Components of a funnel plot

Given a series of observations y_i with the associated precisions ρ_i, a funnel plot is constructed by plotting y_i against ρ_i, showing the target value θ as a horizontal line and plotting the control limits as a function of ρ (Fig. SDC2).

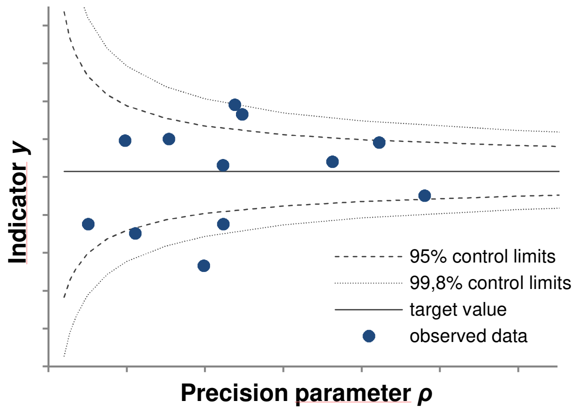

Figure SDC2 Funnel plots visualize whether observed data deviate significantly from a target value.

Funnel plots of cancer incidence

The incidence data available from the GEKID Atlas included age-standardized incidence rates (per 100,000 persons, European standard population) and numbers of incident cases according to year, sex, cancer site and federal state as collected by the federal cancer registries. The funnel plots for regional comparisons of cancer incidence display the age-standardized incidence rates plotted against a measure of their precision. Since the variances of the incidence estimates were not available, the number of incident cases O (number of observed events) was chosen as measure of precision ρ: $\rho = O$. Control limits for the age-standardized rates were estimated based on exact limits for the number of observed cases O. Assuming O is Poisson distributed and using the relationship between the Poisson distribution and the chi-square distribution, the exact limits of O are given by $O_l = \chi^2_{2O,\alpha/2}/2$ and $O_u = \chi^2_{2(O+1),1-\alpha/2}/2$, where O_l, O_u are the lower and upper limits for the observed events and $\chi^2_{n,a}$ denotes the $100a$ percentile of the chi-square distribution with n degrees of freedom (Sahai and Khurshid, 1993). Control limits for the age-standardized incidence rates may be calculated as $\left[\frac{O_l}{N} \cdot 100{,}000;\ \frac{O_u}{N} \cdot 100{,}000\right]$ (Spiegelhalter, 2005). Taking the target value θ as the national age-standardized incidence estimate for Germany and approximating the effective population $N \approx O/\theta \cdot 100{,}000$, the 100(1–α)% control limits for the age-standardized incidence rates can be obtained as

$$y_\alpha(\theta, O) = \left[\frac{\chi^2_{2O,\alpha/2}}{2O/\theta};\ \frac{\chi^2_{2(O+1),1-\alpha/2}}{2O/\theta}\right].$$

Additional information on completeness of registration was incorporated into the funnel plots of cancer incidence by highlighting the cancer registries with a level of completeness of case ascertainment below 90%.

Funnel plots of cancer mortality

The mortality data presented in the GEKID Atlas comprise age-standardized mortality rates (per 100,000 persons, European standard population) and numbers of deaths according to year, sex, cancer site and federal state. Funnel plots of cancer mortality were obtained analogously to the funnel plots of cancer incidence replacing the age-standardized incidence rate by the age-standardized mortality rate and the number of incident cases by the number of deaths. The average age-standardized mortality rates for Germany were taken as target values.

Funnel plots of cancer survival

Regarding cancer survival, the GEKID Atlas provides age-standardized 5-year relative survival estimates (weights according to the International Cancer Survival Standard (Corazziari et al., 2004)), number of cases and standard errors of the estimates according to year, sex, cancer site and federal state. Relative survival was calculated using period analysis and the Ederer II method with state specific life tables. Survival estimates are presented in the GEKID Atlas only for regions with sufficient data quality (see methodological notes of the atlas (Association of Population-based Cancer Registries in Germany, 2015)). The funnel plots of cancer survival display the age-standardized 5-year relative survival estimates plotted against the precision of the estimates taken as the inverse of the square of their standard errors: $\rho = 1/VAR = 1/SE^2$. In order to obtain control limits for relative survival in the range [0,1], a complementary log-log transformation has been applied to the survival function and control limits for the transformed function have been constructed assuming normal distribution. The control limits for relative survival are obtained by back-transformation of the control limits of the transformed function (Kalbfleisch and Prentice, 2002). The 100(1–α)% control limits for relative survival are given by

$$y_\alpha(\theta, SE) = exp\{-exp\left[\ln\left(-ln(\theta)\right) \pm Z_{1-\alpha/2} \cdot SE/\left(\theta \cdot ln(\theta)\right)\right]\}$$

where $Z_{1-\alpha/2}$ denotes the 100(1–α/2) percentile of the standard normal distribution ($Z_{1-\alpha/2} \approx 1.96$ for α=0.05; $Z_{1-\alpha/2} \approx 3.09$ for α=0.002).