Detrimental Genetic Effects of Ionizing Radiation across Europe after the Chernobyl Accident

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Motivation

Data & Statistical Methods

Results

- Increased thyroid cancer, stillbirths, birth defects, and infant deaths after Chernobyl
- Increased sex odds (SO) after the atomic bomb tests globally
- Increased sex odds (SO) after Chernobyl in Europe
- Increased sex odds (SO) near nuclear facilities (NF)

Conclusion

Outlook
Motivation

- Detrimental genetic effects in exposed human populations have been considered and investigated ever since the discovery of the mutagenic properties of X-rays
- Man made ionizing radiation poses an ongoing increasing environmental and human risk underestimated and not yet fully understood
- The most important public health criteria available for studying those effects in man are
  - cancer
  - birth defects
  - stillbirths
  - neonatal deaths, infant deaths
  - human birth sex odds
- The Chernobyl accident resulted in the exposure of a large number of people to ionizing radiation and created a new situation for epidemiology
Data & Statistical Methods

- **Data**
  - Official national or regional annual or monthly statistics on live births, stillbirths, perinatal mortality, and infant deaths
  - Published congenital malformation data (e.g., Down syndrome, cleft lip and palate)
  - Congenital malformation registry data (e.g. Bavaria, Germany, 1984 - 1991)
  - Cancer registry data (e.g. Czech Republic)

- **Statistical Methods**
  - Logistic model – example: \(
    \log \text{odds} \left( \pi_x \right) = \text{intercept} + \alpha \times d5(x) \)
  - Spatial-temporal trend models with dummy-coding and spatial-temporal interactions
Results: Thyroid cancer in adults in Belarus and the Czech Republic

Mahoney MC et al. 2004

Figure 3. Annual age-adjusted thyroid cancer incidence rate, by calendar year, gender, and area of exposure. Belarus, 1970–2001

Mürbeth S et al. 2004

Figure 2. Crude and directly age-standardized incidence of thyroid carcinoma in females, males and both genders combined in the Czech Republic, change-point (CP) and reduced change-point (CPr) linear logistic regression models (see Table 1).
Results: Stillbirths in Europe

Scherb H et al. 1999

Figure 2 European stillbirth proportions 1980–1992 and synoptic linear logistic regression model according to data in Table 2 and model information in Table 6
Results: Birth defects in Bavaria, Germany, 1984 – 1991

Scherb and Weigelt 2003

<table>
<thead>
<tr>
<th>Radiation Dose (mSv/a)</th>
<th>OR per mSv/a</th>
<th>95% CL</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.11</td>
<td>1.51</td>
<td>[1.34, 1.70]</td>
<td>&lt; 0.0001</td>
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<tr>
<td>0.16</td>
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<td>0.23</td>
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<td>0.39</td>
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<tr>
<td>0.65</td>
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</tbody>
</table>
Results: Male sexual organ defects in Bavaria, Germany, 1984 – 1991

odds ratio (OR) for jump in October 1986: OR = 2.26, 95% CL [1.58, 3.23], p-value < 0.0001
Results: Infant death in Germany, 1970 – 2008

Sex odds of infant death (SO ID; < 1 year; 1970 - 2008) in Germany, Jump SOR 1987: 1.054, 95%CI=[1.019, 1.091], p=0.0024
Results: Increased sex odds (SO) after the atomic bomb tests globally

23 European countries 1950 — 1990; USA 1950 — 1990


PTBT: Partial Test Ban Treaty
Results: Increased sex odds (SO) after Chernobyl in Europe

38 European countries 1975 — 2007; USA 1975 — 2002

Live birth sex odds

Europe

USA

Chernobyl gender gap

Results: Increased sex odds (SO) after Chernobyl in Europe

Less exposed countries: France and Germany

Highly exposed countries: Belarus and Russian Federation
Results: SO near nuclear facilities, Germany and Switzerland
Results: Increased sex odds near nuclear facilities (NF)

In probability theory and statistics, the Rayleigh distribution is a continuous probability distribution. As an example of how it arises, the wind speed will have a Rayleigh distribution if the components of the two-dimensional wind velocity vector are uncorrelated and normally distributed with equal variance. The distribution is named after Lord Rayleigh. (WIKIPEDIA)
A reciprocal distance law (1/r) was applied in the KiKK (Germany) study, but here it works only when data are restricted to distances greater than 10 km.

Kusmierz R, Voigt K, Scherb H 2010

Improved paper ESPR
Conclusion

- Low-dose ionizing radiation increases
  - thyroid cancer in adults
  - congenital malformations
  - stillbirths
  - infant deaths
  - secondary sex odds in humans

- Our results most clearly disprove the prevailing believe (e.g. by UNSCEAR) that radiation-induced genetic effects have yet to be detected in human populations

- For a fundamental criticism concerning the basis of radiation safety standards see The Lesvos Declaration, 6 May 2009.
Outlook

- Important data on underestimated environmental and health topics are partly available

- However, often there is no (optimal) utilization of the existing data bases

- Thus, greater input from mathematicians and statisticians is urgently needed to scrutinize those data

- To achieve this goal, the full spectrum of different data analysis approaches should be considered and applied appropriately

- Improved interdisciplinary skills are needed at all stages of environmental health research
Thank you for your attention

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