Original Article

The correlation between high background radiation and blood level of the trace elements (copper, zinc, iron and magnesium) in workers of Mahallat's hot springs

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Abstract

Background: Blood trace elements of people who are living or working in areas with high radioactivity have an important role in vital processes. The scope of this work is to measure the concentrations of blood trace elements of permanent workers in Mahallat's hot springs.

Materials and Methods: In this study, 30 persons of hot springs permanent workers in Mahallat (mean background dose: 21.6 mSv) were selected as a sample group and 30 persons with similar social class who received a normal background dose and were not engaged in any type of radiation work were selected as a control group. Five milliliters of blood sample was taken from each person and after preparation of the samples, the concentration of copper, iron, zinc and magnesium was measured with atomic absorption spectrometry.

Results: The average concentration of copper, iron, zinc and magnesium in the irradiated group was 0.67±0.11, 1.54±0.41, 1.76±0.34 and 19.78±1.42, respectively and in the control group, was 0.78±0.06, 1.06±0.15, 0.85±0.05 and 20.34±0.57, respectively. Values of copper and magnesium in workers were found to be less than that of the control group. The mean concentration of iron and zinc in permanent workers was significantly more than that of the control group ($P<0.05$). Overall, no meaningful statistical correlation was found between the concentration of magnesium among the permanent presence in the area ($P>0.05$).

Conclusions: The results showed that increases in the average concentrations of Zn and Fe and decreases in the concentration of Cu of workers was observed. The finding also showed that the probability of chronic exposure effects on body trace element concentrations was increases and each value of the doses could be dangerous.

Key Words: Atomic absorption spectrometry, high background radiation, mahallat, trace element

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INTRODUCTION

Several areas have been identified with high background radiation in different parts of the earth, among which are Ramsar city in the north of Iran and Mahallat's hot springs in central Iran, as the radiation dose received by the permanent workers in this area has been estimated to be 21.6 milli-

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Sievert.[1,2] People who are working or living in areas with high radioactivity are exposed to prolonged and low doses of background radiation; therefore, they can be exposed to low doses of radiation effects. There is no consensus on the biological effects of the low doses and the mechanisms of the biological responses to such radiations are ambiguous to a large extent, which requires more research.[3,4] Most arguments are about DNA radiation because of its sensitivity to radiation. However, some radiation effects are not addressed in the field of DNA damage, such as radical chain reactions, lipid peroxidation in membrane, reduction of enzymatic activity, ionic currents, activation of ion channels and changes in the concentration of trace elements.[5,6]

Trace elements are necessary in all vital processes and their importance becomes increasingly clear as the measurement methods progress.[7] Their acceptable range for maintaining physiological function of the body is very critical and a slight change in the amount of these elements may cause serious changes in physiological activities of body.[8,9] Moreover, with respect to biological effects of low doses of trace elements, researchers investigate important though small changes in organisms; therefore, these elements can be considered as a parameter for studying the chronic effects of radiations.

Recently, numerous studies have reported a correlation between the effect of low doses of X-ray on the blood concentration of trace metals and the structural changes in the hair and nails of radiographers.[10,11] Furthermore, studies on the effects of chronic exposure to doses of X-ray and gamma-ray in animal models have shown changes in the concentration of trace elements in blood and irradiated tissues.[3,12] The effects of high doses of X-ray and gamma-rays have also shown statistically significant changes in the amount of trace elements in different tissues of irradiated rats.[3] Copper, zinc, iron and magnesium are important elements in physiological functions of body tissues. Concentration of these elements in the body is controlled by the homeostasis system, and its acceptable range for maintenance of cell structural properties and functions of body tissues is very limited. Copper is the main component of many metal-containing enzymes like ceruloplasmin, which has antioxidant activity. The presence of copper is necessary to control tissue inflammation, defense against free radicals of cellular respiration and formation of connective tissues.[13,14] Iron is used in vital activities including oxidative cellular mechanisms, oxygen transport to tissue, and also in the structure of many crucial enzymes and proteins of the body and fights with free radicals generated in tissues in substitution reactions with zinc.[15] Zinc has an anticancer role and fights with free radicals. Zinc as an antioxidant protects the membrane against lipid peroxidation and is necessary for wound healing.[16] Magnesium exists in the structure of many enzymes and is effective in phosphate-transfer reactions. This element is required for maintaining the structure of macromolecules like DNA and RNA.[17] Considering that there were few studies on the effects of high background radiation and the reports on the effect of low doses of radiation on the changes in concentration of copper, zinc, iron and magnesium in the body, the present study was conducted to present more information on the concentration of these elements in people exposed to high background radiation compared with other people.

MATERIALS AND METHODS

In this analytical descriptive study, blood serum was used as a suitable index for assessment of elements in the body as this was a common method in clinical studies.[18] Regarding the normal range for the concentration of copper and iron in the body, in this study, the minimum significant difference and reliability coefficients were determined as 95% and selected samples were 60 people, of whom 30 were the workers of hot springs who were present there permanently and the other 30 with the same economical and cultural status were living in Mahallat city who were exposed to a normal level of background radiation. The studied workers of hot springs were 28-70 years old with 3-50 years of service. According to the previous studies on the assessment of the amount of dose the permanent workers received, those workers received almost 21.6 milli-Sievert per year.[2] As the confounding factors in this study were liver and kidney diseases, taking certain medications and smoking, people of the two groups were selected from the candidates consuming ordinary foods with no special dietary habits and not having any acute or chronic diseases. These participators were not taking any medications and sampling was performed at specific times in the morning in order to minimize the effect of meals and the probable fluctuation in the amount of those elements. To eliminate the errors caused by environmental contamination, pipettes, glass containers and test tubes were placed in a chamber containing 20 L of 10% chloridric acid in order to clean the metal-contaminated surface of the equipment and then they were rinsed three-times with deionized water and dried.

A blood sample of 5 mL was drawn from the participators' vein in the elbow using a plastic syringe.

To remove serum from the blood, the samples were centrifuged for 10 min at a speed of 3500 rpm. Samples were kept in a refrigerator at 20°C until all samples were collected. Concentrations of copper, zinc, iron and magnesium in the blood serum were measured using atomic absorption spectrometry (AAS) (pu 9100; Philips: UK). Flame was used as the atomizer and a mixture of air and acetylene was used as an oxidant and a fuel [Table 1].

In order to measure the concentration of these elements, their calibration curve was drawn using standard solutions of copper, zinc, iron and magnesium with concentrations of 0.25, 0.50, 0.72, 1.00 and 1.25 mg/L. Once the concentration of the elements in the irradiated and control groups was measured, the collected data were analyzed using SPSS software and ANOVA test.

RESULTS

Mean concentration of copper, iron, zinc and magnesium in the irradiated group were 0.67±0.11, 1.54±0.41, 1.76±0.34 and 19.78±1.42 mg/L, respectively, and in the control group were 0.73±0.06, 1.06±0.15, 0.85±0.05 and 20.34±0.57 mg/L, respectively. These results are shown in Table 2 and Figure 1. Statistical comparison of the two groups using the independent t-test showed a significant difference in concentration of copper between the two groups ($P<0.05$) as the copper had been reduced in the permanent workers' blood ($P<0.01$). Mean concentrations of iron and zinc in the permanent workers' blood were significantly higher than that of the control group ($P<0.05$). Although the mean concentration of magnesium in the permanent workers' blood was less than that of the control group, no meaningful statistical correlation was found between the concentration of this element and the permanent presence in the area ($P>0.05$).

DISCUSSION

People residing in areas with high background radiation are exposed to higher background radiation than other people due to their location. Although they receive a low dose with a low rate, this amount is of importance as this rate of exposure is in excess of the normal dose received annually by other people. Because not enough studies have been conducted on the effect of high background radiation on the function of different parts of the body, in this study, the concentration of trace elements in blood samples of the participants was analyzed. Common biological samples for measuring the concentration of different elements include blood, hair and urine. Although hair samples are prepared more easily, they are prone to environmental contamination. Urine samples are of limited value because the concentration of trace elements in urine depends on their concentration in meals and also they may be contaminated with the environment. Therefore, blood samples are considered more appropriate for the analysis of trace elements. Because, in using whole blood the contamination of anticoagulants with trace elements might occur or the environmental pollution might reach the system during acidic digestion, the concentration of copper, zinc, iron and magnesium was measured and analyzed in blood serum of the workers who, on average, spent 75 years in the area with high radiation and in blood serum of the control group by the AAS method. Given that the mean concentration of those elements agreed with the normal range for these elements in related texts, it can be concluded that there was no systemic error that might be attributed to observing safety regulation while taking samples and proper adjustment of the instrument. The concentration of copper in workers who received higher background radiation than the control group showed a significant reduction. High background radiation with a reliability coefficient of

Table 1: Conditions of AAS device for measuring the concentration of copper, zinc, ironand magnesium by a flame of air-acetylene[18]

Element	Lamp current (mA)	Wave length (nm)	Gap width (nm)	Gas flow (L/min)
Zinc	8	231.9	0.5	0.9-1.2
Iron	12	248.3	0.2	0.8-1.2
Copper	4	324.8	0.5	0.9-1.2
Magnesium	3	258.2	0.5	0.9-1.2

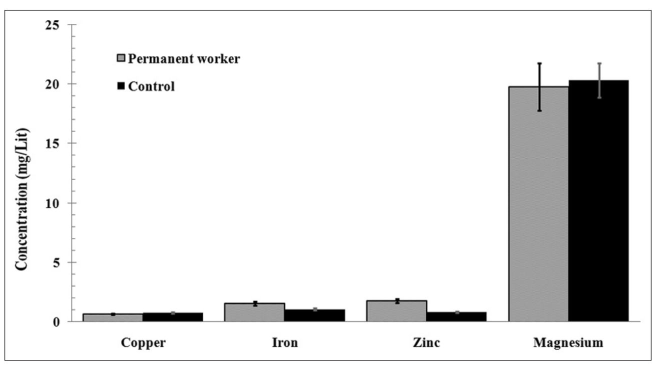

Figure 1: Comparison of difference in concentration of trace elements between the irradiated and the control groups

Table 2: Mean concentration of copper, zinc, iron and magnesium in the studied people(μg/mL)

Group	Number	Copper*	Iron*	Zinc*	Magnesium*
Permanent workers	30	0.67 ± 0.11	1.54 ± 0.41	1.76 ± 0.34	19.78 ± 1.42
Control people	30	0.78 ± 0.06	1.06 ± 0.15	0.85 ± 0.05	20.34 ± 0.57

*: Mean ± standard deviation

95% is effective in concentration of copper in blood serum. The mean concentration of iron and zinc, with a reliability coefficient of 95%, in the permanent workers' blood was more than that in the control group. Although the mean concentration of magnesium in the permanent workers' blood was less than that of the control group, no meaningful correlation was found between the concentration of this element and the permanent presence in the area. Different studies have been conducted in this regard including Chatterjee *et al*.'s study on the radiographers' blood, which reported the reduction of copper and zinc and increase in the concentration of iron in radiographers' blood compared with the control group.[18] A study by Bolouri *et al*. in Iran on the effect of radiation on copper and zinc showed a significant reduction in copper in female radiographers in comparison with the control group.[19] Another study by Ebrahiminia *et al*. in Iran, which examined the correlation between radiation and trace elements in radiographers working in the diagnostic and treatment wards showed an increase in the concentration of copper in radiographers compared with the control group. The mean concentration of iron in radiographers was reported to be more than that of the control group although this difference was not statistically significant. Furthermore, there was a significant reduction of zinc in female radiographers. Those researchers did not find any meaningful relationship between the concentration of magnesium and radiography.[20] The difference between the results of the present study and the results of the previous study may be related to the used blood sample, as Chatterjee *et al*.'s study and the study done in Iran used whole blood and the present study used blood serum.[18,19] Moreover, it should be considered that humans are not genetically equal and uniform; therefore, the sensitivity to radiation may differ by individual. At low doses, vitamin C acts as an antioxidant and the role of antioxidant enzymes against free radicals and developing resistance to radiation is important and nutrition is of special importance in this respect. Changes in trace elements influenced by radiation of X-ray and gamma-rays may be due to defects in the mechanisms of absorption, desorption and distribution of these elements in various tissues. In terms of molecular structure, radiation can change the genetic structure of the cell in a way that the controlling gene of the plasma membrane for adjustment of these elements is damaged or the intercellular communication is disrupted. Radiation causes the expression of some genes that are involved in inflammatory reactions and dilation of capillaries and changes in endothelial cells of the membrane and by increasing permeability of small vessels, disrupts the dynamics of copper and iron. Changes in the structure of the cell membrane which are due to the interaction between free radicals and vital molecules like proteins and fats in the membrane, influence the ion gradient and permeability of the membrane. Any factor that causes loss of cell membrane integrity starts an oxidative damage and causes permeation of trace metals from the cellular components. Results of the present study enhance the probability that chronic exposure to radiation affects certain metals in blood serum.

CONCLUSIONS

Results showed that increases in average concentrations of Zn and Fe and decreases in Cu of the workers was observed. The finding also showed that the probability of chronic exposure effects on body trace element concentrations was increased and each value of the doses could be dangerous.

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