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Annual Birth Sex Odds (1971-2021) in the Vicinity of Military Training Grounds in Germany: Interrupted Time Series Analysis

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Abstract

Background: Increases in human birth sex odds have been documented after the atomic bomb tests, after Chernobyl, and in the vicinity of nuclear facilities. Little attention has been paid to contaminations in the vicinity of training areas possibly affecting the health of women and their offspring. In the military training grounds Bergen and Munster in Germany, projectiles containing depleted uranium were fired in the summer of 1983.

Method: Counts of annual live births by gender for five municipalities near the military areas were obtained from the *Lower Saxony State Office for Statistics*. Time trend analyses employing logistic regression for male proportions and Poisson regression for gender-specific absolute birth counts were carried out. Possible level shifts in the sex odds and the birth count from 1984 onward were estimated and tested.

Results: The sex odds trend from 1971 to 2021 revealed a significant jump in 1984 with a sex odds ratio (SOR) of 1.097, 95% CI (1.038, 1.159), and p-value 0.0010. The rest of Lower Saxony, by which the regression was adjusted as a negative control, showed no corresponding change point effect from 1984 onwards: sex odds ratio (SOR) 0.999, (0.995, 1.004), p-value 0.7436.

Conclusion: This observation corroborates previous findings of increased sex odds after the atmospheric nuclear tests, after the Chernobyl accident, and near nuclear facilities, especially after distinct radiological events.

Keywords: Depleted Uranium; Lethal Sex-Linked Mutation; Radiation-Induced Genetic Effect

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Introduction

Ionizing radiation may induce cancer and a great variety of detrimental genetic effects [1-5]. The human sex odds at birth were elevated in affected European countries after the atomic bomb tests and after Chernobyl [6, 7], and were associated with distance from nuclear facilities in Austria, Germany, France, and Switzerland [8-10]. Since nutrition is a key driver in women's health [11], detrimental reproductive effects including distorted birth sex ratios [12, 13] may be induced by food and by ground or tap water radiologically contaminated with depleted uranium. "*Depleted uranium (DU) is generally considered an emerging pollutant, first extensively introduced into the environment in the early nineties in Iraq, during the military operation called "Desert Storm". DU has been hypothesized to represent a hazardous element both for soldiers exposed as well as for the inhabitants of the polluted areas in the war zones*" [14]. In this context, little attention has been paid to contaminations in the vicinity of military training grounds. The usage of projectiles containing depleted uranium near Bergen and Munster in Germany in the summer of 1983 [15] provides an opportunity to study the secular birth sex ratio trend at the municipality level during 51 years from 1971 to 2021 before and after this event in 1983. A similar case report has been provided previously demonstrating an increased birth sex ratio within 5 km of the nuclear power plant Leibstadt in Switzerland after an INES-2 incident in 2010 [16].

Method

The Lower Saxony State Office for Statistics provided annual counts of female and male births by municipality (LSN-Online: Tabelle Z1100001). Figure 1 presents the municipalities of the Heidekreis, Lower Saxony, Germany. The municipalities of major interest are Bispingen, Faßberg, Munster, Soltau, and Wietzendorf (BFMSW) surrounding the training ground Munster and downwind of the training ground Bergen. Table 1 lists the birth counts by year and by gender of BFMSW combined and the corresponding birth counts of the remainder of Lower Saxony, as well as the respective sex odds. Parsimonious Poisson regression and logistic regression allowing for interrupted trends [17-19] from 1984 onward in absolute births and birth sex odds was employed, respectively. The Wald-Chi^2 statistic was used to test whether potential

Figure 1: Heidekreis in Lower Saxony, Germany; the municipalities Bispingen, Faßberg, Munster, Soltau, Wietzendorf surround the training ground Munster and lie downwind training ground Bergen (dark area).

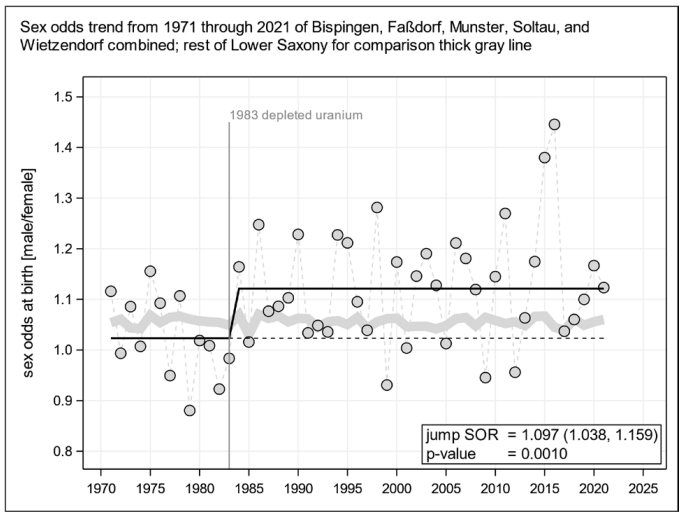

Figure 2. Annual birth sex odds 1971-2021 in the combined municipalities Bispingen, Faßberg, Munster, Soltau, and Wietzendorf (BFMSW); logistic regression allowing for a jump in 1984 (solid line); null-effect model (broken line); complement Lower Saxony minus BFMSW as a negative control (thick gray line).

level shifts in 1984 were 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, GENMOD, and SGPLOT, SAS Institute Inc.: SAS/STAT User's Guide, Cary NC: SAS Institute Inc., 2014.

Results

The gray dots in Figure 2 show the annual sex odds from 1971 to 2021 in the combined municipalities Bispingen, Faßberg, Munster, Soltau, and Wietzendorf (BFMSW). The thick gray line in Figure 2 depicts the sex odds trend in the remainder of Lower Saxony, for comparison and control. Table 2 compiles the aggregated data for a most parsimonious test of the null hypothesis that the sex odds did not change in the presumably exposed area BFMSW from 1984 onward adjusted for the rest of Lower Saxony. The p-value for this test is 0.0010.

Table 1: Birth counts by year and gender and annual sex odds of Bispingen, Faßberg, Munster, Soltau, and Wietzendorf (BFMSW) combined, and the corresponding birth counts and sex odds of the remainder of Lower Saxony.

Year	Birth counts by region					
	BFMSW			Rest of Lower Saxony		
	Male	Female	Sex Odds	Male	Female	Sex Odds
1971	385	345	1.116	49716	47176	1.054
1972	311	313	0.994	44884	42319	1.061
1973	304	280	1.086	40031	38364	1.043
1974	281	279	1.007	38661	37097	1.042
1975	260	225	1.156	36923	34556	1.068
1976	260	238	1.092	36917	35019	1.054
1977	263	277	0.949	35439	33289	1.065
1978	259	234	1.107	35132	32932	1.067
1979	243	276	0.88	34553	32565	1.061
1980	272	267	1.019	36600	34613	1.057
1981	235	233	1.009	36747	34807	1.056
1982	251	272	0.923	36380	34504	1.054
1983	238	242	0.983	34818	33192	1.049
1984	234	201	1.164	34293	32075	1.069
1985	257	253	1.016	33852	32867	1.03
1986	247	198	1.247	36594	34187	1.07
1987	295	274	1.077	37332	35136	1.063
1988	277	255	1.086	38979	36525	1.067
1989	289	262	1.103	39103	37042	1.056
1990	339	276	1.228	42166	39671	1.063
1991	306	296	1.034	42489	40031	1.061
1992	303	289	1.048	42443	40634	1.045
1993	289	279	1.036	43141	40870	1.056
1994	297	242	1.227	41629	39352	1.058
1995	315	260	1.212	41196	39223	1.05
1996	322	294	1.095	42810	40229	1.064
1997	293	282	1.039	43573	41759	1.043
1998	346	270	1.281	41900	39691	1.056
1999	269	289	0.931	41160	38765	1.062
2000	304	259	1.174	40639	38234	1.063
2001	258	257	1.004	38,203	36,521	1.046
2002	267	233	1.146	37,177	35,516	1.047
2003	269	226	1.19	35,836	34,232	1.047
2004	265	235	1.128	35,649	34,222	1.042
2005	237	234	1.013	34,044	32,478	1.048
2006	258	213	1.211	33,398	31,458	1.062
2007	222	188	1.181	33,467	31,449	1.064
2008	225	201	1.119	32,984	31,477	1.048
2009	208	220	0.945	31,867	29,933	1.065
2010	237	207	1.145	32,232	30,454	1.058
2011	226	178	1.27	31,214	29,662	1.052
2012	196	205	0.956	31,366	29,711	1.056
2013	218	205	1.063	31,961	30,495	1.048
2014	222	189	1.175	34,055	31,940	1.066
2015	276	200	1.38	34,434	32,273	1.067
2016	292	202	1.446	38,179	36,542	1.045
2017	252	243	1.037	36,953	35,572	1.039
2018	264	249	1.06	37,658	35,481	1.061
2019	253	230	1.1	37,272	35,531	1.049
2020	266	228	1.167	37,809	35,816	1.056
2021	246	219	1.123	39,102	36,874	1.06
Total	**13,701**	**12,522**	**1.094**	**1,914,960**	**1,814,361**	1.055

The interaction effect region∗sex∗period in the corresponding 2x2x2-table is SOR 1.097, (1.038, 1.159). The finding for the control region is SOR 0.999, (0.995, 1.004), p-value 0.7436. Changes in the fraction "sex odds" are difficult to interpret since they depend on changes in the numerator and/or the denominator. Therefore, we studied additionally the trends in the absolute counts of male and female births [8]. Assuming in a first step that the increase in the sex ratio in BFMSW from 1984 to 2021 is solely due to a loss in the denominator, i.e., a loss of girls, we estimate 867 (341, 1424) unborn or missing girls equivalent to every 12th-11th girl not born. A less conservative but a more realistic approach is to assume a loss in boys also [8]. Figure 3 shows the corresponding analysis based on polynomial Poisson regression of the absolute counts. It shows a drop in boys of 6.94% and a drop in girls of 15.09% from 1984 onward. The somewhat less precise but more informative Poisson regression yields 756 mission boys (p-value 0.2015) and 1606 missing girls (p-value 0.0038). The sex odds of the missing children is thus 0.47, which is in good qualitative agreement with the sex odds 0.3 in missing children, which we initially derived from national Danish data in the Chernobyl context [3].

Discussion

Globally, approximately 100 to 110 boys are born for every 100 girls. However, in populations of different genetic backgrounds, or in population groups under specific medical conditions you can see even more extreme deviating sex ratio values [20]. The analysis of the ratio of male to female offspring at birth (male/female, secondary sex ratio, sex odds) is a simple and non-invasive way to monitor the reproductive health of a population [12, 21, and 22]. Radiation is one of the few stressors known to elevate the sex odds while dropping total births [8-10, 16, 23, and 24]. Therefore, the sex odds is a useful, however neglected sentinel indicator for possibly genetically relevant changes in the environment inducing detrimental sub-clinical or yet unnoticed clinical genetic effects. Studies on the toxic effects of uranium have found that exposure to uranium might occur through inhalation of particles, intake of food and water, as well as through skin contact. Uranium in the environment has been increasing due to the leakage of nuclear wastes, the release of mine tailings into the environment, and military conflicts [25]. The present case report is the first study

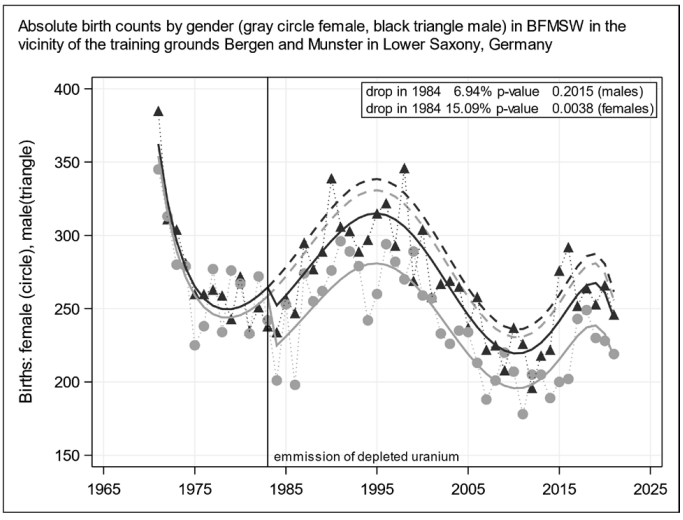

Figure 3. Absolute birth counts by gender of the combined municipalities Bispingen, Faßberg, Munster, Soltau, and Wietzendorf (BFMSW) adjacent to the training grounds Bergen and Munster in Germany; sex specific 7th degree polynomial Poisson regression allowing for drops in 1984 (solid lines); null-effect models (broken lines); drop in male newborns 6.94% p-value 0.2015; drop in female newborns 15.09% p-value 0.0038.

Table 2. Region∗sex∗period 2x2x2-table with the births in Lower Saxony by region, gender, and period, including pertinent statistics for assessing the significance of the corresponding region∗sex∗period interaction [19].

Periods, Odds, Odds Ratio, Odds Ratio Ratio, and Inference Statistics	**Region**			
	BFMSW		**Rest of Lower Saxony**	
	male	**female**	**male**	**female**
Period 1: Before 1984	3,562	3,481	496,801	470,433
Period 2: From 1984	10,139	9,041	1,418,159	1,343,928
Period Odds (PO)	2.846	2.597	2.8546	2.8568
Sex Period Odds Ratio (SPOR)	1.0959		0.9992	
Region Sex Period Odds Ratio Ratio (RSPORR)	1.0968			
Log(RSPORR)	0.0924			
Variance of Ln(RSPORR)	0.0008			
Standard Error	0.028			
Wald-Chi-Square	10.9038			
p-value (Probability Greater Wald-Chi-Square)	**0.001**			

to investigate the secular gender proportion in the vicinity of military training areas before and after a test of armor-piercing projectiles containing depleted uranium in 1983. The persistent increase of the sex odds in five municipalities in the vicinity of the training grounds from 1984 by a factor of 1.097 is equivalent to the loss of approximately every 12th-11th girl. If boys are considered also, the loss amounts to even every 9th child. This distinct observation corroborates numerous previous investigations demonstrating elevated genetic detriment under escalated radiological conditions [10, 13].

Abbreviations

95%-CI or (. , .)	95%-confidence interval
DU	Depleted uranium
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, since only publicly available data and previously published information are 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 is contained in the Tables and the Figures included in this paper.

Competing Interests

The author declares that he has no conflicts of interest.

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