Perinatal mortality after the Fukushima accident

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Letter to the editor

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Sir,

Recently, Scherb et al. reported an increase of perinatal mortality after the accident at the Fukushima Dai-ichi nuclear power plant (FDNPP) [1]. Their study region consisted of nine prefectures surrounding the FDNPP. They applied linear logistic regression with an upward shift (change point) in 2012-2014 relative to the trend in 2001-2011. The number of excess perinatal deaths was estimated at 318 (95% confidence interval (CI): 136, 519). In a letter to the editor, appearing in the Medicine Correspondence Blog [2], Körblein criticised the use of a linear trend model. He showed that the shift in 2012-2014 was not statistically significant when a linear-quadratic time trend was applied instead of a linear trend.

Here, we revisit the Japanese data in more detail. We use a slightly different study region, an extended study period, and a different statistical model including the data of a control region to check for a possible increase in perinatal mortality after the Fukushima nuclear accident.

Data

Numbers of live births, stillbirths and early neonatal deaths, 2002 through 2015, are provided online by the Japanese government [3]. Stillbirths are defined in Japan as foetal deaths after 22 weeks of pregnancy. For our study region we adopted the classification of contaminated prefectures by dose level in the UNSCEAR 2013 report [4], i.e. Fukushima Prefecture and six nearby prefectures (Iwate, Miyagi, Gunma, Tochigi, Ibaraki, and Chiba). Japan minus the study region (group 4) was defined as the control region. Our study region includes two prefectures less (Tokyo, Saitama) than the study region in [1]. The yearly perinatal mortality (y) is defined as the number of stillbirths (SB) plus early neonatal deaths (NEO), divided by the number of live birth (LB) plus SB, i.e. y = (SB+NEO) / (LB+SB).

Regression model for the study region

To model the long-term trend of the data, we use an exponential trend with a constant, the same model that we had applied in our study of perinatal mortality in Germany after the Chernobyl accident [5]. The constant allows for a lower limit of perinatal mortality. To compare our result with that in [1], we estimate the possible increase after 2011 with a dummy variable cp defined as cp=1 in 2012-2015 and cp=0 otherwise. The regression model has the following form:

(1) $$E\big(y(t)\big) = \alpha + \exp(\beta_1 + \beta_2 \cdot t + \beta_3 \cdot cp)$$

Here, the dependent variable E(y(t)) is the expected perinatal mortality, parameter α gives the size of the asymptotic lower limit of perinatal mortality, β_1 and β_2 are trend parameters, and β_3 indicates a possible shift after 2011. Iteratively reweighted non-linear regression with statistical program R [6] is used for data analysis, and a two-sided p-value <0.05 is considered statistically significant. With this model, the effect of cp is not statistically significant (p-value =0.28, *F*-test).

Combined regression of data from the study and control region

In a second step, we perform a combined regression of the data from the study and control region. We allow for different trends, but we assume the same value of α for both regions.

Then the regression model has the following form:

$$(2) \quad E\big(y(t)\big) = \alpha + \exp(\beta_1 + \beta_2 \cdot study + \beta_3 \cdot t + \beta_4 \cdot tstudy + \beta_5 \cdot cp \cdot study)$$

Here, *study* is a dummy variable that denotes the data from the study region, and *tstudy* is an interaction term that estimates the difference between the time trend in the study region and the trend in the control region.

The regression with model (2) fits the data well (deviance=25.8, df=22), see Figure 1. The parameter estimates with standard errors (SE), t-values, and p-values are listed in Table 1. Parameter β_5 is estimated at 0.263 (95% CI: 0.038, 0.543), p=0.028, indicating a change in the trend of perinatal mortality in the study region in 2012. The estimate of α is significant (α=0.0028 ± 0.0004, p<0.001) which shows the superiority of our model to the model used in [1]. From the difference between the numbers of observed and expected perinatal deaths in the study region, 185 (27, 446) excess deaths are determined in 2012-2015. This corresponds to an increase of 8.4% (1.2%, 20.3%).

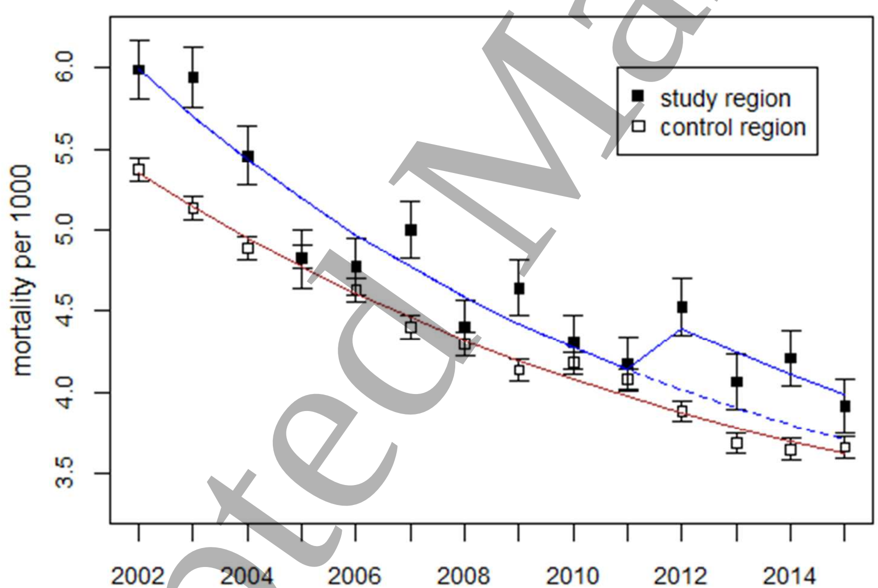

Figure 1. Perinatal mortality rates in the study and control regions and regression lines. The broken line is the extrapolation of the trend before 2012. The error bars are standard deviations.

Table 1. Results of combined regression model (2) for perinatal mortality

Parameter	Estimate	SE	t-value	p-value
α	0.0028	0.0004	7.340	<0.001
β_1	-5.7893	0.0953	-60.753	<0.001
β_2	0.2429	0.0651	3.733	0.001
β_3	-0.0850	0.0209	-4.078	<0.001
β_4	-0.0103	0.0111	-0.930	0.363
β_5	0.2643	0.1126	2.346	0.028

Comparison between study and control region

In addition to the combined regression, we directly compared study and control region by graphically displaying the odds ratios for perinatal mortality. The odds ratios are defined as y/(1-y) where y is perinatal mortality. They show an increase after 2012, in agreement with the result of the combined regression (see Figure 2).

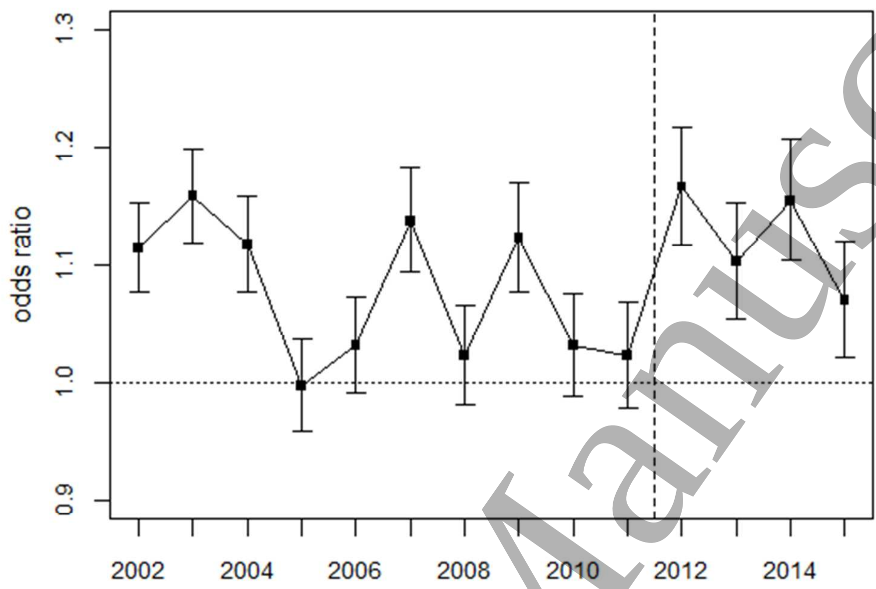

Figure 2: Odds ratios of perinatal mortality in the study region to the rates in the control region. Error bars are standard deviations. The vertical line indicates beginning of 2012.

To conclude, our analysis finds a significant increase of perinatal mortality rates after the Fukushima accident in a study region consisting of Fukushima Prefecture and six neighbouring prefectures. The increase is statistically significant but substantially smaller than reported by Scherb et al. [1]. The difference in the results is the consequence of different trend models; linear logistic regression was used in [5] while we used a more flexible model allowing for a natural lower limit of perinatal mortality.

It is noteworthy that we had found a significant 5% increase of perinatal mortality in Germany in 1987, one year after the Chernobyl accident [5], which was later confirmed by Scherb et al. [7].

Due to its ecological design, the study could not investigate the causes of the observed increase in perinatal mortality. The question whether the observed increase is enduring can only be answered with data from future years; continued research is therefore recommended.

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