mothers (EBF-Mothers), Mixed-feeding-Mothers (MF-Mothers) According to Range of UIC and Status of Iodine Nutrition**

Rang UIC (µg/L)	Status of Iodine Nutrition	EBF-Infants (N = 123)	MF-Infants (N = 115)	EBF-Mothers (N = 123)	MF-Mothers (N = 115)
< 20	Severe	0	0	4,07 (5)	0
20-49	Moderate	2.44 (3)	5.22 (6)	32.52 (40)	35.65% (41)
50-99	Mild	16.26 (20)	10.43 (12)	39.84 (49)	26.96% (31)
100-199	Normal	28.46 (35)	26.96 (31)	14.63 (18)	23.48% (27)
200-299	Risk of IHH*	13.00 (16)	18.26 (21)	5.69 (7)	10.43% (12)
>300	Risk of IHH*	39.84 (49)	39.13 (45)	3.25 (4)	3.48% (4)

\* IHH: Iodine-Induced Hyperthyroidism

Figures in parentheses are the number of infants or lactating mothers

and severe iodine deficiency (UIC <20 mcg/L) was not observed in any age group. This, according to the WHO/UNICEF/ICCIDD criteria indicated an optimal status of iodine nutrition [1].

The median UIC (220 µg/L) observed in this study for all breastfed infants was higher than values reported for infants in iodine sufficient population in other countries, for example, in France, in Italy and in New Zealand [15,17,20, 21]. In addition, the prevalence of mild to moderate iodine deficiency was, in general, lower than the values reported in the countries mentioned above. Niger adopted the Universal Dietary Salt Iodization (USI) program in 1996. However, our results seem suboptimal when we compared them with observations reported in some areas where the USI strategy was also implemented for example in China Iran and in Papua New Guinea [22-26]. In the present study, mild to moderate iodine deficiency still persisted at 17, 23% of infants aged 1 to 17 months. When we considered the new cut-off point [13], 34% of all the infants had UIC below 150 µg/L which indicated suboptimal status of iodine nutrition. This should be a concern, because up to the age of two years, the brain of the infant is vulnerable to suboptimal intake of iodine, which may cause sub clinical iodine deficiency and thus have a devastating effect on child intelligence [1,14].

The median UIC (68 µg/L) for breastfeeding mothers observed here was far lower than the recommended minimum adequate UIC of 100 µg/L and the prevalence of moderate to severe status of iodine nutrition (36.14%) was higher than the 20% tolerated in a given population, indicating inadequate intake of dietary iodine [1]. When we considered the new cut-off point, 83% of all lactating mothers had UIC below 150 µg/L; indicated that iodine deficiency was of public health significance in this population. Thus, despite the universal dietary salt iodization, breastfeeding women in our sample appeared more vulnerable on iodine nutrition status. The higher prevalence of suboptimal status of iodine nutrition among lactating mothers should be a concern, because of the association between sub clinical iodine deficiency in lactating mothers and the potential risk of abnormal brain development in breast-fed infants [27-30].

The median UIC observed in the present study for EBF-Infants and MF-Infants was 220 µg/L. This finding was different from that reported by Temple *et al* [23] whose reported median UIC for breast-fed infants was lower than that of mixed-fed and from that of Zhang *et al* [31] who, contrary, reported that the UIC of breast-fed infants was higher than that of mixed-fed although the difference was not statistically significant. Less than 20% of EBF-Infants and

MF-Infants had UIC below 100 µg/L. However using the new cut-off point, the UIC in 40% of EBF-Infants was below 150 µg/L compared to 31% in MF-Infants. Iodine deficiency must be considered as a major public health problem in these infants. The lower UIC in lactating women may partly be due to the loss of iodine in breast milk [1,14]. In addition, Dosso is a region bounded by two international borders making it difficult to control the importation, distribution and marketing of iodized salt. As we know customary taboo in the region prevents salt intake during pregnancy most especially when pregnant women's feet begin to swell but we do not have such information on lactating mothers.

Iodine deficiency had multiple adverse effects on growth and development in humans. Thyroid hormones are important for growth and development especially for the brain during the fetal period and the first year of life. Hence, it is important to ensure that the diet of lactating mothers contains adequate amounts of iodine knowing that maternal milk is the sole source of iodine for EBF-infants thyroid hormones formation whereas in MF-infants food intake could be a supplementary source of iodine [14].

The median UIC for EBF-Mothers was relatively lower than the median UIC of MF-Mothers. In addition 64% of MF-Mothers and 76% of EBF-Mothers had UIC below the cut-off points for optimal iodine status of 100 µg/L and severe iodine deficiency was observed in 4% of EBF-Mothers. However using the new cut-off point [13] 88% of EBF-Mothers and 78% of MF-Mothers had UIC below 150 µg/L. This indicated suboptimal status of iodine nutrition in both groups, with greater severity amongst the EBF-Mothers. The exacerbation of iodine deficiency observed among EBF-Mothers compared to MF-Mothers might be related to iodine excretion in milk [22]. Our results strongly indicated that iodine deficiency was a significant public health problem in lactating mothers. An adequate dietary intake of iodine was needed during lactation not only to provide for breast-fed infants but also for maintaining the metabolic status of the mothers [1,14,16,32].

Tables 3 and 5 showed the percent of infants and lactating mothers at risk of iodine-induced hyperthyroidism (IH). Most individuals can tolerate relatively high intake of iodine without any obvious adverse effect [1,14,33]. However, excessive daily iodine intake (over 1000.0 µg per day) may be potentially harmful to susceptible individuals [1,14,23,33-35].

The Kholmogorov-Smirnov test indicated that the UIC were not normally distributed, thus non parametric tests were used to analyse the data. No significant relationship ( $p > 0.05$ ) was found between infant nutritional iodine status and age, type of feeding, and gender of the infants as well as educational level, occupational group, parity and age of the mother. This confirmed previous observations reported from France [16]. However significant relationship was found between maternal iodine status and their educational level and the infant age ( $p < 0.05$ ). Spearman's correlation test indicated weak ( $r = 0.167$ ,  $p = 0.01$ ) significant correlation between the UIC in lactating mothers and their infants. Also weak significant correlation ( $r = 0.194$ ,  $p = 0.032$ ) was observed between the UIC of EBF-Infants and EBF-Mothers. The correlation was weak and non-significant ( $r =$

0.145,  $p = 0.125$ ) between the UIC of the MF-Infants and MF-Mothers. Ours results are different from those of others that reported a weak and non significant correlation and a weak non significant negative correlation between the UIC of the EBF-Infants and EBF-Mothers and the UIC of the MF-Infants and MF-Mothers respectively [23].

## CONCLUSION

The median UIC for the infants was above the 100 µg/L recommended cut-off point and 82.77 per cent had adequate iodine status of but mild to moderate iodine deficiency still existed in 17.23% of them. The prevalence of iodine deficiency was exacerbated (34.03%) when the new cut-off point of 150 µg/L was considered. Iodine deficiency was a significant public health problem among lactating mothers as their median UIC value was below the range of optimal iodine status. In addition, only 30 percent of them had adequate iodine status and less than 17% when the new cut-off point of 150 µg/L was considered. Iodine deficiency was more severe in EBF-mothers compare to MF-mothers. Our results strongly suggested an urgent need to provide iodine supplement to lactating women in Dosso, Niger.

## DECLARATION OF INTEREST

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

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## CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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