from 100 μg/L to 299 μg/L indicate that the individual has no iodine deficiency [5].

Despite global efforts to curb iodine deficiency through measures such as the universal salt iodization (USI) program, some previously iodine-sufficient countries have experienced a resurgence of iodine deficiency. Based on a report by the Iodine Global Network [6], countries such as Norway, Finland, and Germany have experienced iodine insufficiency in 2019 despite being previously classified as iodine sufficient. The United States has also seen a dramatic decrease in urine iodine concentrations from 1974 to 2010 [1].

In Iran, a salt iodization program was started in 1996 and iodized salt was reported to be the main dietary iodine source [7]. In 2013 data from the fifth national survey in Iran [8] showed that in all provinces, iodized salt consumption of households was 98%. In 2018 Shamsollahi and coworkers [7] showed that >80% of available salts in Iran have a suitable or acceptable concentration of iodine.

Some studies in Iran [9, 10] have shown mild to moderate iodine concentrations in adult and pregnant women populations despite iodine sufficiency in children [11]. Nazeri et al. [10] believe that the reduction of daily salt intake can contribute to the reduction of urine iodine concentrations, as demonstrated in their study. Accordingly, we designed this study to evaluate the urine iodine status and salt intake among adult households in Sadra city, Fars province, southern Iran, as well as to assess its possible influencing factors compared with the results of the study by Nazeri et al. [10] in Tehran.

Methods

Subjects

This cross-sectional study was performed in the city of Sadra, located 15 km northwest of Shiraz, Fars province, Iran. With a population of 122,226, it is the fourth most populous city in the province. Subjects were selected using cluster sampling. The city was divided into 2 clusters. In each cluster, 25 houses were randomly selected based on the postal code. In each house, the mother and a member aged >18 y, who did not meet the exclusion criteria, were selected. Data were collected from February 1, 2021 to November 30, 2021. Inclusion criteria were: age >18 y and residence in Sadra city. Exclusion criteria were: thyroid disorders or use of thyroid-related drugs, diuretic medications, pregnancy, or lactation. A data collection form [Supplementary Material] containing questions about gender, age, education level, thyroid disorder and related drug use history, blood pressure and related drug use history, salt container storage (in sunlight vs. dark and out of sunlight), and the cooking stage at which the salt was usually added (before cooking, during cooking, or after cooking) was used.

Ethical review

Signed informed consent was taken from all participants, and the study was approved by the ethics committee of Shiraz University of Medical Sciences (Approval code: IR.SUMS.MED.REC.1398.568). The research assistant, a trained laboratory technician, explained the project to the participants and emphasized its benefits for the entire community. The subjects were asked to cooperate during various stages from completing the questionnaire to submitting blood and urine samples and performing an ultrasound. At each stage, if an abnormal test or ultrasound finding was detected, the individual was referred to an endocrinologist.

Caregivers were also asked for permission to use their data in future research. The results of the tests remained completely confidential and data analysis was done anonymously. The participants were not paid to participate but were reimbursed for travel to the study sites.

Thyroid examination and salt sample collection

A preweighed container of iodized salt was given to each household to be exclusively used for 14 d, including during food preparation and in table salt shakers. Then, the amount of salt used was measured and divided by the number of people in each household. Participants were also examined and subjected to ultrasonography for goiter or thyroid nodules by an endocrinologist at the Endocrinology and Metabolism Research Center of the Shiraz University of Medical Sciences. Thyroid volume was calculated from the length, width, and depth of the thyroid gland using the formula: width $\times$ length $\times$ depth $\times$ π /6 [12].

Urine and serum biochemical analysis

Urine samples over 24 h were taken from 2 residents of each household. Urine collection started with the second urine passed in the morning and ended with the first urine passed the following morning in a labeled 2.5 L plastic container. Subjects were also invited to undergo a blood test in the fasting state for assessing thyroid function including thyroid stimulating hormones (TSH), thyroxine (T4), and triiodothyronine (T3). Urine and blood analyses were performed before using the labeled salt package. Urine containers were sent to the Valfajr health center in Shiraz and stored at −20°C until analysis.

The UIC (μg/L) was measured using the Sandell-Kolthoff method as recommended by the WHO [5, 13]. Inter- and intra-assay coefficients of variation were 9.6% and 10.4%, respectively. The urine sodium level (mEq/L) was analyzed by emission flame photometry (Corning 480), in 50 participants with a coefficient of variation of 2%. Salt intake was estimated using urinary sodium excretion (1 g salt was equivalent to 17.1 mmol sodium) within 24 h in 50 study subjects [14].

Serum TSH was analyzed using an immunoradiometric assay (IRMA), whereas serum T4 and T3 were determined by radioimmunoassay (RIA) kits. Inter- and intra-assay coefficients of variation for TSH, T4, and T3 were 3.5%–2.4%, 4.5%–3.3%, and 3.8%–4.7%, respectively.

WHO guidelines [5] define a median adult UIC of >100 μg/L as sufficient. Therefore, UIC cutoffs intended for school children and extended to the general population by the WHO were used as a proxy. Median UIC values of <20 μg/L, 20–49 μg/L, 50–99 μg/L, and 100–199 μg/L were labeled as severe, moderate, and mild deficiency, and sufficiency, respectively [9]. The completion of 24-hour urine collection was assessed using urine creatinine concentrations. Urine creatinine values of <500 mg/d indicated incomplete urine collection and the corresponding samples were excluded.

reported in Tehran by Nazeri et al. [10] using univariate logistic regression. However, this statistical significance was diminished when adjusting for household salt-iodine content and daily salt intake, suggesting that these factors were interconnected when leading to lower UIC concentrations [10]. Based on these results, we hypothesize that subjects with higher education levels are more likely to use iodized salt.

In this study, we found a positive correlation between TSH and UIC concentrations and a negative correlation between T4 and UIC concentrations, which contrasts with the negative correlation seen between these 2 factors, especially in iodine-deficient areas [31]. Previous studies showed no association between UIC and serum TSH or T4 [32]. Data from the national health and nutrition examination survey (NHANES) III indicated that higher urinary iodine excretion was significantly related to higher TSH concentration [33]. Although individuals with higher concentrations of urinary iodine excretion in our study had higher TSH and lower T4 concentrations, these concentrations were within the physiological range. The right-shift in the distribution of TSH in iodine-sufficient areas could be affected by hereditary and genetic influences on the set point of thyroid hormones [34].

During food preparation, some methods such as heating and washing can decrease the amount of salt-iodine content. Microwaving, boiling, washing, and poor salt preservation conditions including storage in sunlight can decrease the effective iodine content [35]. The WHO estimates a salt-iodine loss of ~20% from retail until the food is served on the table [5]. Nevertheless, we found no significant difference in UIC between subjects who stored salt in the dark and those who did so in direct sunlight. Moreover, there was no difference in UIC between subjects that added salt before food preparation, during food preparation, or after the food was fully prepared.

We found no significant correlation between daily per capita salt intake and UIC concentrations. However, we found a significant positive correlation between UIC and urine sodium content, which is a more accurate method for measuring salt consumption [14, 36]. Similar results were found by Nazeri et al. [10]. These results along with those of other studies [10, 37, 38] and the WHO declaration [5] illustrate the link between salt consumption and iodine status. This can also further link the higher UIC concentrations found in Sadra city and the higher salt consumption than the results from Tehran [10].

In this study, we found a negative correlation between thyroid volume and UIC. Iodine deficiency has a goitrogenic effect and this negative correlation was anticipated. Some previous studies [39, 40] explained that the association between iodine status and thyroid volume was inconsistent; there was no correlation between thyroid volume and UIC in iodine-sufficient areas. The volume of the thyroid gland may be population-specific and some genetic and environmental factors may contribute to variations in thyroid volume, especially in iodine-sufficient areas [41].

This study has some limitations. The first limitation is its cross-sectional design and limited population in one city in the Fars province of Iran. Another possible limitation is that the iodine concentrations in the salt used by these study subjects were not measured.

In conclusion, iodine status in the adult population in the city of Sadra was categorized as sufficient, whereas it was insufficient in the adult and pregnant women populations of Tehran, the capital city of Iran. A significant contributing factor can be the higher use of salt among the population of Sadra than that of Tehran. High iodine concentrations in the environment, such as water and earth, can also hypothetically influence the iodine status. Studies with larger sample sizes and in other parts of the country are warranted.

Author disclosures

MJ, AH, AS, no conflicts of interest.

Data availability

Data described in the manuscript, codebook, and analytic code will be made available upon request to AS pending application and approval.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cdnut.2022.100013.

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