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Factors associated with the consumption of table salt with inadequate iodine concentrations: a population analysis at a Peruvian household level

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Abstract

Objective: Iodine deficiency is a public health problem, especially in Peru, where it affects women of childbearing age and school-age children. The objective of the study was to conduct a household-level analysis of the factors associated with the consumption of table salt with inadequate amounts of iodine in Peru.
Design: Analytical cross-sectional study using Peruvian household-level data from the Demographic and Family Health Survey. Table salt iodine concentrations were considered as the dependent variable ('inadequate' with iodine levels <30 PPM and 'adequate' with levels ≥30 PPM). The association between iodine concentrations in salt and independent variables was evaluated using crude and adjusted log-binomial regression models.
Setting: Peru.
Participants: A total of 25 007 households were included.
Results: In Peru, 21·8 % households had inadequate table salt iodine concentrations. Belonging to the poorer and poorest wealth index, living in the Highlands natural region, and living with women of childbearing age with native mother tongue were identified as factors associated with inadequate iodine concentrations in table salt.
Conclusions: There is an urgent need to ensure that table salt with adequate iodine concentrations is available for poor populations, residents of the Highlands and households with ethnic presence. Likewise, it is necessary to promote good storage practices, greater regulation/law enforcement and better monitoring of the companies that manufacture or sell this product. Furthermore, the population needs to be informed of the disorders associated with iodine deficiency.

Keywords
Dietary
Iodine
Table salt
Health surveys
Cross-sectional studies
Peru (MeSH, NLM)

Iodine is an essential micronutrient for the production of thyroid hormones, which act on organ metabolism, growth and brain development[1]. Iodine deficiency in children, women of childbearing age and pregnant women can lead to the development of goitre, infertility, increased risk of thyroid cancer and cretinism[1–3]. In 2011, more than 240 million school-age children had poor iodine consumption globally (13·7 % in Latin America)[4]. In Peru, there are also areas where more than 10 % of school-age children suffers from goitre due to iodine deficiency. Although there are currently no national studies on the prevalence of diseases caused by insufficient consumption of this micronutrient, some studies point to a sustained reduction and elimination of these diseases across Peru[5].

One of the most cost-effective public health strategies to ensure adequate iodine consumption in the diet is the iodination of the salt used in food preparation. Some estimates indicate that salt iodisation would generate an annual expenditure of $500 million in low- and middle-income countries; however, the treatment of iodine-deficiency disorders can cost more than $35 billion in these countries[6]. As a result, the WHO promotes the use of iodised salt and recommends that the amount of iodine in human salt should be at least 20–40 mg/kg to provide a preventive

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effect against the development of diseases due to deficiency of this micronutrient[7]. In Peru, Decree-law N°. 17387 of 1969 declared the mandatory fortification of salt with iodine[8], and the Ministry of Health (MINSA in Spanish) established adequate iodine levels in salt as being from 30 to 40 mg/kg[9].

Following the implementation of iodised salt consumption measures in Peru, some studies have reported that both iodine consumption and household iodised salt composition could be influenced by socio-demographic characteristics at a household level. Taking women and schoolchildren as a unit of analysis, evaluations in Peruvian subpopulations report that the level of ioduria in this population is adequate according to the figures recommended by the WHO[10]. However, the lowest median of ioduria was identified in rural populations and in provinces in the Highlands and Amazon regions. In addition, it has been reported that some salt brands marketed in these regions in Peru have lower iodine values than those recommended by the WHO and Peruvian law[11,12]. In addition, in 2008 the proportion of households with iodine-deficient consumption was reported as being higher in the rural Highlands and Amazon of Peru (20 % of households with poor iodine consumption) compared to urban areas of the coast and the mountains (less than 10 % of households with poor iodine consumption)[13]. In this sense, it is essential to have up-to-date information on the use of salt with adequate iodine levels as well as the characteristics that influence the availability of this product at a national household level.

With the use of the Demographic and Family Health Survey (ENDES in Spanish), the National Institute of Statistics and Informatics of Peru (INEI in Spanish) collects information on demographic, health and basic characteristics of the households surveyed as well as quantified information on the level of iodine in table salt used in these households. Therefore, the objective of this study was to perform a household-level analysis of the factors associated with the consumption of table salt with inadequate amounts of iodine in Peru, using the ENDES 2019 database.

Methods

An analytical cross-sectional study using ENDES 2019 data was carried out. ENDES is a Peruvian survey with representativeness at the national level, by urban–rural area and the 25 departments of the Peruvian territory. Since 1986, INEI has been performing ENDES based on the design of the Demographic and Health Surveys (DHS). This survey collects information by applying three questionnaires related to household, individual and health. Since 2000, ENDES has been collecting information about salt iodisation at the household level. The survey sampling design is two-staged, probabilistic of balanced type, stratified and independent. The first stage is the selection of conglomerates and the second stage is the selection of homes. Data collection information, details of sampling, and data processing can be found in the survey report[14].

Study variables

The availability of iodine in table salt for human consumption depends on several factors such as iodination of salt, distribution of the amount of iodine in individual salt packages, and environmental and preservation conditions[15,16]. However, the ENDES only provides information on inadequate iodine concentrations measured in table salt consumed in households. In this way, the iodine test in cooking salt was performed using the Ioditest kit which is widely used in Peru for qualitative testing of the presence of iodine[17]. The salt sample and the iodine test were performed by previously trained interviewers in each of the selected dwellings. After the salt has been placed in a container and mixed with the Ioditest, the level of iodine is determined by changes in coloration as white or without colouring, light purple, blue or purple, and dark purple corresponding to the iodine levels of 0 parts per million (PPM), 7 PPM, 15 PPM, and more than 30 PPM, respectively[18]. For analysis, the variable was coded as 'inadequate' with iodine levels of less than 30 PPM and 'adequate' with iodine levels of greater than or equal to 30 PPM.

Based on the literature on the subject[11,19,20], we considered as independent variables the sex (male/female) and educational level (until primary, secondary, higher) of the head of the household, the ethnicity of any women in the household (considered as 'yes' when at least one woman of childbearing age living in the household had a native mother tongue and 'no' when no woman in the home spoke a native language), overcrowding (considered as 'yes' when a household was composed of more than three people per bedroom and 'no' when it was composed up to three), presence of pregnant women in the home (yes/no) and the number of children under 5 years of age at home (none, one, two or more). Characteristics such as area of residence (urban/rural), natural regions (coast/highlands/amazon) and wealth index quintile (quintile 1 (poorest), quintile 2 (poor), quintile 3 (medium), quintile 4 (richer), and quintile 5 (richest)) were also included in the analysis.

Data analysis

The households surveyed with complete data on measurements of the level of iodine in salt and independent variables of interest were included in the analysis. Using the *svy* command, complex sampling of the survey and weighting factors were taken into account. Absolute frequencies and weighted proportions were reported for all study variables. Associations between the variable presence of iodine in salt and independent variables were also evaluated using a log-binomial regression models. First, crude analysis was performed. An adjusted analysis was then performed between

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the dependent variable and the variables that resulted in a $P < 0{\cdot}20$ in the crude analysis. Finally, the prevalence ratio (PR) and adjusted PR (aPR) were estimated with their 95 % CIs, respectively. The statistical analyses were performed using Stata 14 (StataCorp.). For all the analyses, a *P*-value <0·05 was considered as statistically significant.

Ethics

Approval of the study was not requested by an ethics committee as it was an analysis of secondary data that are freely accessible and available in a public domain that does not allow to identify respondents (http://iinei.inei.gob.pe/microdatos/).

Results

A total of 25 007 households were included. Regarding the characteristics of the head of household, 71·8 % was men and 42·7 % had a secondary education. In terms of household characteristics, 6·3 % of the households surveyed had at least one woman of childbearing age with a native mother tongue and 79·1 % belonged to urban areas. Only 15·1 % of the households was overcrowded. Most also had only one child under the age of 5 years (35·0 %), and 4·3 % had at least one pregnant woman in the household. The largest proportion of households were in the coastal region (59·9 %) and were ranked in the second quintile of wealth (21·5 %). Likewise, in relation to the iodine levels in the table salt, it was found that 78·2 % of households had adequate iodine levels in the salt; while in households with inadequate iodine levels, 12·8 % had a level of 15 PPM, 4·6 % had 7 PPM and 4·3 % had 0 PPM (Table 1).

A total of 21·8 % (95 % CI 20·7, 22·9) of Peruvian households had inadequate table salt iodine content. Most of these households had a female head of household (22·4 %), and 24·9 % had up to primary education compared to the Peruvian households with adequate table salt iodine content, in which 78·5 % had a male head of household and 80·5 % had a higher education. Regarding ethnicity, 40·5 % of households with inadequate salt iodine content had a woman with a native mother tongue compared to 59·5 % in the group of households with adequate salt iodine levels. Likewise, 23·3 % of Peruvian households with inadequate salt iodine content had at least one pregnant woman and 22·1 % had at least one child under the age of 5 compared to 76·7 % and 77·9 % of households with adequate salt iodine levels, respectively (Table 2).

In relation to household characteristics, the highest proportion of households with adequate salt iodine concentrations was found in urban areas (80·6 %) and in the coastal region (82·3 %), while in rural areas and in the Highlands' natural region, salt with inadequate iodine content was found in 30·6 % and 32·3 %, respectively. In relation to the wealth index, the highest proportion of salt composition with adequate iodine concentrations was observed in households in quintile 4 (83·5 %), while the highest proportion of households with inadequate salt iodine concentrations corresponded to quintile 1 (poorest) (31·3 %) (Table 2).

Households with a woman of childbearing age with a native mother tongue more often had table salt with inadequate iodine concentrations (aRP 1·33; 95 % CI 1·20, 1·48). Regarding the characteristics of the home, it was found that the homes located in the regions of the Highlands (aRP 1·47; 95 % CI 1·30, 1·66) had a higher frequency of inadequate iodine concentrations in salt compared to the coast region. According to the household welfare quintile, quintile 1 (aRP 1·45: 95 % CI 1·16, 1·81) and quintile 2 (aRP 1·32; 95 % CI 1·08, 1·61) showed a higher frequency of having inadequate salt iodine concentrations (Table 3).

Discussion

This study conducted an analysis of the factors associated with the consumption of inadequate concentrations of iodine in table salt in Peruvian households. It was found that 28·1 % of households used table salt with inadequate iodine concentrations. Regarding the associated factors, the households of the poorest quintiles located in the natural regions of the Highlands and with a woman of childbearing age with a native mother tongue were associated with inadequate iodine concentrations in table salt. According to the Decree-law Nº. 17387[8] in Peru, it is mandatory for table salt for human consumption to contain 30–40 PPM of iodine to ensure adequate concentration of this micronutrient. Taking this into account, the present study considered table salt with a value of 30 PPM or greater to have adequate iodine concentrations. Despite the mandate that salt-producing plants must comply with this decree, our results suggest that a considerable percentage of the salt for human consumption sold to the population contains inadequate amounts of this micronutrient, and that living in the Peruvian Highlands, as well as in poverty increase the probability of possessing this type of table salt. The reasons behind these results may be related to the amount of iodine added to salt during iodisation, inadequate distribution of iodine in individual salt bags and loss of iodine due to environmental conditions and inadequate preservation which may occur in the poorest areas of the Peruvian Highland[15,16]. Therefore, adequate regulation of compliance with Decree No. 17387 is needed in salt-producing plants in order to ensure that they comply with the health and production standards and obtain optimal iodine concentrations in table salt.

Inadequate concentrations of iodine in table salt were more frequent in households belonging to the lower welfare quintiles compared to the wealthiest quintiles. This is consistent with the results of previous studies in low- and

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Table 1 Characteristics of the households included in the study (*n* 25 007)

Characteristics	*n*	Weighted %†	95 % CI
Area of residence			
Urban	17 287	79·1	78·4, 79·7
Rural	7720	20·9	20·3, 21·6
Natural regions			
Coast	10 314	59·5	58·3, 60·6
Highlands	8591	26·4	25·3, 27·6
Amazon	6102	14·1	13·3, 14·9
Wealth index			
Quintile 5 (richest)	2718	18·6	17·4, 19·7
Quintile 4	3698	19·2	18·2, 20·3
Quintile 3	4913	21·1	20·1, 22·1
Quintile 2	6615	21·5	20·6, 22·6
Quintile 1 (poorest)	7063	19·6	18·8, 20·3
Overcrowding			
No	19 599	84·9	84·2, 85·6
Yes	5408	15·1	14·4, 15·8
Sex of the head of the household			
Male	18 717	71·8	70·7, 72·9
Female	6290	28·2	27·1, 29·3
Educational level of the head of the household			
Until primary	6905	24·9	24·0, 25·8
Secondary	10 958	42·7	41·6, 43·9
Higher	7144	32·4	31·2, 33·6
Ethnicity of any women at household			
No	22 446	93·7	93·2, 94·2
Yes	2561	6·3	5·8, 6·8
Number of children under 5 years of age at household			
None	6512	56·8	55·9, 57·8
One	14 277	35	34·1, 35·9
Two or more	4218	8·2	7·9, 8·5
Presence of pregnant women			
No	23 936	95·7	95·2, 96·1
Yes	1071	4·3	3·9, 4·8
Households by iodine level* in the table salt			
Adequate	19 472	78·2	77·1, 79·3
Inadequate			
15 PPM	3276	12·8	11·9, 13·7
7 PPM	1186	4·6	4·1, 5·2
0 PPM	1073	4·3	3·9, 4·8

*By Ioditest.
†Estimates include the weights and ENDES sample specifications.

middle-income countries, in which salt consumption with adequate iodine concentrations was found in households belonging to the highest wealth quintile compared to poorer households[21–23]. Similarly, a study in pregnant women in Tanzania reported that the poorest households were associated with a higher prevalence of iodine deficiency[24]. In addition, Muktar *et al.* reported that the poorest households in Ethiopia were associated with iodine deficiency in school children[25]. In Peru, Tarqui-Mamani *et al.* found that households with extreme poverty and poverty had the highest consumption of salt with inadequate iodine concentrations[11]. Thus, in households with the greatest economic disadvantages, the possession of iodised salt is low, leading the WHO to recommend food-grade salt iodisation as a strategy for the prevention and control of iodine deficiency and prioritising equitable access to this product in all age groups[26].

Households located in the natural region of the Highlands were also found to be associated with the consumption of inadequate iodine concentrations in salt. A study conducted in the Peruvian territory in 2008 reported that the natural regions of the rural Highlands and Amazon had the lowest consumption of salt with iodine concentrations of 15 PPM, with the highest consumption being described in the Peruvian capital, Metropolitan Lima[13]. This pattern of lower iodine concentrations and consumption of iodised salt in these regions still persisted in 2019 and may be due to the problems related to accessibility to this product, inadequate storage practices and poor regulation in the region of the Highlands, in addition to greater rural territory, higher proportions of poverty and high rates of inadequate regulation enforcement. In this regard, it has been reported that destabilisation of iodine levels in salt may be associated with wet conditions and increased temperature in storage[27]. This could be relevant in the Highlands region, as this region is characterised by its climatic variability (average relative humidity of 54·3 % and maximum temperature of 25°C)[28], which could influence the quality and concentrations of iodine in salt for human consumption under inappropriate storage conditions. On

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Table 2 Sample distribution of households by iodine level in the table salt, ENDES 2019†

	Iodine level in the salt				
	Adequate		Inadequate		
Characteristics	OR	95 % CI	OR	95 % CI	*P* value*
Area of residence					
Urban	80·6	79·3, 81·9	19·4	18·1, 20·7	<0·001
Rural	69·4	67·6, 71·1	30·6	28·9, 32·4	
Natural regions					
Coast	82·3	80·6, 83·9	17·7	16·1, 19·4	<0·001
Highlands	67·7	65·9, 69·5	32·3	30·5, 34·1	
Amazon	80·8	78·9, 82·6	19·2	17·4, 21·1	
Wealth index					
Quintile 5 (richest)	82·8	79·5, 85·6	17·2	14·4, 20·5	<0·001
Quintile 4	83·5	81·1, 85·7	16·5	14·3, 18·9	
Quintile 3	80·4	78·2, 82·4	19·6	17·6, 21·8	
Quintile 2	76·2	74·3, 78·1	23·8	21·9, 25·7	
Quintile 1 (poorest)	68·7	66·8, 70·5	31·3	29·5, 33·2	
Overcrowding					
No	78·5	77·3, 79·7	21·5	20·3, 22·7	0·150
Yes	76·9	74·9, 78·8	23·1	21·2, 25·1	
Sex of the head of the household					
Male	78·5	77·3, 79·6	21·5	20·4, 22·7	0·470
Female	77·6	75·3, 79·7	22·4	20·3, 24·7	
Educational level of the head of the household					
Until primary	75·1	73·3, 76·7	24·9	23·3, 26·7	<0·001
Secondary	78·4	76·9, 79·8	21·6	20·2, 23·1	
Higher	80·5	78·4, 82·5	19·5	17·5, 21·6	
Ethnicity of any women at household					
No	79·5	78·3, 80·6	20·5	19·4, 21·7	<0·001
Yes	59·5	56·3, 62·7	40·5	37·3, 43·7	
Number of children under 5 years of age at household					
None	78·4	76·7, 79·9	21·6	20·1, 23·3	0·618
One	77·9	76·5, 79·2	22·1	20·8, 23·5	
Two or more	79·0	77·4, 80·6	21·0	19·4, 22·6	
Presence of pregnant women					
No	78·3	77·2, 79·4	21·7	20·6, 22·8	0·489
Yes	76·7	71·7, 81·0	23·3	19·0, 28·3	

*Using χ^2 test statistics.
†Estimates include the weights and ENDES sample specifications.

the other hand, it has recently been reported that in low- and middle-income countries, the lowest consumption of iodised salt was found in rural areas compared to urban areas[21,29]. Therefore, despite the eradication of endemic goitre in the Highlands after 1986 and the privatisation of salt production with adequate iodine concentrations in 1992[5], greater emphasis should be placed on these regions with high rural rates in order to increase the coverage of iodised salt consumption and maintain a low prevalence of endemic goitre.

Regarding ethnicity, it was found that households with a woman of childbearing age with a native mother tongue were associated with the possession of table salt with inadequate amounts of iodine. It has been reported that ethnicity is a factor associated with the consumption of iodine-enriched foods in the American population. This difference is attributed to the study by Caldwell *et al.* who reported that according to ethnicity in the USA, iodised salt consumption in pregnant women among the Hispanic population and the non-Hispanic black population was higher compared to the white population[30]. However, when measuring ioduria in this population, the distribution was inverted, with higher figures in the white population followed by the Hispanic population and the non-Hispanic black population. These differences may be attributed to other sources of iodine in industrialised foods such as marine products followed by dairy products, in addition to salt for human consumption[27]. Furthermore, a study on the concentration of salt in households compared to retail stores in Ethiopia reported that inappropriate practices in traders such as exposing iodised salt to sunlight were associated with ethnicity, resulting in loss of iodine in salt[31]. On the other hand, Appiah *et al.* reported that in the Ghanaian population, ethnicity was associated with having good knowledge of the benefits of iodised salt and the dangers associated with iodine deficiency at the household level, and having such knowledge was associated with the increased use of iodised salt[32]. The results of these studies indicate the variability of iodised salt consumption according to ethnicity. It also seems that greater knowledge of the benefits of consumption of iodised salt increases its consumption while reducing the problems associated with inadequate consumption of iodine in the diet.

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Table 3. Crude and adjusted prevalence ratios of consumption of table salt with inadequate iodine concentrations, ENDES 2019†

	Crude			Adjusted*		
Variable	PR	95 % CI	*P* value	PR	95 % CI	*P* value
Area of residence						
Urban	Ref.			Ref.		–
Rural	1·58	1·44, 1·72	<0·001	1·03	0·91, 1·17	0·650
Natural regions						
Coast	Ref.			Ref.		
Highlands	1·82	1·64, 2·03	<0·001	1·47	1·30, 1·66	<0·001
Amazon	1·09	0·95, 1·24	0·221	0·90	0·78, 1·04	0·154
Wealth index						
Quintile 5 (richest)	Ref.			Ref.		
Quintile 4	0·96	0·77, 1·19	0·708	0·95	0·77, 1·19	0·675
Quintile 3	1·14	0·93, 1·40	0·210	1·14	0·93, 1·39	0·210
Quintile 2	1·38	1·14, 1·68	<0·001	1·32	1·08, 1·61	0·006
Quintile 1 (poorest)	1·82	1·51, 2·19	<0·001	1·45	1·16, 1·81	0·001
Overcrowding						
No	Ref.			Ref.		
Yes	1·07	0·98, 1·18	0·148	0·95	0·87, 1·04	0·249
Sex of the head of the household						
Male	Ref.			Not included		
Female	1·04	0·93, 1·16	0·469			
Educational level of the head of the household						
Until primary	Ref.			Ref.		
Secondary	0·87	0·79, 0·95	0·002	1·04	0·95, 1·13	0·398
Higher	0·78	0·69, 0·89	<0·001	1·07	0·94, 1·21	0·299
Ethnicity of any woman in the household						
No	Ref.			Ref.		
Yes	1·97	1·79, 2·18	<0·001	1·33	1·20, 1·48	<0·001
Number of children under 5 years of age in the household						
None	Ref.			Not included		
One	1·02	0·94, 1·12	0·613			
Two or more	0·97	0·88, 1·07	0·540			
Presence of pregnant women						
No	Ref.			Not included		
Yes	1·07	0·88, 1·31	0·485			

PR: prevalence ratio.
*Adjusted for all the variables with a $P < 0·20$ in the crude analysis.
†Estimates include the weights and ENDES sample specifications.

One of the limitations of the study is its cross-sectional design that does not allow causal relationships between study variables. In addition, as this was a secondary data analysis, the available data do not provide information on the causes of the inadequate concentration of iodine in table salt, and the adequacy or not of the iodine content in the table salt was determined by a semi-quantitative method. Likewise, there is the possibility of inaccuracy of the information provided by respondents and data collected by the interviewers. Despite these limitations, ENDES is a widely used survey that evaluates socio-demographic characteristics in the Peruvian population and has national representativeness. In addition, this survey is conducted under DHS program format, allowing comparability of information from other countries using the same survey format.

Iodine is an essential micronutrient for brain development and human metabolism. Iodine deficiency generates disorders that decrease productivity in countries and increase the burden of disease from preventable diseases, especially in women of childbearing age and school-age children[1–4,11,12]. Therefore, longitudinal studies focused on areas with higher ratios of salt with inadequate iodine concentrations are needed to provide more information to improve the monitoring of this micronutrient at a population level in order to prevent iodine-deficiency disorders. Moreover, measures must be taken by the Peruvian Ministry of Health to ensure the consumption of salt with adequate iodine concentrations, starting with the regulation of compliance with Law N° 17387 as well as adequate storage by salt-producing plants and providers[8]. Likewise, these measures should be accompanied by promotion strategies to inform the population of the effects of deficient iodine consumption on health.

In conclusion, it was found that more than 25 % of Peruvian households used table salt with inadequate iodine concentrations. It was also found that the main factors associated with the consumption of table salt with inadequate amounts of iodine in Peru were homes with the greatest poverty located in the Highlands' natural region and living with at least a woman of childbearing age with a native mother tongue. These findings contribute to the need for the Peruvian government to intensify control over the iodine fortification of salt for human consumption in Peruvian homes nationwide to reduce health consequences due to the deficiency of this micronutrient.

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