

Child Mortality Estimation

Explanatory Notes

September 2015

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

1. Strategy

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 2015.

To increase the transparency of the estimation process, the UN IGME has developed a child mortality database 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.

2. Data Sources

Nationally-representative estimates of under-five mortality can be derived from a number of 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 USAID-supported Demographic and Health Surveys (DHS) and periodic population censuses have become the primary source of data on under-five and infant mortality in developing countries. These surveys ask women about the survival of their children, and it is these reports 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-5 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 survey not previously available. All the data are uploaded in the CME info database.

2.1 Data from civil registration systems

For data from civil registration, the calculation of U5MR and IMR is derived from a standard period abridged life table. The inputs are number of deaths for age group <1 year (noted D_0) and for the age group 1-4 (D_1), as well as the mid-year population for the same age groups (P_0 and P_1).

The formulae are as follows:

Given that: ${}_nq_x$ is the probability of dying between age x and age $x+n$,

$$M_0 = D_0 / P_0, \text{ death rate for age } <1,$$

$$M_1 = D_1 / P_1, \text{ death rate for age group 1-4,}$$

Then: ${}_1q_0 = M_0 / [1 + (1 - a) * M_0]$

where a is the fraction of year lived by an infant

$a = 0.1$ for low mortality country and $a = 0.3$ for high mortality country

$${}_5q_0 = 1 - (1 - {}_1q_0)(1 - {}_4q_1)$$

where ${}_4q_1 = 4 * M_1 / [1 + 4(1 - 0.4) * M_1]$

Finally: $IMR = {}_1q_0 * 1000$ and $U5MR = {}_5q_0 * 1000$

2.2 Survey data

The majority of survey data comes in one of two forms: the full birth history (FBH), whereby women 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 (SBH), 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).

FBH data, collected by all DHS surveys 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 is 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 (4).

In general, SBH 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 to 29 through 45 to 49. This method is well known, but has several shortcomings. Starting with the 2014 round of estimation, the 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 main benefits of the new method over the previous one: First, it generally has lower sampling errors. 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, it 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 and therefore are not selected for. Third, the method tends to show less fluctuation across time, in particular in countries with relatively low fertility and mortality. The IGME considers the improvements in the estimates based on time since first birth worthwhile when compared to the estimates derived from the classification by age of mother, hence in cases where the microdata is available, the IGME has reanalyzed the data using the new method.

Moreover, following advice from the Technical Advisory Group (TAG) of the IGME, child mortality estimates from SBH were not included if estimates from FBH in the same survey were available (5).

2.3 Adjustment for missing mothers in high-HIV settings

In populations severely affected by HIV/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 downwards. 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 the IGME developed a method to adjust HIV/AIDS related mortality for each survey data observation from FBH during HIV/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 (6). This method was applied to all World Fertility Surveys, as well as the Demographic and Health Surveys.

2.4 Adjustment for rapidly changing child mortality driven by HIV/AIDS

To capture the extraordinarily rapid changes in child mortality driven by HIV/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/AIDS, and then UNAIDS estimates of HIV/AIDS under-five mortality were added to estimates from the regression model. This method was used for 17 countries where the HIV prevalence rate exceeded 5% 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 and in HIV/AIDS epidemic.
3. Use UNAIDS estimates of HIV/AIDS child mortality (7) to adjust the data points from 1980 onwards to exclude HIV deaths.
4. Fit the standard statistical model (see Section 3) to the observations to HIV-free data points.
5. Extrapolate the model to the target year, in this case 2015.
6. Add back estimates of deaths due to HIV/UNAIDS (from UNAIDS)
7. For the epidemic period, a non-HIV curve of IMR is derived from U5MR using model life tables (see Section 4) and then the UNAIDS estimates of HIV/AIDS deaths for children under age 1 are added to generate the final IMR estimates.

2.5 Adjustment for under-reporting of infant deaths

There are concerns about incompleteness of early infant mortality data from civil registration in some European countries. 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) (8,9). 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. The international discrepancies in data may have existed for some time, but they have been overlooked because of much higher infant mortality rates. Now that rates are so much lower, however, differences in registration may be more important in explaining inter-country differences in infant mortality (10).

Therefore, child mortality was first adjusted before running the regression model as follows. The UN IGME examined the strong evidence that early neonatal deaths are under-reported for the Russian Federation and

agreed that an adjustment of the order of 25% should be made to the Russian estimates of infant mortality based on the published analyses. As this problem was also known to be present for some other of the Eastern European countries (11), UN IGME carried out an analysis of the ratio of early neonatal (under 7 day) deaths to total neonatal deaths. The average value of this ratio for Western European countries was 0.77 with few values below 0.7. A statistical analysis of this ratio for available country-years found that the ratio was significantly lower than the Western European average for the following countries: Belarus, Bulgaria, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Romania, Russian Federation, Slovakia, Spain. In only four countries did this ratio change significantly over time, and in all cases it was decreasing not increasing.

Based on this analysis, it was decided to apply a 10% upward adjustment to under-5 mortality for Belarus, Hungary and Lithuania; and a 20% adjustment for the other countries, including the Russian Federation. In all cases, a single country-specific correction factor was applied to the entire time series, except for Estonia from 1992 onwards.

2.6 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. As a result, different surveys often yield widely different estimates of U5MR for a given time period. In order to reconcile these differences and take better account of the systematic biases associated with the various types of data inputs, the 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 2015. This method is described in the following section.

3. Improved estimates for levels and trends in under-5 mortality

3.1 Summary

Estimation and projection of under-5 mortality rates (U5MR) was undertaken 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 IGME child mortality estimates published in September 2013 (12) and September 2014 (13). The infant mortality rate (IMR) is obtained by either applying the B3 estimation method or by applying a model life table to the U5MR estimates as described in Section 4.

In the B3 model, $\log(\text{U5MR})$ is estimated with a flexible splines regression model, explained in section 3.2. The spline regression model is fitted to all U5MR observations in the country. An observed value for U5MR is considered to be the true value for U5MR multiplied by an error factor, i.e. $\text{observed U5MR} = \text{true U5MR} * \text{error}$, or on the log-scale, $\log(\text{observed u5mr}) = \log(\text{true U5MR}) + \log(\text{error})$, 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 all countries in the world.

Figure 1 displays plots of the U5MR over time for Senegal, used here for illustrative purposes. The B3 estimates are in red. 90% 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.

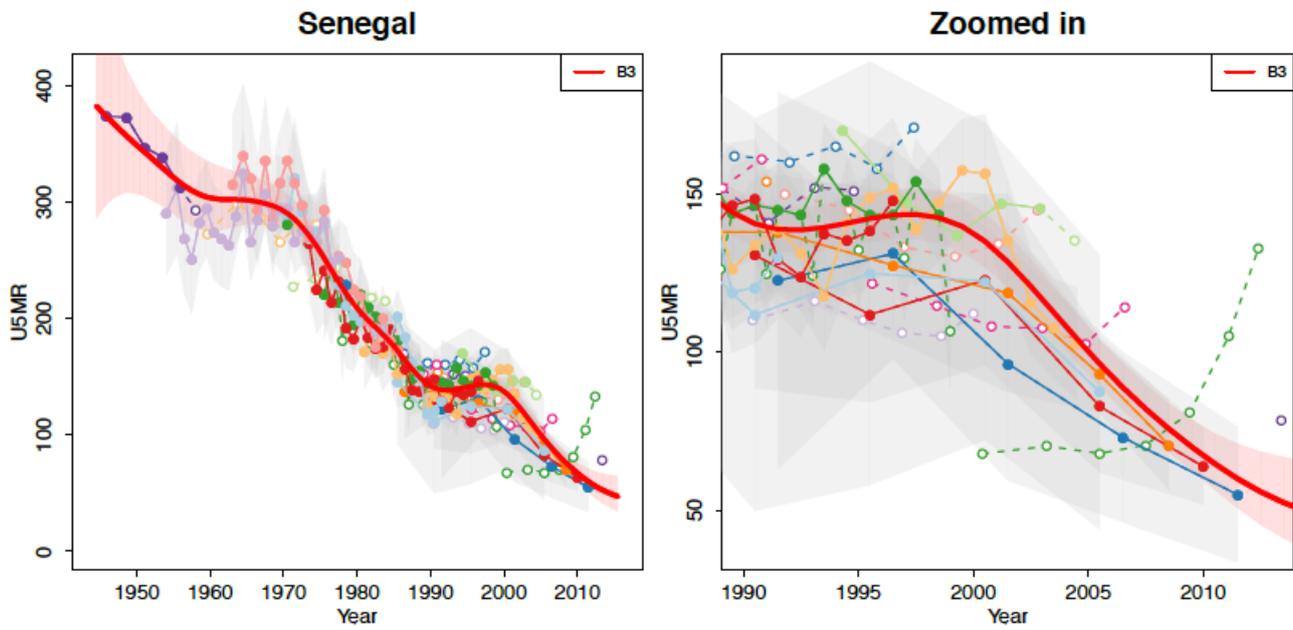


Figure 1: Illustration of the B3 model for Senegal. Left: Plot of the U5MR over time for Senegal, with the B3 estimates in red. Right: Zoomed in version of the plot on the left.

The B3 method was developed and implemented for the UN IGME by Leontine Alkema and Jin Rou New from the National University of Singapore with guidance and review by the TAG of the UN IGME. A more complete technical description of the B3 model is available elsewhere (14, 15).

3.2 Splines regression

The splines regression fitting method is illustrated in Figure 2 for Norway. Splines are smooth curves, placed 2.5 years apart, that add up to 1 at any point in time. For any year, the estimated $\log(\text{U5MR})$ is the sum of the non-zero splines in that year multiplied by the corresponding spline coefficients (displayed by dots). For example, $\log(\text{U5MR})$ in 1980 in Norway is given by the sum of the yellow and grey splines to the left of black line (at the year 1980) and the black and red splines to the right, multiplied by their respective spline coefficients in the same colour.

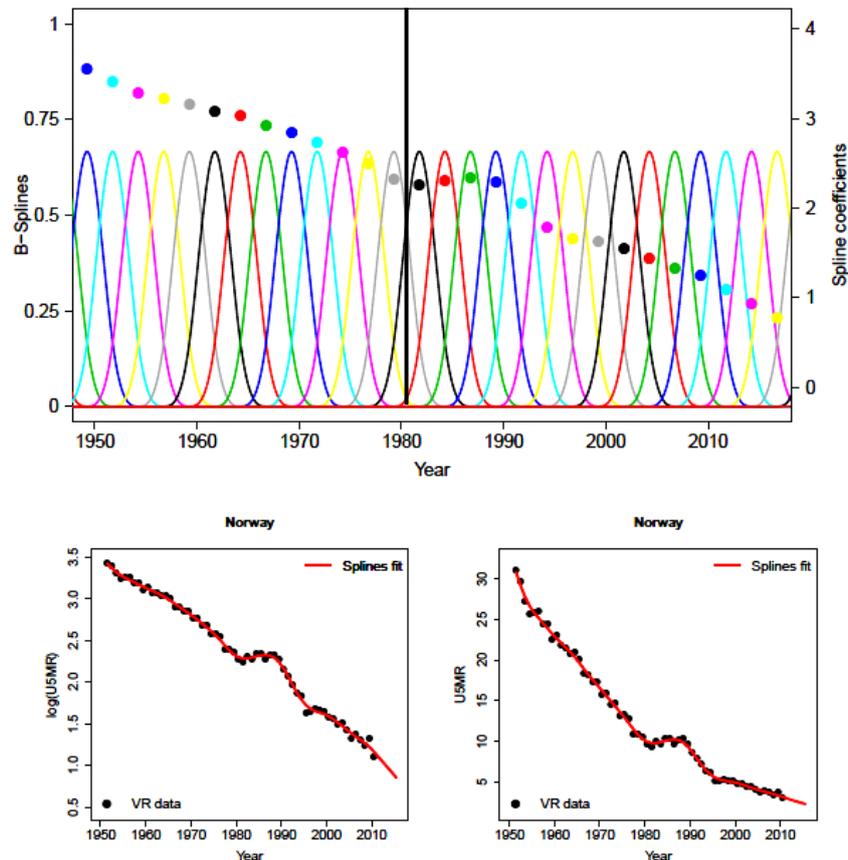


Figure 2: Illustration of the B-splines regression model for Norway. Top row: B-splines and the estimated spline coefficients. Bottom row: Observed $\log(\text{U5MR})$ and U5MR (black dots) plotted against time, together with the spline estimates (red line).

The spline coefficients determine what the resulting fitted curve looks like. When estimating the spline coefficients, we obtain a flexible yet reasonably smooth U5MR curve by assuming that the difference between two adjacent coefficients (for example for years 1981 and 1983.5) is given by the difference between the previous two coefficients (for years 1978.5 and 1981) with an estimated data-driven “distortion term” added to it. For example, in Norway during the early 1980s, these distortion terms are estimated to be around zero when U5MR did not change much, but they are negative in the late 1980s when the U5MR started to decline again. The resulting fit in Norway illustrates that the spline fit is able to follow the observed changes in the data closely.

The variance of the distortion terms determines the smoothness of the fit during the observation period; large fluctuations in these distortion terms imply that the trend can vary greatly from one period to the next. The amount of smoothing is country-specific for the majority of countries. An average global level of smoothing is used for countries with a small number of live births, countries with both vital registration (VR) and non-VR data included in the fitting and countries with a gap of more than 5 years in their VR data. Due to the

nature of the data in such countries, a small variance for the distortion terms tends to be estimated, so a global level of smoothing helps to reduce fluctuations in the trend.

After the most recent observation period ends, country-specific U5MR projections are obtained through the estimation of “future spline coefficients”, or equivalently, by projecting the differences between adjacent spline coefficients. The mean projected difference in spline coefficients is given by the estimated difference in the two most recent adjacent spline coefficients, and the uncertainty therein is based on the variability in the observed distortions in the country’s past. Based on out-of-sample validation exercises, this approach is shown to work well for the majority of countries but leads to unnecessarily wide uncertainty intervals (or extreme extrapolations) for a subset of countries where the most recent change in spline coefficients is very uncertain (or an extreme value). We avoid such uncertain and extreme U5MR extrapolations in longer-term projections by combining the country-specific projected differences in spline coefficients with a global distribution of observed differences in the past. This final step results in the removal of very extreme U5MR extrapolations in the country-specific U5MR projections.

3.3 Why was the B3 model implemented?

For evaluating progress in reducing U5MR, accurate estimates of the rate of reduction and the uncertainty associated with it are required. The B3 method was recommended by the TAG starting in 2013 because compared to the previous loess estimation approach:

- The B3 model better accounts for data errors (including biases and sampling and non-sampling errors in the data),
- Splines can better capture short-term fluctuations in the U5MR and ARR, and
- The B3 model performs better in out-of-sample validation exercises.
- In summary, as compared to the previous estimation approach, the B3 model is better able to take into account evidence of acceleration in the decline of U5MR from new surveys.

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 Republic of Korea, where a nonstandard 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, 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 (16). The advantage of this approach is that it avoids potential problems with the under-reporting of neonatal deaths in some countries and ensures that the internal relationships of the three indicators are consistent with established norms.

5. Estimates by sex

In 2012, the UN IGME produced estimates of U5MR for males and females separately for the first time (17). In many countries, fewer sources have provided data by sex than have provided data for both sexes combined. For this reason, the UN IGME, rather than estimate U5MR trends by sex directly from reported mortality levels by sex, uses the available data by sex to estimate a time trend in the sex ratio (male/female ratio) of U5MR instead. Bayesian methods for the UN IGME estimation of sex ratios with a focus on the estimation and identification of countries with outlying levels or trends were used (18).

For each country-year, we assume that the sex ratio of infant mortality $SI(c,t)$ $S_{1,c,t}$ which refers to the ratio of the probability of dying before age one for boys as compared to girls for country c in year t is given by:

$$SI(c,t) = WI(c,t) * PI(c,t),$$

where

- $WI(c,t)$ refers to the expected sex ratio for that country-year,
- Country multiplier $PI(c,t)$ represents the relative advantage or disadvantage of infant girls to boys compared to other countries at similar levels of infant mortality.

Sex ratios of mortality tend to change as overall mortality decreases. To account for the relation between the level of infant mortality and the expected sex ratio, the term W gives the expected sex ratio for the country-year based on the UN IGME-estimated IMR for that country-year. The relation between the IMR level and the expected sex ratio, $WI(c,t) = f(IMR(c,t))$ is modeled using a B-splines regression model. The parameters of this model are estimated based on all available data such that $f(IMR)$ represents a “global relation” between infant mortality and sex ratios. The country multiplier $PI(c,t)$ is modeled with a time series model, whereby the multiplier fluctuates around country-specific level $\beta I(c)$ which is estimated using a hierarchical model.

For children aged 1-4, the sex ratio of child mortality is modelled as $S4(c,t) = W4(c,t)*P4(c,t)$, where $W4$ refers to the expected sex ratio for the country-year given the country-year-specific CMR for both sexes combined (again modeled with a B-splines regression model) and country multiplier $P4$ represents the relative advantage or disadvantage of girls to boys compared to other countries at similar levels of child mortality. $P4(c,t)$ is also modeled with a time series model, whereby the multiplier fluctuates around country-specific level $\beta 4(c)$ which is estimated using a hierarchical model.

Estimates of the sex ratio of under-5 mortality are obtained from estimates on the sex ratios on infant and child mortality. If data are available on the sex ratio for under-5 mortality but not on the sex ratio of infant mortality (e.g., based on summary birth histories), the data on under-5 mortality are used to inform the estimates for infant and child mortality sex ratios.

Figure 3 shows observed sex ratios for infant, child and under-5 mortality, with the estimated global relation between these ratios and the overall level of mortality. Figure 4 shows two illustrative examples of country estimates.

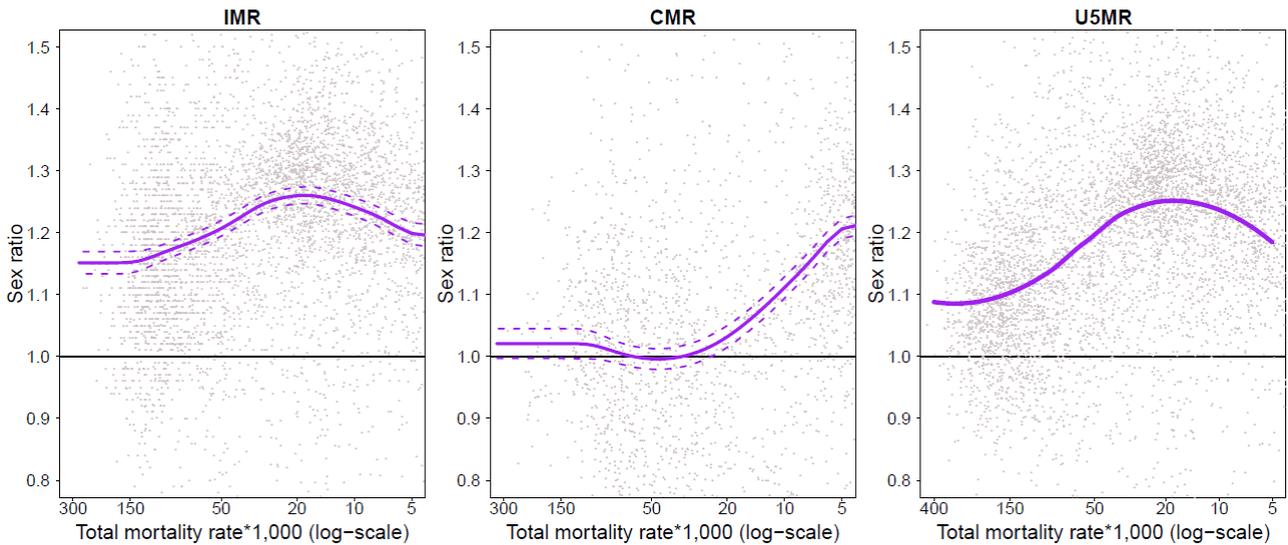
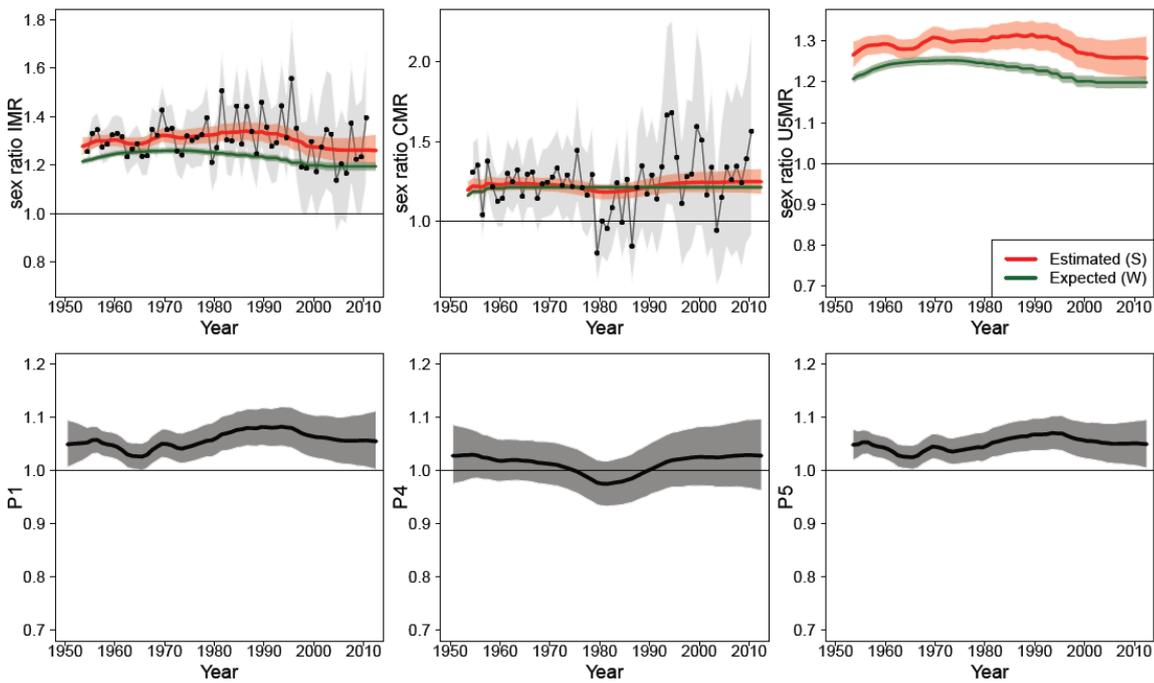


Figure 3: Observed sex ratios (gray dots) are plotted against estimated total mortality rates (on the log scale) for infants, children and the under-five year olds. The estimated global relation between expected sex ratios (W 's) and total mortality for the IMR and CMR are in purple solid lines. Dashed lines represent 90% uncertainty intervals. For U5MR, the purple line illustrates the relation between sex ratios and total U5MR based on the relations for IMR and CMR for all included country-years.

Country A



Country B

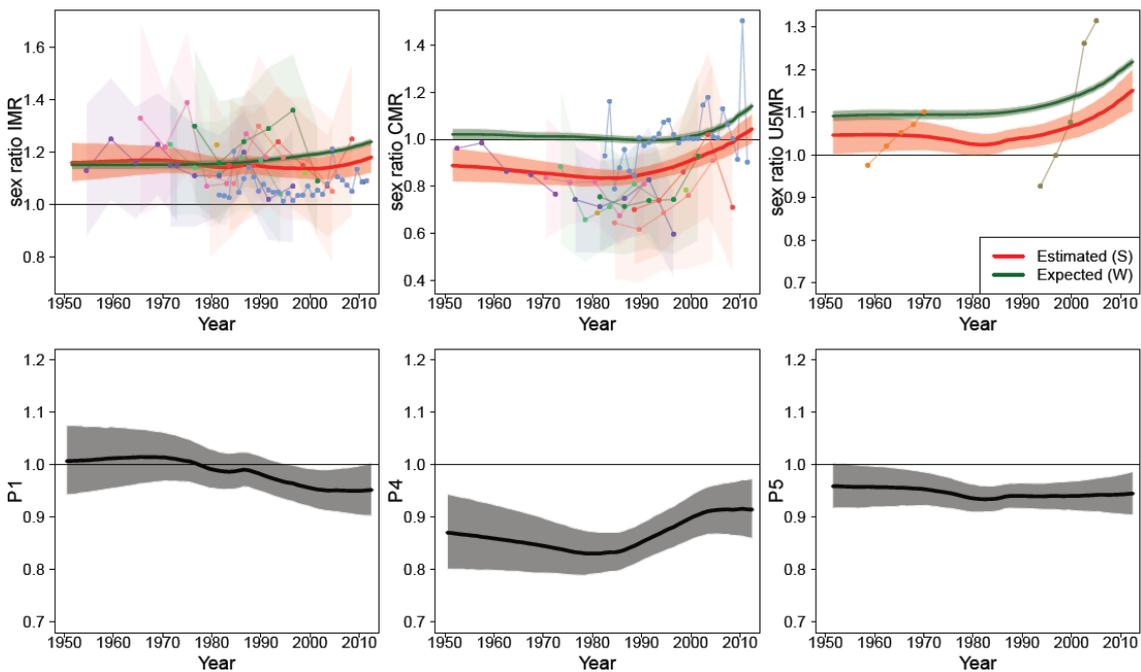


Figure 4: Illustrative example of country estimates of sex ratios S and country multipliers P for two countries. In country A, for a subset of observed country-years for infants and under-five year olds, the sex ratio of mortality of boys versus girls is higher than expected based on the estimated world level relation between sex ratios and mortality levels. In country B, for a subset of observed country-years for infants and for all years for the 1-4 and under-five year olds, the sex ratio of mortality of boys versus girls is lower than expected based on the estimated world level relation between sex ratios and mortality levels.

Explanation of each country plot: Top row: Estimated country-specific sex ratio S (red) for the three age groups and expected sex ratio W (green). Observations are displayed by dots. Shaded areas around observations illustrate sampling errors (where available) and different colors differentiate data series. Bottom row: Estimated country multipliers P for the three age groups. Shaded areas illustrate the 90% credible bounds.

6. Calculating number of deaths

The absolute number of deaths among infants and children in a given year and country is calculated using the central death rates of age groups 0 and 1-4 years, M_0 and M_1 , computed from the estimated U5MR and IMR as follows. First, the probability of dying between exact ages 1 and 5 is derived as follows: ${}_4q_1 = (U5MR - IMR)/(1000-IMR)$. Then:

$$M_0 = IMR / [1000 - (1-a) * IMR]$$

$$M_1 = 4 * {}_4q_1 / 4 * [1 - (1-0.4) * {}_4q_1]$$

where a is the fraction of year lived by an infant

= 0.1 for low mortality country and $a = 0.3$ for high mortality country

Finally, country population estimates from the *World Population Prospects: the 2015 revision* (19) are used to convert the death rates to numbers of deaths.

7. Methods to generate estimates of neonatal mortality

The neonatal mortality rate (NMR) is defined as the probability of dying before 28 days per 1000 live births. In 2015 the UN IGME method for estimating NMR were updated. The new Bayesian methodology is similar to that used to estimate U5MR and estimates by sex. It has the advantage that, compared to 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 (20).

We model the ratio $R(c,t)$, which refers to the ratio of NMR to the difference of U5MR and NMR in country c and year t , i.e. $R(c,t) = NMR/(U5MR - NMR)$. For each country-year, we assume that the ratio is given by:

$$R(c,t) = W(c,t) * P(c,t),$$

where

- $W(c,t)$ refers to the expected ratio for that country-year,
- Country multiplier $P(c,t)$ represents country-specific trends in the ratio over time that differ from the expected level.

As U5MR decreases, the proportional share of mortality in the first month of life tends to increase. The $W(c,t)$ term accounts for this relationship; it is the expected ratio for the country-year based on the UN IGME-estimated U5MR for that country-year. It is modeled as a linear function of U5MR with a changing slope:

$$W(c,t) = \beta_0 \quad \text{if } U5MR(c,t) < U_{cut}$$

$$W(c,t) = \beta_0 + \beta_1 * U5MR(c,t) \quad \text{if } U5MR(c,t) \geq U_{cut}$$

U_{cut} is an estimated constant that represents the level of U5MR after which as U5MR increases, the ratio $NMR/(U5MR - NMR)$ decreases. The parameters of this model are estimated based on all available data such that $W(c,t)$ represents a 'global relation' between the ratio and U5MR.

The country multiplier $P(c,t)$ is modeled with a B-splines regression model. The $P(c,t)$ represents a country-specific intercept, which is modeled hierarchically, and fluctuations around that intercept over time. For any particular country the ratio can overall be higher- or lower-than-expected given the level of U5MR in that country, but the fluctuations allow this relationship to change over time within a country. A degree of smoothness is imposed on the fluctuations to ensure relatively smooth trajectories for any given country through time. We model the ratio of $NMR/(U5MR - NMR)$; estimates of NMR are obtained by recombining the estimates of the ratio with UN IGME-estimated U5MR.

For neonatal mortality in HIV-affected and crisis-affected populations, the ratio is estimated initially for non-AIDS and non-crisis deaths. After estimation, crisis neonatal deaths are added back on to the neonatal deaths to compute the total estimated neonatal death 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.

To obtain the number of neonatal deaths, live births were applied to neonatal mortality rates. The live births were calculated by taking the infant population from the World Population Prospects: the 2012 revision (19) and subtracting the deaths at different neonatal periods while accounting for the fraction of period lived before the death. Upon analyzing child death data from VR and DHS, it was consistent with the assumption that after day zero, neonatal deaths fit to an exponential survival curve. In terms of fraction of the neonatal period, this translates to an average 4.7 days (lived by a neonate who dies in neonatal period) or 0.0129 of the infant period. Testing different fractions of neonatal to infant deaths and fractions of period lived by before a neonatal death resulted in the constant of 0.5 years lived by infants who die in the post neonatal period. These two fractions constants are then applied to the deaths fractions of each period.

TAG recommended that for neonatal mortality in HIV-affected populations, the NMR be estimated initially on using neonatal and child mortality observations for non-AIDS deaths, calculated by subtracting from total death rates the estimates HIV death rates in the neonatal and 1-59 month periods respectively, and then AIDS neonatal deaths be added back on to the non-HIV neonatal deaths to compute the total estimated neonatal death rate.

8. Child mortality due to conflict and natural disasters

Estimated deaths for major crises were derived from various data sources from 1990 to present. Natural disasters were obtained from the CRED International Disaster Database (21), with under-5 proportions estimated as described elsewhere (22), and conflict deaths were taken from UCDP/PRIO datasets as well as reports prepared by the UN 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 were >10% of under-five non-crisis deaths
3. Crisis U5MR > 0.2 per 1,000
4. Number of under-five crisis deaths >10 deaths.

or

1. High quality vital registration data are available and should not be smoothed by the B3 model

These criteria resulted in 16 different crises being explicitly incorporated into the IGME estimates. Crisis deaths were included in the U5MR estimates by first excluding data points from crisis years, fitting the B3 model to the remaining data, and then adding the crisis-specific death rate to the fitted B3 curve. Crisis death estimates are uncertain but presently no uncertainty around crisis deaths is included in the U5MR uncertainty intervals, instead, we assume the relative uncertainty in the adjusted U5MR is equal to the relative uncertainty in the non-adjusted U5MR; this assumption will be revisited in future years. The IGME also reviewed recent crises, namely the Ebola virus disease outbreak in West Africa and the Nepal 2015

earthquake. Based on currently available data, neither of these crises appear to have led directly to under-five deaths greater than 10% of non-crisis under-five deaths and were therefore not explicitly included in these estimates. However, it is noted that the broader impact of these disasters on health systems could lead to a greater number of deaths than is currently estimated, and the IGME will review new data, if available, in the next estimation round.

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