United Nations Inter-agency Group for Child Mortality Estimation (UN IGME)

Child Mortality Estimation

Explanatory Notes

October 2017

The United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), which includes members from UNICEF, WHO, the World Bank Group and United Nations Population Division, was established in 2004 to advance the work on monitoring progress towards the achievement of child survival goals.

UN IGME's Technical Advisory Group, comprising leading academic scholars and independent experts in demography and biostatistics, provides guidance on estimation methods, technical issues and strategies for data analysis and data quality assessment.

UN IGME updates its neonatal, infant and under-five mortality estimates annually after reviewing newly available data and assessing data quality. In 2017, UN IGME for the first time generated country-specific trend estimates of the mortality in children aged 5–14, that is, the probability that a child aged 5 dies before reaching his or her fifteenth birthday. These estimates and estimates for children under age 5 are presented in the 2017 report and are available for download at childmortality.org.

In this document, we summarize the methods UN IGME uses to generate estimates of mortality among children under age 5 and children aged 5–14.

1. Overview

UN IGME follows the following broad strategy to arrive at annual estimates of child mortality:

1. Compile and assess the quality of all available nationally representative data relevant to the estimation of child mortality, including data from vital registration systems, population censuses, household surveys and sample registration systems.
2. Assess data quality, recalculate data inputs and make adjustments, if needed, by applying standard methods.
3. Fit a statistical model to these data to generate a smooth trend curve that averages over possibly disparate estimates from the different data sources for a country.
4. Extrapolate the model to a target year – in this case, 2016.

To increase the transparency of the estimation process, UN IGME has developed a child mortality web portal, CME Info (<www. childmortality.org>). It includes all available data and shows estimates for each country as well as which data are currently officially used by UN IGME. Once the new estimates are finalized, CME Info will be updated to reflect all available data and the new estimates.

UN IGME estimates are based on national available data from censuses, surveys or vital registration systems. UN IGME does not use any covariates to derive its estimates. It only applies a curve fitting method to good-quality empirical data to derive trend estimates after data quality assessment. Countries often use a single source for their official estimates or apply different methods from UN IGME methods to derive official estimates. The differences between UN IGME estimates and national official estimates are usually not large if the empirical data are of good quality. UN IGME aims to minimize the errors for each estimate, harmonize trends over time, and produce up-to-date and properly assessed estimates of child mortality. In the absence of error-free data, there will always be uncertainty around data and estimates, both nationally and internationally. To allow for added comparability, UN IGME generates such estimates with uncertainty bounds. Applying a consistent methodology also allows for comparisons between countries, despite the varied number and types of data sources. UN IGME applies a common methodology across countries and uses original empirical data from each country but does not report figures produced by individual countries using other methods, which would not be comparable to other country estimates.

2. Data sources

Nationally representative estimates of under-five mortality can be derived from several different sources, including civil registration and sample surveys. Demographic surveillance sites and hospital data are excluded, as they are rarely representative. The preferred source of data is a civil registration system which records births and deaths on a continuous basis. If registration is complete and the system functions efficiently, the resulting estimates will be accurate and timely. However, in the developing world most countries do not have well-functioning vital registration systems, and household surveys, such as the UNICEF-supported Multiple Indicator Cluster Surveys (MICS), the Demographic and Health Surveys (DHS) supported by the United States Agency for International Development (USAID), and periodic population censuses have become the primary source of data on mortality among children under age 5 and among children aged 5–14. These surveys ask women about the survival of their children, and it is these reports (or microdata upon availability) that provide the basis of child mortality estimates for a majority of developing countries.

The first step in the process of arriving at estimates of levels and recent trends of the under-five mortality rate or infant mortality rate is to compile all newly available data, and add the data to the CME database. Newly available data will include newly released vital statistics from a civil registration system, results from recent censuses and household surveys and, occasionally, results from some older census or survey not previously available.

The full set of empirical data used in this analysis is publicly available from the UN IGME web portal CME Info (<www.childmortality. org> under “underlying data,” as well as on the country-specific charts). In this round of estimation, a substantial amount of newly available data has been added to the underlying database for under-five, infant and neonatal mortality. Data from 64 new surveys or censuses were added for 40 countries and data from vital registration systems or sample vital registration systems were updated for 131 countries. In total, more than 6,600 country-year data points for 400 series were added or updated. The database, as of September 2017, contains 18,000 country-year data points from more than 1,500 series across 195 countries from 1990 (or earlier, up to 1940) to 2017. The increased empirical data have substantially changed the estimates generated by UN IGME for some countries from previous editions partly because the fitted trend line is based on the entire time series of data available for each country. The estimates presented in this report may differ from and are not necessarily comparable with previous sets of UN IGME estimates or the most recent underlying country data. For mortality among children aged 5–14 years, data were calculated from censuses and surveys, or vital registration records of population and deaths in the age group. The database for mortality among children aged 5–14 contains more than 5,500 data points.

Whatever the method used to derive the estimates, data quality is critical. UN IGME assesses data quality and does not include data sources with substantial non-sampling errors or omissions as underlying empirical data in its statistical model to derive UN IGME estimates.

2.1 Data from civil registration systems

Civil registration data are the preferred data source for child mortality estimation. The calculation of the under-five mortality rates (U5MR), infant mortality rates (IMR), neonatal mortality rates (NMR) and mortality rates among children aged 5–14 from civil registration data is derived from a standard period abridged life table. For civil registration data (with available data on the number of deaths and mid-year populations), initially annual observations were constructed for all observation years in a country. For country-years in which the coefficient of variation exceeded 10 per cent, deaths and mid-year populations were pooled over longer periods, starting from more recent years and combining those with adjacent previous years, to reduce spurious fluctuations in countries where small numbers of births and deaths were observed.

The coefficient of variation is defined to be the stochastic standard error of the 5q0 (5q0=U5MR/1,000) or 1q0 (1q0=IMR/1,000) observation divided by the value of the 5q0 or 1q0 observation. The stochastic standard error of the observation is calculated using a Poisson approximation using live birth numbers from the World Population Prospects, given by sqrt(5q0/ lb) (or similarly sqrt(1q0/lb), where 5q0 is the under-five mortality rate (per 1 live birth) and lb is the number of live births in the year of the observation.11 After this recalculation of the civil registration data, the standard errors are set to a minimum of 2.5 per cent for input into the model. A similar approach was used for neonatal mortality and mortality among children aged 5–14. In previous revisions, UN IGME adjusted vital registration (VR) data for deficient completeness in the reporting of early infant deaths in several European countries.[1]

2.2 Survey data

The majority of survey data comes in one of two forms: the full birth history, whereby women of reproductive ages from 15 to 49 are asked for the date of birth of each of their children, whether the child is still alive, and, if not, the age at death; and the summary birth history, whereby women are asked only about the number of their children ever born and the number that have died (or, equivalently, the number still alive).

Full birth history data, collected by all DHS and, increasingly, also MICS surveys, allow the calculation of child mortality indicators for specific time periods in the past. This allows DHS and MICS to publish child mortality estimates for five 5-year periods before the survey, that is, 0 to 4, 5 to 9, 10 to 14, etc. UN IGME has re-calculated estimates for calendar year periods, using single calendar years for periods shortly before the survey, and then gradually increasing the number of years for periods further in the past, whenever microdata from the survey are available. The cut-off points for a given survey for shifting from estimates for single calendar years to two years, or two years to three, etc., are based on the coefficients of variation (a measure of sampling uncertainty) of the estimates.[2]

In general, summary birth history data, collected by censuses and many household surveys, use the age of the woman as an indicator of exposure time and exposure time period of the children, and use models to estimate mortality indicators for periods in the past for women aged 25–29 through 45–49. This method is well known, but has several shortcomings. Starting with the 2014 round of estimation, UN IGME changed the method of estimation for summary birth histories to one based on classification of women by the time that has passed since their first birth. The new method has several advantages over the previous one. First, estimates based on time since first birth generally have lower sampling errors, and second, it avoids the problematic assumption that the estimates derived for each age group adequately represent the mortality of the whole population. As a result, the new method has less susceptibility to the selection effect of young women who give birth early, since all women who give birth necessarily must have a first birth. Third, the method tends to show less fluctuation across time, particularly in countries with relatively low fertility and mortality. UN IGME considers the improvements in the estimates based on time since first birth worthwhile when compared with the estimates derived from the classification by age of the mother; hence, in cases where the microdata are available, UN IGME has reanalyzed the data using the new method.[3]

Moreover, following advice from the Technical Advisory Group (TAG) of UN IGME, child mortality estimates from summary birth histories were not included if estimates from full birth histories in the same survey were available.[4]

2.3 Adjustment for missing mothers in high-HIV settings

In populations severely affected by HIV and AIDS, HIV-positive (HIV+) children will be more likely to die than other children, and will also be less likely to be reported since their mothers will have been more likely to die also. Child mortality estimates will thus be biased downward. The magnitude of the bias will depend on the extent to which the elevated under-five mortality of HIV+ children is not reported because of the deaths of their mothers. The TAG of UN IGME developed a method to adjust HIV/AIDS-related mortality for each survey data observation from full birth histories during HIV and AIDS epidemics (1980–present), by adopting a set of simplified but reasonable assumptions about the distribution of births to HIV+ women, primarily relating to the duration of their infection, vertical transmission rates, and survival times of both mothers and children from the time of the birth.[5] This method was applied to all direct estimates from full birth histories.

2.4 Systematic and random measurement error

Data from these different sources require different calculation methods and may suffer from different errors – for example, random errors in sample surveys or systematic errors due to misreporting. Thus, different surveys often yield widely different estimates of U5MR for a given time period, as illustrated in Figure 1. To reconcile these differences and take better account of the systematic biases associated with the various types of data inputs, TAG has developed a new estimation method to fit a smoothed trend curve to a set of observations and to extrapolate that trend to a defined time point – in this case, 2016. This method is described in the following section.

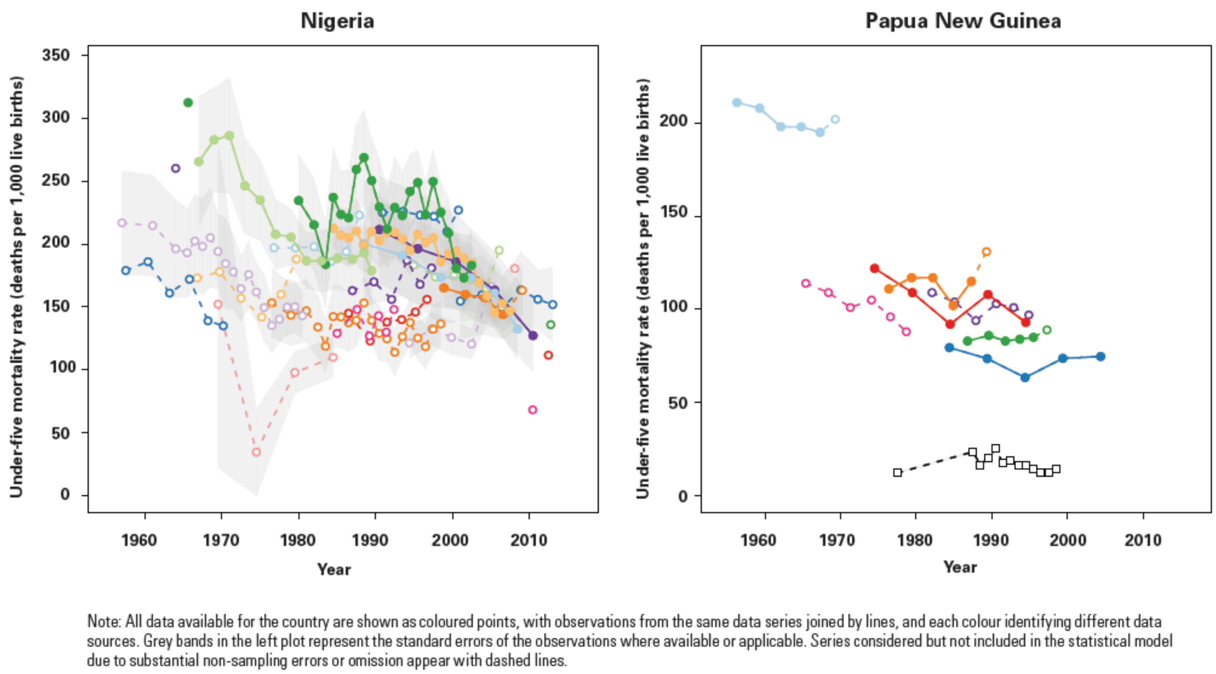


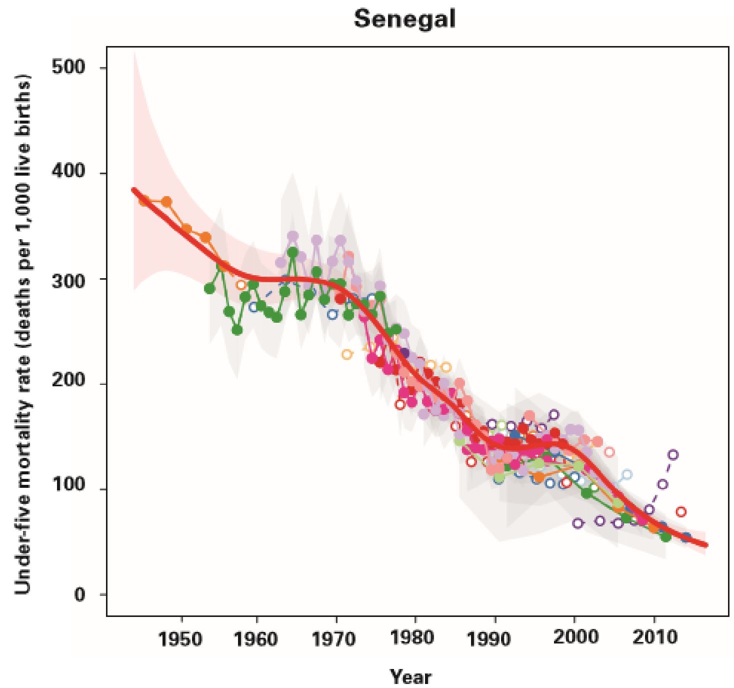
Figure 1 Empirical data of under-five mortality rate in Nigeria and Papua New Guinea

3. Estimation of under-five mortality rates

Under-five mortality rate (U5MR) estimates were produced using the Bayesian B-splines bias-adjusted model, referred to as the B3 model. This model was developed, validated and used to produce previous rounds of UN IGME child mortality estimates published in September 2013,[6] September 2014[7] and September 2015.[8]

In the B3 model, log (U5MR) is estimated with a flexible splines regression model. The spline regression model is fitted to all U5MR observations in the country (i.e., country-year data points). An observed value for U5MR is considered to be the true value for U5MR multiplied by an error factor – i.e., observed U5MR = true U5MR * error, or, on the logscale, log(observed u5mr) = log(true U5MR) + log(error), where error refers to the relative difference between an observation and the truth. While estimating the true U5MR, properties of the errors that provide information about the quality of the observation – or in other words, the extent of error that we expect – are taken into account. These properties include: the standard error of the observation; its source type (e.g., DHS versus census) and if the observation is part of a data series from a specific survey (and how far the data series is from other series with overlapping observation periods). These properties are summarized in the so-called data model. When estimating the U5MR, the data model adjusts for the errors in the observations, including the average systematic biases associated with different types of data sources, using information on data quality for different source types from every country.

Figure 2 displays the plot of the U5MR over time for Senegal, used here for illustrative purposes.



Note: The B3 estimates are in red. Ninety per cent uncertainty intervals for the U5MR are given by the pink bands. All data available for the country are shown as coloured points, with observations from the same data series joined by lines. Solid points and lines represent data series/observations that were included for curve-fitting. Grey bands in the left plot represent the standard errors of the observations where available or applicable.

Figure 2 Empirical under-five mortality data and estimates from the B3 model for Senegal

Compared with the previously applied Loess estimation approach, the B3 model better accounts for data errors, including biases and sampling and non-sampling errors in the data. It can better capture short-term fluctuations in the under-five mortality rate and its annual rate of reduction, and thus is better able to account for evidence of acceleration in the decline of under-five mortality from new surveys. Validation exercises show that the B3 model also performs better in short-term projections.

The B3 method was developed and implemented for UN IGME by Leontine Alkema from the University of Massachusetts, Amherst, and Jin Rou New from the National University of Singapore, with guidance and review by the TAG of UN IGME. A more complete technical description of the B3 model is available elsewhere.[9]

4. Estimation of infant mortality rates

In general, the B3 model described above is applied to the U5MR for all countries (except for the Democratic People's Republic of Korea, where a non-standard method was employed). For countries with high-quality VR data (covering a sufficient period of time and deemed to have high levels of completeness and coverage), the B3 model is also used to estimate IMR, but is fitted to the logit transform of r – i.e., log(r/1-r), where r is the ratio of the IMR to the median B3 estimates of U5MR in the corresponding country-year. This is to restrict the IMR to be lower than the U5MR. For the remaining countries, the IMR is derived from the U5MR, through the use of model life tables that contain known regularities in age patterns of child mortality.[10] The advantage of this approach is that it avoids potential problems with the underreporting of neonatal deaths in some countries and ensures that the internal relationships of the three indicators are consistent with established norms. For Sahelian countries (Burkina Faso, Chad, the Gambia, Mali, Mauritania, the Niger and Senegal), the relationship from model life tables does not apply between infant and child mortality, thus a logit transform of the ratio of IMR/U5MR is used to estimate IMR from U5MR using data from full birth histories and a multilevel regression with country-specific intercept.

5. Adjustment for rapidly changing under-five and infant mortality driven by HIV and AIDS

To capture the extraordinarily rapid changes in child mortality driven by HIV and AIDS over the epidemic period in some countries, the regression models were fitted to data points for the U5MR from all other causes than HIV and AIDS, and then estimates of HIV and AIDS under-five mortality from the Joint United Nations Programme on HIV/AIDS (UNAIDS) were added to estimates from the regression model. This method was used for 17 countries where the HIV prevalence rate exceeded 5 per cent at any point in time since 1980. Steps were as follows:

1. Compile and assess the quality of all newly available, nationally representative data relevant to the estimation of child mortality.
2. Adjust survey data to account for possible biases in data collection related to the HIV and AIDS epidemic.
3. Use UNAIDS estimates of AIDS child mortality[11] to adjust the data points from 1980 onward to exclude AIDS deaths.
4. Fit the standard B3 model to the observations to AIDS-free data points.
5. Extrapolate the model to the target year – in this case, 2016.
6. Add back estimates of deaths due to AIDS (from UNAIDS).
7. For the epidemic period, a non-AIDS curve of IMR is derived from U5MR using model life tables and then the UNAIDS estimates of AIDS deaths for children under age 1 are added to generate the final IMR estimates.

6. Estimates of under-five and infant mortality by sex

In 2012, UN IGME produced estimates of U5MR for males and females separately for the first time.[12] In many countries, fewer sources have provided data by sex than have provided data for both sexes combined. For this reason, rather than estimate U5MR trends by sex directly from reported mortality levels by sex, UN IGME uses the available data by sex to estimate a time trend in the sex ratio (male/female ratio) of U5MR instead. Bayesian methods for UN IGME estimation of sex ratios with a focus on the estimation and identification of countries with outlying levels or trends were used. A more complete technical description of the new model is available elsewhere.[13]

7. Estimates of neonatal mortality

The neonatal mortality rate (NMR) is defined as the probability of dying before 28 days per 1,000 live births. In 2015, the UN IGME method for estimating NMR was updated. The new Bayesian methodology is similar to that used to estimate U5MR and estimates by sex. It has the advantage that, compared with the previous model, it can capture data-driven trends in NMR within countries and over time for all countries. A more complete technical description of the new model is available elsewhere.[14]

For neonatal mortality in HIV-affected and crisis-affected populations, the ratio is estimated initially for non-AIDS and non-crisis mortality. After estimation, crisis neonatal deaths are added back on to the neonatal deaths to compute the total estimated neonatal mortality rate. No AIDS deaths are added back to the NMR, thereby assuming that HIV/AIDS-related deaths only affect child mortality after the first month of life.

8. Estimation of mortality in children aged 5–14

For the first time this year, UN IGME produces country-specific trend estimates of the mortality in children aged 5–14 – that is, the probability that a child aged 5 dies before reaching his or her fifteenth birthday (10q5). The methods used are similar to those that are used to estimate under-five mortality rates (U5MR). In 39 countries, there were not enough data inputs to estimate the probability 10q5 from vital registration, surveys or censuses. For these cases, the probability 10q5 was modelled based on an expected relation between mortality in the age groups 0–4 and 5–14, as observed in countries with sufficient data series. A linear regression was used to regress log (10q5) against log (U5MR), with region-specific dummies, and the coefficients of this regression were used to predict the probability 10q5 between 1990 and 2016 for countries with insufficient data sources based on the estimates of the under-five mortality rate. The advantage of this approach is that no model life tables are used (since such life tables are based on the historical experience of countries with high-quality vital registration data and do not always adequately reflect age patterns of mortality in low- and middle-income countries).

In populations severely affected by HIV and AIDS, HIV-positive (HIV+) children will be more likely to die than other children, and will also be less likely to be reported since their mothers will have been also more likely to die. However, no adjustment was included for HIV-related biases in the age group 5–14, since no method currently exists to estimate the magnitude of this bias in the probability 10q5. This bias should be less severe when estimating mortality in the age group 5–14, as compared with the under-five mortality rate, because in the absence of treatment, the majority of children infected through their mothers, will die before reaching age 5.

9. Estimating child mortality due to conflict and natural disasters

Estimated deaths for major crises were derived from various data sources from 1990 to the present. Estimated deaths from natural disasters were obtained from the CRED International Disaster Database,[15] with under-five proportions and for children aged 5–14 estimated as described elsewhere,[16] and conflict deaths were taken from Uppsala Conflict Data Program/ Peace Research Institute Oslo datasets as well as reports prepared by the United Nations and other organizations. Estimated child deaths due to major crises were included if they met the following criteria: (1) the crisis was isolated to a few years; (2) under-five crisis deaths or crisis deaths among children aged 5–14 were > 10 per cent of non-crisis deaths in the age group; (3) crisis U5MR > 0.2 per 1,000 or crisis 10q5 was > 0.2 per 1,000; and (4) the number of under-five crisis deaths or among children 5–14 years old was > 10 deaths or (5) in the event that high-quality vital registration data were available and should not be smoothed by the B3 model.

These criteria resulted in 16 different crises being explicitly incorporated into the UN IGME estimates for under-five mortality and 38 different crises for mortality among children aged 5–14. Because the background mortality rates were relatively low in the age group 5–14, crisis deaths represented a larger share of deaths, and thus more crises met these criteria than for under-five mortality. Crisis deaths were included in the estimates by first excluding data points from crisis years, fitting the B3 model to the remaining data, and then adding the crisis-specific mortality rate to the fitted B3 curve. Crisis death estimates are uncertain but presently no uncertainty around crisis deaths is included in the uncertainty intervals of the estimates. Instead, we assume that the relative uncertainty in the adjusted estimates is equal to the relative uncertainty in the non-adjusted estimates; this assumption will be revisited in the near future.

UN IGME has assessed recent humanitarian crises, namely, in the Syrian Arab Republic and Yemen. Based on the scarce currently available data and the difficulties to estimate a broader impact of these crises on health systems, UN IGME decided to hold the estimates constant from the start of each of these crises while increasing the uncertainty over the crisis time, where applicable direct crisis deaths have been added to the constant trend estimate. UN IGME will review new data, if available, in the next estimation round and revise estimates accordingly.

10. Estimation of uncertainty intervals

Given the inherent uncertainty in child mortality estimates, 90 per cent uncertainty intervals (UIs) are used by UN IGME instead of the more conventional 95 per cent ones. While reporting intervals that are based on higher levels of uncertainty (i.e., 95 per cent instead of 90 per cent) would have the advantage that the chance of not having included the true value in the interval is smaller, the disadvantage of choosing higher uncertainty levels is that intervals lose their utility to present meaningful summaries of a range of likely outcomes if the indicator of interest is highly uncertain. Given this tradeoff and the substantial uncertainty associated with child mortality estimates, UN IGME chose to report 90 per cent UIs, or, in other words, intervals for which there is a 90 per cent chance that they contain the true value, to encourage wider use and interpretation of the UIs.

11. Extrapolation to common reference year

If the underlying empirical data refer to an earlier reference period than the end year of the period the estimates are reported, UN IGME extrapolates the estimates to the common end year, in this round to 2016. UN IGME does not use any covariates to derive the estimates, but uses the past trend in a country and the global trend to extrapolate to the target year. The average extrapolation period in the 2017 round of estimation was 4.5 years for under-five mortality, with half of the countries having data points within the past 3.5 years. For about 70 countries, the latest available child mortality estimate was more than 5 years old.

12. Calculating number of deaths for children under age 5

A birth-week cohort method is used to calculate the absolute number of deaths among neonates, infants and children under age 5. First, each annual birth cohort is divided into 52 equal birth-week cohorts. Then each birth-week cohort is exposed throughout the first five years of life to the appropriate calendar year- and age-specific mortality rates depending on cohort age. For example, the twentieth birth week cohort of the year 2000 will be exposed to the infant mortality rates in both 2000 and 2001.

All deaths from birth-week cohorts occurring as a result of exposure to the mortality rate for a given calendar year are allocated to that year and are summed by age group at death to get the total number of deaths for a given year and age group. Continuing with the above example, deaths from the twentieth birth-week cohort of the year 2000 would contribute to infant deaths in year 2000 and 2001. Any deaths occurring among the twentieth birth-week cohort of year 2000 after the twentieth week in 2001 would contribute to under-five deaths for year 2001 and so forth. Under-five deaths in each calendar year are calculated by summing up all the deaths under age 5 across all age group cohorts in that year. The annual number of live births estimates in each country used to calculate the annual under-five deaths come from the World Population Prospects: the 2017 Revision.[17]

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[1] There were concerns about the completeness of early infant mortality data from civil registration. A European report on perinatal indicators, for example, noted a wide variation in how European countries define infant mortality, due to differences in birth and death registration practices (that is, differences in the cut-off points for acceptable weight or estimated gestation period to be registered as a birth and subsequent death). This discrepancy can lead to under-reporting of infant deaths by some countries, particularly when compared with countries that use a broader definition for live birth. UN IGME previously carried out an analysis of the ratio of early neonatal (under seven days) deaths to total neonatal deaths, which showed that several countries, many in Eastern Europe, had significantly lower values than what would be expected, suggesting an undercounting of early infant deaths. The results of this analysis were used as an upwards adjustment of 10 per cent or 20 per cent to under-five mortality rates across all years for several countries in previous UN IGME reports. This year, this assessment was revisited using the latest data, and the clear signal of underreporting is no longer apparent across countries. Therefore, UN IGME has removed these adjustment factors in the estimates for this publication. Going forward, UN IGME will assemble finer age-specific child mortality data, and attempt to determine the current level of underreporting bias in different countries, and how that bias has changed over time. This analysis could lead to a different adjustment approach in future estimates.

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