Efficacy of a Salt Iodization Program on Iodine Status and Intakes in Schoolchildren of São Miguel Island, Azores, Portugal

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Keywords

Iodine status · Schoolchildren · Salt iodization · São Miguel · Azorean islands

Abstract

Introduction: Iodine is an essential micronutrient and its deficiency can severely impact children's development. In 2012, the Thyroid Study Group of the Portuguese Society of Endocrinology, Diabetes and Metabolism discovered that the median urinary iodine concentration (mUIC) level in schoolchildren of São Miguel was far too low at 70.9 µg/L. In response, the government implemented a salt iodization program to help normalize levels. This investigation evaluated the efficacy of such an approach. **Methods:** Urinary iodine concentration (UIC) was evaluated in 362 schoolchildren from São Miguel using the fast colorimetric method. **Results:** mUIC was 106.7 µg/L, significantly higher than that observed in 2012 ($p < 0.001$). Over half (55.5%) of the schoolchildren had a UIC >100 µg/L versus 23.0% in 2012 ($p < 0.001$). 9.4% of schoolchildren had a UIC <50 µg/L, significantly lower than the 30.6% reported in 2012 ($p < 0.001$). **Discussion/Conclusion:** Five years after the implementation of the government salt iodization program, the mUIC in-

creased from 70.9 to 106.7 µg/L. This study confirms the efficacy of the adopted measures in schoolchildren population.

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Introduction

Iodine is an essential micronutrient for thyroid hormone synthesis, and its deficiency during childhood has been shown to impair growth, cognition, and motor function [1, 2]. In order to meet iodine requirements for disease prevention, the World Health Organization (WHO), the iodine Global Network (IGN), the European Food Safety Authority, and the United Nations Children's Fund (UNICEF) recommend a daily intake ranging from 70 to 130 µg for schoolchildren aged 6–12 years [3, 4].

Dietary iodine is almost completely excreted through urine, so urinary iodine concentration (UIC) levels are excellent indicators of recent iodine intake [5]. According to the criteria of the WHO based upon epidemiological evidence, a daily iodine intake of 150 µg, corresponding to a median UIC (mUIC) above 100 µg/L, is sufficient to

meet health requirements for children and adults [6]. From this, it was estimated that in 2003, 59.9% of European schoolchildren had a UIC <100 µg/L [7]. According to the UNICEF, an mUIC in the range 100–299 µg/L indicates adequate iodine intake among school-age children. mUIC should only be used to characterize the iodine status of a population and not to quantify the proportion of the population with iodine deficiency or excess. Besides that, not more than 20% of samples should be <50 µg/L [8].

In 2012, the Thyroid Study Group of the Portuguese Society of Endocrinology, Diabetes and Metabolism carried out a study on iodine intakes in Portuguese schoolchildren. Findings revealed that in mainland Portugal, the mUIC was 105.5 µg/L and 11.8% had a UIC <50 µg/L [9]; in the Azores islands, the mUIC was 72.7 µg/L and 26.3% had a UIC <50 µg/L; and in São Miguel (containing >50% of the Azorean population), the mUIC was 70.9 µg/L and 30.6% had a UIC <50 µg/L [10]. These data align with earlier research reported by Oliveira et al. [11], discovering that schoolchildren inhabiting São Miguel had a UIC ranging from 7 to 47 µg/L and a prevalence of goiter between 11 and 41%. More recently, Linhares et al. [12] reported an mUIC of 75.4 µg/L in São Miguel schoolchildren [12]. Collectively, this shows that iodine deficiency is a chronic problem for most schoolchildren in São Miguel.

The WHO and UNICEF recommend salt iodination as a safe, cost-effective, and sustainable strategy to meet iodine requirements [6], and a recent Cochrane review validated this upon showing that supplementation with iodized salt (IS) was an efficient way to improve iodine status in children [13]. According to the Portuguese legislation, the concentration of potassium iodide in IS must be between 25 and 35 mg/kg of salt [14].

In Azores, where severe iodine deficiencies have been observed, the local government followed suit in 2014 by implementing multiple strategies for increasing iodine intake, namely: (1) a public policy advising to the use of IS within all Azorean households; (2) mandatory use of IS in every catering facility of the Regional Health Service; (3) mandatory use of IS in every meal prepared by the School of Education's Regional Service; (4) a television advertisement espousing the importance of consuming foods naturally rich in iodine and fortified with IS; and (5) a leaflet delivered to all households educating on the consequences of iodine deficiency and the importance of consuming the aforementioned foods. In the present study, we analyzed mUIC and daily iodine intakes in schoolchildren from the biggest island of the Azores ar-

chipelago, São Miguel, 5 years following the program's debut to determine whether these measures were effective at correcting iodine deficiencies.

Methods

Participants

The study sample was selected using the simple random sampling method. The procedure began by listing the 73 primary schools in São Miguel island, and then, 10 schools were randomly selected. Second, the list of all the students, aged between 6 and 12 years, from these 10 schools was obtained, and 500 schoolchildren (50 per school) were also randomly selected and invited to participate. 362 schoolchildren accepted the invitation and provided a urine sample. Demographic questionnaires collected information pertaining to child age, gender, thyroid health, vitamin and/or mineral supplementation, household use of IS, and whether the child eats at school. Individuals taking medication for thyroid disorders were excluded.

Assessment of Iodine Intake

UIC was measured using a fast colorimetric method [15] as per the recommendations of the WHO and IGN [6], and is appropriate for population studies. Urine was collected between May and June 2019 and analyzed in the Laboratory of Endocrinology of Instituto Português de Oncologia in Lisbon. This was the same method and laboratory used in the 2012 study [10].

Statistical Analyses

Descriptive statistics were based on absolute and relative frequencies, medians, means, and standard deviations. Shapiro-Wilk test was used to test the normality of numerical variables; Kruskal-Wallis test was used to compare continuous data between groups; χ^2 tests were used to compare proportions between groups; Spearman's Rho correlation was used to determine correlations between continuous variables. All analyses were performed using IBM SPSS Statistics (v. 24); $p < 0.05$ was considered statistically significant.

Results

Participants

A total of 362 children participated in the study, reflecting a participation rate of 72.4%. Of these participants, 182 were female (50.3%) and 180 were male (49.7%). The mean age was 8.9 ± 1.26 years (age range 6–12).

Iodine Status

Table 1 shows that the mUIC was 106.7 µg/L, significantly higher than 70.9 µg/L observed in the schoolchildren of São Miguel in 2012 ($p < 0.001$) and quite similar to that observed in those living in mainland Portugal (105.5 µg/L) [10]. Table 1 also shows that 55.5% of the schoolchildren had a UIC >100 µg/L versus 23.0% in 2012

Table 1. Distribution of UIC according to WHO/IGN/UNICEF criteria and mUIC in 2019 (São Miguel island) and 2012 (Azores and mainland Portugal) study in schoolchildren

	Children, <i>n</i> (%)			
	2019		2012	
	São Miguel island <i>N</i> = 362	São Miguel island <i>N</i> = 235	Azores islands <i>N</i> = 676	Mainland Portugal <i>N</i> = 3,680
UIC, µg/L				
<50	34 (9.4)	72 (30.6)	178 (26.3)	436 (11.8)
<100	161 (44.5)	181 (77.0)	530 (78.4)	1,726 (47.1)
≥100	201 (55.5)	54 (23.0)	146 (21.6)	1,954 (52.9)
mUIC, µg/L	106.7	70.9	72.7	105.5
<i>p</i> value	<0.001			

UIC, urinary iodine concentration; mUIC, median urinary iodine concentration; *N*, number of subjects.

Table 2. Iodine status, household iodized salt use, and school meals consumed by children from schools of São Miguel

Region	School	UIC%, µg/L			Household iodized salt, %	School meal, %
		<50	<100	≥100		
South coast	Ponta Delgada (<i>N</i> = 48)	10.4	62.5	37.5	66.7	86.4
	Lagoa (<i>N</i> = 39)	7.7	38.5	61.5	60.0	70.3
	Vila Franca do Campo (<i>N</i> = 37)	18.9	48.6	51.4	47.1	47.4
	Povoação (<i>N</i> = 35)	8.6	45.7	54.3	42.9	41.9
Inland	Furnas (<i>N</i> = 29)	17.2	62.1	37.9	51.9	65.5
North coast	Capelas (<i>N</i> = 28)	14.3	53.6	46.4	56.0	55.6
	Rabo de Peixe (<i>N</i> = 44)	2.3	27.3	72.7	43.6	93.2
	Ribeira Grande (<i>N</i> = 31)	6.5	41.9	58.1	46.4	100.0
	Maia (<i>N</i> = 33)	6.1	27.3	72.7	37.9	63.6
	Nordeste (<i>N</i> = 38)	5.3	39.5	60.5	28.6	64.9

UIC, urinary iodine concentration; *N*, number of subjects.

($p < 0.001$) and 9.4% of the schoolchildren were found to have a UIC <50 µg/L, significantly lower than the 30.6% reported in 2012 ($p < 0.001$).

Iodine Status and IS Use

Nearly half of households (48.3%) answered affirmatively that they used IS, and over two-thirds (69.8%) of the schoolchildren eat school meals mandatorily prepared with IS (Table 2).

Iodine Status and Fluoride Content in Drinking Water

As an ancillary analysis, we investigated the relationship between the fluoride content in drinking water and

the mUIC according to published methods by Cabral [16]. Although not significant, we found a trend toward a negative correlation ($r = 0.43$; $p = 0.207$), with higher fluoride concentrations tied to lower mUIC levels.

Discussion

It is well established that most iodine comes from the ocean, and thus, it is concentrated in foods of marine origin [5], and due to sea proximity, iodine deficiency should not be expected in São Miguel. However, iodine deficiency has been reported in many other islands populations [17–19], and several

factors could contribute to this. These are delineated below.

It is possible that iodine content of soil is being carried into the ocean by heavy rainfalls [5], since the precipitation levels are higher than 3,000 mm/year in high altitude areas in São Miguel [12, 20]. Competitive inhibitors of the sodium/iodide symporter as dietary substances in foods may interfere with thyroid metabolism. Among these factors are thiocyanates, perchlorate in drinking water, cigarette smoking, selenium, iron and vitamin A deficiencies, and high fluoride ingestion [5, 21, 22]. An interesting particularity of Azores Islands is that volcanic environments are notorious for exposing inhabitants to excessive amounts of fluoride [23]. People living especially close to volcanos in this island were found to be exposed to the hydrogen fluoride released during degassing episodes [19, 20]. This is problematic because when volcanic gases permeate groundwater, they increase its fluoride content [23]. Likewise, in an investigation carried out in 2 São Miguel island villages nearby active volcanos, endemic dental fluorosis was reported [16]. In a study carried out by Linhares et al. [24], they reported significantly higher levels of fluoride in bones from mice in the volcanic village of Furnas compared to those from one seaside village ($p < 0.001$).

This is the first line of research conducted in schoolchildren from Azores to evaluate the success of the 2014 salt iodization program. Our data show significant increase in mUIC from 70.9 µg/L in 2012 to 106.7 µg/L, and this result is quite similar to that observed for those living in mainland Portugal (105.5 µg/L) [10]. We also found that the percentage of children with UIC <50 µg/L decreased from 30.6 to 9.4% [10]. This is likely attributed to the intake of IS at home and the high number of children eating school meals effectively prepared with IS, which in 2012 was not commercially available. Our group conducted a similar study assessing the efficacy of a governmental program, implemented in 2016, for a universal 200 µg/daily iodine supplement to pregnant women, and the results showed an improvement in mUIC from 44.6 µg/L in 2012 [10] to 77.4 µg/L in 2019, although still below the WHO/IGN/UNICEF recommendations [25].

Conclusion

When comparing the 2012 versus 2019 mUIC results for São Miguel schoolchildren, we see with confidence that the IS program implemented by the Azorean government was effective. Future research examining children

from every island of the archipelago is needed to confirm the present findings.

In 2018, the European Union Thyroid Consortium released the Krakow Declaration on Iodine [26] defending universal salt iodization is the best way to prevent iodine deficiency. The authors support this mandate for increasing iodine levels in children.

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Statement of Ethics

The research was conducted ethically in accordance with the World Medical Association Declaration of Helsinki and was approved by the ethics committee of Hospital do Divino Espírito Santo in Ponta Delgada, Azores (reference number 933/CES/2018). All parents or guardians were informed about the research protocol and have given their written informed consent.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

C.S.M. and R.C. contributed to the conception of the work and the acquisition and interpretation of data, drafted the work, and revised it critically. S.P. contributed to the conception of the work, did the laboratory work, and critically revised the work for important intellectual content. I.M. contributed to the analysis and interpretation of data and critically revised the work for important intellectual content. E.L. and R.C. contributed to the conception of the work and critically revised the work for important intellectual content. All the authors approved the final version to be published.

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