Original Article

Association between endocrine function and radiation exposure

Xiuting Li[1,2]*, Baoli Zhu[3]*, Lei Tu[1]*, Pengfei Yu[2], Haiyan Song[1], Xin Liu[3], Liangliang Zhao[3], Wenhui Guo[4], Tongtong Zhao[1], Jing Liu[1], Ying Cao[5], Jun Wang[2], Dandan Yang[3]

[1]Nanjing Prevention and Treatment Center for Occupational Diseases, Nanjing 210042, China; [2]Key Lab of Modern Toxicology, Ministry of Education, Department of Toxicology, School of Public Health, Nanjing Medical University, Nanjing 211166, China; [3]Jiangsu Provincial Center for Disease Control and Prevention, Nanjing 210028, China; [4]School of Public Health, Nanjing Medical University, Nanjing 211166, China; [5]Department of ENT, Huai'an Second People's Hospital, Huai'an 211700, China

Contributions: (I) Conception and design: B Zhu, X Li, J Wang; (II) Administrative support: H Song, D Yang, T Zhao; (III) Provision of study materials or patients: L Tu, L Zhao, J Liu; (IV) Collection and assembly of data: X Li, X Liu, Y Cao; (V) Data analysis and interpretation: X Li, W Guo, P Yu; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

*These authors contributed equally to this work.

Correspondence to: Dandan Yang. Jiangsu Provincial Center for Disease Control and Prevention, No. 172 Jiangsu Road, Nanjing 210009, China. Email: yangdan1997@163.com; Jun Wang. Department of Toxicology, School of Public Health, Nanjing Medical University, 818 Tianyuan East Road, Nanjing 211166, China. Email: wangjun@njmu.edu.cn.

Background: To observe the relationship of change in endocrine function within radiation exposure and try to evaluate the correlated factors about thyroid function and glucose metabolism.

Methods: A total of 1,784 subjects from physical examination organization for occupational health from year 2015 to 2016 were investigated.

Results: The abnormal proportion of T3 and T4 of female were higher than male. Glucose level showed a significant increase in overweight (5.35±1.01) and decrease in underweight group (4.77±0.47) compared with normal group (5.05±0.85). Subjects whose exposure time longer than 3 years were likely to get higher T4 level than those less than 3 years ($P<0.05$) and serum T4 was significantly associated with body mass index (BMI) in the T4 normal group.

Conclusions: Changes in thyroid function and glucose metabolism may appear after long time exposure to radiation.

Keywords: Thyroid; body mass index (BMI); glucose; thyroxine

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Introduction

There has been a growing focus on endocrine dysfunction especially thyroid dysfunction after radiation exposure recent years, which may impact on morbidity even mortality. Thyroid dysfunction contains hyperthyroidism, hypothyroidism and some subclinical thyroid dysfunction, which may be associated with dyslipidemia (1-3), which has been proved to be a risk factor for ischemic heart disease and the all-cause mortality (4,5). With respect to this side, the relation between changes in thyroid function and radiation exposure might be important, as radiation is associated with increased thyroid dysfunction as well as morbidity (6-9). There have been many epidemiological studies placing emphasis on thyroid function (10-13), but little has paid attention to the relation between radiation and thyroid function.

Thyroid dysfunction caused by radiation exposure or other reasons may be associated with change in body mass index (BMI), weight and even induced obesity and metabolic consequences including diabetes (14-16). On the basis of above theories, we decided to observe the likely relationship of endocrine function changes (such as thyroid function and glucose metabolism) within radiation exposure.

In the current study, we explored glucose metabolism and thyroid function parameters. We have gathered data from the physical examination center, which has general health survey arranged for occupational health. Most of radiation workers participated were exposed to X-ray, which gave us the opportunity to research only one type of radial without interference and to evaluate the relation between some hormone levels about endocrine system and radiation exposure in a cross-sectional stage.

Methods

Subjects and questionnaire

The study enrolled hospital radiation operators most of whom were radiologists, they were recruited consecutively at the physical examination organization for occupational health from year 2015 to 2016. The annual effective dose equivalents of all subjects were less than 0.24 mSv, which was far below our national standard (10 mSv).

Subject information was collected with a questionnaire that was carried out through interviews in the forms of face-to-face. The questionnaire generally included demographic data, medical conditions including previous and present, radiation exposure, pharmaceutical preparations, previous radiation exposure to X-ray, hereditary factors, smoking and drinking status. In our study, ever drinkers was identified as subjects who drank a bottle of beer or fifty grams of wine per day and for at least one year, however, the rest were never ones. Workers who had one cigarette per day for at least one year were identified as ever ones, all others were never smokers.

Blood glucose and thyroid related hormones

Overnight fasting plasma glycemia were detected from blood samples that were collected in the morning. Serum levels of FT3 (free triiodothyronine), T3 (triiodothyronine), TSH (thyroid stimulating hormone), T4 (thyroxine) and FT4 (free thyroxine) were determined using a commercially available ELISA kit according to the specifications. A glucometer was used to detect serum glucose.

Statistical analysis

We entered all data into a computerized database using the statistical analysis Epidata 3.1, all analyses were performed by SAS 9.1.3 (SAS Institute, Cary, NC, USA) and SPSS 22.0 (SPSS Inc., USA) software. Student's *t*-tests and Univariate analysis of variance were used for the analysis of continuous data. Qualitative data were evaluated using Pearson χ^2 test. Relationships between BMI, plasma glucose and thyroid hormones were analyzed with spearman's correlation analysis. P<0.05 was generally accepted as statistically significant.

Results

In all, 2,129 subjects participated in this survey. All subjects exposed to other types of radiation except for X-ray (n=192) were excluded. Of the 1,937 remaining subjects, 153 were excluded because of missing values for one or more analyzed factors, finally leaving 1,784 subjects to be included in the analyses.

Descriptive characteristics of all subjects including many factors with significant association are shown in *Table 1*. The abnormal proportion of T3 and T4 in female were higher than them in male, with rate 1.3% of T3 and 1.5% of T4 in female compared to 0.2% and 0.4% in male (P<0.05), respectively. Abnormal rate of FT4 increased, accompanying with the growth of age (P<0.05). Nevertheless, abnormal rate of T4 decreased with BMI rose (P<0.05). There is a little incredible to detect that smokers were unlikely to approach abnormalities of T3 and TSH, on the contrary, subjects who never smoke may be susceptible to abnormality potentially (P<0.05), with frequency 0.0% of T3 and 3.3% of TSH in non-smokers, compared to 0.75% of T3 and 5.5% of TSH in ever smokers. We were pleased to observe the relation between the degree of education and FT4 level. In the group of junior high school, abnormal proportion of FT4 was 4.2%, while in group high school degree, it decreased to 1.0% and further to 0.6% in college and above obviously (P<0.05). In addition, T3 and FT3 levels may be associated with exposure time of X-ray. On the basis of this survey, abnormal rate of T3 (1.4%) and FT3 (1.0%) were higher in group <3 years than that in group ≥3 years (0.3% and 0.1%, respectively; P<0.05). However, there may be no significant association between thyroid-related hormone level and drinking status, safeguard procedures.

When considering three groups according to BMI, glucose level showed a significant increase in overweight (5.35±1.01) and decrease in underweight group (4.77±0.47) compared with normal group (5.05±0.85) (*Figure 1*). When taken all subjects as a whole, BMI was positively related with level of plasma glucose (r=0.20, P<0.01).

As *Figure 2A,B* has shown, we compared serum T3,

Table 1 Descriptive characteristics of all subjects

Variable	Total		T3					T4					TSH					FT3					FT4				
			Normal		Abnormal		P	Normal		Abnormal		P	Normal		Abnormal		P	Normal		Abnormal		P	Normal		Abnormal		P
	N	%	N	%	N	%		N	%	N	%		N	%	N	%		N	%	N	%		N	%	N	%	
Sex																											
Male	1,250	100.0	1,248	99.8	2	0.2		1,245	99.6	5	0.4		1,196	95.7	54	4.3		1,248	99.8	2	0.2		1,240	99.2	10	0.8	
Female	534	100.0	527	98.7	7	1.3	0.004	526	98.5	8	1.5	0.018	502	94.0	32	6.0	0.084	531	99.4	3	0.6	0.162	530	99.3	4	0.7	0.587
Age (years)																											
<30	588	100.0	583	99.1	5	0.9		585	99.5	3	0.5		560	95.2	28	4.8		587	99.8	1	0.2		585	99.5	3	0.5	
30–41	595	100.0	592	99.5	3	0.5		591	99.3	4	0.7		572	96.1	23	3.9		591	99.3	4	0.7		593	99.7	2	0.3	
>41	600	100.0	599	99.8	1	0.2	0.251	594	99.0	6	1.0	0.599	565	94.2	35	5.8	0.283	600	100.0	0	0.0	0.074	591	98.5	9	1.5	0.049
Smoke																											
Never	1,238	100.0	1229	99.3	9	0.7		1,227	99.1	11	0.9		1,170	94.5	68	5.5		1,233	99.6	5	0.4		1,227	99.1	11	0.9	
Ever	546	100.0	546	100.0	0	0.0	0.037	544	99.6	2	0.4	0.189	528	96.7	18	3.3	0.027	546	100.0	0	0.0	0.161	543	99.5	3	0.5	0.336
Drink																											
Never	1,478	100.0	1,469	99.4	9	0.6		1,465	99.1	13	0.9		1,404	95.0	74	5.0		1,473	99.7	5	0.3		1,465	99.1	13	0.9	
Ever	306	100.0	306	100.0	0	0.0	0.183	306	100.0	0	0.0	0.086	294	96.1	12	3.9	0.260	306	100.0	0	0.0	0.390	305	99.7	1	0.3	0.279
BMI (kg/m^2)																											
<18	59	100.0	58	98.3	1	1.7		56	94.9	3	5.1		55	93.2	4	6.8		59	100.0	0	0.0		58	98.3	1	1.7	
18–24	900	100.0	895	99.4	5	0.6		893	99.2	7	0.8		859	95.4	41	4.6		898	99.8	2	0.2		893	99.2	7	0.8	
>24	825	100.0	822	99.6	3	0.4	0.361	822	99.6	3	0.4	0.000	784	95.0	41	5.0	0.715	822	99.6	3	0.4	0.787	819	99.3	6	0.7	0.718
Protection																											
Never	307	100.0	304	99.0	3	1.0		305	99.3	2	0.7		287	93.5	20	6.5		307	100.0	0	0.0		305	99.3	2	0.7	
Ever	1,477	100.0	1,471	99.6	6	0.4	0.191	1,466	99.3	11	0.7	0.607	1,411	95.5	66	4.5	0.088	1,472	99.7	5	0.3	0.307	1,465	99.2	12	0.8	0.557
Education																											
Junior high school	48	100.0	48	100.0	0	0.0		47	97.9	1	2.1		43	89.6	5	10.4		48	100.0	0	0.0		46	95.8	2	4.2	
High school	302	100.0	302	100.0	0	0.0		301	99.7	1	0.3		288	95.4	14	4.6		302	100.0	0	0.0		299	99.0	3	1.0	
College and above	1,434	100.0	1,425	99.4	9	0.6	0.159	1,423	99.2	11	0.8	0.385	1,367	95.3	67	4.7	0.186	1,429	99.7	5	0.3	0.295	1,425	99.4	9	0.6	0.022
Exposure time (years)																											
<3	286	100.0	282	98.6	4	1.4		283	99.0	3	1.0		270	94.4	16	5.6		283	99.0	3	1.0		284	99.3	2	0.7	
≥3	1,498	100.0	1,493	99.7	5	0.3	0.020	1,488	99.3	10	0.7	0.347	1,428	95.3	70	4.7	0.505	1,496	99.9	2	0.1	0.007	1,486	99.2	12	0.8	0.605

BMI, body mass index.

T4, TSH, FT3 and FT4 levels between different degrees referred to exposure time of radiation. Subjects whose duration time longer than 3 years were likely to have higher T4 contents than those who contact less than 3 years (P<0.05). Unfortunately, no significant associations had been found between exposure time and serum T3, TSH, FT3 and FT4 levels.

Normal T4 subjects and abnormal ones were researched separately. In this study, serum T4 was significantly and positively related with BMI in the T4 normal group. Within normal T4 level, T4 was a little weak positive-correlated with BMI (r=0.06, P<0.01). For the T4 abnormal, relation between BMI and serum T4 were not statistical associated.

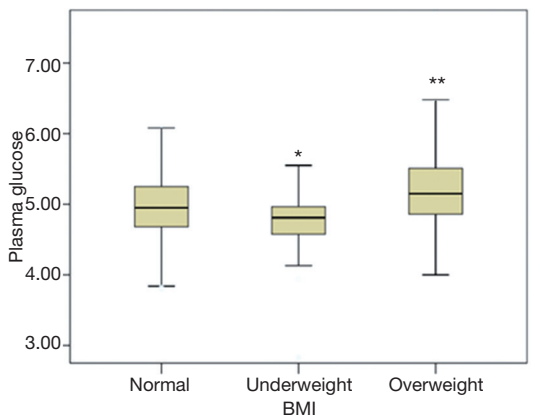

Figure 1 Changes of plasma glucose in BMI groups (control, underweight, overweight). Blood samples were collected from normal (n=900), overweight (n=825), underweight (n=59) subjects. *, P<0.05; **, P<0.01 versus normal subjects. BMI, body mass index.

Discussion

We demonstrate a relevancy between thyroid function and gender in this study population, and with individuals grow older, the regulation function of thyroid related hormones appear to decline.

Another interesting result is the significant correlation between thyroid hormone levels and smoking status, subjects who never smoke may be susceptible to abnormal T3 and TSH compared to smokers. However, whether smoking is a protective factor against thyroid dysfunction needs to be considered carefully and scientifically.

The education degree influenced the thyroid hormones, with higher degree following lower abnormal incidence, implying the importance of knowledge and self-cultivation. When relating exposure time, subjects contacting X-ray longer than 3 years were unlikely to get abnormal, with the possible reason of physiologic compensatory reaction of organism, which will lead body to pathological symptom if they do not take remedial measures immediately after longer exposure.

Overall, there was a significant association of T4 level with exposure time when grouping the participants by radial exposure time and testing for hormone levels. These results indicate that thyroid function appears to change when workers are exposed to longer time of radial. However, this is not difficult to understand as higher radial levels are more

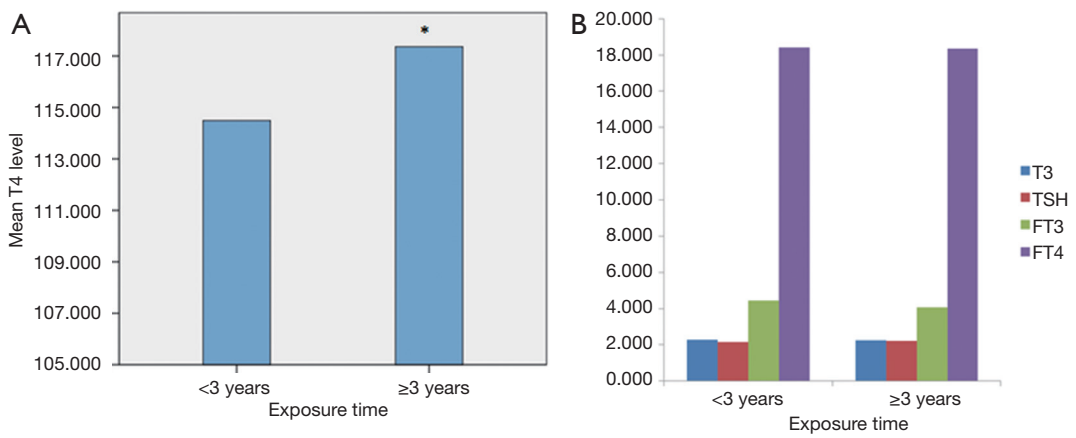

Figure 2 Changes of thyroid related hormones with exposure time. (A) Changes of serum T4 levels in exposure time <3 and ≥3 years (unit of T4: nmol/L). *, P<0.05; (B) serum T3, TSH, FT3 and FT4 levels in both exposure time <3 and ≥3 years (units: T3, nmol/L; TSH, mIU/L; FT3, pmol/L; FT4, pmol/L).

detrimental, and a larger significant effect on thyroid would be expected if things continue on this way.

The present study has found an association between T4 and BMI. This relationship about them has been reported in some studies (17,18), considering that it may be mediated by leptin which is a type of protein produced by adipocytes, and adipocytes can regulate TRH secretion (19). It is well known that thyroid hormones associate with the maintenance of body weight (20). As we all known, hyperthyroidism is connected with weight loss and hypothyroidism is relative to a decreased metabolic rate (21,22), it is not a stretch to infer that abnormal weight is associated with hormonal changes, especially those related to thyroid function (23). It is well elucidated that the hypothalamic-pituitary-thyroid (HPT) axis participate in a large amount of metabolic processes, including energy expenditure and thermogenesis, affecting energy balance (24,25). Abnormal weight such as obesity may be the phenotypic expression of energy imbalance (26), accompanying with the results that abnormal weight may have altered HPT axis activity (27,28). Nevertheless, in abnormal weight status, whether determined changes of thyroid function are discussed controversially (29-32). However, measures of BMI were found to be positively related to T4 in our model, although in group of normal thyroid function.

Moreover, individuals whose weight being out of normal range are also the major patients suffered from metabolic syndrome deriving from insulin resistance, cardiovascular disease, and type 2 diabetes (33-36). In accordance with them, we found that BMI was closely related to plasma glucose level. As BMI increased, accompanying with glucose level arose, until pathological changes such as obesity and diabetes.

Although no causal association has been proved by these observational data, there are plausible medical explanations and other researches pointing in the same direction. Unfortunately, only few studies have reported the relevance between thyroid function and metabolic disorders so far. Since given that the increasing prevalence of abnormal weight, diabetes, and thyroid dysfunctions, further study in-depth the association between circulating thyroid function parameters and glucose-metabolic dysfunction are urgently needed in the future research.

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Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/jphe.2017.03.07). XL serves as an unpaid Section Editor of *Journal of Public Health and Emergency* from Jun 2017 to Dec 2019. BZ serves as an Editor-in-Chief of *Journal of Public Health and Emergency* from Jan 2017 to Dec 2022. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by The Regional Bioethical Committee at Jiangsu Provincial Center for Disease Control and Prevention (approval number: JSJK2015-B008-02) and written informed consent was obtained from all patients.

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