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The Interplay between Demographic Factors, Household Iodized Salt, and Urinary Iodine Concentration in School-Aged Children of Abarkouh, Iran

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ABSTRACT

Background: In Abarkouh, despite Iran's national iodine sufficiency, the stability of iodine levels in salt and the influence of demographic factors on IDD risk in this specific population have not been thoroughly assessed. This study aims to determine the quantitative relationships between urinary iodine concentration (UIC), the prevalence of goiter, and behavioral disorders as a consequence of height, weight, and salt iodine concentration. **Methods:** The urinary and salt iodine concentrations were measured using the Chlorometric method and iodine detector kit, respectively. The differences between the two groups and the relationship between these variables and endpoints were determined using t-test and Pearson correlation with a significance level of 0.05, respectively. Quantitative relationships between them were also modeled using linear and nonlinear models' artificial neural network (ANN) in MATLAB2020. **Results:** According to the results and linear modeling, iodine concentration and behavioral disorders based on variables of height, weight, and iodine salt concentration were randomly distributed. Also, limited nonlinear relationships between UIC and variables of height, weight, salt iodine concentration and behavioral disorders were obtained as a consequence of variables of height, weight, salt iodine concentration, and urinary output in ANN ($R<0.7$). **Conclusion:** Modeling the relationship between these variables using ANN showed there were limited nonlinear relationships between urinary iodine and variables of height, weight, and iodine salt concentration. Thus, to determine the effective factors and the quantitative relationship between them, it is suggested to study other variables in future studies.

Introduction

Iodine deficiency is one of the most common micronutrient deficiencies, affecting 30% of the world's population (Ma and Skeaff, 2017). These disorders are one of the health-related problems in Iran and have been diagnosed with severe iodine deficiency in many areas. Iodine deficiency causes adverse health consequences that are collectively known as iodine deficiency disorders (IDD). To reduce the risk of IDD, it is important to assess the iodine status of a population by using several

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biochemical, clinical and dietary indices (Ma and Skeaff, 2017). Iodine intake is especially critical for fetus, newborns, children, and pregnant and lactating women. Although both iodine deficiency and excess may cause adverse effects (Zimmermann and Boelaert, 2015), Adverse effects of less iodine intake from iodine-rich drinking water affect thyroid volume (Tvol) and total goiter rate (TGR) (Chen *et al.*, 2016). Thyroid and goiter rates in children have been regarded as indicators that reflect long-term population iodine nutrition, as recommended by both the world health organization (WHO). On the basis of other studies, it can be concluded that IDD during the gestation may cause several disorders in the neonatal cognitive and social behaviors (Ahmed, 2017). Iodine deficiency can also slow down growth and reduce school-based learning and concentration in students (Hay *et al.*, 2017). For example, the TGR was 10.96% in children from Hebei province whose median UIC was 418 mg/L (Liu *et al.*, 2019), indicating excessive iodine intakes. The TGR increased from 12% to 38% as the median UIC increased from 520 to 1961 mg/L in Jiangsu province (Zimmermann, 2019). Iran's national salt iodization program, initiated in 1989, is widely recognized as a public health success story, having effectively shifted the population from severe iodine deficiency to iodine sufficiency While Iran's mandatory salt iodization program has long been considered a success, recent national studies indicate a need for vigilant monitoring to maintain optimal iodine status. A large-scale cross-sectional study conducted in 2022 on adults in Iran (Jeddi *et al.*, 2023) found that while the median urinary iodine concentration (UIC) was within the adequate range, a significant portion of the population had UIC levels indicative of excess iodine; this suggested a potential shift in the nature of iodine nutrition. Furthermore, a comprehensive review (Baffa *et al.*, 2024) of studies concluded that although the national median UIC is optimal, the iodine content in a considerable percentage of salt samples exceeds the recommended level, highlighting the importance of continuous quality control in salt production and distribution to prevent iodine-induced thyroid disorders; it further ensures the sustained elimination of iodine deficiency.

In this regard, monitoring is performed to identify and diagnose these disorders on time. Therefore, in case of these disorders, programs are proposed to control it. To date, in Iran, programs based on food enrichment, especially table salt with iodine, have been implemented. According to monitoring, this enrichment has played a major role in reducing iodine deficiency disorders such as goiter. However, proper follow-up and implementation of these programs are essential to reduce the effects of iodine deficiency (Azizi *et al.*, 2023). It is necessary to monitor iodine intake in conjunction with iodine concentration in the body and determine the relationships and factors that affect the concentration of iodine in the body and its consequences.

The most commonly used measures of iodine status in a population are biochemical. UIC can be determined in urine samples. The measurement of UIC is recommended by WHO/UNICEF/ICCIDD (World Health Organization, 2007) to assess the iodine status in a population. UIC is a good biomarker of short-term iodine status (i.e. days) (Zimmermann *et al.*, 2008) because ~90% of dietary iodine is excreted into the urine. Therefore, a higher excretion of urinary iodine is indicative of a high recent dietary iodine intake and vice versa (Campanozzi *et al.*, 2019). In previous studies, the main focus has been on determining the concentration of iodine in the body and disorders caused by this deficiency.

Accordingly, a study conducted in 2024 in Yazd province showed that the prevalence of goiter, especially grade II goiter, has decreased in Abarkouh. The level of urinary iodine was also significantly increased after the salt iodine scheme. Some urinary iodine also exceeded the WHO standard. In 2024, Yazd province was declared free of iodine deficiency disorders (Mozaffari-Khosravi *et al.*, 2003). The novelty of this study is that it provides novel insights by investigating the iodine status in the under-researched, high-risk region of Abarkouh, Yazd, where environmental factors

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predispose the population to deficiency. Its primary innovation lies in explicitly examining how demographic factors mediate the relationship between household iodized salt usage and the biological endpoint of urinary iodine concentration in a vulnerable school-aged child population.

The city of Abarkouh, located in Yazd province, represents a pertinent location for such an investigation. Despite Iran's national iodine sufficiency, the stability of iodine levels in salt and the influence of demographic factors on IDD risk in this specific population have not been thoroughly assessed (Hooshmand *et al.*, 2024). There is a pressing need to move beyond national averages and evaluate the micro-dynamics of iodine nutrition at the local level to ensure the long-term sustainability of the UIC program. Thus, this study aims to determine the impact of some factors on these disorders, and the quantitative relationship between them has received less attention. The relationship between independent parameters and endpoints resulting from iodine deficiency in the body was modeled using both linear and nonlinear models. Due to the accuracy and power of the artificial neural network model, in this study, the authors tried to use ANN to predict endpoints, including UIC and behavioral disorders.

Materials and Methods

Sampling and sample size

In this cross-sectional descriptive study, students were randomly selected by cluster sampling from primary schools in center of Iran. At first, according to the population of Yazd province (33514 people), five primary public schools were randomly selected. The sample size was calculated using Cochran's formula, which resulted in a total of 100 students. In order to control the bias in the sample size, 10% was added to the sample size. Finally, the sample size included 110 students.

Data collection

Data were obtained from 110 children aged 7-12 years old in each of the selected primary schools.

The WHO recommendation was used to determine urinary iodine (Mohammadi *et al.*, 2018). Since a urine sample of 80-120 is sufficient to achieve 95% confidence and 10% accuracy in this study, 10 ml of urine from 110 students were randomly selected and obtained (Ma *et al.*, 2018). Accordingly, 24-hour urine was taken from 110 students. Samples were sent to the laboratory in sterilized plastic containers and ice packs as soon as possible. The method of urinary iodine test in this study was a Chlorometric method (oxidation with ammonium sulfate using spectrophotometer). To measure salt iodine, students were asked to bring 10 g of salt to test for salt iodine. Salt iodine was also measured by an iodine detector kit (The titration method recommended by the British Pharmacopoeia). The prevalence of goiter will also be monitored by a physician referred by the Health Network. Questionnaires for students' behavioral disorders (Rutter Form for Teachers) were also completed by teachers. Goiter prevalence was determined according to WHO criteria, and their behavioral disorders were determined by the Rutter questionnaire, and their relation with iodine deficiency was assessed.

Inclusion and exclusion criteria

Inclusion was limited to school-age children (7-12 years) residing in Abarkouh who gave informed consent. Participants were excluded if they had a known thyroid disorder or had taken iodine-containing supplements within the prior month.

Linear and nonlinear modeling

Due to the accuracy and power of the artificial neural network model, in this study, the authors tried to use ANN to predict endpoints, including UIC concentration and behavioral disorders. Among the tested models, the best model was selected based on correlation coefficient (R^2), P-value <0.05, and root mean square error (RMSE). Due to the lack of dependence of the results on linear models, the quantitative correlation between variables was determined using an artificial neural network as one of the powerful methods in nonlinear modeling. In this study, ANN was performed by a feed-forward back propagation algorithm in MATLAB 2020 (Jalili *et al.*, 2021). In this model, there are several inputs, hidden layers,

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and outputs and the number of neurons in each hidden layer has a significant effect on the response. In this study, the number of neurons in the hidden layer was determined based on two equations 1 and 2 (Azizi *et al.*, 2021):

Eq. 1 $\frac{2(i+o)}{3} < n < i(i+o) - 1$

Eq. 2 0.5i-2<n<2i+2

i=number of inputs, o= the number of outputs and n=number of hidden layer neuron.

The assigned weight was also used to determine the relationship between the layers. Initially, the network was trained with real data from UIC on the degree of behavioral disorders in both boys and girls. In the database obtained from this model, 70, 15, and 15% of the data were used for training, validation, and testing, respectively. Weight and bias were then determined using training, and the amount of error in the validation was monitored. After that, the training was stopped following the increase in validation error with a specific repetition. Finally, the best structure to determine the iodine concentration prediction and the behavioral disorders' rate in both groups was determined based on mean square error (MSE) and correlation coefficient (R).

Ethical considerations

This study was conducted with the approval of Shahid Sadoughi University of Medical Sciences and Health Services, Medical Ethics Committee with code: IR.SSU.SPH.REC.1398.042.

Data analysis

Statistical analysis was performed by ANOVA, t-test, and the correlation between variables was determined by Spearman correlation coefficient. Data were recorded in Excel and entered into MATLAB2020 for statistical analysis.

Results

The mean of the studied indices in both groups is shown in **Table 1**. According to **Table 1**, the concentration of urinary iodine mean in girls and boys were 16.90±7.04 μg/l and 18.80±6.90 μg/l, respectively.

Table 1. Mean values of studied variables in elementary students.

Variable	Urinary iodine (μg/l)	Weight (kg)	Height (cm)	TGR (%)	Salt iodine (ppm)	Rutter questionaries' score
Girls	16.90±7.04[a]	38.20±10.80	142.50±7.40	33	20.20±12.50	2.30±3.10 (0-13)
Boys	18.80±6.90	34.50±7.10	137.50±4.90	30	17.60±12.80	8.10±3.30 (0-18)
P-value[b]	0.96	<0.0001	0.01	-	0.34	
CV						
Girls	8.70-30.00	24.40-77.80	121-160	-	11.70-24.50	
Boys	11.80-30.00	22.50-60.30	128-148	-	12.00-25.00	

***TGR**: Total goitrt rate; **CV**: Coefficient of variation; **TGR**: total goiter rate; [a]: Mean SD; [b]: Student t-test.*

Correlation between variables and UIC

In this study, the correlation between urinary iodine and its variables including height, weight, and salts iodine is shown in **Table 2**. According to the analysis, there was little correlation between UIC and height as well as weight in both groups, so their trend of change has been negative with the height increasing (R=-0.09 in girls, R=-0.02 in boys). Thus, with less effect, higher iodine intake was found in taller individuals, while decreased iodine uptake was effective in reducing height in students. There was also a negative correlation between UIC and girls' weight (R=-0.11). However, in the boy's group, urinary iodine can slightly increase only with weight gain (R=0.02).

Correlation between variables and goiter

Goiter prevalence is one of the adverse health effects of iodine deficiency. In this study, its prevalence was determined according to WHO, UNICEF and ICCIDD guidelines. Results showed that about 37.2% and 29.1% of girls and boys had a goiter, respectively. As UICs were higher in boys than in girls (**Table 2**), higher rates of goiter prevalence were more likely in girls.

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Table 2. The correlation between urinary iodine concentration and weight, height and salt iodine**.**

Sex	Weight (kg)	Height (cm)	Salt iodine (ppm)
Boys	-0.02	-0.02	0. 56
Girls	-0.11	-0.09	0.53

The correlation between goiter prevalence and independent variables as well as urine iodine was expressed in **Table 3**. Furthermore, the risk of goiter in girls decreased with increasing UIC (R=-0.14). However, there was a direct correlation between increased urinary iodine and increased risk of goiter in boys (R=0.1). Thus, it can be said that the use of iodine excretion as an indicator of goiter prevalence in boys is a little validity. In addition, iodine is another factor that has been effective in reducing the prevalence of goiter in both boys and girls (R=0.33 in boys, R=0.27 in girls). On the other hand, weight gain was another factor influencing goiter prevalence in girls (R=0.15) but no such correlation was observed for boys (**Table 3**).

Table 3. The correlation between goiter and study variables.

Sex	Weight (kg)	Height (cm)	Salt iodine (ppm)	Urinary iodine (µg/l)	Behavioral disorders
Girls	-0.15	0.03	0.27	-0.14	-0.17
Boys	-0.06	-0.11	0.33	-0.1	-0.37

Correlation between variables and behavioral disorders

The association of behavioral disorders with independent variables such as weight, height and concentration of iodine in salt as well as the concentration of iodine in urine was expressed in **Table 4**. Statistical analysis showed there was the highest correlation between salt iodine concentration and reduction of behavioral disorders in boys (R=-0.55), while this relationship was not observed for girls. With increasing UIC in both groups, the total score of the questionnaire decreased slightly (R=-0.07 in boys, R=-0.22 in girls, **Table 4**).

Table 4. The correlation between variables and behavioral disorders

Sex	Weight (kg)	Height (cm)	Salt iodine (ppm	Urinary iodine (µg/l)
Girls	-0.08	-0.06	-0.8	-0.22
Boys	0.17	0.35	-0.55	-0.07

The Modeling of urinary iodine based on independent variables

to fit the best model, first, the distribution of UIC and behavioral disorders versus height, weight, and concentration of iodine in salt for both boys and girls was performed (**Figure 1**). According to **Figure 1**, the iodine concentration in the urine had a random distribution with the parameters studied in this study. Based on the statistical models studied, the UIC in boys had a normal distribution that was more correlated with the Gaussian model compared with other models. Similar results were observed for girls' UIC versus weight gain. But the iodine concentration in girls follows the Fourier series, which indicates a repeated frequency of iodine concentration to height, and the highest correlation was observed in the eighth series (R^2=0.52 and RMSE=5.3).

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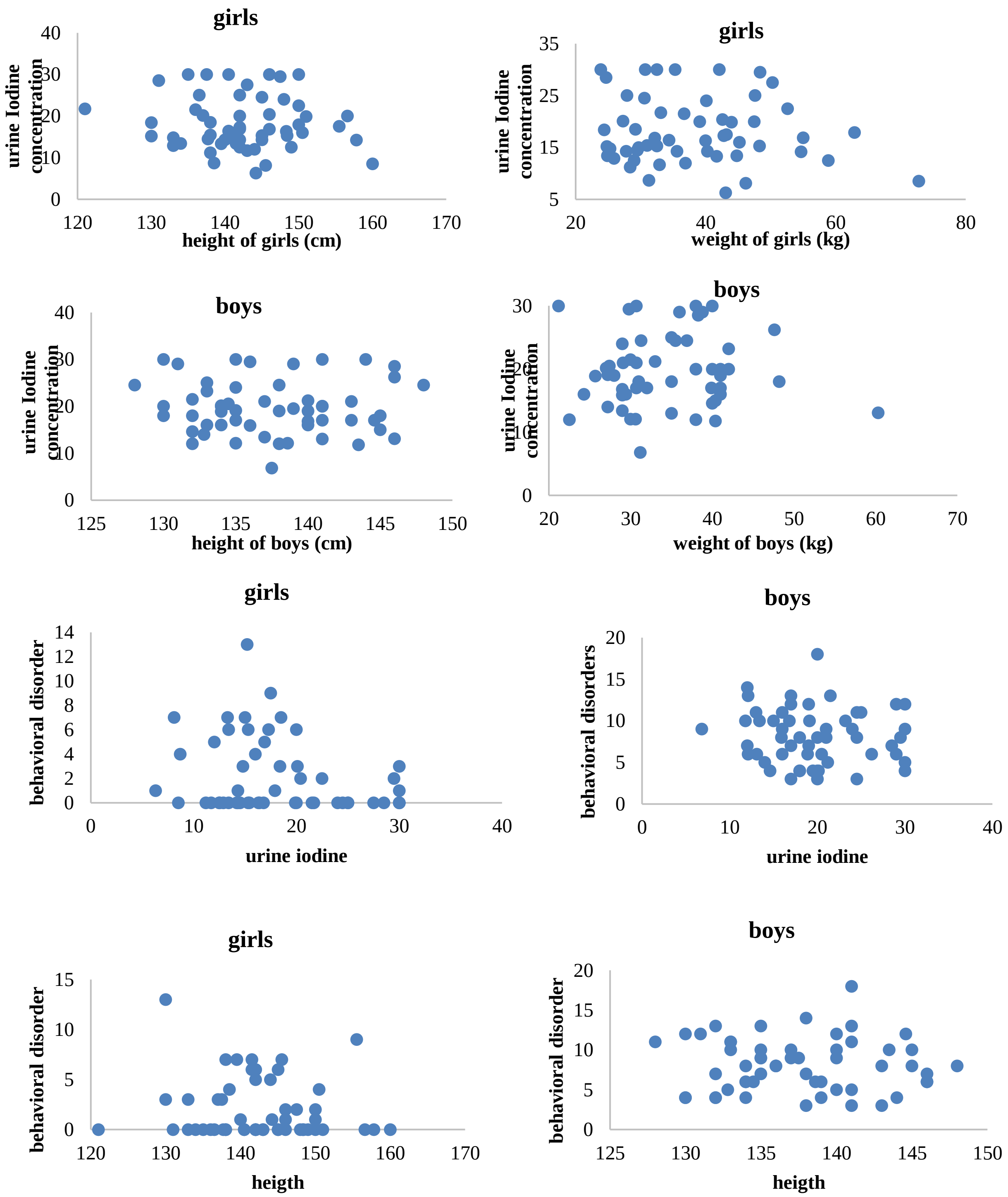

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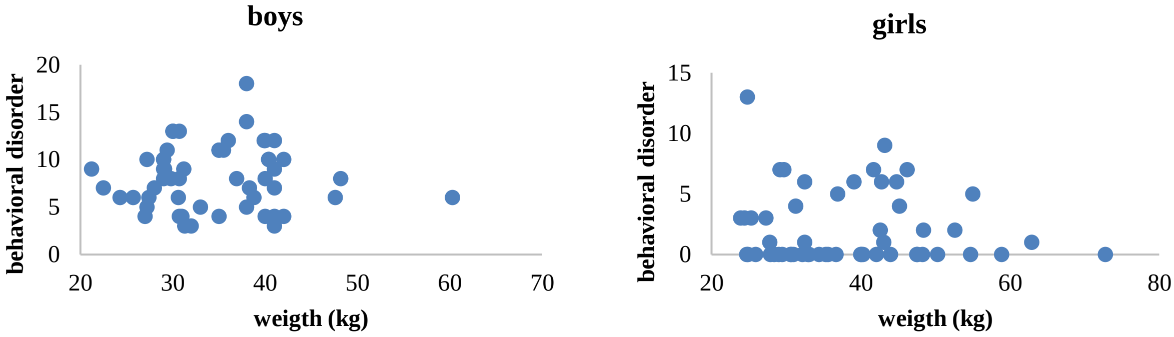

Figure 1. Distribution of UIC based on body weight and height (based on smoothing spline).

According to **Table 5**, the UIC in both groups was randomly distributed in height and weight because it was most correlated with smoothing spline model. Of these two groups, the most random distribution belonged to girls (R=0.69 iodine and weight, R=0.6 iodine and height). Thus, linear functions cannot predict changes in iodine concentration in these groups. This is because the current method of determining the concentration of urinary iodine in behavioral disorders does not include all the numbers in a range. Due to these limitations, nonlinear models have been used to predict the changes in the endpoints studied. The best artificial neural network structure for predicting UIC and behavioral disorders depend on independent parameters. The results of this modeling using the Levenberg-Marquardt algorithm and the number of 3-8 neurons and 4-10 neurons in the hidden layer for UIC and behavioral disorders for girls were 3: 7: 1 and 4: 5: 1, respectively. For boys, the optimal structure was 3: 6: 1 and 4: 4: 1, respectively because it showed the lowest MSE and the highest correlation (See **Figure 2**). The performance of optimal structures for both endpoints of UIC and behavioral disorders in both groups is shown in **Figures 2** and **3**.

According to **Figure 3**, MSE was lower than average in girls and boys, but the correlation was higher for boys (R = 0.54). Thus, UIC in boys can be predicted with greater confidence by ANN.

Table 5. Distribution of urinary iodine concentration in students by mathematical models.

Categories	Mathematical model	P-value	Sum of square	R^2	Adj-R^2	RMSE
Boys	Smoothing spline	0.99	980.9	0.43	-0.018	5.759
Weight	Gaussian	7	1097	0.36	-0.02	5.77
Height	Smoothing spline	0.99	1243	0.28	-0.025	5.78
Girls	Smoothing spline	0.99	657.2	0.69	0.088	6.02
Weight	Gaussian	7	1183	0.44	0.0095	6.28
Height	Smoothing spline	0.98	817.3	0.6	0.27	5.37
	Fourier	8	1017	0.52	0.29	5.3

Discussion

In this study, the dependence of UIC on elementary students was investigated regarding variables such as weight and height distribution and iodine content in their salt intake. According to Table 1, the concentration of urinary iodine mean in girls and boys were 16.9±7.04 µg/l and 18.8±6.9 µg/l, respectively. Comparing these results with the classification provided by WHO, it can be seen that the iodine intake in this region was below the WHO recommended limit. Thus, in this area students suffer from iodine deficiency. In other studies in southern Europe, Nigeria, Nepal, and New Zealand, mean urinary iodine levels in

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children of 5 to 12 were 90, 148, 193, and 68 µg/l, respectively (Gelal *et al.*, 2009, Ma and Skeaff, 2014, Santiago-Fernandez *et al.*, 2004). However, urinary iodine levels in children under 5 in Arbesu Fernandez study were 184 µg/l. In this case, the effect of iodine deficiency in the diet of these children appears, because many of the essential iodine in the body can be supplied through breast milk at an early age.

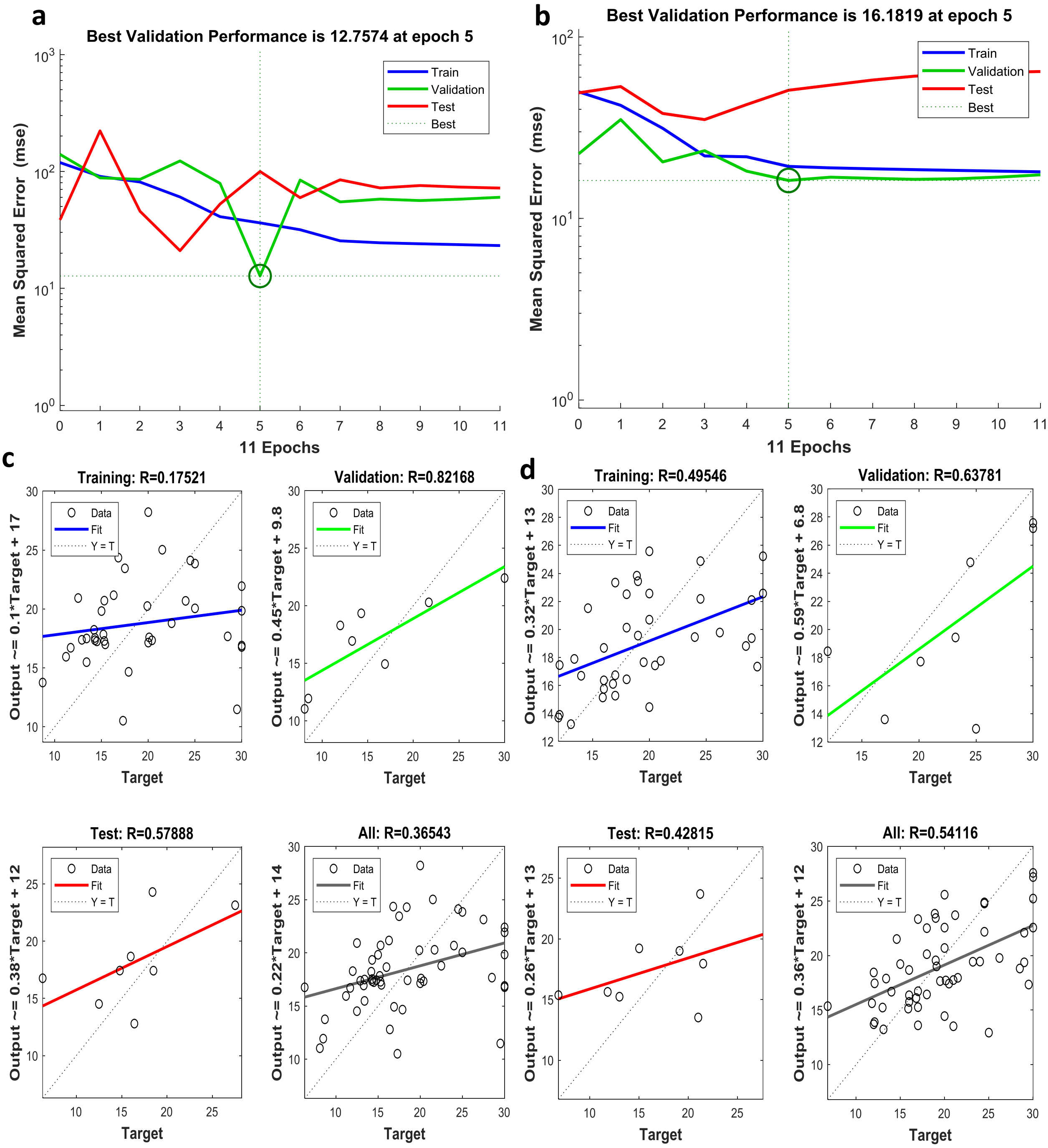

Figure 2. The performance and efficiency of ANN for predicting iodine a) performance of ANN in girls; b) performance of ANN in boys; c) regression of ANN in girls; d) regression of ANN in boys.

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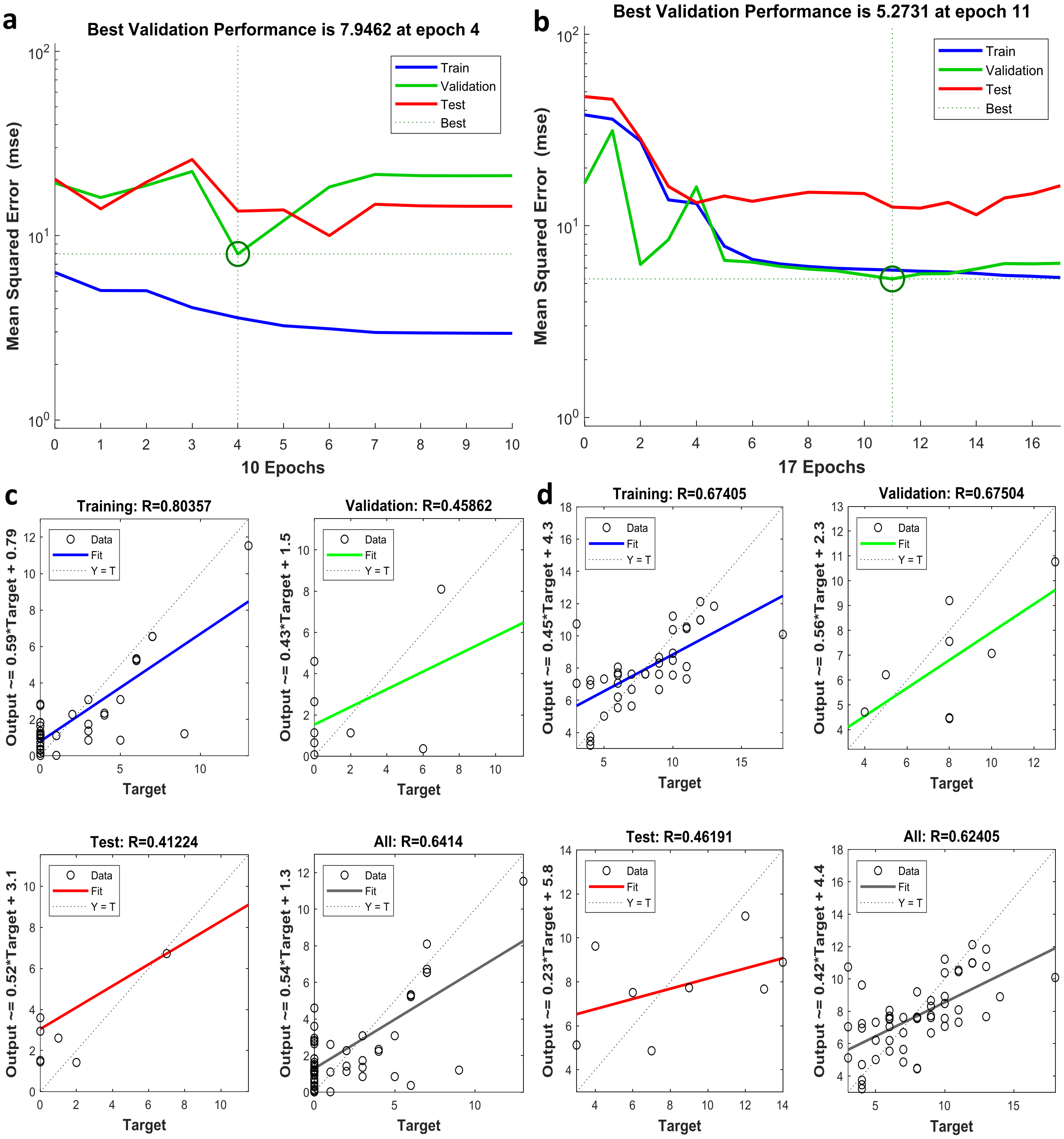

Figure 3. Performance and efficiency of ANN for predicting behavioral disorders a) girls; b) boys; c) regression in girls; d) regression in boys.

While school-age diets vary investigation of other variables including physical conditions are necessary. The height and weight mean in girls were higher than boys (*P*>0.05). Moreover, the mean iodine content of salt in the girl's group was higher than boys (*P*=0.3). However, the mean urinary iodine in boys was higher than girls (*P*>0.05). The results showed that the iodine concentration was 30 ppm for 60% of girls and 49% of boys. In previous studies, about 85% of people used iodized salts, and their iodine concentration was more than 15 ppm (Kharabsheh *et al.*, 2004). The mean iodine concentration in children was 10 times higher than the mean urinary iodine in this study. Thus, in addition to the use of iodized salt, proper salt storage is essential to

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maintain its iodine concentration, which seems to be overlooked in many homes. In explaining these results, it can be pointed out that the range of the variables under study was higher in girls and had a significant effect on the mean. Although all data were within 2σ, there was a significant difference between UIC in both groups (*P*=0.05). Besides, the score of Rutter questionnaire were 2.3 and 8.1 for girls and boys respectively. As a result, 94.5 and 54.5% of girls and boys had attained score of less than 9. Scores of 9-12 was documented for 1.8 and 27.3% of girls and boys, and the rest was related to a score of higher than 12. Therefore, it implies that behavioral disorders in boys (16.3) were higher than girls (2%).

Independent variables such as weight, height, and iodine concentration in food, including salt consumption, were studied for their effects on three endpoints: iodine levels, goiter prevalence, and behavioral disorders. On the other hand, office iodine in the body as one of its endpoints had an effect on behavioral disorders and the prevalence of goiter, and the correlation between them was determined. According to the analysis, there was little correlation between UIC and height as well as weight in both groups, so that their trend of change has been negative with height increasing (R=-0.09 in girls, R=-0.02 in boys). Thus, with less effect, higher iodine intake was found in taller individuals, while decreased iodine uptake was effective in reducing height in students. There was also a negative correlation between UIC and girls weight (R=-0.11in girls). However, in the boy's group, urinary iodine can slightly increase only with weight gain (R=0.02 in boys). Based on these results, evaluation of thyroid function in underweight girls is necessary.

Furthermore, the results of this study showed a direct correlation between iodine intake and urinary iodine levels in male and female students (R=0.56 in boys, R=0.53 in girls). Other studies have also shown a similar correlation between urinary iodine and salt iodine (Kapil *et al.*, 2014). Thus, getting more iodine through salt can be effective in providing body with iodine. But, as the studied girls were close to puberty and had hormonal changes, the effect of salt intake was less than that of boys.

Goiter prevalence is one of the adverse health effects of iodine deficiency. In this study, its prevalence was determined according to WHO, UNICEF, and ICCIDD guidelines. Results showed that about 37.2% and 29.1% of girls and boys had a goiter, respectively. Also, the risk of goiter in girls decreased with increasing UIC (R=-0.14). Other studies have also shown that increased urinary iodine levels decrease the likelihood of goiter in students (Kharabsheh *et al.*, 2004). However, there was a direct correlation between increased urinary iodine and increased risk of goiter in boys (R=0.1). Thus, it can be said that the use of iodine excretion as an indicator of goiter prevalence in boys is of little validity. In addition, iodine is another factor that has been effective in reducing the prevalence of goiter in both boys and girls (R=0.33 in boys, R=0.27 in girls). On the other hand, weight gain was another factor influencing goiter prevalence in girls (R=0.15) but no such correlation was observed for boys because iodine deficiency and thyroid dysfunction in girls affect their weight gain.

Statistical analysis showed there was the highest correlation between salt iodine concentration and reduction of behavioral disorders in boys (R=-0.55), while this relationship was not observed for girls. In other studies, in southern European countries, IQ increased by increasing UICs above 100μg/l (Soriguer *et al.*, 2000). Thus, although salt iodine concentration was not effective in girls 'score, and consequently, behavioral disorder index, it can reduce the behavioral disorders of boys by increasing iodine concentration in boys' salt intake. On the other hand, with increasing UIC in both groups, the total score of the questionnaire decreased slightly (R=-0.07 in boys, R=-0.22 in girls). These results, along with the results of goiter prevalence in students, may confirm the fact that boys' bodies’ iodine is supplied from other sources. The results also showed that along with other factors affecting behavioral disorders, the higher the risk of goiter among students, the more their behavioral disorders increased (R=0.37 in boys,

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R=0.17 in girls).

In previous studies, iodine deficiency has been dependent on living conditions (Xu *et al.*, 2017). This was while according to the results of the present study, iodine deficiency disorders were similar in both sexes, which indicated no dependence on demographic characteristics and iodine salt concentration. Based on the statistical models studied, the UIC in boys had a normal distribution that was more correlated with the Gaussian model than other models. Similar results were observed for girls' UIC versus weight gain. But, the iodine concentration in girls follows the Fourier series, which indicates a repeated frequency of iodine concentration to height, and the highest correlation was observed in the eighth series (R^2=0.52 and RMSE=5.3).

Thus, linear functions cannot predict changes in iodine concentration in these groups because the current method of determining the concentration of urinary iodine in behavioral disorders does not include all the numbers in a range. Due to these limitations, nonlinear models have been used to predict changes in the endpoints studied. The best artificial neural network structure for predicting UIC and behavioral disorders depend on independent parameters. The relationship between urinary iodine concentration (UIC), salt iodine concentration, height, weight, and behavioral disorders was analyzed using an artificial neural network model. The modeling results, which employed the Levenberg-Marquardt algorithm, indicated that for girls, UIC and behavioral disorders could be predicted with configurations of 3-8 neurons and 4-10 neurons in the hidden layer, respectively. Specifically, the results were 3:7:1 for UIC and 4:5:1 for behavioral disorders. The relationship between urinary iodine concentration (UIC), salt iodine concentration, height, weight, and behavioral disorders was analyzed using an artificial neural network model. The modeling results, which employed the Levenberg-Marquardt algorithm, indicated that for girls, UIC and behavioral disorders could be predicted with configurations of 3-8 neurons and 4-10 neurons in the hidden layer, respectively. Specifically, the results were 3:7:1 for UIC and 4:5:1 for behavioral disorders. MSE was lower than average in girls and boys, but the correlation was higher for boys (R=0.54). Thus, UIC in boys can be predicted with greater confidence by ANN. Although in previous studies the rate of iodine deficiency in pregnant women has been well predicted by the ANN as an iodized salt-dependent outcome (Murillo-Llorente *et al.*, 2020), such strong relationships have not been found in this study. These results can be due to differences in the physical condition and nutrition of these groups. Consequently, the variables examined in this study, including weight, height, and the iodine concentration of salt alone, are insufficient to accurately predict iodine levels, which serves as a measure of iodine deficiency. On the other hand, the rate of MSE error for predicting behavioral disorders in girls was higher than average. However, according to the existing correlation coefficient, the prediction of behavioral disorders by the artificial neural network may be satisfactory in some cases (Abbasi *et al.*, 2021).The results showed the limited ability of this nonlinear model to predict both endpoints, especially iodine concentration using independent variables. Thus, it is suggested that further studies be conducted on the effect of other parameters regarding iodine concentration and disorders.

Among the limitations of the study were the lack of measurement of thyroid hormone concentrations, iodine and its metabolites in the blood, and iodine in other foods consumed by the participants due to lack of funding available to conduct the study. This research provides critical, localized evidence that can directly inform and refine public health policy; it moves beyond national averages to ensure that iodine deficiency prevention programs are effectively targeted to the specific socioeconomic and environmental realities of Abarkouh region.

Conclusion

In this study, UIC, the prevalence of goiter, and behavioral disorders, as a consequence of height, weight, and salt iodine concentration were investigated. The study results showed that the

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average iodine concentration in the boys' group was higher than girls. But, in both groups, it was less than the value recommended by WHO. There was also an insignificant and negative relationship between UIC and height and weight variables. The prevalence of goiter was higher in girls than boys. However, the rate of behavioral disorders was higher in boys and was inversely related to the prevalence of goiter in this group. There were limited nonlinear relationships between urinary iodine and variables of height, weight, and iodine salt concentration as behavioral disorders as a height consequence, weight, and salt and UIC.

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Authors' contributions

Abbasi F. completed statistical analyses and drafted the initial manuscript. Jalili M and Azizi M provided content and supervised data collection. Ehrampush MH managed the study progress. All authors designed the study, obtained resources, and supervised manuscript preparation. All authors reviewed and approved the final version.

Conflict of interest

The authors declared no conflict of interest related to the study.

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References

Abbasi F, et al. 2021. The toxicity of SiO 2 NPs on cell proliferation and cellular uptake of human lung fibroblastic cell line during the variation of calcination temperature and its modeling by artificial neural network. *Journal of environmental health science and engineering.* **19 (1)**: 985-995.

Ahmed R 2017. Maternal thyroid hormones trajectories and neonatal behavioral disorders. *Journal of diabetes and endocrinology.* **3 (2)**: 18-21.

Azizi E, Abbasi F, Baghapour MA, Shirdareh MR & Shooshtarian MR 2021. 4-chlorophenol removal by air lift packed bed bioreactor and its modeling by kinetics and numerical model (artificial neural network). *Scientific reports.* **11 (1)**: 1-10.

Azizi F, Delshad H, Hedayati M & Mirmiran P 2023. Iodine status in Iran: from deficient to replete. *Lancet diabetes & endocrinology.* **11 (12)**: 903-904.

Baffa LD, et al. 2024. Prevalence of iodine deficiency and associated factors among school-age children in Ethiopia: a systematic review and meta-analysis. *Systematic reviews.* **13 (1)**: 142.

Campanozzi A, et al. 2019. Iodine deficiency among Italian children and adolescents assessed through 24-hour urinary iodine excretion. *American journal of clinical nutrition.* **109 (4)**: 1080-1087.

Chen W, et al. 2016. Associations between iodine intake, thyroid volume, and goiter rate in school-aged Chinese children from areas with high iodine drinking water concentrations. *American journal of clinical nutrition.* **105 (1)**: 228-233.

Gelal B, et al. 2009. Assessment of iodine nutrition status among school age children of Nepal by urinary iodine assay. *Southeast Asian journal of tropical medicine and public health.* **40 (3)**: 538.

Hay I, Hynes KL, Burgess J & Otahal P 2017. Learning difficulties and mild Iodine deficiency. In *41st Annual International Academy for Research in Learning Disabilities (IARLD) Conference*, p. .

Hooshmand S, Yousefian F, Rahimi H, Mohammadzadeh M & Dehghani R 2024. Household salt consumption and urinary iodine levels in schoolchildren aged 8–10 in Darab City, Iran: 2022. *Scientific reports.* **14 (1)**: 28349.

Jalili M, et al. 2021. Ambient air pollution and cardiovascular disease rate an ANN modeling: Yazd-Central of Iran. *Scientific reports.* **11 (1)**: 16937.

[DOI: 10.18502/jnfs.v11i1.20921]

Jeddi M, Habib A & Salehi A 2023. Sustained elimination of iodine deficiency within the third decade after compulsory iodine supplementation policy in the south of Iran: A population-based cross-sectional study. *Current developments in nutrition.* **7 (1)**: 100013.

Kapil U, et al. 2014. Status of iodine deficiency among pregnant mothers in Himachal Pradesh, India. *Public health nutrition.* **17 (9)**: 1971-1974.

Kharabsheh, Belbesi, Qarqash & Azizi 2004. Goiter prevalence and urinary iodine excretion in schoolchildren of Jordan. *International journal for vitamin and nutrition research.* **74 (4)**: 301-304.

Liu S, et al. 2019. Iodine deficiency disorders (IDD). In *Endemic Disease in China*, pp. 37-60. Springer.

Ma ZF & Skeaff SA 2014. Thyroglobulin as a biomarker of iodine deficiency: a review. *Thyroid.* **24 (8)**: 1195-1209.

Ma ZF & Skeaff SA 2017. Assessment of population iodine status. In *Iodine deficiency disorders and their elimination*, pp. 15-28. Springer.

Ma ZF, Venn BJ, Manning PJ, Cameron CM & Skeaff SA 2018. The sensitivity and specificity of thyroglobulin concentration using repeated measures of urinary iodine excretion. *European journal of nutrition.* **57 (4)**: 1313-1320.

Mohammadi M, Azizi F & Hedayati M 2018. Iodine deficiency status in the WHO Eastern Mediterranean Region: A systematic review. *Environmental geochemistry and health.* **40 (1)**: 87-97.

Mozaffari-Khosravi H, Deghani A & Afkhami M 2003. Goiter prevalence and urinary iodine levels in 6-11 year-old students in Yazd in 2002, 10 years after initiation of iodized salt scheme. *Iranian journal of endocrinology & metabolism.* **5 (4)**: 283-291.

Murillo-Llorente MT, Fajardo-Montañana C & Perez-Bermejo M 2020. Artificial neural network for predicting iodine deficiency in the first trimester of pregnancy in healthy women. *Tohoku journal of experimental medicine.* **252 (3)**: 185-191.

Santiago-Fernandez P, et al. 2004. Intelligence quotient and iodine intake: a cross-sectional study in children. *Journal of clinical endocrinology & metabolism.* **89 (8)**: 3851-3857.

Soriguer F, et al. 2000. The auditory threshold in a school-age population is related to iodine intake and thyroid function. *Thyroid.* **10 (11)**: 991-999.

World Health Organization 2007. Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers.

Xu C, Liang Z & Luo Y-J 2017. Role of medical resource level in iodine deficiency disorder. *Military medical research.* **4 (1)**: 1-8.

Zimmermann MB 2019. Iodine deficiency. In *The thyroid and its diseases*, pp. 101-107. Springer.

Zimmermann MB & Boelaert K 2015. Iodine deficiency and thyroid disorders. *Lancet diabetes & endocrinology.* **3 (4)**: 286-295.

Zimmermann MB, Jooste PL & Pandav CS 2008. Iodine-deficiency disorders. *Lancet.* **372 (9645)**: 1251-1262.

[DOI: 10.18502/jnfs.v11i1.20921]