Global Maternal Health (GMatH) Model Overview

Zach Ward
IDM Annual Symposium
May 24, 2023

www.gmath-model.org
Co-authors:
Rifat Atun (Harvard)
Gary King (Harvard)
Brenda Sequeira Dmello (CCBRT: Comprehensive Community Based Rehabilitation in Tanzania)
Sue Goldie (Harvard)

Funding:
Z.J.W. and S.J.G. received support from the John D. and Catherine T. MacArthur Foundation (grant no. 10-97002-000-INP). The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.
Maternal mortality is a major global health challenge. Although progress has been made globally in reducing maternal deaths, measurement remains challenging given the many causes and frequent underreporting of maternal deaths. We developed the Global Maternal Health microsimulation model for women in 200 countries and territories, accounting for individual fertility preferences and clinical histories. Demographic, epidemiologic, clinical and health system data were synthesized from multiple sources, including the medical literature, Civil Registration Vital Statistics systems and Demographic and Health Survey data. We calibrated the model to empirical data from 1990 to 2015 and assessed the predictive accuracy of our model using indicators from 2016 to 2020. We projected maternal health indicators from 1990 to 2050 for each country and estimate that between 1990 and 2020 annual global maternal deaths declined by over 40% from 387,500 (95% uncertainty intervals (UI) 320,600–714,000) to 337,600 (95% UI 307,900–364,100), and are projected to decrease to 327,400 (95% UI 287,800–360,700) in 2030 and 320,200 (95% UI 267,100–374,600) in 2050. The global maternal mortality ratio is projected to decline to 167 (95% UI 142–188) in 2030, with 58 countries above 140, suggesting that on current trends, maternal mortality Sustainable Development Goal targets are unlikely to be met. Building on the development of our structural model, future research can identify context-specific policy interventions that could allow countries to accelerate reductions in maternal deaths.

The Sustainable Development Goals include a target to reduce the global maternal mortality ratio (MMR) to less than 70 maternal deaths per 100,000 live births by 2030, with no individual country exceeding 140. However, on current trends the goals are unlikely to be met. We used the empirically calibrated Global Maternal Health microsimulation model, which simulates individual women in 200 countries and territories to evaluate the impact of different interventions and strategies from 2022 to 2030. Although individual interventions yielded fairly small reductions in maternal mortality, integrated strategies were more effective. A strategy to simultaneously increase facility births, improve the availability of clinical services and quality of care at facilities, and improve linkages to care would yield a projected global MMR of 72 (95% uncertainty interval (UI) = 58–87) in 2030. A comprehensive strategy adding family planning and community-based interventions would have an even larger impact, with a projected MMR of 58 (95% UI = 46–70). Although integrated strategies consisting of multiple interventions will probably be needed to achieve substantial reductions in maternal mortality, the relative priority of different interventions varies by setting. Our regional and country-level estimates can help guide priority setting in specific contexts to accelerate improvements in maternal health.


Maternal Mortality Estimation

Measurement of maternal mortality is fraught with difficulty:

- Inadequate data collection and absence of vital registration systems in many countries
- Relatively rare: large samples are needed for stable estimates
- Difficult to identify: not a single diagnosis but composite of many distinct conditions, each with their own pathophysiology
- Underreporting: many maternal deaths are missed, especially in early pregnancy and from complications of induced abortion
Aggregate vs Structural Models

- Aggregate models: based solely on previous trends of the outcome of interest
  - Estimate cross-sectional country-level association between aggregate factors and levels of maternal mortality
  - Gross domestic product (GDP) the largest driver of trends

- Structural models: based on a defined system of causal components and their relationships
  - Can offer more robust estimates for complex systems
    - Synthesize data on various factors from multiple sources
    - Use information on related processes/outcomes observed with more certainty to estimate ultimate outcomes of interest
  - Causal structure allow for counterfactual scenarios to be run
    - Estimate potential impact of interventions
Model Overview

Global Maternal Health (GMatH) microsimulation model
- Simulates the reproductive histories of individual women in 200 countries and territories
  - 6 subgroups of urban/rural and maternal education (low/medium/high) within each country -> account for impact of demographic trends
  - Individual-level heterogeneity in family planning preferences and history of maternal complications
- Causal framework
  - Simulate ‘natural history’ (i.e. in the absence of any intervention) of various reproductive processes
  - Also explicitly model coverage levels and impact of relevant clinical and health system interventions
- Allows counterfactual outcomes to be estimated by varying the coverage levels and/or impact of the modelled interventions
Model Overview

Global Maternal Health (GMatH) microsimulation model

- Simulates the reproductive histories of individual women in 200 countries and territories
  - 6 subgroups of urban/rural and maternal education (low/medium/high) within each country -> account for impact of demographic trends
  - Individual-level heterogeneity in family planning preferences and history of maternal complications

- Causal framework
  - Simulate ‘natural history’ (i.e. in the absence of any intervention) of various reproductive processes
  - Also explicitly model coverage levels and impact of relevant clinical and health system interventions
  - Allows counterfactual outcomes to be estimated by varying the coverage levels and/or impact of the modelled interventions
Individual-Level Reproductive Lifecycle

Demographics
- Population size, age structure; Lifetables; Urbanization; Education; Injury-related Deaths; Migration

Population-Level Trends

Biology

Family Planning Behaviour
- Age of sexual debut
- Desired # children; Current living children

Events
- Sexual debut
- Spacing/limiting intention

Obstetric Complications

Health System

Clinical Interventions
Population size, age structure; Lifetables; Urbanization; Education; Injury-related Deaths; Migration

Demographics

Population-Level Trends

Individual-Level Reproductive Lifecycle

Biology

- Natural fecundity; Lactational amenorrhea
- Sex ratio – primary; Twinning rates

Family Planning Behaviour

- Age of sexual debut
- Desired # children; Current living children
- Contraception
  - Unmet need; Method mix; Failure rate; Duration of use

Events

- Sexual debut
- Spacing/limiting intention
- Conception; Simulate fetus # and sex

Obstetric Complications

Health System

Clinical Interventions
Individual-Level Reproductive Lifecycle

**Demographics**
- Population size, age structure; Lifetables; Urbanization; Education; Injury-related Deaths; Migration

**Biology**
- Age of sexual debut
- Natural fecundity; Lactational amenorrhea
- Sex ratio – primary; Twinning rates

**Family Planning Behaviour**
- Age of sexual debut
- Desired # children; Current living children
- Contraception
  - Unmet need;
  - Method mix;
  - Failure rate;
  - Duration of use
- Induced abortion;
  - Sex ratio – secondary

**Events**
- Sexual debut
- Spacing/limiting intention
- Conception; Simulate fetus # and sex
- Pregnancy loss

**Obstetric Complications**
- Anemia
- Indirect
- Antenatal care
- Ectopic pregnancy management

**Health System**
- Maternal death

**Clinical Interventions**
Demographics
Population size, age structure; Lifetables; Urbanization; Education; Injury-related Deaths; Migration

Individual-Level Reproductive Lifecycle

Biology
- Natural fecundity
- Lactational amenorrhea
- Sex ratio – primary; Twinning rates
- Miscarriage
- Ectopic pregnancy
- Anemia
- Month of delivery; Stillbirth risk

Family Planning Behaviour
- Age of sexual debut
- Desired # children; Current living children
- Contraception
  - Unmet need; Method mix; Failure rate; Duration of use
- Induced abortion
  - Sex ratio - secondary

Events
- Sexual debut
- Spacing/limiting intention
- Conception; Simulate fetus # and sex
- Pregnancy loss
- Delivery
- Risk direct complications

Obstetric Complications
- Direct
  - Preeclampsia/eclampsia; Obstructed labour; Postpartum hemorrhage; Sepsis; Other direct
- Indirect
- Antenatal care
- Delivery Site
- Elective c-section
  - Preventive
    - Active management of labour; Partograph; Clean Delivery
  - Curative
    - Hypertension management; Assisted delivery; Hemorrhage management; Antibiotics

Health System
- Recognition/referral; Transportation; Referral facility

Clinical Interventions
- Ectopic pregnancy management

Population-Level Trends
Model Parameter Inputs

~ 50 parameter groups

- Hierarchical modelling approach with up to five levels: global, country income group, area [i.e. continent], region, and country
  - Many parameters vary by subgroup (urban/rural + education)

- Synthesized the best available epidemiologic and clinical evidence from various sources: randomized clinical trials, observational studies, meta-analyses, expert opinion, census data, and primary survey data
  - Individual-level Demographic and Health Survey (DHS) data for over 4.6 million women from 322 surveys in 83 countries

~450,000 parameters
GMatH (Global Maternal Health) Model

Model Overview

The Global Maternal Health (GMatH) microsimulation model simulates the reproductive histories of individual women in 203 countries and territories, accounting for heterogeneity in education and urban/rural location, family planning preferences, and history of maternal complications. The structural nature of the model allows for more robust estimates of maternal mortality to be made, and provides a causal framework in which counterfactual scenarios can be modeled to evaluate the impact of different policies aimed at improving maternal health.

- **Model Inputs**: To develop the model we synthesized the best available epidemiologic and clinical evidence from various sources, including randomized clinical trials, observational studies, meta-analyses, expert opinion, census data, and primary survey data, and explicitly accounted for uncertainty in all of these inputs.
- **Datasets and Definitions**: More information on the datasets used in the model and the calculated maternal health indicators is available here.
- **Model Calibration**: We calibrated the model to empirical data on a range of maternal health indicators.

Acknowledgements

Model development was supported by the John D. and Catherine T. MacArthur Foundation, 10-07002-000-1NP (PI: Sue J. Goldie).

www.gmath-model.org
## Calibration Targets

Calibrated to empirical primary data (no modelled estimates)

Fit to data from 1990-2015, reserving 2016-2020 estimates a test set

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertility Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fertility rate (TFR) (age 15-49)</td>
<td>186 (6,633)</td>
<td>120 (249)</td>
<td>UN World Fertility data</td>
</tr>
<tr>
<td>Contraceptive prevalence (age 15-49)</td>
<td>74 (235)</td>
<td>20 (21)</td>
<td>DHS data</td>
</tr>
<tr>
<td>Twinning rate</td>
<td>107 (107)</td>
<td>0 (0)</td>
<td>Smits 2011, Pison 2015</td>
</tr>
<tr>
<td><strong>Process Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anemia prevalence (by severity)</td>
<td>48 (291)</td>
<td>16 (48)</td>
<td>DHS data</td>
</tr>
<tr>
<td>Stillbirth rate</td>
<td>93 (656)</td>
<td>0 (0)</td>
<td>Blencowe 2016</td>
</tr>
<tr>
<td>Facility delivery %</td>
<td>121 (286)</td>
<td>84 (85)</td>
<td>DHS data, WHO GHO database</td>
</tr>
<tr>
<td>C-section rate</td>
<td>161 (479)</td>
<td>60 (69)</td>
<td>UNICEF Maternal and Newborn Health Coverage Database</td>
</tr>
<tr>
<td>Spontaneous/operative vaginal delivery %</td>
<td>24 (48)</td>
<td>0 (0)</td>
<td>WHO Global Survey on Maternal and Perinatal Health Database</td>
</tr>
<tr>
<td><strong>Mortality Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal deaths (total) (CRVS data)</td>
<td>123 (2,311)</td>
<td>70 (117)</td>
<td>WHO Mortality Database</td>
</tr>
<tr>
<td>Maternal deaths by cause (CRVS data)</td>
<td>114 (11,216)</td>
<td>69 (928)</td>
<td>WHO Mortality Database</td>
</tr>
<tr>
<td>Pregnancy-related mortality ratio</td>
<td>56 (137)</td>
<td>0 (0)</td>
<td>DHS data</td>
</tr>
<tr>
<td>Miscellaneous (maternal deaths, maternal mortality ratio, pregnancy-related mortality ratio)</td>
<td>22 (96)</td>
<td>3 (8)</td>
<td>Country-specific sources</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>22,495</td>
<td>1,525</td>
<td></td>
</tr>
</tbody>
</table>
Calibration Targets

Calibrated to empirical primary data (no modelled estimates)

Fit to data from 1990-2015, reserving 2016-2020 estimates a test set

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fertility Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fertility rate (TFR) (age 15-49)</td>
<td>186 (6,633)</td>
<td>120 (249)</td>
<td>UN World Fertility data</td>
</tr>
<tr>
<td>Contraceptive prevalence (age 15-49)</td>
<td>74 (235)</td>
<td>20 (21)</td>
<td>DHS data</td>
</tr>
<tr>
<td>Twinning rate</td>
<td>107 (107)</td>
<td>0 (0)</td>
<td>Smits 2011, Pison 2015</td>
</tr>
<tr>
<td><strong>Process Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anemia prevalence (by severity)</td>
<td>48 (291)</td>
<td>16 (48)</td>
<td>DHS data</td>
</tr>
<tr>
<td>Stillbirth rate</td>
<td>93 (656)</td>
<td>0 (0)</td>
<td>Blencowe 2016</td>
</tr>
<tr>
<td>Facility delivery %</td>
<td>121 (286)</td>
<td>84 (85)</td>
<td>DHS data, WHO GHO database</td>
</tr>
<tr>
<td>C-section rate</td>
<td>161 (479)</td>
<td>60 (69)</td>
<td>UNICEF Maternal and Newborn Health Coverage Database</td>
</tr>
<tr>
<td>Spontaneous/operative vaginal delivery %</td>
<td>24 (48)</td>
<td>0 (0)</td>
<td>WHO Global Survey on Maternal and Perinatal Health</td>
</tr>
<tr>
<td><strong>Mortality Indicators</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal deaths (total) (CRVS data)</td>
<td>123 (2,311)</td>
<td>70 (117)</td>
<td>WHO Mortality Database</td>
</tr>
<tr>
<td>Maternal deaths by cause (CRVS data)</td>
<td>114 (11,216)</td>
<td>69 (928)</td>
<td>WHO Mortality Database</td>
</tr>
<tr>
<td>Pregnancy-related mortality ratio</td>
<td>56 (137)</td>
<td>0 (0)</td>
<td>DHS data</td>
</tr>
<tr>
<td>Miscellaneous (maternal deaths, maternal mortality ratio, pregnancy-related mortality ratio)</td>
<td>22 (96)</td>
<td>3 (8)</td>
<td>Country-specific sources</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>22,495</td>
<td>1,525</td>
<td></td>
</tr>
</tbody>
</table>

Computationally intensive model!
- Multi-threaded simulation (6 cores) ~ 20 mins
- ‘Relay’ simulated annealing
  - Best-fitting hyperparameters are passed to next search chain
Posterior Predictive Checks

Maternal mortality indicators

• Training Set (1990-2015):
  • Coverage probability: 96.0%
  • Mean absolute error by cause: 10.6 deaths

• Testing Set (2016-2020):
  • Coverage probability: 96.0%
  • Mean absolute error by cause: 10.5 deaths
Extended Data Fig. 2: Estimated maternal deaths and MMR by area and country income group, 1990–2050. A. Maternal deaths. B. Maternal mortality ratio (maternal deaths per 100,000 live births). Lines represent means. Shaded areas indicate 95% uncertainty intervals.

Fig. 2 | Projected MMR by country in 2030. Mean projected MMR (maternal deaths per 100,000 live births) by country in 2030.
### Table 2 | Maternal health policy interventions

<table>
<thead>
<tr>
<th>Intervention Description</th>
<th>Modelled implementation</th>
<th>Estimated global mean (95% UI), 2022</th>
<th>2030 target (minimum coverage)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Family planning interventions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contraception</td>
<td>Reduce unmet need through availability and access to contraception for spacing and limiting</td>
<td>Reduce unmet need for contraception. No change in the methods used or desired family size</td>
<td>40.3 (-46.8, -44.0)</td>
</tr>
<tr>
<td>Medical abortion</td>
<td>Reduce mortality due to 'unsafe' abortion through availability and access to safe medical abortion</td>
<td>Increase proportion of abortions that are 'safe'. No change in probability of abortion</td>
<td>89.6% (83.8 - 95.5%)</td>
</tr>
<tr>
<td><strong>Community-based interventions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ANC</td>
<td>Improve health status (for example, prenatal care during pregnancy and knowledge of complications during pregnancy)</td>
<td>Increase probability and number of ANC visits</td>
<td>Pm, 56.8% (42.7 - 78.4%) No. of visits vary: 3.2 (1.4 - 5.0)</td>
</tr>
<tr>
<td>SBAs for home delivery (SBA-home)</td>
<td>Improve availability and accessibility to trained SBA for home births and care of basic interventions by SBA</td>
<td>Increase proportion of home births attended by an SBA, as well as use of clean birth kits to reduce sepsis, and management of moderate hemorrhage. No change in SBA referral probabilities</td>
<td>SBA: 37.1% (27.1 - 52.0%) Clean delivery: 58.2% (46.4 - 69.8%) Hemorrhage management: 87.5%ields (9.8 - 13.6%)</td>
</tr>
<tr>
<td><strong>Facility-based interventions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility births</td>
<td>Increase proportion of women that give birth in medical facilities instead of at home, in order to increase access to scaling levels of obstetrical care depending on the level of the facility</td>
<td>Increase proportion of facility births. No change in distribution of facility levels</td>
<td>83.0% (80.5 - 85.0%)</td>
</tr>
<tr>
<td><strong>Availability of clinical services</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-EmOC services</td>
<td>Improve availability of basic interventions at non-EmOC facilities</td>
<td>Improve availability of clean delivery, active management of the third stage of labor (AMTSL), partograph, assisted delivery for moderate obstructed labor, treatment of eclampsia and pre-eclampsia, moderate hemorrhage and sepsis at SBA facilities. No change in quality of care</td>
<td>Clean delivery: 70.5% (67.8 - 73.2%) AMTSL: 78.6% (71.9 - 85.4%) Parograph: 79.1% (44.7 - 73.2%) Assisted delivery: 52.4% (46.3 - 58.5%) Hypertension management: 93.1% (84.7 - 94.2%) Sepsis management: 79% (62.2 - 86.3%)</td>
</tr>
<tr>
<td>Basic EmOC (BEmOC) facilities</td>
<td>Improve availability of basic interventions at BEmOC facilities</td>
<td>Improve availability of clean delivery, AMTSL, partograph, assisted delivery for moderate obstructed labor, treatment of eclampsia and pre-eclampsia, moderate hemorrhage and sepsis at EmOC facilities. No change in quality of care</td>
<td>Clean delivery: 93.2% (97.2 - 97.2%) AMTSL: 98.3% (90.1 - 98.5%) Parograph: 86.3% (58.3 - 95.2%) Assisted delivery: 46.6% (89.7 - 70.7%) Eclampsia and pre-eclampsia: 92.2% (86.1 - 98.0%) Hypertension management: 66.2% (42.9 - 78.3%) Hemorrhage management: 78.5% (70.9 - 86.7%) Sepsis management: 93% (85.9 - 97.3%)</td>
</tr>
<tr>
<td>Comprehensive EmOC (CEmOC) facilities</td>
<td>Improve the availability of comprehensive set of interventions at CEmOC facilities</td>
<td>Improve availability of clean delivery, AMTSL, partograph, assisted delivery for moderate to severe obstructed labor, treatment of eclampsia and pre-eclampsia, moderate to severe hemorrhage and sepsis at CEmOC facilities. No change in quality of care</td>
<td>Clean delivery: 97.6% (96.5 - 98.6%) AMTSL: 98.5% (94.7 - 98.8%) Parograph: 94.1% (87.1 - 99.7%) Assisted delivery: 94.6% (88.8 - 97.7%) Eclampsia and pre-eclampsia: 97.8% (93.2 - 99.0%) Hypertension management: 92.4% (98.8 - 99.0%) Hemorrhage management: 94.3% (84.2 - 98.9%) Sepsis management: 97.5% (94.5 - 98.9%)</td>
</tr>
</tbody>
</table>

### Table 2 (continued) | Maternal health policy interventions

<table>
<thead>
<tr>
<th>Intervention Description</th>
<th>Modelled implementation</th>
<th>Estimated global mean (95% UI), 2022</th>
<th>2030 target (minimum coverage)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linkages to care</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Referral</td>
<td>Improve recognition and referral of pregnancy complications to health facilities</td>
<td>Increase referral of complications from SBA-home, non-EmOC and BEmOC facilities</td>
<td>SBA-home: 73.3% (71.1 - 75.5%) Non-EmOC: 92.8% (91.1 - 94.3%) BEmOC: 98.6% (98.6 - 99.8%)</td>
</tr>
<tr>
<td>Transportation</td>
<td>Improve availability of timely transportation for women seeking emergency care at a health facility</td>
<td>Increase transportation from home, SBA-home, non-EmOC and BEmOC facilities</td>
<td>Home: 24.0% (22.8 - 25.0%) SBA-home: 61.5% (61.2 - 61.7%) Non-EmOC: 64.4% (64.1 - 64.7%) BEmOC: 97.7% (97.4 - 98.0%)</td>
</tr>
<tr>
<td>Targeted transfers</td>
<td>Improve targetting of referrals to facilities that are a higher level than the current referral site, as opposed to transferring a woman to another facility of the same level (that is, horizontal transfer)</td>
<td>Reduce horizontal transfers</td>
<td>Non-EmOC: 6.3% (2.7 - 5.5%) EmOC: 62.8% (6.8 - 9.1%)</td>
</tr>
</tbody>
</table>

Estimated global means and 95% UIs for 2022 are weighted by population (both counts across countries and demographic subgroups). The 2030 targets are informed by the 2022 estimated means among high-income countries.

### Table 3 | Integrated strategies to reduce maternal mortality

<table>
<thead>
<tr>
<th>Strategy Description</th>
<th>Contraception</th>
<th>Medical abortion</th>
<th>ANC</th>
<th>SBA-home</th>
<th>Facility births</th>
<th>Non-EmOC services</th>
<th>BEmOC services</th>
<th>CEmOC services</th>
<th>Referral</th>
<th>Transportation</th>
<th>Targeted transfers</th>
<th>Quality of care</th>
</tr>
</thead>
<tbody>
<tr>
<td>Family planning</td>
<td>Improve the ability of women to access and use facilities and services</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community</td>
<td>Improve community-based pregnancy care and referral pathway for emergency care at health facilities</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facilities</td>
<td>Increase facility births; improve availability of comprehensive set of interventions at health facilities; improve referral pathway for emergency care at health facilities</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Facilities + quality</td>
<td>Increase facility births; improve availability of comprehensive set of interventions at health facilities; improve referral pathway and quality of care at health facilities</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Comprehensive</td>
<td>Improve family planning, community-based, facility based and system relevant aspects of maternal health</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

#### System-relevant interventions

- **Quality of care**: Improve the quality of care that women receive at health facilities.
- **Comprehensive**: Improve family planning, community-based, facility based and system relevant aspects of maternal health.
Fig. 1 | Projected global MMR according to an integrated strategy. The lines indicate the means, the shaded regions indicate the 95% CIs and the dashed line indicates the SDG target 3.1 of a global MMR of 70 by 2030.

Extended Data Fig. 2 | Projected Reduction in Maternal Deaths 2030–2050 by Region and Integrated Strategy. Reduction is mean percent reduction in projected maternal deaths in 2030–2050 (cumulative) compared to Baseline projections. Horizontal lines indicate 95% uncertainty intervals, calculated as the 2.5 and 97.5 percentiles of the simulation results.

Questions?

www.gmath-model.org