Research Square

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Assessment of thyroid gland function in healthcare staff occupationally exposed to ionizing radiation

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Research Article

Keywords: Thyroid gland, ionizing radiation, thyroid hormone, radiation exposure, occupational exposure

Posted Date: August 7th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10175367/v1

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Additional Declarations: No competing interests reported.

Abstract

Background: Several studies suggest that chronic low-dose exposure of healthcare workers to ionizing radiation impacts thyroid function. The aim of this work was to examine thyroid function and evaluate the effects of chronic radiation exposure in the occupational environment on thyroid hormone levels.

Methods A comparative observational cross-sectional study was conducted on 233 participants, including 117 radiation-exposed workers and 116 non-exposed healthcare workers as a control group. Demographic data as well as some clinical features were obtained from the participants. The concentrations of thyroid hormones, comprising thyroid-stimulating hormone (TSH), free triiodothyronine (fT3), and free thyroxine (fT4), were measured using the electrochemiluminescence immunoassay (ECLIA) method. Appropriate descriptive and analytical statistics were performed to analyze the data.

Results TSH levels were significantly higher in the radiation-exposed group than in non-exposed group, whereas lower fT3 and fT4 values were found among the radiation-exposed group ($p<0.05$) after adjusting for possible confounding variables (age, sex, and BMI). Moreover, radiation exposure and sex interact in their effects on thyroid hormone levels. TSH levels had a positive correlation and fT4 levels had a negative correlation with working duration in the radiation exposure environment, but no significant correlation was found for T3 levels.

Conclusion This study illustrates the significant effect of ionizing radiation exposure on thyroid hormone levels among radiation-exposed workers. This finding emphasizes that thyroid function should be checked repeatedly among this professional group and highlights the importance of adhering to radiation safety practices.

Background

Ionizing radiation (IR) is most commonly present in the medical field. Studies have shown that radiology personnel encounter different amounts of ionizing radiation depending on what they do at their workplace [1–3]. Hence, radiation protection measures require constant surveillance and enhancement [4, 5]. The need for supervision and regulation of radiation exposure in the workplace arises as a result of the acute radiation effect in exposed personnel over a long period. Thyroid gland hormones, including triiodothyronine (T3) and thyroxine (T4), are produced to control growth and metabolic functions [6]. Thyroid-stimulating hormone (TSH), produced by the pituitary gland, regulates the production of thyroid hormones (T3 and T4) [7, 8]. Typically, the measurement of T3, T4, and TSH levels in the blood is used to diagnose thyroid disorder [9].

Gamma and X-rays have the ability to remove electrons from their natural atom or alter DNA sequences, which can lead to different illnesses, such as cancer, acute radiation syndrome, and genetic disorders [10]. Research has shown that doses greater than 100 mSv increase cancer risk [11, 12]. These risks include the incidence of cancers, including thyroid cancer and leukemia, among those who have been exposed most likely to tobacco smoke [13, 14].

Among the occupational health hazards, ionizing radiation is especially damaging to the thyroid, and the adverse effects of radiation include hypothyroidism and cancer. A meta-analysis revealed that occupational-related radiation exposure increases thyroid cancer risk by 67% Qu et al. [15]. Also, Saenko & Mitsutake [16] reported that ionizing radiation can directly interfere with DNA in thyroid gland cells and thus produce mutations leading to growths that may be cancerous. Other studies have shown that low-dose exposure may produce lasting alterations in TH levels among healthcare workers exposed over time [17–20]. Furthermore, Cioffi et al. [21] reported a significant association between low doses of ionizing radiation and alteration in thyroid function and recorded higher TSH and lower fT3 and fT4 in workers exposed to occupational radiation. Whereas El-Benhawy et al. [10] demonstrated a lower TSH levels and higher fT3 hormone levels in occupational radiation-exposed individuals. According to these heterogeneous findings, there is a need to screen the thyroid function of medical radiation workers, with confounder assessment, to clarify the relationship between ionizing radiation and thyroid function for the enhancement of prevention strategies.

Although the available literature includes several studies that established the effects of ionizing radiation on the thyroid in different populations, there is a lack of such research focusing on radiology workers in local healthcare settings. Filling this gap provides an opportunity to provide localized data that can guide national health policies and protective measures, tailored to the regional healthcare context, to improve the support of healthcare workers in resource-limited environments. Therefore, this study aimed to assess the effects of ionizing radiation exposure on the thyroid function of healthcare workers in radiology departments.

Methods

An observational cross-sectional research design was employed to assess the quantitative changes in thyroid hormone levels among healthcare staff. The study sample included two groups: the radiation-exposed group consisted of radiology staff occupationally exposed to ionizing radiation (including radiologic technologists, technicians, and radiographers), and the control group consisted of non-exposed healthcare workers (including administrative and laboratory personnel) purposively selected from the same institutions. Most radiation exposed workers serve on more than one radiography modality and in more than one radiology department.

We used G*Power software to determine the sample size for a two-sample comparison of independent means. The calculation was based on previously published literature [21–23]. We targeted a sample size of 270 participants (135 per group) to achieve statistical power above the conventional threshold of 80% at an alpha level of 0.05. Using a purposive sampling technique, participants were recruited from several major public and private hospitals and diagnostic centers in Sana'a city, Yemen.

We applied predefined inclusion criteria include participants who served in their current position for at least 2 years and who had no thyroid disorders. To control the interference of confounding factors on thyroid hormone levels, subjects with known prior thyroid interventions, chronic systemic diseases

(renal, hepatic, cardiac, diabetic, or autoimmune), severe obesity (BMI greater than 35 kg/m^2), or recent use of medications that affecting thyroid function were excluded. We further implemented an age and sex matching strategy to increase the internal validity of our comparison and to confirm that the control group was reflective of the exposed group in terms of those demographic parameters.

In addition, individuals with incomplete data were excluded, resulting in 233 participants available for analysis (117 radiation-exposed workers and 116 non-exposed controls). The final sample had an adequate statistical power > 85% to detect a medium effect size (Cohen's d = 0.40), which would allow the generalization of the results and lead to reliable and consistent findings.

One venous blood sample was collected from each participant to measure TSH, fT3, and fT4 concentrations via the electrochemiluminescence immunoassay (ECLIA) method using Cobas e 411 analyzer (Roche). The demographic and health information was collected via a questionnaire. Appropriate descriptive and analytical statistics were conducted to examine the data and assess the relationship between radiation exposure and thyroid function via IBM SPSS software version 24.0.

Results

Demographic data of the study participants

This study included 117 radiology workers and 116 age-matched non-exposed health professionals. Table 1 presents a comparison of the mean values and significant differences in age, body mass index (BMI), and number of weekly working days, as well as sex distribution between the radiation-exposed and non-exposed groups.

Table 1
Demographic data of the study groups

Item	Radiation exposed group	Non-exposed group	*P*- value
Age (years) Mean (SD)	32.28 (9.30)	31.11 (7.34)	> 0.05
BMI (kg/m^2) Mean (SD)	23.99 (4.31)	23.52 (3.64)	> 0.05
Working days Mean (SD)	5.89 (1.09)	5.54 (1.04)	> 0.05
Sex: n (%)			
Female	53 (45.30%)	55 (47.41%)	> 0.05
Male	64 (54.70%)	61 (51.59%)	

The results in Table 1 showed no significant differences in demographic variables between both research groups (all p > 0.05).

Thyroid hormone tests

The thyroid hormone test results of the radiation-exposed and control groups are presented in Table 2 to show the effects of ionizing radiation on thyroid function.

Table 2 Comparison of thyroid hormone levels among the study groups

Thyroid hormone/Gender	**Radiation exposed** mean ± SD	**Non-exposed** mean ± SD	***P*-Value**
TSH (mIU/L)			
Men	2.20±1.08	1.81±1.05	0.046
Women	1.95±1.07	1.61±0.88	0.091
All	2.12±1.08	1.77±0.99	0.01
fT3 (pg/ml)			
Men	3.51±0.56	3.59±0.50	0.375
Women	2.89±0.30	3.25±0.44	0.000
All	3.33±0.58	3.44±0.51	0.641
fT4 (ng/dl)			
Men	1.26±0.21	1.37±0.19	0.006
Women	1.23±0.22	1.31±0.19	0.055
All	1.26±0.21	1.34±0.19	0.001

The results showed significant alterations in TSH and T4 levels among radiation-exposed workers, characterized by elevated TSH levels of 2.12 ± 1.08 vs 1.77 ± 0.99 (p = 0.01), and reduced fT4 levels (1.26 ± 0.21 vs. 1.34 ± 0.19; p = 0.001) compared with those in controls (non-exposed group). Additionally, the exposed group had slightly lower T3 levels (3.33 ± 0.58 vs. 3.44 ± 0.51; p = 0.641) compared with those in control group. However, the mean fT3 for exposed women was significantly lower than that for non-exposed women (2.89 ± 0.30 vs. 3.25 ± 0.44; p-value = 0.000).

Furthermore, there was a notable interaction effect between exposure to radiation and sex in the levels of thyroid hormones, where the means of the TSH and T4 levels of the exposed men were significantly different from those of non-exposed men (2.20 ± 1.08 vs. 1.81 ± 1.05 ; p = 0.046) and (1.26 ± 0.21 vs. 1.37 ± 0.19; p = 0.006), respectively.

Associated factors among radiation-exposed workers

Table 3 presents the mean levels of TSH, fT3, and fT4 hormones among the radiation-exposed group categorized by various associated factors such as age, smoking status, body mass index (BMI), exercise habits, qat chewing habit, exposure period, and family history of thyroid diseases.

Table 3
Factors associated with thyroid hormone levels among radiation-exposed workers

Associated factor	Group	TSH (mIU/L)			T3 (pg/ml)			T4 (ng/dl)		
		Mean	SD	Sig.	Mean	SD	Sig.	Mean	SD	Sig.
Age (year)	≤ 30	2.11	1.03	0.35	3.32	0.49	0.23	1.24	0.17	0.88
	31–45	2.26	1.32		3.19	0.57		1.27	0.22	
	> 45	1.97	0.95		3.20	0.74		1.25	0.26	
Smoke	Yes	1.79	0.90	0.04	3.35	0.83	0.87	1.26	0.26	0.72
	No	2.29	1.12		3.32	0.47		1.24	0.19	
BMI	< 18	2.04	1.48	0.66	3.33	0.43	0.07	1.28	0.14	0.84
	18–24	2.07	0.90		3.23	0.47		1.26	0.17	
	> 24	2.25	1.27		3.51	0.73		1.24	0.26	
Doing exercise	Yes	1.98	0.95	0.25	3.24	0.75	0.26	1.24	0.23	0.60
	No	2.22	1.15		3.38	0.42		1.26	0.19	
Qat chewing	Yes	2.12	1.08	0.90	3.43	0.59	0.01	1.26	0.22	0.87
	No	2.15	1.10		3.11	0.48		1.25	0.17	
Family history with hypothyroidism	Yes	1.71	0.68	0.24	3.59	1.30	0.53	1.45	0.45	0.20
	No	2.16	1.10		3.31	0.47		1.24	0.16	
Family history with hyperthyroidism	Yes	2.70	1.64	0.63	3.00	0.78	0.58	1.22	0.27	0.86
	No	2.12	1.11		3.33	0.58		1.25	0.22	
Family history with other thyroid diseases	Yes	1.81	0.72	0.34	3.53	1.24	0.59	1.43	0.43	0.20
	No	2.16	1.11		3.31	0.47		1.24	0.18	

Smoking was significantly associated with lower TSH levels ($p = 0.04$), whereas qat chewing habit was significantly associated with elevated fT3 levels ($p = 0.01$). However, other factors, including age, BMI, doing exercise, and family history of thyroid disorders, did not significantly affect thyroid hormone concentrations in the exposed group ($p > 0.05$).

Comparison of adjusted means of thyroid hormone levels

We conducted a univariate analysis of covariance (ANCOVA) to compare the adjusted means of thyroid hormone levels between the study groups, controlling for confounding factors such as age, sex, and BMI. The results shown in Table 4 revealed a significant increase in the TSH levels in the radiation-exposed group compared with those in the control group (F = 5.141, *p* = 0.024), whereas significant decrease in fT4 and fT3 levels were observed in the exposed group, (F = 5.176, *p* = 0.024) and (F = 8.635, *p* = 0.004), respectively. Moreover, the observed power values were within the acceptable range to support the validity of the findings and detect true differences between the radiation-exposed and control groups.

Table 4
ANCOVA results for adjusted mean values of thyroid hormone levels

Thyroid hormone	**Radiation-exposed group (n = 115)**	**Control group (n = 113)**	**Observed Power**	**F**	**p-value**
	Adjusted mean (SE)	**Adjusted mean (SE)**			
TSH (mIU/L)	2.113 (0.098)	1.790 (0.099)	0.701	5.141	0.024
T3 (pg/mL)	3.309 (0.048)	3.463 (0.048)	0.620	5.176	0.024
T4 (ng/dL)	1.258 (0.018)	1.339 (0.019)	0.833	8.635	0.004
SE: standard errors					

Correlation between working period and hormonal levels in radiation-exposed workers

Pearson's correlation coefficient (r) was calculated to assess the association between the duration of work in the radiology department and hormone levels among radiation-exposed workers (Table 5). There is a strong positive association between years of working and the TSH level and a negative association with the fT4 level.

Table 5
Correlations between years of working and hormone levels

variables	**Correlation coefficient (r)**	***p*-value**
Years of working and TSH	0.38	< 0.001
Years of working and fT4	− 0.32	0.001
Years of working and fT3	− 0.11	0.241

Discussion

The results revealed no significant differences between the radiation-exposed and non-exposed groups in terms of age, BMI, or weekly working days (all $p > 0.05$). Furthermore, both study groups exhibited

relatively similar sex distributions, which indicated two well-matching groups.

The findings indicated that radiation-exposed participants experienced a significant change in thyroid hormone levels than non-exposed healthcare workers did. In particular, they have higher TSH values and lower fT3 and fT4 values. In addition, after further adjusting for confounding factors (age, sex, and BMI) using ANCOVA test, the results confirmed that there was no significant impact of confounding factors on thyroid hormone levels, indicating that occupational radiation is a primary predictor of thyroid disorders in the exposed workers. Compared with those of control group, the adjusted mean of TSH was significantly higher, whereas the adjusted means of fT3 and fT4 were significantly lower in radiation-exposed workers. These findings suggest the possible danger of developing hypothyroidism or dysregulation because of occupational ionizing radiation exposure at the workplace.

This pattern has been partially supported by earlier studies, Alawneh et al. [24] reported an increase in TSH levels among radiology staff, whereas Wong et al. [18] reported a decrease in concentrations of fT3, and fT4 among medical radiation workers. Consistent with our findings, Guo et al. [9] recorded a strong correlation between exposure to occupational radiation and changes in thyroid hormones.

In addition, our results agree with those of Cioffi et al. [21], who reported significantly higher TSH levels and lower fT3 and fT4 levels in exposed healthcare subjects, although other studies showed different responses in thyroid hormone levels. For example, Lu et al. [25] reported higher fT4 levels in X ray-exposed group than in control group, potentially reflecting differences in sample composition, environment, or exposure dose.

Although sex did not significantly affect TSH or fT4 levels, it presented an additional effect on the fT3 concentration. These observations agree with that of Yang et al. [26], who reported lower fT3 levels in males than in females in the radiation-exposed group, suggesting an interaction between sex and radiation exposure. In addition, our finding aligns with the observations of Ren et al. [19] who stated that sex might play a role in the development of thyroid dysfunction under the impact of ionizing radiation, and that women usually tend to have more hormonal changes than men do.

Among radiation-exposed workers, smoking was significantly associated with lower TSH levels, while qat chewing slightly increased fT3 levels, whereas other demographic and lifestyle factors, including physical exercise and family history of thyroid disease, did not significantly affect thyroid hormone levels.

Radiology workers' susceptibility to the effects of low and chronic radiation doses revealed that the potential health hazards at the workplace remain an important area of study in the field of occupational health. There is a need to continue monitoring the thyroid function of health care workers, especially those in radiology departments and other comparable settings associated with radiation exposure.

Another interesting finding is the significant correlation between the changes in TSH and fT4 and the duration of working in the radiation-exposed environment. This means that the more years of radiation

exposure is, the more likelihood that TSH will increase and that fT4 will decrease. This finding indicates the existence of an accumulative dose-response relationship, as the duration of radiation exposure is associated with thyroid hormonal alterations. This result is supported by the finding of Wong et al. [18], who reported an important relationship between the duration of exposure and a decrease of thyroid hormone levels.

Our study prompts a reconsideration of current radiation protection and safety protocols, thus necessitating a regular thyroid function survey for exposed workers. Moreover, these outcomes suggest the role of genetic and environmental factors in thyroid disorders.

The strengths of this study include a relatively convenient and balanced sample size, a comparative design, and the objective measurement of thyroid hormones that address a regional gap in the occupational radiation literature, as well as providing valuable data from a low-resource setting.

However, the cross-sectional nature of this study limited its ability to estimate longitudinal changes in thyroid function. Also, the lack of individual cumulative dosimetry data limits the assessment of dose–response relationships. In addition, possible nutritional confounders such as dietary iodine may limit the attribution of thyroid dysfunction to occupational exposure alone. Nonetheless, our findings revealed that radiation exposure in occupational settings is associated with the risk of thyroid dysfunction in radiology staff in a limited resource setting. We recommend future longitudinal studies, including dose estimations and additional assessment methods, such as thyroid autoantibodies and ultrasonography, to detect minor alterations in thyroid function and dose–response relationships.

Conclusions

This study demonstrated that radiation-exposed individuals have significant alterations in thyroid function. The results indicate that hypothyroidism is a potential risk in healthcare workers exposed to ionizing radiation. Additionally, our findings highlight the importance of thyroid function follow-up for radiation-exposed workers as well as strict compliance with radiation protection measures. The relationship between thyroid function disorders induced by ionizing radiation may be affected by confounding factors. Hence, these variables should be considered further in longitudinal multicenter studies to detect subtle alterations in thyroid function across diverse populations.

Abbreviations

TSH
Thyroid-stimulating hormone
fT3
Free Triiodothyronine
fT4
Free Thyroxine
TH

Thyroid hormone
IR
Ionizing Radiation
BMI
body mass index
DNA
deoxyribonucleic acid
SPSS
statistical package for the social sciences

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the research ethics committee/University of Science and Technology (ID: 1447/00103/UREC/UST). All study procedures which involving human participants were in accordance with the principles outlined in the Declaration of Helsinki. In addition, all participants provided written informed consent.

Availability of data and materials

The data used and analyzed in this research are available from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests regarding this research authorship and publication.

Funding

This research received no external funding.

Authors' contributions

Abdullah Taher Naji and Abdulhabib R. Alqubaty designed the study, collected and analyzed data, wrote the original manuscript; Mohamed S. Al-Hakimi and Adeeb Salah helped in literature searching and data collection, and revised the manuscript critically for important content. All authors read and approved the final manuscript.

Acknowledgements

The authors extend sincere gratitude to all healthcare staff who participated in this study for their donation of blood samples. Also, special thanks go to the Medical Laboratory staff (Basem Haidarh, Waed Ghazi, Adel Mothafar, Mohamed Alshehri, Mohammed Radman, Abdualrahman bagubair, Dawod

Abo-ras, Abdalrahman sayfan, Anas Albaz, and Abdullah Khalid) who assisted in collecting participants' data and blood samples.

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