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Impact of low level radiation on concentrations of some trace elements in radiation workers

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Introduction: Small variations in trace element levels may cause important physiological changes in the human body. This study aims to evaluate five important trace elements in radiation workers.

Method: In this study, 44 radiation workers and an equal number of non-radiation workers were selected as the case and control group, respectively. The concentrations of iron, magnesium, zinc, copper, and selenium in the serum of the participants were measured using an Atomic Absorption Spectrometry (AAS).

Results: The mean concentrations of iron, magnesium, zinc, copper, and selenium for the case group were 107.3 µg/dl, 2.3 mg/dl, 80.9 µg/dl, 112.6 µg/dl and 216.7 ng/ml, respectively. The results for the control group were 121.9 µg/dl, 2.3 mg/dl, 82.3 µg/dl, 112.8 µg/dl and 225.2 ng/ml, respectively.

Conclusions: The mean concentration of iron in the case group was significantly lower than the control group (p-value = 0.012), while the concentrations of other elements in both of the groups were not significantly different. In the case group, except magnesium (p-value = 0.021), no significant relationship was found between age and the elemental concentrations. According to Spearman's test, there was a meaningful statistical correlation between the sex and concentration of iron, Mg, Zn, and Se. Also, the correlation between the concentration of magnesium and the weights of radiation workers was significant (p-value =0.044).

Keywords: atomic absorption spectrometry, Low level radiation, radiation effects, radiation worker, trace element

INTRODUCTION

Radiation workers are categorized as a group of people who are exposed to low radiation doses due to the occupational exposures. Since the occupational radiation dose will be added to the natural background radiation, the accumulated dose may cause biological effects. There is no agreement about biological effects and mechanisms of biological reactions to these radiations (1-3). Due to the sensitivity of DNA, most of studies have focused on the DNA related issues. However, some other effects of radiation such as changes in the concentrations of trace elements are not included in DNA damages (4-6).

A trace element, in analytical chemistry, is known as an element in a sample that has an average concentration of less than 100 parts per million measured in atomic count or less than 100 micrograms per gram. Similar to vitamins and other minerals, they are playing an important role in human health (7). Small changes in the amount of a trace element lead to important changes in physiological activities (8, 9). Recent studies have shown that chronic and low-dose x-rays would make significant changes in the levels of trace elements in different rat tissues (10-13).

Copper has antioxidant activity and its role in some micro-vascular control mechanisms has been proven

(14). Zinc is present in all organs, tissues, and fluids of the body. It is critical for the cell survival. Zinc is important for several human functions, including growth and development, bone metabolism, neuropsychiatric and immune functions, and wound healing (15, 16). Also, zinc is useful for ultraviolet protection (17). Iron has several vital functions in the body. It serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells, and as an integrated part of enzyme systems in various tissues (18). Magnesium is a main factor in many important enzymatic reactions. About 30–40 percent of the body's magnesium is found in muscles and soft tissues, one percent is found in extracellular fluid, and the remainder is in the skeleton (19, 20). Selenium has been implicated in the protection of body tissues against oxidative stress, maintenance of defense against infection, and modulation of growth and development (21). Table 1 shows the reference ranges of the studied concentrations.

Table 1. The reference range for the studied trace elements (22)

Several relevant attempts have been reported on this subject. Chatterjee et al. studied the concentrations of iron, copper and zinc in radiographers blood (23). In Iran, Barghi et al. and Ebrahiminia et al. evaluated the effect of low doses on concentrations of two trace elements (24, 25).

The aim of this study was to compare the level of five important trace elements, iron, magnesium, zinc, copper, and selenium, in the serum of 44 radiation workers as the case group and an equal number of hospital staffs with no history of exposure as the control group.

MATERIALS AND METHODS

A case–control study was conducted to assess the effect of occupational exposure on concentrations of five blood trace elements in radiation workers. Voluntarily, 44 employed radiation workers and an equal number of hospital staffs with no history of exposure were selected as the case and control group, respectively. As table 2 shows, the mean age and the number of men and women of both the groups were almost identical. Radiation workers had at least two years of work experience in dealing with ionizing radiation at diagnostic radiology departments. Regarding to the case group, the number of patients who were imaged every six hours by them were 9 to 23, and their average monthly working hours were 180 h. Also, they usually worked with equipments ranged from 40 to 120 kVp and 20 to 500 mA. According to the available reports documented by the radiation safety officer, the exposures of radiation workers were less than 0.05 mSv per two months which would not exceed the permissible doses. So the absorbed dose of the control group members was in the level of natural background radiation. The background radiation from X and gamma rays has been previously reported by Rostampour et al. (26). All the studied participants had no known history of any acute and chronic (hypertension, diabetes, etc) diseases, smoking, and had similar dietary habits.

Plastic disposable syringes (Shafasaz Co, Tehran, Iran) with stainless steel needles were used for blood sampling. The blood samples were taken from the studied contributors' elbow vein and were collected in cleaned collection vials without anticoagulant. Anticoagulants such as citrate and Ethylenediaminetetraacetic acid (EDTA) were not used in this study, because they would chelate cations such as Cu, Fe, Zn, Mg, and Se, and could interfere with the results. Therefore, to avoid this problem, heparin (H3393-10 KU, Sigma-Aldrich, Germany) was used instead. The samples were then transported to the laboratory. Serum was separated by centrifugation (KUBOTA KN-70, Tokyo, Japan) at 1500 g for 20 min and then was decanted into a new clean tube (22). All samples were stored on a rocker at room temperature and shielded from light. Each serum was analyzed in triplicate.

Table 1. The reference range for the studied trace elements (22et)

Element	Specimen	Reference Range	Conversion Factor	Reference Range (International Units)
Iron	S	M: 65-170 μg/dL F: 50-170 μg/dL	0.179	11.64-30.43 μmol/L 8.95-30.43 μmol/L
Magnesium	S	1.56-2.52 mg/dL	0.5	0.65-1.05 mmol/L
Zinc	S	70-150 μg/dL	0.153	10.7-22.9 μmol/L
Copper	S	M: 70-140 μg/dL F: 80-155 μg/dL	0.157	10.99-21.98 μmol/L 12.56-24.34 μmol/L
Selenium	S or P	78-320 ng/mL	---	---

S: Serum, P: Plasma, M: Male, F: Female

Table 2. Details of the case and control groups, n=88 (22 women and 22 men in each group)

			Age (year)	Weight (kg)	Work experience[a] (year)
Case (n = 44)	Min-Max	Woman	25-47	49-75	4-23
		Man	34-50	57-90	8-26
	Mean ± SD	Woman	34.18 ± 7.35	61.0 ± 8.37	11.23 ± 6.34
		Man	40.0 ± 5.14	71.82 ± 10.05	17.0 ± 5.91
Control (n = 44)	Min-Max	Woman	21-53	48-73	---
		Man	21-48	55-85	---
	Mean ± SD	Woman	25.36 ± 8.62	54.91 ± 7.62	---
		Man	35.09 ± 11.12	73.0 ± 9.64	---

[a] Work experience of the control group was not considered

Table 3. Mean concentrations of studied trace elements in the case and control groups

Trace element	Group	N	Mean	Std. Deviation	Std. Error Mean	P-value
Iron (μg/dl)	Control	44	121.9091	27.41398	4.13281	0.012
	Case	44	107.2955	25.86061	3.89863	
Mg (mg/dl)	Control	44	2.3295	0.42775	0.06449	0.688
	Case	44	2.2880	0.53358	0.08044	
Zn (μg/dl)	Control	44	82.3182	8.21732	1.23881	0.634
	Case	44	80.8409	18.77646	2.83066	
Cu (μg/dl)	Control	44	112.7727	25.06722	3.77903	0.969
	Case	44	112.5909	18.11246	2.73056	
Se (ng/ml)	Control	44	225.1287	33.35461	5.02858	0.921
	Case	44	216.6175	29.56573	4.45723	

Measurements of trace element concentrations in the serums of studied participants were performed using a Philips PU 9100X AAS (Philips, Great Britain). The AAS has supplanted colorimetric techniques as the method of choice to determine trace metals.

Finally, the relationship between the trace element concentrations of the members in both of the studied groups and the concentrations of the trace elements associated with the sex, age and occupation were obtained by two-sample independent t-test and the pearson and spearman's correlation coefficients, respectively.

RESULTS

Table 2 shows the details of both the groups. The mean concentrations of the trace elements including iron, magnesium, zinc, copper and selenium in the case group were found to be 107.3 μg/dl, 2.3 mg/dl, 80.8 μg/dl, 112.6 μg/dl and 216.6 ng/ml, respectively, and in the control group were 121.9 μg/dl, 2.3 mg/dl, 82.3 μg/dl, 112.8 μg/dl and 225.1 ng/ml, respectively. More details including standard deviations (SD) and standard errors of mean have been shown in Table 3.

Table 2. Details of the case and control groups, n=88 (22 women and 22 men in each group)

Table 3. Mean concentrations of studied trace elements in the case and control groups

Table 4 shows the correlation between the concentrations of studied elements and the variables of age, sex, weight, and work experience using the pearson and spearman's correlation coefficients.

Table 4. The correlation between the concentrations of studied elements and the variables of age, sex, weight, and work experience

DISCUSSION

According to table 3, the mean concentrations of the studied trace elements in the case group were lower

Table 4. The correlation between the concentrations of studied elements and the variables of age, sex, weight, and work experience

			Iron	Mg	Zn	Cu	Se
Age	Case	Pearson Correlation Coefficient	0.132	0.347	0.123	-0.017	0.028
		Sig. (2-tailed)	0.394	0.021	0.428	0.915	0.127
		N	44	44	44	44	44
	Control	Pearson Correlation Coefficient	-0.282	0.003	0.231	-0.034	0.012
		Sig. (2-tailed)	0.064	0.983	0.132	0.827	0.086
		N	44	44	44	44	44
Sex	Case	Spearman's Correlation Coefficient	0.397	0.443	0.321	0.077	0.281
		Sig. (2-tailed)	0.008	0.003	0.034	0.619	0.006
		N	44	44	44	44	44
	Control	Spearman's Correlation Coefficient	-0.129	0.305	0.336	-0.143	0.241
		Sig. (2-tailed)	0.404	0.044	0.026	0.354	0.216
		N	44	44	44	44	44
Weight	Case	Pearson Correlation Coefficient	0.225	0.305	0.204	0.009	0.113
		Sig. (2-tailed)	0.141	0.044	0.184	0.954	0.039
		N	44	44	44	44	44
	Control	Pearson Correlation Coefficient	-0.231	0.390	0.271	0.258	0.452
		Sig. (2-tailed)	0.132	0.009	0.75	0.91	0.529
		N	44	44	44	44	44
Work experience	Case	Pearson Correlation Coefficient	0.107	0.188	-0.013	0.276	0.094
		Sig. (2-tailed)	0.490	0.223	0.935	0.070	0.361
		N	44	44	44	44	44
	Control	---					

* Correlation is significant at the 0.05 level (2-tailed).

than those found in the control group. Although the mean concentration of iron in the case group was significantly less than that of the control group (p-value <0.05), the concentrations of other elements were not significantly different in both of the groups.

Pearson test showed that there was no meaningful correlation between the variable of age and concentrations of the trace elements in the control group (p-value > 0.05). In the case group, except Mg (p-value < 0.05), no meaningful statistical correlation was found between the age and trace element concentrations.

In the case group, Spearman's test showed that there was a meaningful correlation between the sex and concentrations of iron (p-value < 0.01), Mg (p-value < 0.01), Zn (p-value < 0.05), and Se (p-value < 0.01), except for Cu with p-value > 0.05. However, in the control group, only a significant correlation was observed for sex variable and concentrations of Mg (p-value < 0.05) and Zn (p-value < 0.05).

Regarding to the variable of weight, Pearson test showed that there was significant correlation between the weights of the case group members and concentrations of Mg (p-value < 0.05) and Se (p-value < 0.05). In the control group, meaningful statistical correlation was found only between the weights of the member and Mg (p-value < 0.01) concentrations. The Pearson test also showed that there was no significant correlation between the variable of work experience (in year) of the case group members and the concentrations of studied trace elements, iron (p-value > 0.05), Mg (p-value > 0.05), Zn (p-value > 0.05), Cu (p-value > 0.05) and Se (p-value > 0.05).

Because there are not enough studies about the effect of radiation on trace elements, this study was conducted on the effect of low level radiation on concentrations of some trace elements such as Fe, Cu, Mg, Zn, and Se in radiation workers. According to the results, the means of concentration of studied elements in the serums of radiation workers were less than that of the control group members, but only Fe had a meaningful reduction in radiation workers ($p < 0.05$).

Chatterjee et al. showed an increase in the concentration of iron and a decrease in the concentrations of zinc and copper in radiographers blood compared with the control group (23). Barghi et al. showed a meaningful reduction of copper concentration in the case group compared with the control group (24). Ebrahiminia et al. showed that the concentration of copper in the case group was significantly higher than those observed in the control group. The concentration of zinc in the case group was also shown to be significantly lower in the females compared with the males. Furthermore, no significant difference was found in magnesium or iron between two groups (25).

The difference between the results of the previous studies (2, 24, 25) and the present study may be due to the different blood sampling approaches that we used the serum and in the other studies the whole blood has been used. Moreover, the genetic differences among studied subjects, various diets of the subjects, and sensitivity or resistance of the body against radiation, which is also a genetic factor, should be considered (27, 28).

Regarding to the significant reduction of the concentration of iron in the case group compared with the control group, chronic exposure and consequently iron oxidation and reduction plays a vital role in certain reactions in the body. Chronic exposure, which causes loss of integrity of the cell membrane, results in oxidative damage and leakage of traces elements of cell components. Damage of cell membrane could be the first stage in the description of the correlation between low level radiation and cancer. Chronic exposure can also alter the physiological processes which depend on trace elements and consequently affects their accumulation and releases them in various tissues (29). The formation of free radicals due to exposure leads to the interaction between them and important molecules such as fats, damages of cell membrane, and consequently impacts on permeability and the ion gradient of the cell membrane. Previous studies about the role of nutritional factors have shown that at low radiation doses, vitamin C, which acts as an antioxidant, is able to protect against free radicals produced by radiation (30). Important reactions in the body caused by exposure, can be adjusted by vitamin E and albumin which reduce the activity of the free radicals (31).

CONCLUSIONS

The results of this study show the potential effects of chronic exposure on concentrations of some trace elements in serum of radiation workers. The biological effects of high levels of radiation exposure are fairly well known, but the effects of low levels of radiation are more difficult to be determined, because the deterministic effects do not occur at these levels. Based on sthocastic effects, it is assumed that any low exposure has an amount of risk. On average, it is known that the risks are analogous to those encountered in other activities considered as safe. Since there is common control over how much radiation is received on the job, this risk can be controlled and minimized. The best approach is to keep the dose As Low As Reasonably Achievable, or ALARA. It is generally believed that mutation rates depend linearly on dose and there is no threshold below which mutation rates would not be increased.

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