Original Research Article: Assessing Ionizing Radiation Health Impacts on Professional Workers: A Study in Tertiary Hospitals, South Southern Nigeria

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Citation E. Omita*, C.E. Orji, K.B. Okeoma, C. Iroegbu, C.A. Aborisade, U. Rilwan. **Assessing Ionizing Radiation Health Impacts on Professional Workers: A Study in Tertiary Hospitals, South Southern Nigeria.** *J. Eng. Ind. Res.* **2023**, 4 (3):167-175.

https://doi.org/10.48309/jeires.2023.3.4

Article info:
Received: 2023-09-23
Accepted: 2023-12-02
ID: JEIRES-2311-1105
Checked for Plagiarism: Yes
Editor who Approved Publication:
Dr. Sami Sajjadifar

Keywords:
Radiation; Ionizing radiation; Health impact; Professional radiation workers; Doses; International commission on radiological protection (ICRP); Tertiary hospitals.

ABSTRACT

The broad spectrum of radiation, encompassing electromagnetic waves, particle radiation, and acoustic radiation, poses potential negative biological consequences, particularly when exposure surpasses the occupation exposure limit (OEL) recommended by the International Commission on Radiological Protection. This study investigates the health implications of ionizing radiation on professional radiation workers in selected tertiary hospitals in South Southern Nigeria. The research evaluates the effective doses incurred by medical and non-medical workers across six different centers (A, B, C, D, E, and F). Among medical workers, center B registers the highest mean effective dose at 0.836±0.200 mSv, followed by center C (0.801±0.313 mSv), center E (0.761±0.123 mSv), center A (0.760±0.250 mSv), center D (0.722±0.120 mSv), and center F with the lowest mean at 0.700±0.067 mSv. A similar pattern is observed for non-medical workers, with center B again exhibiting the highest mean effective dose (0.725±0.200 mSv). While mean differences between medical and non-medical workers are slight, the study underscores that medical workers generally receive higher doses, attributed to their proximity to medical radiation facilities. Statistical analyses, including t-test values and p-values, indicate non-significant differences in means among centers. Importantly, all recorded doses adhere to the International Commission on Radiological Protection (ICRP) limits, affirming a commitment to maintaining radiation exposure within globally recognized safety thresholds. This comprehensive evaluation provides valuable insights into the health impact of ionizing radiation on professional radiation workers in the selected tertiary hospitals in South Southern Nigeria.

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Introduction

Radiation consist of electromagnetic radiation which includes radio waves, microwaves, infrared, visible light, ultraviolet, X-ray and gamma ray, particle radiation (alpha, beta, and neutron particle, and acoustic radiation (ultrasound and seismic). It is frequently categorized as ionizing and non-ionizing, ionizing radiation carries more than 10 eV, which is sufficient to break the chemical bonds in atoms and molecules. This is a significant distinction due to the large differences in how harmful ionizing radiations are to living things. One of the latest advancements in technology is the utilization of ionizing electromagnetic radiation in various fields ranging from science to industry and medical application [1]. Ionizing radiation (IR) mostly X-rays and those emitted by radioactive substances, play a significant role in diagnostic and therapeutic medicine [2]. Despite this vital role, ionizing radiation is globally known as an occupational hazard in the work place due to its potential biological damage [3].

Negative biological consequences may occur if an individual is exposed at a level above the occupation exposure limit (OEL) recommended by the international commission on Radiological Protection [4]. These limits are 20 mSv/year over a period of five-years, with a maximum of 50 mSv/year effective dose. Equivalent dose for skin, hand and feet at 500 mSv/year and 20 mSv/year to the lens of the eye over five years with no single year exceeding 50 mSv/year. Even when they are wearing the proper personal protective equipment (PPE), medical radiation workers are inevitably exposed to long-term low-dose ionizing radiation [5]. Ionizing radiation is used in two-thirds of radiological operations for medical imaging equipment [6]. To ensure that the acceptable limits are not exceeded, occupational (industrial and medical) radiation professionals could be routinely observed using radiation Dosimetry, which is primarily used to protect against ionizing radiation [7]. Dosimeters are primarily used for human ionizing radiation monitoring and for assessing absorbed dosage in industrial and medical radiography. Finger dosimeters and work environment dosimeters are just two examples of the electronic personal dosimeters that are available [8].

Lummis the Instadose (Digital dosimeter) and the Thermoluninescene dosimeter (TLD) are the two most widely used personal radiation dosimeters in Nigeria [9]. It is on the other hand, combines four Thermoluminiscent detectors with anodized aluminum foil [10]. The typical components of TLD are lithium fluoride activated with magnesium and calcium fluoride activated with manganese [11]. Ionizing radiation energy is stored in the dosimeter [12]. TLD is typically heated to a temperature of 300 ^{o}C, releasing the energy held in the form of light, in order to measure the amount of radiation received by the device. The radiation dose each detector receives determines how much light is emitted [13]. The main advantages of TLD are its affordability, good tissue equivalent, simplicity of use, sensitivity, and accuracy. It is reusable and independent of environmental factors [14] and TLD was chosen as the dosimeter for this study because of the aforementioned benefits. This work aimed to determine the health impact of low ionizing radiation of Professional radiation workers in some selected tertiary hospitals in south Southern Nigeria.

Materials and Methods

Study area

This study was conducted in some selected Tertiary hospitals and Radio diagnostic Center in South-South Nigeria namely: Federal Medical Center, (FMC), Asaba, Delta State (Center A), Delta State University Teaching Hospital (DELSUTH) Oghara, Delta State (Center B), University of Port Harcourt Teaching Hospital, (UPHTH), Port Harcourt, Rivers State (Center C), Niger Delta University Teaching Hospital, (NDUTH), Okolobiri. Bayelsa State (Center D), Image Diagnostic Center, (IDC), Port Harcourt, Rivers State (Centre E), Federal Medical Center, (FMC), Yenagoa, and Bayelsa State (Centre F). All the selected eight hospitals and radio-diagnostic Centre have high number of patient flow where high numbers of Medical Radiation Professionals are expected to work in.

Study design

The study was conducted from December 2018 to December 2020 where data collection took eighteen months from June 2019 to December 2020. A comparative cross-sectional study was conducted to assess the effects of ionizing radiation in Medical and Non-Medical Radiation workers in selected government tertiary hospitals and a Radio-diagnostic Centre in South-Southern Nigeria.

Population

The study employed about 60 Professional radiation workers working in Centre A to F. About 15 Radiologist, 25 Medical Radiographer, 13 Resident Doctors in Radiology and 7 Medical Physicists were examined in the selected Hospital and Radio-diagnostic Centers. The study recruited 60 Healthy controls from other department and Units not involved in any radiation activities, with the same range of age, sex, and area of residence with the exposed workers were taken. Hence a total of 120 personnel was examined

Inclusion criteria

All healthy workers with one year (1 year) and above and the radiation workers who work with ionizing radiation were included for this study.

Exclusion criteria

Participants, both exposed and unexposed, who are pregnant, with known history of Diabetes mellitus, cardiovascular diseases, and malignancy, those who have taken chemotherapy or radiotherapy, those who are smoker and radiation workers working with non-ionizing radiation were all excluded.

Variables

The dependent variable in this study is radiation parameters while the independent variables are sex, place of work/hospital, use of protective equipment, and work experience.

Sampling method

Convenient sampling method was used to collect data from the study site. The participants were on job while collecting data. Convenience sampling is a non-probability sampling method where units are selected for inclusion in the sample because they are the easiest for the researcher to access. In medical research, convenience sampling often involves selecting clinical cases or participants that are available around a particular location (such as a hospital) or a medical records database.

Sample size was determined by taking all radiologists, resident doctors in Radiology and Medical Radiographers/medical imaging scientists in the eight hospitals and radio-diagnostic Center available through the data collection period who are fulfilling the explained criteria and who are volunteers to participate by giving their informed consent. In this study, 120 participants were recruited. A total of 60 apparently healthy occupational radiation exposed worker and 60 apparently healthy and unexposed controls were included.

Data collection procedure

Details of socio-demographic background, occupational, and medical history regarding work-related exposure to mutagenic agents, safety measures taken, duration of exposure, use of therapeutic drugs, and smoking was obtained from a questionnaire that was completed by each participant. The information was used to include and exclude participants. Physical Dosimetry was used to collect data on the absorbed dose of ionizing radiation by the radiation workers and Biological Dosimetry is used to collect data on the hematological parameter by all the participants.

Physical dosimetry

The occupational exposure to ionizing radiation was routinely monitored by personal exposure measurement devices (Thermo luminescent dosimeter, TLD). The absorbed radiation dose measured in millisieverts using the TLD was compared with the values of International Commission on Radiological Protection (ICRP) 20 mSv/yr for radiation workers. The TLD badge contains the TLD chips (LiF). The calibration of the TLD reader and chips were done in the secondary standard Dosimetry laboratory which maintains radiation protection standards for Nigeria and is housed at the National Institute of Radiation Protection and Research (NIRPR), University of Ibadan. The NIRPR serves as the custodian of the national secondary traceable with traceability to the IAEA standard laboratory in Vienna. The dosimeter chips were read at the TLD Laboratory, Department of Physics and Engineering physics, Obafemi Awolowo University. Ile-Ife. Nigeria and NNRA Laboratory University of Ibadan.

The preparation of the Thermoluminence Dosimeters was done at the TLD laboratory, Physics, and Engineering Physics Department, Obafemi Awolowo University Ile-Ife Osun State and the Nigerian Nuclear Regulatory Authority Laboratory, Elizabeth Way University of Ibadan, Oyo State. The Harshaw Model 3500 manual TLD Reader was used for the thermoluninescene Dosimetry measurement. The TLD Reader is a personal computer driven manually operated table top instrument. The Harshaw 3500 reader reads a dosimeter per loading and accommodates a variety of TL configuration including chips, disk, rods, and powder. The system consists of major components like TLD Reader and the windows radiation evaluation and management system (WinREMS) Software resident on a personal computer (PC) which is connected to the reader via serial communication port.

Calibration procedure

The purpose of calibrating the TLD is to ensure that all dosimeter in a system will give essentially the same response to a given radiation exposure. The estimated calibration coefficient (ECC), ECC is used as a multiplier with the reader output dosimeter of a designated group of dosimeter maintained as calibration dosimeter. The purpose of the reader calibration is to maintain a consistent output from the reader over a period based on convenient local source. The reader calibration factor (RCF) as in Equation (1), is the factor converts the raw charge data from the PMT (nacocoulombs) to dosimeteric units (rems) or generic unit using the formula.

$$\text{Exposure} = \frac{\text{Estimated Calibration Coefficient (ECC)}}{\text{Reader Calibration Factor (RCF)}} \quad (1)$$

Data quality control

Specimens were analyzed in a laboratory that the essential elements of a quality program, specifically internal quality control (IQC) and external quality assurance (EQA) was been applied each laboratory assay performed to ensure test results accuracy and precision. Samples were properly collected, transported and stored. Analysis was performed following standard operating procedure (SOP) for CBC.

Data analysis and interpretation

The TLD results and that hematological test results were entered into the Statistical Package for Social Sciences (SPSS) software version 21 for statistical analysis. The student t-test was used to compare the radiation dose of radiation workers with Standard value of 20 mSv given by the ICRP, the t-test is also use to compare the hematological parameters of occupational radiation workers with the standard complete blood count Reference limits, and to compare the hematological parameters of healthy radiation professionals and healthy non-radiation workers. Simple regression was used to compare the effects of ionizing radiation on the hematological parameters of radiation workers. Tables, bar charts, and figures are used to display results.

Ethical approval

The study was commenced after getting ethical approval from the Ethical and Research committee of each of the hospital and the Radio diagnostic Center.

Statistical analysis used for the study

The statistical tools used for this research work includes the cumulative mean, standard deviation, and mean difference, t-test.

Mean cumulative

Cumulative mean as in Equation 2 is a statistical measure that calculates the mean of a set of numbers up to a certain point in time or after a certain number of observations, while the effective dose is given in Equation (3) according to [15].

$$\text{Mean Cumulative Radiation Dose (MCRD)} = \frac{\sum \text{Effective dose for n personel}}{\text{total number of personel (n)}} \quad (2)$$

$$\boldsymbol{E.D\ (Sv)} = \sum (W_R \times H_T) \quad (3)$$

Where, W_R is the radiation weighting factor and H_T is the equivalent dose and is given by Equation 4 according to [16].

$$H_T = D_T \times W_R \quad (4)$$

H_T = Equivalent dose, D_T = Absorbed dose (Dose Measurement from the TLD readings for the n personnel), and W_R = Radiation weighting factor and Weighting factor for x-ray = 1 [16].

Standard deviation

The standard deviation is the average distance from the mean value of all values in a set of data [17]. Standard deviation is given by Equation (5) as reported by [17],

$$S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{X})^2}{n-1}} \quad (5)$$

Where, S= Standard Deviation = Square root of Variance, n = 120, and x̄ = cumulative mean

Mean difference

The mean difference, or difference in means calculated by Equation (6) according to [18], measures the absolute difference between the mean values in two different groups. In clinical trials, it gives you an idea of how much difference there is between the averages of the experimental group and control groups [18].

$$\text{Mean Difference} = \bar{X}_A - \bar{X}_B \ (6)$$

T-test

The t-test is a statistical test employed to compare the means of two groups. It is frequently employed in hypothesis testing to establish whether a procedure or treatment actually affects the population of interest or whether two groups differ from one another [19]. A t-test may be used to evaluate whether a single group differs from a known value (a one-sample t-test), whether two groups differ from each other (an independent two-sample t-test). In this study, it is used to compare the mean cumulative radiation dose with the international standard dose given by ICRP [20]. The t-test statistic for testing the significance of difference between means of two groups is given by Equation (7), as reported by [20];

$$t = \frac{\bar{X}_A - \bar{X}_B}{\sqrt{\frac{S_A}{n_A} + \frac{S_B}{n_B}}} \quad (7)$$

$$\bar{X}_A = \frac{\sum_{i=1}^{n} X_A}{n_A} \quad (8)$$

$$\bar{X}_B = \frac{\sum_{i=1}^{n} X_B}{n_B} \quad (9)$$

Where, $\bar{X}_A$ is the sample mean of group A given by Equation (8), $\bar{X}_B$ is the sample mean of group B given by Equation (9), S_A is the standard deviation of group A, S_B is the standard deviation of group B, n_A is the number of observation in group A and n_B is the number of observation in group B [21]. Equations (8) and (9) are the equations for the sample mean of group A and B, respectively.

Results and Discussion

Results

In this section, the population of the personnel employed for the study is presented in Table 1 while the mean doses, mean differences and t-test from the study centers are listed in Table 2.

Table 1: Population of the Personnel Employed for the Study

Personnel	Medical Workers							Non- Medical Workers						
	A	B	C	D	E	F	Total	A	B	C	D	E	F	Total
Radiologists	1	5	5	1	1	2	15	1	5	5	1	1	2	15
Radiographers	4	5	7	2	4	3	25	4	5	7	2	4	3	25
Resident Doctors	1	5	4	1	1	1	13	1	5	4	1	1	1	13
Medical Physicists	1	1	2	1	1	1	7	1	1	2	1	1	1	7
Total	7	16	18	5	7	7	60	7	16	18	5	7	7	60

Table 2: Mean Doses, Mean Differences, and t-test from the study centres

Centers	Medical (mSv) (MPL)	Non-Medical (mSv) (MPL)	Mean Difference	t-test	P-value
Centre A	0.760±0.250 (5)	0.505±0.277 (3)	0.255	1.143640	0.3046
Centre B	0.836±0.200 (5)	0.725±0.200 (3)	0.111	0.497820	0.6397
Centre C	0.801±0.313 (5)	0.613±0.189 (3)	0.188	0.843154	0.4376
Centre D	0.722±0.120 (5)	0.560±0.080 (3)	0.162	0.726548	0.5001
Centre E	0.761±0.123 (5)	0.566±0.143 (3)	0.195	0.874548	0.4218
Centre F	0.700±0.067 (5)	0.478±0.076 (3)	0.222	0.995640	0.3651

Based on the data presented in Table 2, Center (B) has the highest effective dose for medical workers with mean value of 0.836±0.200 mSv, followed by center (C) with mean value of 0.801±0.313 mSv, then centre (E) with mean value of 0.761±0.123 mSv, and then center (A) with mean value of 0.760±0.250 mSv, after that center (D) with mean value of 0.722±0.120 mSv, and center (F) with the lowest mean value of 0.700±0.067 mSv. In the case of non-medical workers, same trend was obeyed, with center (B) has the highest effective dose for medical workers with mean value of 0.725±0.200 mSv, followed by centre (C) with mean value of 0.613±0.189 mSv, and then center (E) with mean value of 0.566±0.143 mSv, after that center (D) with mean value of 0.560±0.080 mSv, and then center (A) with mean value of 0.505±0.277 mSv, and center (F) with the lowest mean value of 0.478±0.076 mSv. On the other hand, it could be understood from the table that, the medical workers are subjected to higher dose compared to the non-medical workers. Although, the mean difference indicated just a slight variation between the medical and the non-medical workers. The high values in medical workers compared to non-medical workers may be due to their closeness with the medical radiation facilities.

The t-test values computed and presented in Table 2 for each center suggest the results of a statistical test, which is commonly used to compare the means of two groups and assess whether the observed differences are statistically significant.

Center (A) (t = 1.143640) indicates a moderate difference between the groups associated with medical and non-medical workers in Center (A). Center (B) (t = 0.497820) suggests a relatively larger difference between the medical and non-medical workers in Center (B) compared to Center (A). Center (C) (t = 0.843154), Center (D) (t = 0.726548), Center (E) (t = 0.874548), and Center (F) (t = 0.995640) has a t-test value almost (but not exactly) similar to Center (B), indicating a similar magnitude of difference.

The p-values you provided in Table 2 correspond to each center's t-test and are associated with a two-tailed test with a significance level (α) of 0.05.

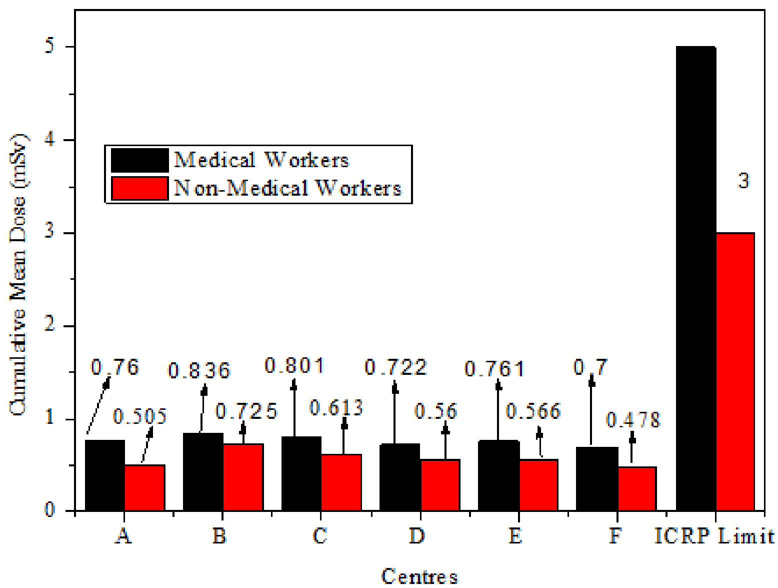

Figure 1: Comparison of cumulative mean dose for various centres with ICRP limits

Center (A) (p = 0.3046), Center (B) (p = 0.6397), Center (C) (p = 0.4376), Center (D) (p = 0.5001), Center (E) (p = 0.4218), and Center (F) (p = 0.3651) are higher than the significance level of 0.05. This showed that the observed difference in means for all Centers is considered to be not statistically significant at the 0.05 level.

Based on the observation from the chart above (Figure 1), the medical workers for all centers have higher doses than the non-medical workers. Interestingly, all these doses fall below the doses prescribed by International Commission on Radiological Protection (ICRP).

Discussion

The data presented in Table 2 illustrates the effective dose for medical and non-medical workers across six different centers, denoted as A, B, C, D, E, and F. For medical workers, center B exhibits the highest mean effective dose at 0.836±0.200 mSv, followed by center C (0.801±0.313 mSv), center E (0.761±0.123 mSv), center A (0.760±0.250 mSv), center D (0.722±0.120 mSv), and center F with the lowest mean at 0.700±0.067 mSv. A similar trend is observed for non-medical workers, with center B again having the highest mean effective dose (0.725±0.200 mSv), followed by center C (0.613±0.189 mSv), center E (0.566±0.143 mSv), center D (0.560±0.080 mSv), center A (0.505±0.277 mSv), and center F with the lowest mean at 0.478±0.076 mSv. This results not in line with the one reported by Maikudi *et al.* (2016) [22] who worked on the Occupational Radiation Monitoring in Tertiary Health Institutions of Northwestern Nigeria.

The comparison between medical and non-medical workers indicates that medical workers generally receive higher doses. Although the mean differences are slight, the higher values for medical workers are attributed to their proximity to medical radiation facilities.

The t-test values, presented in Table 2, provide insights into the statistical significance of the observed differences. Center A exhibits a moderate difference (t = 1.143640), while center B suggests a larger difference (t = 0.497820). Centers C, D, E, and F show t-test values almost similar to center B which indicate a comparable magnitude of difference. The corresponding p-values for each center (A-F) are higher than the significance level of 0.05, suggesting that the observed differences in means are not statistically significant at the 0.05 level. Figure 1 visually supports the trend, indicating that medical workers in all centers consistently receive higher doses than their non-medical counterparts. Importantly, all recorded doses fall below the limits prescribed by the International Commission on Radiological Protection (ICRP).

Conclusion

A research to determine the health impact of low ionizing radiation of professional radiation workers in some selected tertiary hospitals in south Southern Nigeria was conducted by comparing their doses with non-medical radiation workers and ICRP. The study employed medical and non-medical workers from three (6) different hospitals such as Federal Medical Center, (FMC), Asaba, Delta State (Centre A), Delta State University Teaching Hospital (DELSUTH) Oghara, Delta State (Centre B), University of Port Harcourt Teaching Hospital, (UPHTH), Port Harcourt, Rivers State (Centre C), Niger Delta University Teaching Hospital, (NDUTH), Okolobiri, Bayelsa State (Centre D), Image Diagnostic Center, (IDC), Port Harcourt, Rivers State (Centre E) and Federal Medical Center, (FMC), Yenagoa, and Bayelsa State (Centre F). The data reveals variations in effective doses among different centers and between medical and non-medical workers. However, the observed differences are not statistically significant, and all recorded doses adhere to the recommended standards set by the ICRP. Furthermore, the adherence to ICRP limits indicates a commitment to maintaining radiation exposure within internationally recognized safety thresholds. This comprehensive evaluation contributes valuable insights into the health impact of ionizing radiation on professional radiation workers in the selected tertiary hospitals in South Southern Nigeria.

Acknowledgments

The first and corresponding author appreciates the remaining authors for their positive criticism which makes the work worthy of publication in a reputable journal.

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