Iodine nutrition in elementary state schools of Queretaro, Mexico: correlations between urinary iodine concentration with global nutrition status and social gap index

Consumo de iodo em escolas de ensino fundamental de Querétaro, México: correlação entre a concentração urinária de iodo, o estado nutricional geral e o índice de desigualdade social

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ABSTRACT

Objective and methods: To estimate median urinary iodine concentration (UIC), and to correlate it with global nutrition indicators and social gap index (SGI) in 50 elementary state schools from 10 municipalities in the State of Queretaro, Mexico. **Results:** 1,544 students were enrolled and an above of requirements of iodine intake was found (median UIC of 297 µg/L). Iodine status was found as deficient, adequate, more than adequate and excessive in 2, 4, 19 and 25 schools, respectively. Seventy seven percent of table salt samples showed adequate iodine content (20-40 ppm), while 9.6% of the samples had low iodine content (< 15 ppm). Medians of UIC per school were positively correlated with medians of body mass index (BMI) by using the standard deviation score (SDS) (r = 0.47; $p < 0.005$), height SDS (r = 0.41; $p < 0.05$), and overweight and obesity prevalence (r = 0.41; $p < 0.05$). Medians of UIC per school were negatively correlated with stunting prevalence (r = -0.39; $p = 005$) and social gap index (r = -0.36; $p < 0.05$). Best multiple regression models showed that BMI SDS and height were significantly related with UIC ($p < 0.05$). **Conclusions:** There is coexistence between the two extremes of iodine intake (insufficient and excessive). To our knowledge, the observed positive correlation between UIC and overweight and obesity has not been described before, and could be explained by the availability and consumption of snack food rich in energy and iodized salt. Arq Bras Endocrinol Metab. 2013;57(6):473-82

Keywords

Iodine nutrition; obesity; urinary iodine concentration; schoolchildren; stunting; social gap index

RESUMO

Objetivo e métodos: Estimar a concentração de iodo urinário (CIU) mediana e correlacioná-la com os indicadores de nutrição geral e com o índice de desigualdade social (IDS) de 50 escolas estaduais de ensino fundamental de 10 municípios do estado de Querétaro, no México. **Resultados:** Utilizou-se um total de 1.544 crianças e encontrou-se uma ingestão acima das necessidades de iodo (CIU mediana de 297 µg/L). O nível de iodo determinado foi deficiente, adequado, mais do que adequado e excessivo em 2, 4, 19 e 25 escolas, respectivamente. Setenta e sete por cento de amostras de sal de mesa mostraram uma quantidade de iodo adequada (20-40 ppm), enquanto 9,6% das amostras tinham um teor de iodo baixo (< 15 ppm). As medianas de CIU por escola foram correlacionadas positivamente com as medianas do índice de massa corporal (IMC) usando o desvio-padrão da contagem (DP) (r = 0,47; $p < 0.005$), o DP da altura (r = 0,41; $p < 0.05$) e a prevalência de sobrepeso e de obesidade (r = 0,41; $p < 0,05$). As medianas de CUI por escola foram correlacionadas negativamente com a prevalência de desnutrição (r = -0.39; $p = 005$) e com o índice de desigualdade social (r = -0.36; $p < 0,05$). Os melhores modelos de regressão múltipla mostraram que a DP do IMC e a altura foram relacionados significativamente com a CIU ($p < 0,05$). **Conclusão:** Existe uma convivência entre os dois extremos de ingestão de iodo (insuficiente e excessiva). Em nosso conhecimento, a correlação positiva entre a CIU, o excesso de peso e a obesidade não foi descrita anteriormente e poderia ser explicada pela disponibilidade e consumo de alimentos ou refeições ricos(as) em energia e sal iodado. Arq Bras Endocrinol Metab. 2013;57(6):473-82

Descritores

Nutrição com iodo; obesidade; concentração urinária de iodo; crianças em idade escolar; desnutrição; índice de desigualdade social

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INTRODUCTION

Iodine deficiency is still one of the most important nutritional deficiencies worldwide (1). According to the World Health Organization (WHO), the United Nations Children Fund (Unicef), and the International Council for Control of Iodine Deficiency Disorders (ICCIDD), iodine deficiency is the main cause of preventable brain damage (2). Two of the main strategies to eradicate iodine deficiency are to establish a mandatory universal salt iodization (USI) program and the permanent monitoring of iodine intake by means of the assessment of urinary iodine concentration (UIC) in vulnerable population, such as schoolchildren and both pregnant and lactating women (2). A median value of UIC below 100 µg/L in schoolchildren indicates iodine deficiency, and the monitoring of UIC is recommended at least every three years in a representative national sample (2). In Mexico, the last two national studies regarding iodine nutrition were performed between 1998 and 1999, the National Nutrition Survey (NNS-1999) (a probabilistic survey) and the Thyromobile program (with 23 sentinel sites), reported a median UIC of 235 and 176 µg/L, respectively (3-5). According to the USI program in Mexico, it is estimated that 94% table salt available in the market has more than 15 ppm of iodine (6); however, there are regions with still insufficient iodine content in table salt (7). In these regions, the sources of table salt are local and from artisanal producers that do not guarantee adequate iodine content (7). There are no recent national surveys about iodine content in table salt in households of Mexico, and the consumption pattern of iodized salt is poorly understood. Moreover, Mexico is considered a nutrition transition country with serious problems of overweight and obesity and a reduction of infectious diseases and nutritional deficiencies (8). The NNS-1999 reported a prevalence of overweight and obesity in schoolchildren (5 to 11 years of age) of 18.4%; seven years later, the National Health and Nutrition Survey-2006 reported a prevalence of overweight and obesity of 26.2% (3,9). On the other hand, the control of chronic undernutrition has been notably improved in the last years. In this regard, stunting prevalence in schoolchildren in 1999 was 16.1%, whereas in 2006 it was 9.9% (3,9). However, other nutritional deficiencies, such as anemia in schoolchildren have not improved significantly; in 1999, anemia prevalence was 19.5%, whereas in 2006 it was 16.6% (3,9). This nutritional context makes it mandatory to describe the current situation of iodine nutrition in Mexico. In this cross-sectional study, we describe iodine nutrition status in Mexican children from elementary state schools in municipalities considered vulnerable to iodine deficiency and its relationship with the global nutrition status and the social gap index, a socioeconomic indicator.

SUBJECTS AND METHODS

Setting and subjects

This cross-sectional study was performed in 10 municipalities from the state of Queretaro, Mexico. The municipalities studied were Amealco, Colon, El Marques, Huimilpan, Jalpan de Serra, Landa de Matamoros, Pedro Escobedo, Pinal de Amoles, San Joaquin, and Toliman. The state of Queretaro is located at the center of the country (20° 40'-20° 1' N, 99° 2'- 100° 36' W) (10), approximately 270 km to the northwest of Mexico City. According to the 2010 national census, the state of Queretaro has 1,827, 937 inhabitants, with the total population of the 10 municipalities studied representing 24.2% of the total population of the state (10). Table 1 shows major geographic and sociodemographic characteristics, such as total population (10), schoolchildren population (11), extreme poverty (12), social gap index (SGI) (12), prevalence of stunting (13), and range of altitude (14) of each municipality studied. Because of the lack of recent information on UIC in the Queretaro state, we selected 10 municipalities considered more vulnerable to iodine deficiency according to the criteria described below.

Historic records of endemic goiter: the municipalities selected based on this criterion were Jalpan de Serra, Landa de Matamoros, and Toliman (15,16). Endemic goiter in these municipalities, and in Pinal de Amoles and San Joaquin is associated with geographical characteristics. Jalpan de Serra, Landa de Matamoros, Pinal de Amoles, San Joaquin, and Toliman are part of the Sierra Madre Oriental, an important mountain range. Iodine-deficient soils are common in mountainous areas (17). On the other hand, because iodine deficiency is associated with poverty and chronic undernutrition (18,19), high rates of stunting prevalence were used as a second criterion. High stunting rate was considered as a prevalence > 10%, which is more than the current national prevalence (9). The municipalities selected based on this criterion were Amealco, Pinal de Amoles, San Joaquin, and Toliman (Table 1) (13). Finally, high rates of congenital hypothyroidism were used as a third criterion of selection. High rate of congenital hypothyroidism was considered as a rate > 4.2/10,000 live births; which is more than the average of the national prevalence (20,21). For this selection we used data from 2007, and the municipalities selected based on this criterion were Colon, El Marques, Huimilpan, and Pedro Escobedo (22,23).

We studied iodine nutrition in children from 50 randomly selected localities (76% rural and 24% urban) (14), 5 from each municipality. From each locality, one state elementary school was selected as the survey site. Only schools with more than 30 children between 6 to 12 years of age were included in this study (11). The Principal from each school was asked to randomly select 30-35 children of both genders to participate in the study. In general, it is accepted that 30 urine samples are enough to calculate the median of UIC (2). However, in 7 cases, the number of children that took part in the day of data collection was less than 30, and in some cases, age range was between 5 to 16 years old. Because of the difficulties to return to these locations, we decided to include all the children available on the day of the data collection. Only 1.2% of children studied were younger than 6 years old, and only 2.5% were older than 12 years old. The range of subjects sampled from each school was 23 to 36 children, and all data were collected from May 2010 to July 2011.

This study was approved by the Bioethical Committee of the School of Medicine of the Autonomous University of Queretaro. All participants voluntarily took part in the study and written consent was obtained from at least one parent or guardian.

LABORATORY ANALYSIS

We asked the children to bring a sample of ≈ 40 g of table salt from their homes. All table salt samples were analyzed qualitatively to identify the presence of iodate using a kit (Bioteccsa Laboratorios, Sonora, Mexico). A representative subsample of table salt samples (between 10.9 and 24.6%), from each municipality was randomly selected to quantitatively determine iodine concentration. Quantitative iodine analyses of table salt were performed using the sodium thiosulfate titration method (2).

On the other hand, spot urine samples were obtained from schoolchildren in 40-mL sterile plastic urine sample containers. Samples were placed in polyethylene tubes and kept at 4-10°C until arriving to the laboratory, where they were stored at -20°C until further analysis. UIC determinations were performed by the Sandell-Kolthoff method after sample digestion with ammonium persulfate, according to Pino and cols. (24). Intra- and interassay coefficients of variation were 6% and 8%, respectively. Median UIC was expressed in micrograms per liter (µg/L). External quality control assessment of the analytical procedure of UIC was carried out by the Laboratory of Micronutrients (LM) of the Cayetano Heredia Peruvian University. The Laboratory of Micrutrients is included in the Ensuring the Quality of Iodine Procedures of the Centers for Disease Control and Prevention, and is a member of the Regional Resource Laboratory for the International Resource Laboratories for Iodine Network.

Table 1. Socio-demographic and geographic characteristics of the studied municipalities

Municipality	Total population*	Schoolchildren population**	Extreme poverty***, %	Social gap index ***	Schoolchildren stunting prevalence⁺, %	Altitude range⁺⁺, m
Amealco	62,197	10,216	25.4	0.52864	14.7	2,356 - 2,770
Colon	58,171	8,904	11.4	-0.22066	9.7	1,751 - 2,573
El Marques	116,458	15,580	8.8	-0.72830	7.9	1,859 - 2,206
Huimilpan	35,554	5,738	12.4	-0.23528	7.5	1,933 - 2,431
Jalpan de Serra	25,550	3,983	18.2	-0.45104	9.6	756 - 1,503
Landa de Matamoros	19,929	3,464	24.2	-0.00523	12.1	1,033 - 1,612
Pedro Escobedo	63,966	8,873	7.2	-0.72304	5.5	1,915 - 2,200
Pinal de Amoles	27,093	5,278	34.9	0.68236	19.7	1,661 - 2,337
San Joaquin	8,865	1,365	25.3	0.34660	15.6	1,597 - 2,450
Toliman	26,372	3,932	17.3	0.30120	12.5	1,468 - 1,937

Reference: 10*, 11**, 12***, 13⁺, 14⁺⁺.

The iodine nutrition status in children was determined according to the recommended WHO/Unicef/ICCIDD criteria (2), as follows: insufficient iodine intake was defined as a population median UIC < 100 µg/L; adequate intake of iodine as UIC 100-199 µg/L; iodine intake above the requirements as UIC 200-299 µg/L; and excessive intake of iodine as UIC ≥ 300 µg/L.

Anthropometric measurements and global nutrition status indicators

The weight and height of the children were determined by standard anthropometric procedures (25). For the anthropometric measurements, shoes of the subjects were removed, their pockets emptied, and they wore light indoor clothing. Weight was recorded to the nearest 100 g and height to the nearest centimeter. Body mass index (BMI) was estimated for each subject. For homogeneity reasons, height and BMI were expressed as standard deviation standards (SDS). SDS were calculated according to Cacciari and cols. (26). Overweight and obesity prevalence were determined by using the BMI-for-age WHO 2007 criteria (27). A stunted child was defined as ≤ -2 SD, according to the height-for-age WHO standard (27,28).

Social gap index (SGI)

SGI was created by the National Council for Evaluation of Social Development Policy (CONEVAL) that, according to the Mexican law, represents the authority and has the responsibility to establish these guidelines and criteria for the definition, identification, and measurement of poverty (12). The SGI is a measurement obtained by means of a principal component analysis that summarizes 11 indicators categorized in four dimensions: a) education (3 indicators), b) access to health care (1 indicator), c) access to basic services (3 indicators), and d) housing quality and spaces and home assets (4 indicators). High SGI values indicate poor social development. Data used by CONEVAL to calculate the SGI were obtained from the National Census 2010, and provide information at three different levels: state, municipality and locality. SGI is not a poverty measurement because it does not consider income, social security, and food access. SGI data for each locality was obtained from a public database at the internet homepage of the CONEVAL (12).

Statistical analysis

We used Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA), SPSS 16.0 (SPSS Inc. Chicago, IL), and GraphPad Prism 5 (GraphPad Sofware, Inc. La Jolla, CA) to perform the statistical analyses. Values shown are means ± standard deviation, or as medians and ranges in cases of individual UIC, BMI SDS, height SDS data of each child that are not normally distributed. To analyze if data show Gaussian (normal) distributed we used D'Angostino and Person omnibus normality test. Non-parametric Mann-Withney U and Kruskal-Wallis tests were used for comparisons of unpaired groups of UIC. Spearman correlation tests were performed to correlate median UIC with the prevalence of overweight, obesity and stunting because these variables did not show a normal distribution. Because medians had a Gaussian distribution, Pearson correlation tests were performed to relate median UIC with medians of BMI SDS and height SDS and SGI. We grouped data according to three geo-political levels: locality, municipality, and state. Multiple linear regression analyses were performed using the median of UIC from each school as a dependent variable, and altitude, iodine content in table salt, BMI SDS or height SDS and SGI as independent variables (Table 5). The best models obtained during the exploration analysis are reported (Model 1 and Model 2). *P* values < 0.05 were considered statistically significant.

RESULTS

In this study, 1,544 children from 50 localities (10 municipalities) of the state of Queretaro, Mexico, were included, with a male/female ratio of 1.07, and a mean of 9.3 ± 2.1 years of age. Table 2 shows the median height SDS and BMI SDS. As it may be observed, the municipalities of Jalpan de Serra and Pinal de Amoles had the lowest height. In addition, Jalpan de Serra had the lowest BMI. Table 2 also shows the prevalence of stunting, overweight, and obesity. The highest prevalence of stunting was found in Pinal de Amoles (12.3%), and the highest prevalence of overweight and obesity was found in Pedro Escobedo (36%).

Nine hundred sixteen samples of table salt were collected from the studied children, with only 5% of the samples showing negative iodate results (Table 3). Nevertheless, the municipality with the highest percentage of table salt samples negative to iodate was Pinal de Amoles (14.7%). These data are in agreement with the quantitative analysis of iodine content in the subsample of table salt (Table 3). A total of 77.8% table salt samples had iodine content between 20-40 ppm, and 9.6% of the samples had iodine content < 15 ppm. The municipalities with the greatest percentage of table salt samples with insufficient iodine content (< 15 ppm) were Colon and Pinal de Amoles with 26.3 and 20%, respectively.

Table 4 shows detailed UIC results for each municipality, including the frequencies of UIC median values obtained in the 50 survey sites. Due to the wide age range (5 to 16 years) we analyzed separately the 6-12 years group and found no differences in the UIC compared with the whole sample. In all municipalities, UIC medians were above 200 µg/L, and range was from 225 µg/L to 531 µg/L. These values indicate more than adequate iodine intake (median UIC of 200-299 µg/L) in 6 municipalities, and excessive iodine intake in 4 municipalities (≥ 300 µg/L). In spite of this, we found two localities, from the 50 studied, with insufficient iodine intake (50-100 µg/L), one in Landa de Matamoros and the other in Pinal de Amoles. On the other hand, because UIC values obtained from spot urine samples are not useful to estimate individual iodine intake, we used UIC median values from each school to perform a population analysis instead of individual analysis.

Table 2. General characteristics of the locations and scholars by municipality

Municipality	*n*	Age (years)*	Height SDS (median)	BMI SDS (median)	Stunting		Overweight and obesity	
					%	95% CI	%	95% CI
Amealco	150	9.4 ± 2.1	-0.261[a,b]	0.323[a,b]	5.3	1.7-8.9	21.3	14.8-27.9
Colon	154	9.2 ± 2.0	-0.300[a,b]	0.249[a,b]	1.9	-0.3-4.1	26.0	19.1-32.9
El Marques	164	9.3 ± 2.0	-0.256[a,b]	0.485[a,b]	1.8	-0.2-3.8	34.7	27.4-42.0
Huimilpan	153	8.9 ± 2.2	-0.193[a]	0.326[a,b]	7.2	3.1-11.3	20.3	13.9-26.7
Jalpan de Serra	150	9.5 ± 2.1	-0.606[b]	-0.268[c]	10.0	5.2-14.8	17.3	11.3-23.5
Landa de Matamoros	156	9.5 ± 2.1	-0.412[a,b]	0.099[a,b,c]	7.7	3.5-11.9	15.7	10.0-21.4
Pedro Escobedo	161	9.4 ± 1.9	-0.228[a]	0.532[a,b]	1.9	-0.2-4.0	36.0	28.6-43.4
Pinal de Amoles	154	9.2 ± 2.2	-0.632[b]	0.038[b,c]	12.3	7.1-17.5	11.7	6.6-16.8
San Joaquin	153	9.6 ± 2.0	-0.442[a,b]	-0.005[b,c]	8.5	4.1-12.9	20.9	14.5-27.3
Toliman	149	9.1 ± 1.9	-0.254[a,b]	0.508[a]	4.7	1.3-8.1	31.5	24.0-39.0
All	1,544	9.3 ± 2.1	-0.360	0.248	6.1	4.9-7.3	24.7	22.5-26.9

* Mean ± standard deviation. BMI: body mass index; F: female; M: male. SDS: standard deviation score. [a, b, c] Different letters indicate statistically significant differences ($p < 0.05$), according to median value and multiple median comparison tests (Kruskal-Wallis and Dunn's tests). 95% CI: 95% Confidence interval.

Table 3. Qualitative and quantitative analysis of iodine content in table salt samples by municipality

Municipality	Qualitative analysis		Quantitative analysis					
			Iodine concentration, ppm					
	n	Iodate negative, %	*n*	Mean ± SD	Median	< 15, %	≥ 20-40, %	> 40, %
Amealco	117	3.4	18	32.9 ± 6.0	33	0.0	83.3	16.7
Colon	81	4.9	19	23.8 ± 12.3	24	26.3	63.2	5.2
El Marques	79	2.5	18	25.1 ± 5.8	25	5.6	83.3	0.0
Huimilpan	86	0.0	18	31.2 ± 5.0	30	0.0	100.0	0.0
Jalpan de Serra	89	9.0	14	30.8 ± 11.4	34	14.3	64.3	21.4
Landa de Matamoros	128	2.3	14	26.5 ± 8.3	29	7.1	71.4	0.0
Pedro Escobedo	109	8.2	18	28.0 ± 11.1	24	11.1	72.2	16.7
Pinal de Amoles	61	14.7	15	26.2 ± 11.2	27	20.0	73.3	6.7
San Joaquin	79	0.0	15	29.0 ± 10.6	25	13.3	80.0	6.7
Toliman	87	9.2	18	30.4 ± 7.5	30	0.0	83.3	5.6
All	916	5.1	167	28.4 ± 9.4	29	9.6	77.8	7.8

Figure 1A shows a typical non-Gaussian distribution of individual UIC values obtained from spot urine samples. Figure 1B shows the Gaussian distribution of UIC median values obtained in each school. Correlation analyses between UIC and global nutrition status indicators and SGI using data from the 50 schools are shown in Figures 2 and 3. Figures 2A and B show a positive and significant correlation between the median UIC and the median Height SDS (Pearson r = 0.41; p = 0.002), and the median BMI SDS (Pearson r = 0.47; p < 0.001) in each locality. Furthermore, Figure 2C shows a negative and significant correlation coefficient between UIC and stunting prevalence (Spearman r = -0.39; p = 0.003). In contrast, figure 2D shows a positive and significant correlation coefficient between UIC and overweight and obesity prevalence (Spearman r = 0.41; p = 0.002). Correlation coefficients between UIC and overweight prevalence and obesity prevalence yielded Spearman values of r = 0.37 (p = 0.008) and r = 0.30 (p = 0.03), respectively (data not shown). On the other hand, the correlation coefficient between UIC with SGI was negative (Pearson r = -0.36; p = 0.005) (Figure 2).

Table 5 shows a multiple linear regression analysis with UIC as the independent variable and SGI, iodine content in table salt, and BMI SDS as dependent variables (Model 1). Similarly, an instead of BMI SDS, height SDS was included as a dependent variable in Model 2. In both cases BMI SDS (β = 111.36 < 0.05) and height SDS (β = 99.94 < 0.05) were significantly correlated with UIC. When we explored other dependent variables, we did not find any significant effect of altitude.

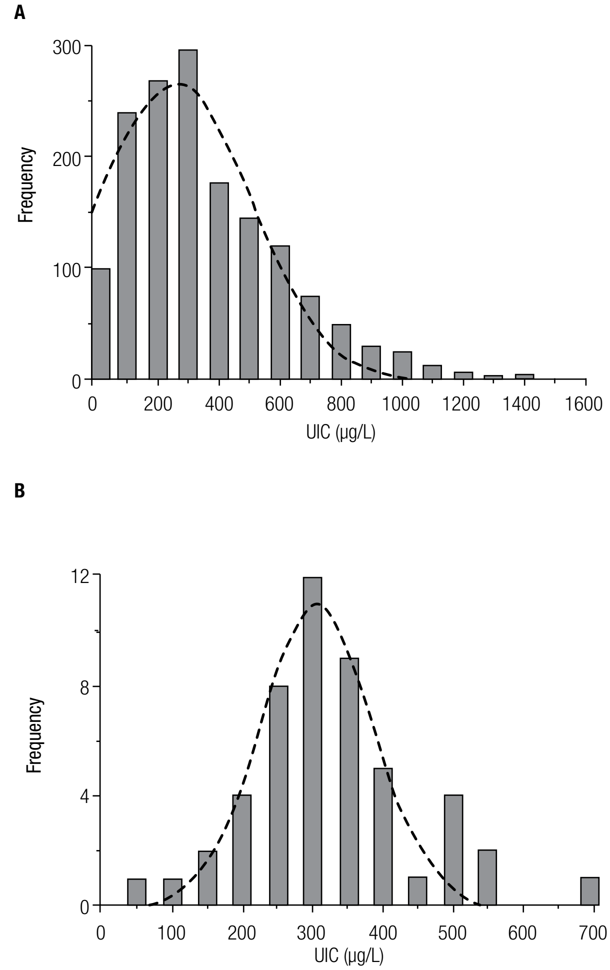

Figure 1. Histograms of urinary iodine concentration (UIC) from 1,544 Mexican schoolchildren (**A**) and from median values of 50 elementary state schools (**B**). UIC median values obtained from each school were normally distributed (K2 = 5.198; p = 0.07).

Table 4. Urinary iodine concentrations by municipality and school

Municipality	Schoolchildren (6-12 years old)				Classification of each school according to UIC median, µg/L				
	n	UIC, median (range), µg/L	n	UIC, median (range), µg/L	Schools n	50-99, n	100-199, n	200-299, n	≥ 300, n
Amealco	142	352 (5-1519)	150	352 (5-1519)[a,b]	5	0	0	0	5
Colon	150	346 (8-1450)	154	346 (8-1450)[b,c]	5	0	0	0	5
El Marques	158	294 (5-1039)	164	302 (5-1257)[b,c]	5	0	1	1	3
Huimilpan	149	295 (5-1166)	153	294 (5-1166)[b,c]	5	0	0	3	2
Jalpan de Serra	141	287 (10-1205)	150	290 (10-1205)[b,c]	5	0	0	3	2
Landa de Matamoros	149	265 (5-1164)	156	262 (5-1164)[c,d]	5	1	0	3	1
Pedro Escobedo	159	260 (5-1124)	161	260 (5-1124)[c,d]	5	0	1	2	2
Pinal de Amoles	144	228 (6-1250)	154	225 (6-1250)[d]	5	1	1	2	1
San Joaquin	149	282 (5-1282)	153	282 (5-1282)[b,c]	5	0	1	3	1
Toliman	147	519 (5-1213)	149	531 (5-1213)[a]	5	0	0	2	3
All	1488	297 (5-1519)	1544	297 (5-1519)	50	2	4	19	25

[a, b, c, d] Different letters indicate statistically significant differences (p < 0.05), according to median value and multiple median comparison tests (Kruskal-Wallis and Dunn's tests).

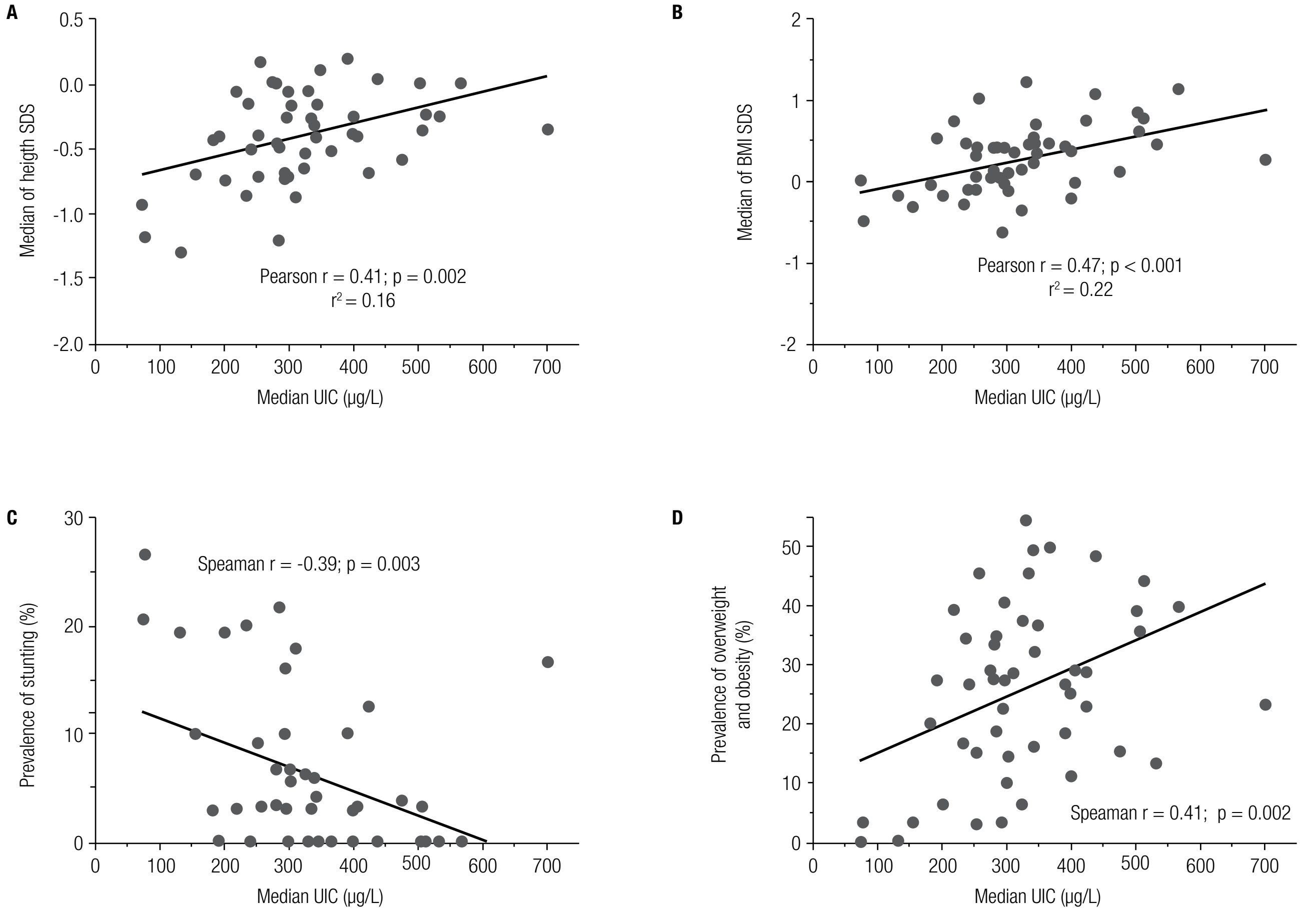

Figure 2. Correlations between median urinary iodine concentration (UIC) and median height standard deviation scores (SDS) (**A**), body mass (BMI) SDS (**B**), prevalence of stunting (**C**), and prevalence of overweight and obesity (**D**). Each dot represents one elementary school (n = 50), the straight-line represents the best-fit line obtained by linear regression analysis.

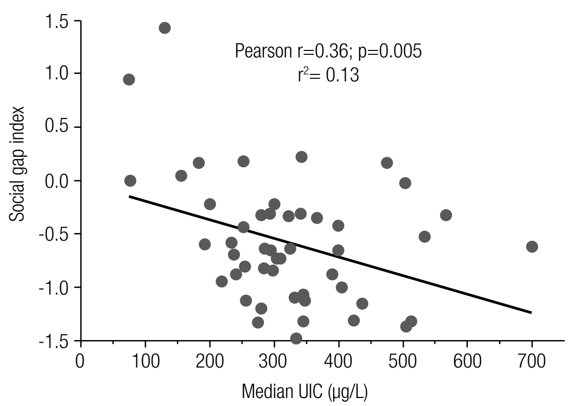

Figure 3. Correlation between median urinary iodine concentration (UIC) and social gap index. Each dot represents one elementary school (n = 50), the straight-line represents the best-fit line obtained by linear regression analysis.

Table 5. Best multiple linear regression models between global nutrition indicators, social gap index, and iodine content in table salt as independent variables and UIC as dependent variable

	Model 1			**Model 2**		
	β	**SE**	***p***	β	**SE**	***p***
Independent variable						
Social gap index	-47.19	31.4	0.07	-46.98	35.63	0.10
Iodine in table salt, ppm	1.52	1.81	0.20	1.31	1.88	0.25
BMI SDS	111.37	41.14	0.004	-	-	-
Height SDS	-	-	-	99.95	54.01	0.04
Constant	219.06	65.35	0.001	295.12	75.10	0.000
R square	0.26		0.001	0.20		0.009

SE: standard error. * p value was calculated with one-tailed test.

DISCUSSION

The results of this study are consistent with previous national data that indicate a sustained elimination of iodine deficiency disorders (IDD) in Mexico (3-5); nevertheless, those studies were performed 14 years ago, and in this lapse of time several and dramatic changes in nutrition have occurred at a national level (8,29). Currently, Mexico is considered a nutrition transition country, with an increase in prevalence of overweight and obesity and a reduction of nutritional deficiencies (8,29). IDD control in Mexico is based almost exclusively in an USI program that guarantees that more than 90% the marketed table salt samples have > 15 ppm of iodine (6), and this is in agreement with our findings. However, we showed that 2 of 50 (4%) elementary schools had insufficient iodine intake (median UIC 50-99 µg/L). This insufficient intake could be explained because there are places where ≥ 20% table salt samples analyzed had insufficient iodine content. This is particularly relevant in places such as Pinal de Amoles, which had the lowest median UIC and the highest SGI and stunting prevalence. This finding is in accordance with previous reports, such as those from Indonesia (19) and India (30). In these studies, iodine deficiency was associated with height SDS and intelligence quotient, and undernutrition and poverty, respectively. The geography and altitude have been traditionally described as important factors regarding iodine availability in soil. However, we did not find a significant association for the altitude on UIC, which is in accordance to the results obtained by Aghini-Lombardi and cols. in a study performed in the south of Italy (31). This apparent discrepancy could be related to the improvement, in recent decades, of the public infrastructure, including road construction and commercial trading, which increases the availability of processed food in remote areas.

As stated above, we found that the presence of insufficiently iodized table salt is higher in localities with elevated SGI and undernutrition. This finding supports the notion that there are localities that depend on the intake of high quality iodized table salt to guarantee adequate iodine nutrition. Other places, such as Colon, with lower stunting prevalence and lower SGI, had excessive iodine intake, although 26% of table salt samples analyzed had insufficient iodine content. This seemingly contradiction could be explained by the access to other dietary sources of iodine, such as processed food, considering the lower SGI and the subsequent higher social development. As mentioned, we identified table salt samples without iodine. Nevertheless, in this study, we did not question socio-cultural and economic factors that could influence iodized salt acquisition and/or consumption. In addition, a potential limitation to this study is that the sample size employed to calculate the median UIC was less than 30 subjects in a few locations, which could prevent an accurate assessment of iodine status.

On the other hand, we describe here a positive and significant correlation between BMI SDS, height SDS, overweight and obesity with UIC. To our knowledge, it is the first time that excessive iodine intake was associated with unhealthy weight. We hypothesized that this association could be explained by the dramatic changes in dietary patterns in the Mexican population (8,29,32,33). At a national level, it is estimated that, from 1989 to 2006, the consumption of industrialized foods increased 6.3%, whereas fruit and vegetable consumption dropped 29% (29). Moreover, in rural areas, over a period of 15 years (from 1989 to 2004), the availability of industrialized food products increased 533% (32). Besides, inside or near most Mexican elementary schools, there are small stores that sell snack foods rich in energy, carbohydrates, fat, and iodized salt (33). In Mexico, it is compulsory for the food industry to employ iodized salt in their products. Therefore, we assume that snack foods are iodine rich, too. Unfortunately, we did not quantify the acquisition and/or consumption of industrialized food in the studied schools. However, the positive and significant association with BMI SDS, height SDS, overweight and obesity and SGI support this hypothesis. Moreover, in Brazil, excessive iodine intake, median UIC 360 µg/L, was related with an excess of iodine content in table salt, where 47% of table salt samples had more than 50 ppm of iodine (5). In our case only 7.8% of table salt samples were above 40 ppm of iodine. More recent data from other Latin American countries, Peru and Venezuela, obtained in a comprehensive USI program, showed median UIC of 262 and 166 µg/L, respectively (34,35).

There are other circumstances or variables that should be taken into account and that are specific of a certain region or country. For example, in developed countries, such as the USA and Switzerland, national median UIC in schoolchildren is 211 and 120 µg/L, respectively (36,37). These UIC levels are lower than in some Latin American countries, and this may be because in the USA and Switzerland, the addition of iodine to salt for direct human consumption or for food industry is not mandatory. On the other hand, in the USA, dairy products seem to play an important role as iodine source (36). In this regard, in New Zealand only the fortification of bread with iodized salt is mandatory since 2009, and it is estimated that this measure contributes for almost a third of total iodine intake (38).

We consider that it is very important to characterize the dietary patterns to identify salt and iodine sources in schoolchildren, because both obesity and excessive intake of iodine could have deleterious effects on thyroid function. On one hand, obesity has been related with an increase of thyroid-stimulating hormone (TSH) levels and thyroid structure alterations (39,40). On the other hand, excessive iodine intake has been related with increase in cumulative subclinical hypothyroidism and autoimmune thyroiditis (41). Further studies are needed to document the impact of both obesity and iodine excess in children thyroid function.

We can conclude that the observed correlation between UIC and unhealthy weight can be explained by the availability and consumption of snack food rich in energy and iodized salt. Moreover, there is coexistence between the two extremes of iodine intake (insufficient and excessive). Because of this, we consider that the generation of a national program for monitoring urinary iodine excretion to reach and keep adequate iodine nutrition by means of an USI program is a priority. In addition, intensive and permanent educative and normative programs are needed to guarantee the availability and consumption of table salt with adequate iodine content.

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