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Original article

Comparison of Radiation Effects on Blood Parameters between Radiation and Non-Radiation Workers using CBC in Alafya and Waddan Hospitals

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Abstract
This study aims to compare the changes in haematological parameters among radiological department staff in Aljufra, Libya, and reveal the effects on the health of such staff using the CBC test. 40 Blood samples were collected from 20 participants from the radiology department and 20 participants from the non-radiology department who were working in Alafia Hospital and Waddan Hospital in the Aljufra region during December 2024-March 2025. EDTA blood samples were collected, and CBC tests were done to screen for changes in haematological parameters. There were significant differences in some CBC parameters between the radiological workers and controls. MCH decreased significantly in female radiological workers compared to males. Moreover, some of the CBC parameters (HCT, MCH, MCV, and RBCs) had a significant relationship with the age and work experience of radiation workers. Radiation has harmful effects on human health. Evidence that haematological parameters are more sensitive to radiation exposure; therefore, a complete blood count (CBC) is the commonly used test for monitoring the health of radiation workers. Using more supporting haematological tests enhances early detection of acute and chronic radiation effects.
Keywords. Radiation, Haematological, CBC, Blood, X-ray.

Introduction

Despite advances in medical technology, the use of radiological investigations remains the most widely used procedure. Radiation workers are frequently exposed to radiation, and the effects of radiation can result in cellular damage [1,2]. There are two types of radiation: ionising radiation and non-ionising radiation. Examples of non-ionising radiation are radio waves, visible light, and microwaves. This type of radiation has enough energy to move atoms in a molecule around, causing them to vibrate, but not enough to move electrons from atoms. Ionising radiation has so much energy that it can move electrons out of atoms (ionisation) [3,4]. Penetration of ionising radiation can destroy living cells or cause them to function abnormally, because the ionising radiation affects the atoms in living cells and poses a health risk by damaging tissue and DNA. Ionising radiation from X-ray machines, cosmic particles, and radioactive elements is emitted as their atoms undergo radioactive decay [4,5,6].

In medicine, thousands of X-ray machines are used daily. Computerized tomography, commonly known as computer tomography (CT) or CAT scan, uses special X-ray equipment to produce detailed images of bones and soft tissues in the body [6,7]. The health effects of ionising radiation are usually classified into two categories: deterministic and stochastic effects. Deterministic effects are a health effect that requires a specific level of exposure to ionising radiation before they can occur, and have a threshold dose below which health effects are not observed. The stochastic effects are probability effects that occur by chance. Stochastic effects, such as the development of cancer, are rare and may occur many years later (Figure 1) [6,8].

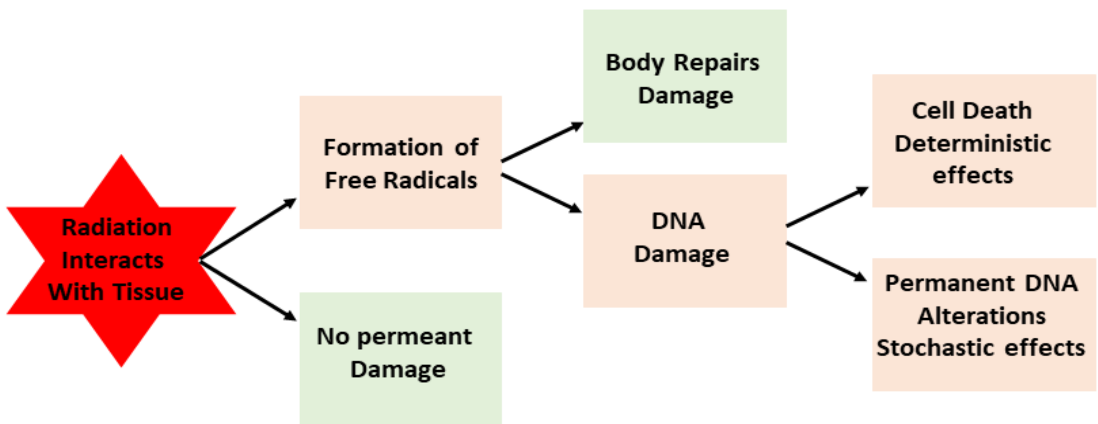

Figure 1. Radiation- Deterministic and Stochastic Effects [8]

Blood is a specialised connective tissue composed of blood cells and extracellular matrix fluid called plasma [9]. Blood Cells named Erythrocytes (Red Blood Cells, RBCs), Leukocytes (White Blood Cells, WBCs), and Thrombocytes or Platelets (PLT). These cells have a limited lifespan and are constantly renewed [9-11]. Functionally, hemoglobin is one of the essential

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components of RBCs, and most oxygen is bound to hemoglobin in RBCs. WBCs play a role in immunity due to their phagocytic ability and antibody production. PLT promotes blood clotting and prevents blood loss [9,10,12].
Complete blood count (CBC) is a series of tests used medically to evaluate the composition and concentrations of various cellular components of blood. It includes RBC count, WBC count, and platelet count, measurement of haemoglobin, haematocrit, and red blood cell indices; total and differential WBC count; mean platelet volume, RBCs, WBC, platelet, and haemoglobin distribution. CBC parameters are very important as they provide useful information for precise diagnosis and management of the patient [13]. Complete blood count is a common blood test used to monitor the overall health and condition of radiation staff [2,14]. Medical staff in the radiology department are always exposed to ionising radiation. Radiation can affect blood production in bone marrow [15,16]. Exposure to ionizing radiation primarily affects blood cells by damaging stem cells in the bone marrow [17,18,19], induces significant alteration in haematological parameters [20,21], immune suppression, and changes in biochemical parameters depending on the dose, duration, and type of radiation [21,22]. Exposure to ionising radiation is known to have lethal effects on blood cells [11,12]. Haematopoiesis is the most sensitive system in the body to radiation compared to other cells [2,23]. In addition, ionising radiation affects haematopoietic cells directly by destroying haematopoietic stem cells or changing the haematopoietic cells' function in vivo and in vitro [14,16]. The effects of ionising radiation on the haematopoietic stem cells are usually classified into direct and indirect effects. The direct effects of ionising radiation include damage to HSCs through apoptosis, cell differentiation, and decreased function [15]. Indirect effects of ionising radiation by reaction with water inside cells and creating both ions and free radicals [15,16]. The most sensitive blood cells are Erythroblasts, the early stage of Erythrocytes. Erythrocytes and Leukocytes are constantly renewed, and they are susceptible. The reduction in blood cell counts recorded within 48 h of exposure serves as a marker for the severity of exposure [11].
Several publications reported different outcomes on CBC changes of radiation workers. A number of studies reported that there were no significant differences in CBC parameters between radiation workers and controls. Mohamed et al (2015) reported that exposure to various gamma radiation doses results in considerably lower RBC count, HGB, and HCT than observed in controls [24]. One study by Ben Rabaa et al. (2015) conducted in Tripoli, Libya, on 102 individuals showed an increase in the number of WBCs, with no differences in the average PLT count and a decrease in the number of PLT, Hb, RBCs, and RBC indices [25]. In addition, a study evaluated the effect of radiation on radiation workers in 5 hospitals in Benghazi, Libya, by and colleagues, reported a decrease in RBC indices and HCT, an increase in lymphocyte count, MCH, and MCHC for both groups. This study also reported variation in MCH, MCHC, WBC, and PLT values, which increased in certain radiation workers and decreased in others. The study concluded that exposure to radiation causes changes and variations in blood parameters, leading to various health damages and carcinogenic effects [26]. The aim of this study is to compare the changes in haematological parameters between male and female radiation workers.

Method

A total of 40 participants from the radiology department and non-radiology workers as controls, male and female, aged between 22 and 62 years, in December 2024-March 2025, were included in this study. The Complete Blood Count test was applied for all participants to determine the changes in haematological parameters, including: Haemoglobin (HGB), Haematocrit (HCT), Red blood cells (RBC), Mean cell volume (MCV), Mean concentration of Haemoglobin (MCH), Mean Corpuscular Haemoglobin Concentration (MCHC), White Blood Cells (WBC), Lymphocytes (LYM), and Platelets (PLT). K_2EDTA (Potassium Ethylene Diamine Tetra Acetic acid) blood samples were collected, and an automated blood analyzer, BC-2800 Mindray, and Sysmex-XP-300 were used to measure the haematological parameters in all samples.
Demographic data, including age, sex, marital status, profession, education level, hospital type and department, work experience, working hours, health status, smoking status, and alcohol consumption, were collected using a questionnaire filled out by all participants. The collected data were analysed in Microsoft Excel, and relationships in the data were investigated with descriptive statistical tests and Student's t-test and *p value,* with a significance threshold of $p < 0.05$.

Results

(Table 1) summarises the obtained results of haematological blood parameters and demographic information of male radiation workers (age and work experience) and male controls shown in (Table 2). The obtained results of haematological blood parameters were within the normal range. The comparison of the haematological blood parameters of male radiation workers and male controls is shown in (Table 3). There was a significant difference between three out of nine haematological blood parameters between the two groups. The mean Haemoglobin HGB concentration of the male radiation workers was 14.65, which was significantly higher than that of the controls ($p < 0.03$). The obtained results of PLT and MCHC were significantly higher than those of the control group ($p < 0.04$, $p < 0.02$), respectively.

Table 1 Blood Haematological Parameters of Male Radiation workers

No	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Age (Years)	Work exp (Years)
1	9.6	5.3	13.6	224	2.5	45.6	86.8	25.8	29.8	28	5
2	7.3	4.9	14.6	371	35.2	42.5	86	29.6	34.4	46	22
3	9.9	5.3	15.6	389	32.3	46.1	86.3	29.2	33.8	27	3y
4	3.9	4.8	13.4	411	30.7	39.4	81.7	27.8	34	46	20

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5	7.1	10	15	339	33	44.1	89.1	30.3	34	43	25
6	7.8	4.6	14.6	337	31.7	42.2	90.9	31.5	34.6	43	24
7	7.3	5.1	15.1	513	37.8	44.3	86.7	29.5	34.1	27	3
8	8.7	5	15.3	204	38.1	44.7	90.1	30.8	34.2	30	10
Average	7.7	5.625	14.65	348.5	30.1625	43.6125	87.2	29.3125	33.6125	36.25	15.571429
median	7.55	5.05	14.8	355	32.65	44.2	86.75	29.55	34.05	36.5	20
min	3.9	4.6	13.4	204	2.5	39.4	81.7	25.8	29.8	27	3
max	9.9	10	15.6	513	38.1	46.1	90.9	31.5	34.6	46	25
STDEVA	1.87388	1.78386	0.78558	99.7969	11.509	2.17153	2.89384	1.80193	1.56062	8.94027804	10.239106

Table 2. Blood Haematological Parameters of Male Controls

No	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Age (Years)
1	5.2	5.5	16.2	174	54.6	50.5	92.1	29.5	32	42
2	9	5.11	15.1	253	32	48.4	94.9	29.5	31.1	32
3	6	5.41	11	228	27.8	38.4	71	20.3	28.6	55
4	7.4	4.76	13.1	180	31.5	40.3	84.7	27.5	32.5	62
5	4.7	4	12.7	313	38.7	36.9	92.7	31.9	34.4	45
Average	6.46	4.956	13.62	229.6	36.92	42.9	87.08	27.74	31.72	47.2
median	6	5.11	13.1	228	32	40.3	92.1	29.5	32	45
min	4.7	4	11	174	27.8	36.9	71	20.3	28.6	32
max	9	5.5	16.2	313	54.6	50.5	94.9	31.9	34.4	62
STDEVA	1.74871	0.60789	2.0511	57.1341	10.6361	6.14451	9.77456	4.44162	2.12061	11.64903429

Table 3. Comparisons of male radiation workers and male controls in term of blood Haematological parameters

	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
MRAW*	7.7	5.625	14.65	348.5	30.1625	43.6125	87.2	29.3125	33.6125
Min	3.9	4.6	13.4	204	2.5	39.4	81.7	25.8	29.8
Max	9.9	10	15.6	513	38.1	46.1	90.9	31.5	34.6
STDEVA	1.87388	1.78386	0.78558	99.7969	11.509	2.17153	2.89384	1.80193	1.56062
* Male Radiation Workers									
M C A	6.46	4.956	13.62	229.6	36.92	42.9	87.08	27.74	31.72
Min	6	5.11	13.1	228	32	40.3	92.1	29.5	32
Max	4.7	4	11	174	27.8	36.9	71	20.3	28.6
STDEVA	1.74871	0.60789	2.0511	57.1341	10.6361	6.14451	9.77456	4.44162	2.12061
p value	0.59	0.42	0.03	0.04	0.49	0.31	0.74	0.22	0.02

Table 4 shows the obtained results of haematological blood parameters of female radiation workers and female controls, as shown in Table 5. Comparisons between the blood parameters of female radiation workers and controls are shown in (Table 6). There was no significant difference in the blood parameters of female radiation workers and the controls.

Table 4. Blood Haematological Parameters of Female Radiation Workers

No	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Age (Years)	Work exp (Years)
1	3.8	3.9	12	293	50	38.2	97	30.4	31.4	30	6
2	7.4	4.34	11.7	234	37.6	38.5	88.8	26.9	30.3	28	6
3	7.4	4.51	12.5	217	30.3	39.5	87.7	27.7	31.6	42	16
4	4.8	4	11.1	266	32.7	36	90.9	27.9	30.8	33	3
5	6.7	4.34	11.4	391	30.9	37.9	87.5	26.2	30	35	10
6	6.6	3.75	9.3	243	31.5	31.9	85.3	24.8	29.1	28	3
7	8.2	4.08	11.7	359	30.7	37.5	92.1	28.6	31.2	27	2
8	4.6	4.16	12	264	31.5	39.7	95.6	28.8	30.2	23	1
9	5.9	4.08	10.4	339	26.2	32.7	80.1	25.5	31.8	42	23
10	4.2	4.49	11.8	347	29.8	37	82.4	26.3	31.9	30	3
11	9.2	4.29	13	195	35.7	37.4	87.2	30.3	34.8	27	3
12	9.3	4.01	12.3	418	33.3	35.7	89	30.7	34.5	48	24
Average	6.5083	4.1625	11.6	297.16	33.35	36.83	88.63	27.84	31.46	32.75	8.33
median	6.65	4.12	11.75	279.5	31.5	37.45	88.25	27.8	31.3	30	4.5

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min	3.8	3.75	9.3	195	26.2	31.9	80.1	24.8	29.1	23	1
max	9.3	4.51	13	418	50	39.7	97	30.7	34.8	48	24
STDEVA	1.88	0.23	0.98	72.19	5.98	2.43	4.88	1.97	1.70	7.56	8.20

Table 5. Blood Haematological Parameters of Female Controls

No	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Age (Years)
1	7.3	3.84	11.3	251	25.8	35.7	93.1	29.4	31.6	36
2	4.2	4.64	13	251	40.9	41.5	89.5	28	31.3	24
3	12.2	3.91	10.6	226	18.9	34	87.1	27.1	31.1	28
4	5.7	4.99	14	196	44	43.2	86.7	28	32.4	31
5	7.6	4.51	12.7	229	32.3	40.2	89.3	28.1	31.5	30
6	17	3.81	10.2	287	13	32.3	84.8	26.7	31.5	36
7	3.8	3.94	12	293	50	38.2	97	30.4	31.4	30
8	5	4.04	11.1	364	28.3	33.7	83.4	27.5	32.9	45
9	6.3	5.3	10.7	223	29.3	34.9	65.8	20.2	30.7	25
10	4.6	4.67	13.5	251	48.8	39.5	84.6	28.9	34.2	25
11	5.7	3.93	12.3	390	29.7	36.8	93.6	31.3	33.4	23
12	5.2	4.93	13.2	284	46.4	40	81.1	26.8	33	26
13	5.8	4	11.8	274	38.7	36.4	91	29.5	32.4	23
14	5.9	4.65	13	361	52.1	38.7	83.2	28	33.6	45
15	12.7	3.51	10.5	221	11.6	31.5	89.7	29.9	33.3	33
Average	7.26	4.31	11.99	273.4	33.98	37.10	86.66	27.98	32.28	30.66
median	5.8	4.04	12	251	32.3	36.8	87.1	28	32.4	30
Min	3.8	3.51	10.2	196	11.6	31.5	65.8	20.2	30.7	23
Max	17	5.3	14	390	52.1	43.2	97	31.3	34.2	45
STDEVA	3.74	0.53	1.21	58.03	13.20	3.45	7.25	2.53	1.06	7.21

Table 6. Comparisons of female radiation workers and controls in term of blood Haematological parameters

	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
FRAW*	6.50	4.16	11.6	297.16	33.35	36.83	88.63	27.84	31.46
Min	3.8	3.75	9.3	195	26.2	31.9	80.1	24.8	29.1
Max	9.3	4.51	13	418	50	39.7	97	30.7	34.8
STDEVA	1.88	0.23	0.98	72.19	5.98	2.43	4.88	1.97	1.70
* Female Radiation Workers									
F C A	7.26	4.31	11.99	273.4	33.98	37.10	86.66	27.98	32.28
Min	3.8	3.51	10.2	196	11.6	31.5	65.8	20.2	30.7
Max	17	5.3	14	390	52.1	43.2	97	31.3	34.2
STDEVA	3.74	0.53	1.21	58.03	13.20	3.45	7.25	2.53	1.06
p value	0.94	0.19	0.21	0.51	0.25	0.45	0.46	0.89	0.19

Comparisons of blood parameters of male and female radiation workers are shown in (Table 7). Out of nine blood parameters, only three parameters were significantly different between male and female radiation workers. The count of RBCs in female radiation workers was 4.16±0.23, which was significantly lower than that of male radiation workers (5.62±1.78, $p < 0.02$). The amount of MCH was significantly higher in male radiation workers (29.32±1.80) compared to female radiation workers (27.84±1.97) ($p < 0.05$), and MCHC was higher in male radiation workers (33.61±1.56) than in female (31.46±1.70, $p < 0.01$).

In this study, the relationships between different blood haematological parameters of radiation workers and their age and work experience were also determined. Table 8 shows the correlation of blood haematological parameters and the age of radiation workers. The results showed that the percentage of Haematocrit ($p < 0.04$), MCH ($p < 0.001$), and the amount of MCV ($p < 0.02$) had a positive correlation with age. In addition, the more experienced radiation workers had a higher RBC count ($p < 0.01$). The remaining blood parameters did not have a significant relationship with age and work experience of radiation workers.

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Table 7. Comparisons of male and female radiation workers in term of blood Haematological parameters

		WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
MRW	Average	7.7	5.625	14.65	348.5	30.16	43.61	87.2	29.31	33.61
	STDEVA	1.87	1.78	0.78	99.79	11.50	2.17	2.89	1.80	1.56
FRW	Average	6.50	4.1625	11.6	297.16	33.35	36.83	88.63	27.84	31.46
	STDEVA	1.88	0.23	0.98	72.19	5.98	2.43	4.88	1.97	1.70
p value		0.26	0.02	0.86	0.11	0.14	0.18	0.75	0.05	0.01

Table 8. Correlation of different blood Haematological parameters with age

	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
PCC*	-0.05	0.23	0.13	0.29	-0.27	-0.02	-0.34	0.14	0.43
p value	0.93	0.31	0.33	0.14	0.74	0.04	0.03	0.001	0.26

**Pearson Correlation Coefficient*

Table 9. Correlation of different blood Haematological parameters with work experience

	WBC (10^9/L)	RBC (10^{12}/L)	HGB (g/dL)	PLT (10^9/L)	LYM (10^9/L)	HCT (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)
PCC*	0.1	0.38	0.25	0.24	-0.23	0.09	-0.28	0.24	0.48
p value	0.07	0.01	0.37	0.23	0.78	0.86	0.47	0.26	0.67

**Pearson Correlation Coefficient*

Discussion

Radiological investigations are widely used in the diagnosis and treatment of patients. Many studies have shown that exposure to ionising radiation can damage human health, such as inducing cancer, invading the haematopoietic system, and causing leukemia [27]. Studies have found that the haematopoietic system has been considered to be one of the most sensitive biological indicators in radiology [28]. Studies have shown that ionising radiation affects blood cells and can change haematological parameters. In addition, haematopoietic system cells are extremely susceptible to radiation; therefore, the peripheral blood count may be a useful biological indicator for determining radiation cellular damage [2,12,18,23,29,30,31]. Some studies have reported that exposure to low-dose radiation affects the immune system; however, other studies have reported no effects [1, 32, 33, 34, 35, 36].

The results obtained in this study revealed that hematological blood parameters were generally within the normal range. This is in line with a study that reported that the overall mean RBCs, WBC, and PLT count among medical workers do not differ considerably from standard ranges [37]. The mean hemoglobin concentration HGB and MCHC were significantly higher in radiation-exposed male workers than in controls. There was no significant difference in the blood parameters of female radiation workers and in controls. The differences between male and female radiation workers were observed in RBCs, MCH, and MCHC, which were higher in male than in female.

Overall, this study did not observe any changes in WBC and their types. However, many studies have shown that prolonged occupational exposure to low doses of ionizing radiation can cause alterations in WBC counts. Ossetrova et, al. (2010) demonstrated that dose-dependent changes in blood cell counts include lymphocytes, neutrophils, and the ratio ofhastrophils-to-lymphocytes [38]. In addition, a study by Ali and colleagues (2018) has reported that CBC parameters as Neutrophil, Monocytes, Basophile, MCV, RDW, and PLT significantly decreased while Lymphocytes, RBCs, HGB, and HCT significantly increased [39].

The results of the relationship between changes in CBC parameters and age, as well as the work experience among radiation workers in this study, indicated that the percentage of HCT, MCH, and the amount of MCV had a poor positive correlation with age, while a higher count of RBCs was associated with more experienced radiation workers. These results were not consistent with those reported by Mahmood et al (2024) and Güngördü, N et al (2023), who examined the changes in CBC parameters among males and female radiological workers according to work experience and reported that the blood parameters (RDW-CV and RDW-SD) were affected by X-ray exposure duration [40,41]. In addition, Duration of exposure and chronic exposure play a great rule for alteration in haematological parameters [38].

Ambarkah (2024) studied the effect of occupational exposure to X-rays and CT scans on blood parameters, iron levels, and lipid levels among radiology technicians in some southern Libyan cities, where the results showed a decrease in haemoglobin levels and red blood cell indices, with no correlation between most blood parameters and duration of radiation exposure, and most radiation workers suffered from anemia [42].

Conclusion

For monitoring and follow-up of the overall health status of radiation workers, CBC is the most commonly used test. As the CBC parameter changes are associated with some demographic characteristics, as described here will have importance in monitoring the health status of radiation workers. More supporting tests of the interaction between radiation, genes, and

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chromosomal changes may be required for early detection of radiation effects and to better understand the mechanisms of radiation effects. Recommendations for organizing hazard of ionizing radiation courses and training for radiation workers to improve their awareness and knowledge about protective tools during working hours.

***Conflict of interest*. Nil**

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