The Effect of Radiation on Secondary Sex Ratio among Radiologists in Shiraz, Iran

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ABSTRACT

Environmental and occupational exposure may play a role in gender offspring. This study aimed to investigate the effect of radiation on gender ratio in the offspring of radiologists and technicians. This cross-sectional study was conducted on 262 participants with a total of 354 children. A data collection form including age, years spent in radiology practice, number of children, sex of each child, observance of radiation protection principles, and intensity of exposure based on International Commission Radiological Protection was completed. Male to female ratio was calculated 0.85 in fathers and 0.75 in mothers in comparison to this ratio estimated in Iran demographic statistics sex ratio which is 1.03. Highly-exposed parents (Prevalence ratio [PR]: 1.67, 95% confidence interval [CI]: 1.11-2.52), as well as fathers (PR: 2.72, 95%CI: 1.56-4.72), had a significant propensity to have female offspring. However, this criterion in female radiologists was not found to be significant (P= 0.57). Moreover, in fathers a significant relationship was found between the years spent in radiology field up to the time of the child's birth or age of the parents' at child's conception with offspring gender (4-6 year: PR: 2.07, 95% CI: 1.15-3.72; ≥7 year: PR:1.81, 95%CI: 1.18-2.78). Highly-exposed radiology male personnel, as well as those exposed to radiation 4 years or more before the offspring's birth, were more likely to have daughters than sons. Although no exact mechanism has been identified for this preponderance, further animal studies are required to evaluate whether x ray is an influential factor in offspring gender.

Key words: Paternal Exposure; Sex Ratio; Radiation; Radiology

INTRODUCTION

Human sex ratio is usually 1050 male to 1000 female[1]. Changes in this ratio prompted us to investigate the influential factors that could play a role in making this ratio skewed. From 1958, the subject of influential factors on offspring gender has been a focus of many studies that led to investigation of the male to female offspring ratio among survivors of Hiroshima and Nagasaki [2]. It has been shown that certain environmental and occupational exposures and endocrine conditions play a role in low propensity for male offspring [3–8] and a statistically significant decline was observed in male to female ratio in the recent 10 years. An opposite radiological hypothesis stated in one study declared that male to female sex ratio increased after radiation effect of Chernobyl nuclear power [9].

Among many factors, in the population with high exposure to Dioxin, mercury and pesticides, a lower proportion of male offspring has been reported [10]. On the other hand, it has been shown that those who were exposed to therapeutic irradiation during childhood did not differ by their offspring gender ratio [11]. Even though a study on low dose ionizing radiation suggests no statistically significant alternation of offspring sex ratio, it has not declined the necessity of more studies [12]. Another study in Japan in 2001 on high radiation-exposed radiologists found the effect of radiation on higher proportion of female offspring. Although no definite mechanism underlying female offspring propensity among radiologists has been identified, radiation-induced mutations in sex chromosomes or endocrine changes have been postulated [3]. Because of ethical problems, most of studies were done on animals and there are few studies on human [13]. Filling the information gap of potential effect of radiation on offspring sex ratio is a key guide for progression in ovulation biology and future population. This is the first study to investigate offspring gender ratio among those who work in radiology clinics in Shiraz and three other cities in Fars province (Iran).

MATERIALS AND METHODS

This cross-sectional study was approved by Shiraz University of Medical Sciences (SUMS) Research Committee. Initially, information was gathered in SUMS Radiology department for all the personnel who work in radiology department. Married radiology specialists or radiology technicians who had worked for at least one year were included. Those who had no child or had no history of intrauterine fertilization or in vitro fertilization or gender selection were excluded. Finally, 261 participants who had 354 children participated in this study. Our subjects were all from radiology department in 5 universities, state and private hospitals and 38 private institutes in Shiraz. A data collection form that addressed the participant's age and sex, years spent in radiology practice, number of children, sex of each child, observance of radiation protection principles, and intensity of exposure based on International Commission Radiological Protection (ICRP) [14] was completed for our study population. Based on the participant's history, we classified the intensity of radiation exposure to high and low according to ICRP and asked whether the person has ever received a radiation dose greater than 10 millisievert/year or not. Then, the participants were categorized into highly-exposed and lightly-exposed groups. Moreover, our results were compared with the number of male and female offspring of Iran population that were born during 1974-2014; it was obtained from Iran demographic statistics. Sex ratio was defined as the ratio of male to female offspring. Prevalence ratio [PR] and 95% confidence interval [CI] was used to analyze the data. All statistical evaluations were made assuming a two-sided test based on a 5% level of significance using STATA version 14.

RESULTS

After initiating their career in radiology field, our study population had 179 male offspring (50.6%) and 175 female offspring (49.4%) (Male/Female ratio: 1.02) (Table 1). Male to female ratio for fathers (Table 2) and mothers (Table 3) were 95:112=0.85 and 63:84=0.75, respectively. Available Iran demographic statistics (1965-2006) demonstrates a rate of 50.9% for male and 49.1% for female offspring, which shows a male/female ratio of 1.03. Although comparison of our study's population offspring gender with Iran population showed no statistically significant difference (Prevalence ratio (PR): 1.01, 95% confidence interval (CI): 0.82-1.25, P= 0.915), when exposure to radiation was classified according to ICRP to low and high, then a statistically significant relationship was found between the intensity of radiation exposure and offspring gender in the total study population (PR:1.67, 95% CI:1.11-2.52, P=0.017) (Table 1). Moreover, fathers with highly radiation intensity had a significant relationship with sex ratio as compared with Iran sex ratio reference population (PR: 2.72, 95%CI: 1.56-4.72, P=0.0005). Additionally, in fathers, years spent in radiology field up to the time of the child's birth or age of the parents at child's conception showed a significant relationship with offspring gender (4-6 year: PR: 2.07, 95% CI: 1.15-3.72, P=0.020; ≥7 year: PR: 1.81, 95% CI: 1.18-2.78, P=0.007) (Table 2). However, there was no significant difference between offspring and radiation exposure in mothers (Table 3).

In addition, Iran population offspring gender data was we compared with three different study age groups of ≤29, 30-40 and >40 years in terms of offspring gender, which showed no statistically significant relationship not only in the total radiologists and technicians but also in fathers and mothers radiologist and technicians.

Table 1: Relationship between offspring gender and study variables in total radiologists

Variables		Number of male offspring	Number of female offspring	Sex ratio (M/F)	Prevalence ratio	95% CI	P value
Reference Population		15709049	15168799	1.035	1.00	1.00-1.00	-
Study Population		179	175	1.02	1.01	0.82-1.25	0.915
Radiation Intensity	High	36	58	0.62	1.67	1.11-2.52	0.017
	Low	143	117	1.22	0.85	0.66-1.08	0.192
Parent's age at child's conception (year)	≤29	79	76	1.04	1.00	0.73-1.37	1.000
	30-40	61	70	0.87	1.19	0.84-1.67	0.337
	>40	8	6	1.33	0.78	0.27-2.32	0.791
Duration of exposure* (year)	1-3	62	43	1.44	0.72	0.49-1.06	0.098
	4-6	42	55	0.76	1.36	0.91-2.02	0.154
	≥7	60	69	0.87	1.19	0.84-1.68	0.334

*Years spent in radiology field up to time of child's birth
Note: all analyses were compared with reference population

Table 2: Relationship between offspring gender and study variables in father radiologists

Variables		Number of male offspring	Number of female offspring	Sex ratio (M/F)	Prevalence ratio	95% CI	P value
Reference Population		15709049	15168799	1.035	1.00	1.00-1.00	-
Study Population		95	112	0.85	1.22	0.93-1.60	0.164
Radiation Intensity	High	16	42	0.38	2.72	1.56-4.72	0.0005
	Low	79	70	1.13	0.92	0.66-1.27	0.624
Parent's age at child's conception (year)	≤29	34	43	0.79	1.31	0.84-2.05	0.256
	30-40	48	56	0.86	1.21	0.82-1.78	0.378
	>40	6	6	1.00	1.04	0.33-3.21	1.000
Duration of exposure* (year)	1-3	37	28	1.32	0.78	0.48-1.28	0.385
	4-6	16	32	0.50	2.07	1.15-3.72	0.020
	≥7	32	54	0.59	1.81	1.18-2.78	0.007
*Years spent in radiology field up to time of child's birth Note: all analyses were compared with reference population							

Table 3: Relationship between offspring gender and study variables in mother radiologists

Variables		Number of male offspring	Number of female offspring	Sex ratio (M/F)	Prevalence ratio	95% CI	P value
Reference Population		15709049	15168799	1.035	1.00	1.00-1.00	-
Study Population		63	84	0.75	1.38	1.00-1.91	0.058
Radiation Intensity	High	20	16	1.25	0.83	0.43-1.60	0.619
	Low	64	47	1.36	0.76	0.52-1.11	0.156
Parent's age at child's conception (year)	≤29	45	33	1.36	0.76	0.49-1.19	0.258
	30-40	13	14	0.93	1.12	0.52-2.37	0.849
	>40	2	0	-	-	-	-
Duration of exposure* (year)	1-3	25	15	1.67	0.62	0.33-1.17	0.156
	4-6	26	23	1.13	0.92	0.52-1.61	0.777
	≥7	24	20	1.20	0.86	0.48-1.56	0.654
*Years spent in radiology field up to time of child's birth Note: all analyses were compared with reference population							

DISCUSSION

In this study, the effect of radiation was analyzed on gender ratio in the offspring of radiologists and technicians. Results of this study showed that intensity of radiation exposure, fathers working with high radiation and the years spent in radiology field had a statistically significant relationship with the offspring's gender. Due to the concerns about the possible harmful effects of exposure to radiation, this physical agent has been the center of attention in recent years [15,16]. Environmental and occupational exposures have been linked to many genetic mutations, congenital malformation, and also offspring gender ratio.

results of this study were in agreement with those of Hama *et al.* [3], demonstrating a reduced male offspring proportion in male radiologists. Also, in line with the previously mentioned study, we found that male radiologists who were highly exposed to radiation had a higher propensity to have daughter. Moreover, sex ratio did differ significantly by the years spent in radiology field up to the time of birth of the offspring. It is concluded that exposure intensity may be an influential factor in gender offspring as well as the time interval of exposure duration before the offspring's birth.

The parents' age did not affect the gender of the offspring. This finding was consistent with the result of study by Hama *et al.* [3]. Comparing radiologists with other medical specialists, Choi *et al.* [17] showed no statistically significant relationship between the male invasive and interventional cardiologists and offspring gender. Cheng *et al.* [18] found no statistically significant difference between those who worked in and out of operation room. Dickinson *et al.* [19] in their study on evaluation of the paternal occupation effect on the sex of the offspring did not report a significant relationship between sex ratio and occupation although their study did not report those who worked in radiation exposed medical fields. Aviation officers [20], although not statistically different from general population, were shown to have more daughters than sons (1 male for every 1.002 females). High background radiation [21] has not been associated with altered sex ratio in the offspring of the inhabitants of a northern city of Iran.

The exact mechanism underlying changes in the offspring sex ratio of occupations exposed to x rays has not been found yet, but some have pointed to the possibility of decreased chance of survival for male zygotes and embryos [3]. Another mechanism for offspring sex ratio has been studied; for instance,

Desai *et al.* [22] have indicated the role of radiofrequency electromagnetic waves in producing reactive oxygen species that cause spermatozoa cell death. Among other possible mechanisms, damage to sex chromosomes has been reported [23]. Saadat did not find a skewed offspring gender ratio in men exposed to electromagnetic fields [6], though electromagnetic field exposure was studied to cause abnormal sperm morphology and motility [24]. It has also been suggested that reduced male offspring proportion could be due to reduced rate of fertilization success or decreased chance of spermatocyte survival [25,26]. Occupational ionizing radiation could lower the secondary sex ratio because of its effect on production or function of gametes [12].The strengths of this study are as follows: 1) our present study is the first one in Iran which has evaluated the effect of radiation on secondary sex ratio. 2) This study is the representative sample of radiologist in Shiraz, Iran. However, the drawbacks of this study should be noted. 1) Relatively small sample size. The authors would like to suggest that future studies should be conducted with a larger sample. 2) To determine the high and low exposure to radiation based on questionnaire and film-badge dosimeter would be problematic; for example, the radiologist and technicians may not remember the exposure to radiation correctly.

Future animal studies should be carried out to determine the effect of x ray on gender of the offspring. Based on different mechanisms involved in these exposures, future studies should be career-specific and include information about occupation of the participant's spouse. Given the fact that offspring gender is influenced by many factors, further studies should be carried out to study the interaction between influential factors on offspring gender to investigate the factors that play a role in gender propensity in radiology field related jobs.

To conclude, highly-exposed radiology male personnel, as well as those who had been exposed to radiation 4 years or more before field up to the time of the child's birth or age of the parents' at child's conception, were more likely to have more daughters than sons. Although no exact mechanism has been identified for this preponderance, further animal studies are required to evaluate whether x ray is an influential factor in offspring gender.

ETHICAL ISSUES

The research was approved by the Ethics Committee of Shiraz university of medical science.

CONFLICT OF INTEREST

The authors have declared no conflict of interest.

AUTHORS CONTRIBUTION

Mahnaz Yadollahi, Mohammad Farahmand and Haleh Ghaem contributed equally to the design of the study along with data analysis, interpretation and preparing the final manuscript. Maryam Foadi, Narges Shamseddini and Mehrdad karajizadeh contributed to data collection, interpretation and draft manuscript. All of authors approved final manuscript.

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REFERENCES

[1] Statistical Centre of Iran, Census 2011 [Internet]. [Cited 2016 Jan 19]. Available from: http://www.amar.org.ir/english/Census-2011

[2] Schull WJ, Neel JV, Hashizume A. Some further observations on the sex ratio among infants born to survivors of the atomic bombings of Hiroshima and Nagasaki. American Journal of Human Genetics. 1966; 18(4):328-38.

[3] Hama Y, Uematsu M, Sakurai Y, Kusano S. Sex ratio in the offspring of male radiologists. Academic radiology. 2001; 8(5):421-24.

[4] James WH. Offspring sex ratios at birth as markers of paternal endocrine disruption. Environmental research. 2006; 100(1):77-85.

[5] James WH. Further evidence that mammalian sex ratios at birth are partially controlled by parental hormone levels around the time of conception. Human Reproduction. 2004; 19(6):1250-56.

[6] Saadat M. Offspring sex ratio in men exposed to electromagnetic fields. Journal of Epidemiology and Community Health. 2005; 59(4):339.

[7] Scherb H, Voigt K. The human sex odds at birth after the atmospheric atomic bomb tests, after Chernobyl, and in the vicinity of nuclear facilities. Environmental science and pollution research international. 2011; 18(5):697-07.

[8] Terrell ML, Hartnett KP, Marcus M. Can environmental or occupational hazards alter the sex ratio at birth? A systematic review. Emerging Health Threats Journal. 2011; 4:7109, DOI: 10.3402/ehtj.v4i0.7109 .

[9] Scherb H, Kusmierz R, Voigt K. Increased sex ratio in Russia and Cuba after Chernobyl: a radiological hypothesis. Environmental health: a global access science source. 2013; 12:63, DOI: 10.1186/1476-069X-12-63.

[10] Mackenzie CA, Lockridge A, Keith M. Declining Sex Ratio in a First Nation Community. Environmental Health Perspectives. 2005; 113(10): 1295-98.

[11] Reulen RC, Zeegers MP, Lancashire ER, Winter DL, Hawkins MM. Offspring sex ratio and gonadal irradiation in the British Childhood Cancer Survivor Study. British journal of cancer. 2007; 96(9):1439-41.
[12] Maconochie N, Roman E, Doyle P, Davies G, Smith PG, Beral V. Sex ratio of nuclear industry employees' children. Lancet (London, England). 2001; 357(9268):1589-91.
[13] Li JH, Jiang DP, Wang YF, Yan JJ, Guo QY, Miao X, *et al.* Influence of electromagnetic pulse on the offspring sex ratio of male BALB/c mice. Environmental toxicology and pharmacology. 2017; 54:155-61, DOI: 10.1016/j.etap.2017.06.015.
[14] Wrixon AD. New ICRP recommendations. Journal of radiological protection: official journal of the Society for Radiological Protection. 2008; 28(2):161-68.
[15] Monazzam MR, Hosseini M, Matin LF, Aghaei HA, Khosroabadi H, Hesami A. Sleep quality and general health status of employees exposed to extremely low frequency magnetic fields in a petrochemical complex. Journal of environmental health science & engineering. 2014; 12:78-83.
[16] Mortazavi SAR, Tavakkoli-Golpayegani A, Haghani M, Mortazavi SMJ. Looking at the other side of the coin: the search for possible bio positive cognitive effects of the exposure to 900 MHz GSM mobile phone radiofrequency radiation. Journal of Environmental Health Science and Engineering. 2014; 12:75-80.
[17] Choi JW, Mehrotra P, MacDonald LA, Klein LW, Linsky NM, Smith AM, *et al.* Sex proportion of offspring and exposure to radiation in male invasive cardiologists. Proceedings (Baylor University Medical Center). 2007; 20(3):231-34.
[18] Cheng B-H, Chuang H-Y, Hsu T-Y, Chang S-Y, Yang C-Y, Wu T-N. The offspring sex ratio of surgeons in a Taiwan Medical Centre. International Congress Series. 2004; 1271:329-33.
[19] Dickinson HO, Parker L. Sex ratio in relation to fathers' occupations. Occupational and environmental medicine. 1997; 54(12):868-72.
[20] Baczuk R, Biascan A, Grossgold E, Isaacson A, Spencer J, Wisotzky E. Sex ratio shift in offspring of male fixed-wing naval aviation officers. Military medicine. 2009; 174(5):523-28.
[21] Saadat M. No change in sex ratio in Ramsar (north of Iran) with high background of radiation. Occupational and environmental medicine. 2003; 60(2):146-47.
[22] Desai NR, Kesari KK, Agarwal A. Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on male reproductive system. Reproductive biology and endocrinology: RB&E. 2009; 7:114-22.
[23] Scholte PJL, Sobels FH. Sex Ratio Shifts among Progeny from Patients Having Received Therapeutic X-Radiation. American Journal of Human Genetics. 1964; 16(1):26-37.
[24] Li DK, Yan B, Li Z, Gao E, Miao M, Gong D, *et al.* Exposure to magnetic fields and the risk of poor sperm quality. Reproductive toxicology (Elmsford, NY). 2010; 29(1):86-92.
[25] Irgens A, Kruger K, Skorve AH, Irgens LM. Male proportion in offspring of parents exposed to strong static and extremely low-frequency electromagnetic fields in Norway. American journal of industrial medicine. 1997; 32(5):557-61.
[26] James WH. The hypothesized hormonal control of mammalian sex ratio at birth--a second update. Journal of theoretical biology. 1992; 155(1):121-28.