Case Report

The Human Secondary Sex Odds in the Vicinity of the Nuclear Power Plant Leibstadt in Switzerland, 2002 to 2019

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Abstract

Background: On August 31, 2010, a radiological INES-2 grade incident occurred at the Swiss nuclear power plant Leibstadt (NPPL). The question arises whether this event or its contemporary concomitants had any impact on the birth sex odds near the site from 2011 onward?

Method: Focus is on the annual live births sex odds within 5 km from NPPL during the symmetrical period of 9 years before and 9 years after the INES-2 incident in 2010. A time trend analysis based on logistic regression was carried out. A possible level-shift in the sex odds trend from 2011 onward was estimated and tested.

Result: The sex odds trend from 2002 to 2019 reveals a significant jump in 2011 with sex odds ratio (SOR) 1.484, 95% CI [1.155, 1.907], p-value 0.0020.

Conclusion: This observation corroborates previous findings of increased sex odds near nuclear facilities, especially after distinct radiological events.

Keywords: INES-2 radiological incident; lethal sex-linked mutation; radiation induced genetic effect

Introduction

The health effects of ionizing radiation, especially radiation induced genetic effects are still little understood [1-4]. There is obvious everyday environmental radiological contamination by nuclear power plants (NPPs), which impacts local environments and produce [5]. Since nutrition is a key driver in women's health [6], detrimental reproductive effects may be induced by radiologically contaminated food, e.g., by tritium in ground and tap water. Childhood cancer was associated with natural background radiation in Switzerland [7] and was increased within 5 km from nuclear power plants in Germany [8]. The human sex odds at birth was elevated in affected European countries after Chernobyl [9] and associated with distance from nuclear facilities in Austria, Germany, France, and Switzerland [10-12]. At the Swiss nuclear power plant Leibstadt (NPPL) on August 31, 2010, a radiological incident occurred, which was classified as INES-2 [13,14]. This study aims to investigate the possible impact of this event or of its surrounding circumstances in 2010 [15] on the birth sex odds trend in the vicinity of NPPL from 2011 onward.

Method

The annual counts of male and female births by municipality were provided by the Swiss Bundesamt für Statistik. The centers of 5 Swiss municipalities are located within 5 km distance form NPPL: Leibstadt (1.5 km), Full-Reuenthal (2.0), Schwaderloch (3.3), Leuggern (3.6), and Koblenz (3.8). Table 1 lists the birth counts by year, gender, and municipality. A parsimonious logistic regression model assuming an interrupted or piece-wise constant birth sex odds trend allowing for a level shift from 2011 onward was employed [16]. The Wald-Chi2 statistic was used to test whether a potential level shift in 2011 was different from zero. A p-value < 0.05 was taken to represent a statistically significant result. Data was processed with MS-Excel-365 (2016) and SAS/STAT software 9.4, namely SAS-PROCs LOGISTIC and SGPLOT, SAS Institute Inc.: SAS/STAT User's Guide, Cary NC: SAS Institute Inc., 2014.

Results

The gray dots in Figure 1 show the annual sex odds from 2002 to 2019 in the combined municipalities Full-Reuenthal, Koblenz, Leibstadt, Leuggern, and Schwaderloch. These municipalities are the only ones in Switzerland situated within 5 km from NPPL. The thick gray line in Figure 1 depicts the sex odds trend in whole Switzerland, for comparison.

Note, the sex odds near Leibstadt from 2011 onward may be compared to several negative controls, so to speak. The first control is the vicinity of Leibstadt in the period before 2011. The further controls are all of Switzerland in the three periods 2002 to 2010, 2011 to 2019, and 2002 to 2019. In none of those possible negative controls, unnatural sex odds of approximately 1.5 can be observed, as is the case in the 5 km vicinity of Leibstadt from 2011 onward. The solid black line in Figure 1 represents the segmented logistic regression allowing for a jump in 2011 [16]. The jump sex odds ratio (SOR) is 1.484, 95% CI [1.155,

Table 1: Birth counts in the 5 km vicinity of NPPL by municipality in Switzerland, year, and sex; the three bottom rows contain the municipality-specific 2. 2-tables of sex by period and the corresponding sex odds ratios for those 2 tables.

Year	Leibstadt		Full-Reuenthal		Schwaderloch		Leuggern		Koblenz		Total		Sex odds
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	
2002	6	4	4	4	4	3	8	7	10	3	32	21	1.524
2003	10	8	2	6	1	1	5	5	4	6	22	26	0.846
2004	3	9	3	4	2	2	8	9	3	5	19	29	0.655
2005	5	8	9	4	4	1	11	8	11	7	40	28	1.429
2006	4	4	1	3	1	1	3	7	5	5	14	20	0.700
2007	12	5	2	2	0	2	5	7	6	6	25	22	1.136
2008	6	10	6	3	4	2	5	5	10	9	31	29	1.069
2009	4	4	2	3	1	1	9	10	8	7	24	25	0.960
2010	4	9	1	4	3	2	10	10	7	10	25	35	0.714
2011	8	6	4	2	4	5	13	5	9	1	38	19	2.000
2012	7	6	0	3	2	4	10	6	10	9	29	28	1.036
2013	7	8	5	3	4	2	10	11	4	3	30	27	1.111
2014	4	4	2	2	3	2	8	3	4	8	21	19	1.105
2015	7	6	9	3	4	1	16	5	7	5	43	20	2.150
2016	5	6	2	1	2	2	14	10	16	9	39	28	1.393
2017	7	4	6	6	3	2	12	3	10	7	38	22	1.727
2018	11	8	4	2	4	3	14	6	5	8	38	27	1.407
2019	4	6	4	4	7	1	16	9	8	5	39	25	1.560
≤ 2010	54	61	30	33	20	15	64	68	64	58	232	235	0.987
≥ 2011	60	54	36	26	33	22	113	58	73	55	315	215	1.465
SOR*	1.255		1.523		1.125		2.07		1.203		1.484		

*sex odds ratio (SOR) from 2011 versus before 2011

1.907], p-value 0.0020. This level-shift model has a deviance of 17.3 with 16 degrees of freedom. This is equivalent to 8.1% overdispersion, which means good compliance of the data with the binomial assumption of logistic regression. As an alternative to the before/after comparison in the 5 km vicinity of Leibstadt one can compare the sex odds near Leibstadt with the remainder of Switzerland from 2011 onward. The SOR for this contrast is 1.385, 95% CI [1.165, 1.648], p-value 0.0002. If the sex odds jump in Figure 1 is interpreted as a loss of girls from 2011 onward compared to before, this level-shift represents 104, 95%-CI (33, 195), lost girls in the 9-year-period from 2011 to 2019, in which period actually 530 children were born (315 boys, 215 girls, SO 1.465). If we restrict the comparison of the sex odds near Leibstadt with the rest of Switzerland to the period after 2010, the number of theoretically lost girls is smaller but more precisely estimated: 83, 95%-CI (35,139). For detailed discussions and examples of overall lost children under the perspective of lost boys see [10,11].

Discussion

The analysis of the ratio of male to female offspring at birth (male/female, secondary sex ratio, sex odds) may be a simple and non-invasive way to monitor the reproductive health of a population [17-19]. Generally, 104 to 106 boys are born for every 100 girls. However, subpopulations or specific medical conditions may involve deviating sex odds [20]. Radiation is one of few stressors known to elevate the sex odds while dropping total births [10-12,21, and 22]. From these observations it may be concluded that the sex odds are useful, however neglected sentinel indicators for possibly detrimental changes in the environment inducing sub-clinical or yet unnoticed clinical effects. An officially acknowledged INES-2 level incident at a nuclear power plant in Europe is a relatively rare event. Careful consideration of the spatiotemporal vicinity of NPPL revealed a long-term nearly 50% increase of the sex odds after the radiological incident in 2010. This means that within 5 km from NPPL in Switzerland after 2010 approximately every 3rd girl expected to be conceived got lost, under
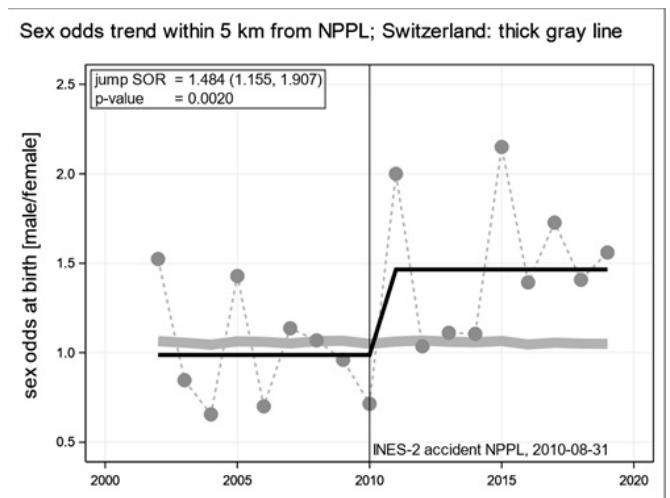

Figure 1: Sex odds trend (gray dots) within 5 km from NPPL in Switzerland and parsimonious segmented logistic regression allowing for a jump in 2011 (solid black line), jump SOR 1.484, 95% CI [1.155, 1.907], p-value 0.0020; Switzerland: thick gray line for comparison; for the municipality-specific annual birth counts involved see Table 1.

the simplifying assumption that boys were not affected [10]. This distinct finding near a Swiss nuclear power plant immediately after a serious radiological event strengthens previous evidence that elevated environmental or occupational ionizing radiation may increase secondary sex odds at the population level.

Abbreviations

95%-CI or 95%-confidence interval

INES-2: International Nuclear and Radiological Event Scale, level 2

NPPL: Nuclear Power Plant Leibstadt, Switzerland

SAS: Statistical Analysis System, software produced by SAS

Institute Inc.

SO: Sex Odds

SOR: Sex Odds Ratio

Declarations

Ethical Approval and Consent to Participate

Not applicable. Ethics approval and consent to participate are not required and not necessary, since only publicly available data and previously published information is being used.

Consent for Publication

Not applicable. Only anonymous data is being used.

Availability of Supporting Data

The employed data has exclusively been published previously and/or it is contained in the Tables and in the Figures included in this paper.

Competing Interests

The author declares that he has no conflicts of interest.

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Authors' Contributions

Not applicable.

Competing Financial Interests Declaration

The author declares he has no actual or potential competing financial interests.

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