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Determination of Iodide Amounts in Urine and Water by Isotope Dilution Analysis

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ABSTRACT

Urinary iodide and iodine in drinking water were determined in 318 healthy children aged 0 to 18 yr living in Izmir and environmental rural and urban areas in the western part of Turkey. The method is based on substochiometric isotope dilution analysis. Iodide was precipitated by substoichiometric amounts of $AgNO_3$. Iodide-131 was used as a tracer. Electrophoresis was performed to separate $Ag^{131}I$ from excess $^{131}I^-$. The $Ag^{131}I$ zone was cut off the electrophoresis paper and counted with a NaI(Tl) scintillation counter. Count rates were plotted versus added KI concentrations. The unknown iodide amount was found by using these linear plots. Iodide concentration ranges were within 1.8 – 100.45 µg/L in the analyzed drinking water samples. The mean value was 44.14 ± 17.33 µg/L and the median was 58.08 µg/L. Urinary iodide concentration ranges were 0.22 – 142.22 µg/L. The median of the distribution was 37.71 µg/L and the mean was 40.30 ± 24.05 µg/L. The results show that the examined area suffers moderate iodine deficiency.

Index Entries: Isotope dilution analysis; iodine deficiency; urine; iodine-131; drinking water; urinary iodide excretion in children; Aegean region.

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INTRODUCTION

Iodine is an important trace element for human health. It is a distinctive component of thyroid hormones and has an important role for growth and development. Iodine is found in relative abundance in marine plants and animals, in deposits of organic origin, in certain natural mineral water, in sedimentary phosphate rock, and in association with certain mineral deposits *(1)*. Most of the iodine ingested by humans comes from food of animal and plant origin. This iodine is absorbed in the soil. For this reason, iodide-deficiency disorders may occur in areas with poor iodine concentrations.

The World Health Organization (WHO) recommendation of daily iodine intake is 50–200 μg *(3)*. Iodine deficiency is a problem for almost all countries of the world, with about 1600 million people (mostly in developing countries) currently at risk of iodine-deficiency disorders (IDD) *(1–5)*. The negative effects of iodine deficiencies on growth and development are called iodine-deficiency disorders. Although all age groups can be affected by iodine deficiency, the riskiest groups are pregnant, fetus, newborn, and infant *(1,2)*. The most common consequence of iodine deficiency is goiter in all age groups. The goiter rate is accepted as a reliable indicator of iodine deficiency in a population. In addition goiter, low school success and low IQ level are the other important consequences of iodine deficiency *(6)*. Although, the goal of WHO was to iodine-deficiency disorders eliminated by the year 2000, iodine-deficiency disorders have still been seen in Turkey and in many other countries, and it occurs in under negatively developed countries with poor economies (*1,3,6*). Because most iodide is excreted in the urine, urinary iodide excretion is currently the most convenient laboratory marker of iodine deficiency *(7)*. The determination of urinary iodide concentration is a valuable tool in epidemiological studies of iodine supplementation, particularly in the diagnosis of iodine deficiency and in controlling goiter *(8)*. Because of the difficulty in measuring dietary iodine intake directly, urinary iodine concentrations are usually used as an index of iodine intake. In healthy individuals, fecal iodine excretion is negligible. Iodine is eliminated from the body mostly as urinary iodide.

High-performance liquid chromatography (HPLC) *(9)*, inductively coupled plasma–mass spectrometry (ICP-MS) *(10)*, intracavity laser spectrometry *(11)*, energy-dispersive x-ray spectrometry *(12)*, and the optimized potentiometric method *(13)* are some techniques used to measure iodide concentrations in biological and environmental samples. These techniques are expensive, especially for developing countries. The other common method of iodide analysis is the kinetic spectrophotometric method based on a catalytic redox reaction of As(III)–Ce(IV) *(14)*. However, there have been conflicting evaluations of the determination of iodide in the presence of an excess of chloride by this method. Although neutron activation analysis has the required sensitivity and accuracy and

is therefore considered the "gold standard" for measuring inorganic iodide, it is not suitable for routine practice because of the specialized facilities needed; moreover, the quality of iodide in urine requires a time-consuming separation procedure to remove interfering radioisotopes of chlorine, sodium, and bromine *(15,16)*. Therefore, a method that can determine iodide concentrations in water and urine and suitable for routine analysis has been developed in this study.

MATERIALS AND METHODS

Materials

Gelman paper electrophoresis equipment was used for electrophoresis procedures. Tennelec PCA II 8196 Channel Analyzer equipped with a 3×3 NaI(Tl) well-type scintillation detector was set for counting procedures.

Reagents

All chemicals were purchased from Merck. $Na^{131}I$ was supplied by the Department of Nuclear Medicine. All solutions were prepared in doubly distilled water. A 40,000-µg/L stock KI solution was prepared by dissolving 40 mg of KI in 1000 mL of doubled distilled water. The 5-, 10, 15-, 20-, 40-, 60-, 80-, 100-, and 150-µg/L KI solutions were prepared using this stock solution. These solutions were stored in the dark. Solutions of 0.1N Na_2SO_3 and $2\times10^{-6}N$ $AgNO_3$ were prepared.

Procedures

Collection of Water and Urine Samples:

Drinking water samples were collected from Izmir City and environmental rural and urban areas (28 settled place). These are tap water, well water, deionised water or bottled commercial water which are consumed by owners of the collected urine samples. A total of 318 children were assessed during the study. They were randomly selected among healthy children. Their age were between 0–18. Dietary habits of families using iodinated or noniodinated salts were recorded. Clinical examinations were performed by Pediatric Endocrinology Group. Height, weight and head circumference, thyroid examinations were recorded on a detailed checklist. Thyroid examinations were made by palpation. Collected urine and water samples were stored in a deep freeze until using.

Analysis Procedure: Procedures similar to those used in earlier studies have been applied *(17,18)*. Five microliters of water or filtered urine samples were put in each of a series of tubes. Equal volumes with increasing iodide concentrations and equal volumes of identical $^{131}I^-$ solutions were added to dissolved samples. Less than equivalent

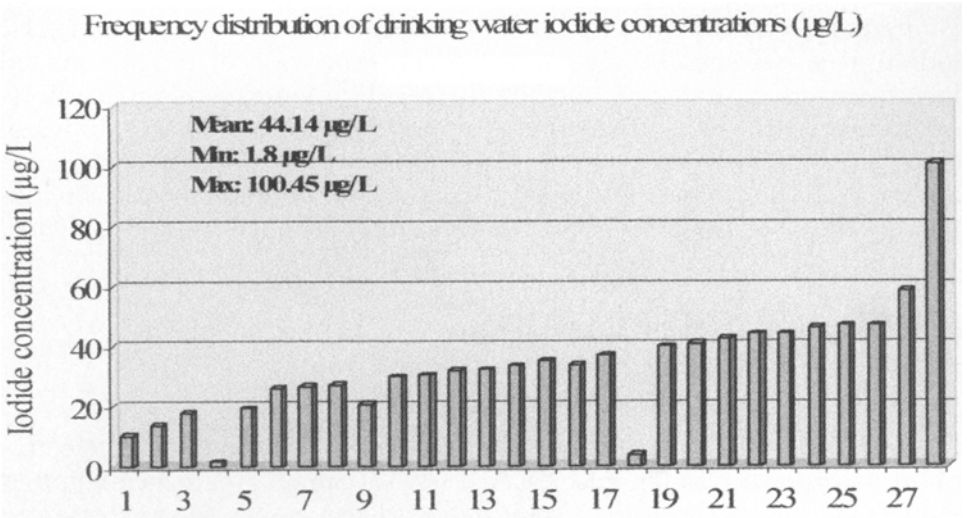

Fig. 1. Frequency distribution of drinking water iodide concentrations (µg/L).

amounts of $AgNO_3$ were added and they were rested for 15–20 min. Five microliters of Na_2SO_3 to prevent oxidation of iodide and 5 µL of dioxan were added, consecutively. Five microliters from each test tube were transferred to cellulose acetate electrophoresis strips premoistened by buffer solution. Electrophoresis was performed with a Gelman electrophoresis chamber. The buffer solution was a mixture of *n*-butanol/water/acetic acid (4/2/1). Migration time and applied voltage were 2 h and 300 V, respectively. While excess $^{131}I^-$ migrates because of electrophoresis on paper, the $Ag^{131}I$ precipitate remains stationary and this fraction of paper is counted with a NaI(Tl) scintillation detector of multichannel analyzer using the 364-keV gamma peak of ^{131}I. These count rates were plotted versus iodide concentrations by using a computer curve-fit program. A linear decreasing plot was obtained and used as a calibration curve. Three parallel experiments were performed with each sample.

RESULTS

The precision of the method was evaluated using standard solutions (7–7500 µg/L) *(17)*. It is observed that the entire range of our values are in agreement within a maximum error of ± 10.15. Thus, the procedure yields accurate results at the microgram level. The minimum detection limit was determined to be 1 µg/L. Relative standard derivations are not higher than 14%. Each sample was analyzed at least three times. The iodide concentrations ranges are within 1.8–100.45 µg/L in analyzed

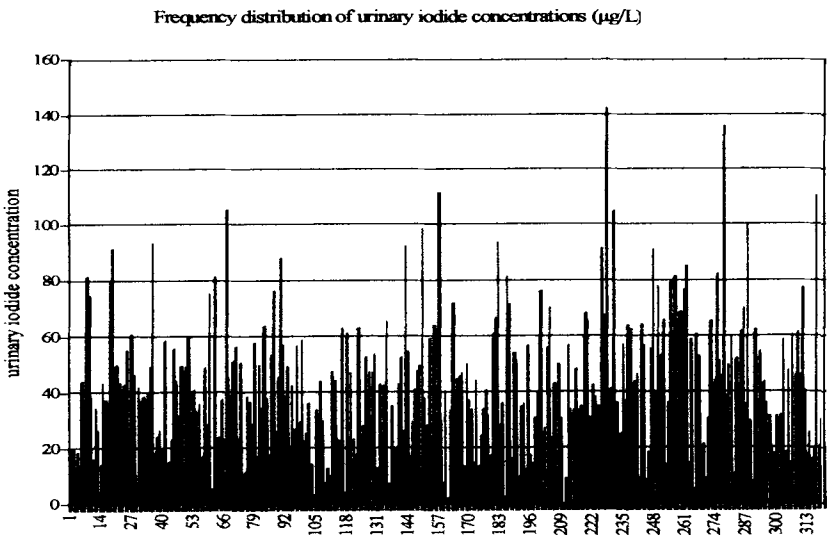

Fig. 2. Frequency distribution of urinary iodide concentrations (µg/L).

drinking water samples. The mean value is 44.14 ± 17.33 µg/L and the median is 58.08 µg/L. Figure 1 shows frequency distributions of drinking water concentrations.

The frequency distribution of urinary iodide in 318 healthy children is given in Fig. 2. The median of the distribution is 37.71 µg/L. Maximum urinary concentration is 142.22 µg/L, the minimum is 0.48 µg/L, and the mean is 40.30 ± 24.05 µg/L. When estimates of iodine intakes derived from urinary iodide excretion values were compared with a graded scheme of severity for endemics of iodine-deficiency disorders, it was found that 22.95% of children suffer severe iodine deficiency, 46.22% moderate, and 30.18% mild. These results show that the western part of the Aegean region has moderate iodine deficiency.

The goiter rate is 6.25% for all children, 3.65% the 0- to 12-yr age, and it is 10.81% after 12 yr of age. According to goiter examinations, the examined area suffered mild iodine deficiency. On the other hand, the goiter rate is much more higher for some areas such as the rural area of Ödemiss (Birgi, Bozdağ, Ovakent), Zeytindağ, Çandarlı, Menderes (Görece, Değirmendere, Özdere), and some urban areas of Bornova and Karşıyaka with a lower socioeconomic status population (Table 1). It is 20% to 25% for Ödemiş and its environs. The mean urinary iodide excretion is 46.90 ± 25.55 for Ödemiş. Although the urinary concentration values still indicate moderate iodine deficiency, goiter rates are higher than other areas. Goitrogens also may be effective as well as less iodine intakes for this region. A pediatric endocrinology research group of Ege University recently found that goiter prevalence is about 43% for school children in Birgi *(19)*.

Table 1
Goiter Rates and Urinary Iodine Distributions in Some Areas

Area	Goiter rate (%)	Mean Urinary Iodide concentrations (μg/L)	Range (μg/L)
Bornova	10-33	34.76-49.96	5.03-93.18
Karabağlar	18	42.47	13.68-71.81
Bergama-Zeytindağ	50	43.41	8.31-91
Menderes	33-66	48.02	5.21-85.2
Ödemiş	20-25	36.04-66.88	8.24-100.2

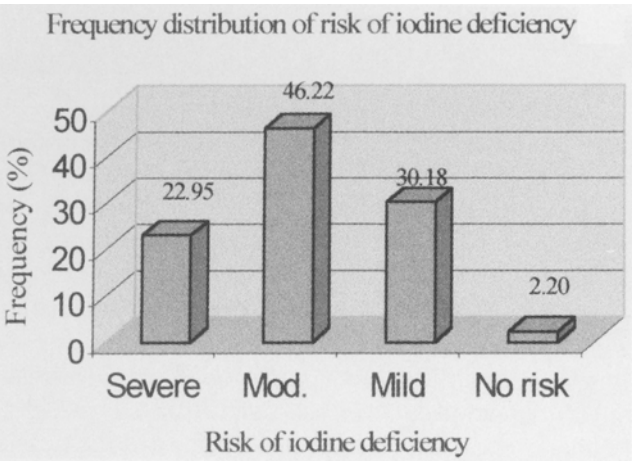

Fig. 3. Frequency distribution of risk of iodine deficiency (< 20 μg/L, severe iodine deficiency; 20–50 μg/L, moderate iodine deficiency; 50–99 μg/L, mild iodine deficiency).

DISCUSSION

The finding in this study indicates that risk of iodine deficiency persists in young children living in Izmir and its environs. Although this situation is not common for many industrialized countries, in some recent studies among 10- to 16-yr-old school children indicate an average goiter prevalence of 16.7% European countries such as France (7).

The severity of iodine deficiency can be assessed using the criteria shown in Fig. 3; according to WHO. Iodine deficiency in children is characteristically associated with goiter. The goiter rate increases with age, reaching a maximum at adolescence. According to WHO reports, girls have a higher prevalence than boys. In this work, the goiter rate for girls in adolescent is 36.40% of all children with goiters.

Although it was reported that the goiter rates in schoolchildren over 6 to 12 yr of age provide a convenient indicator of the presence of iodine

deficiency in a community, because of the goiter is the late clinical effect of iodine deficiency, examination of urinary iodine concentrations is a more convenient method for determining iodine-deficiency disorders *(3,4)*. On the other hand, advised thyroid size examination is by ultrasound instead of palpation. Goiter examinations by palpation is easy and quick, and requires no instruments. Its fairly reliable when thyroids are grossly enlarged, but, unfortunately, palpation is quite inaccurate in distinguishing mild thyroid enlargement. Where thyroids are not grossly enlarged and ultrasonagraphy is not available, examination by palpation alone may not be worthwhile, because of its inherent inaccuracy *(4)*. In this case, because most ingested iodine excretes by urine, urinary iodide examinations seem a more reliable indicator for iodine-deficiency determinations.

This study consisted of a pilot study in urban and rural areas for collecting the first data of urinary iodide examinations for iodine deficiency for the Aegean region. More detailed studies have been planned for this subject.

CONCLUSION

The aim of this study was to develop an effective, simple and accurate method for iodide determination that can be used in water, urine, and other environmental and biological materials.

Generally, isotope dilution analysis (IDA) has been used for iodine determination by counting $Ag^{131}I$ precipitate *(16)*. In this work, $Ag^{131}I$ was counted after separation by electrophoresis. The total time for sample preparation did not exceed 3 h, as many samples could be prepared in parallel; hence, the method could prove useful for epidemiological surveys in areas of suspected iodine deficiency. The results show that the determined method has many advantages, such as eases, quickness, and low cost. It might be recommended in the fight against iodine deficiency.

On the other hand, obtained results show that an iodization program for the Aegean region may be necessary, and more detailed studies for all of Turkey should be conducted.

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