Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

A global analysis of the contribution of maternal mortality to lifetime uncertainty

Ursula Gazeley

ursula.gazeley@ndph.ox.ac.uk

Nuffield Department of Population Health, Oxford, UK https://orcid.org/0000-0003-3309-7411

Jesús Daniel Zazueta-Borboa

University of Oxford

Wen Su

University of Oxford

José Manuel Aburto

University College London

Article

Keywords:

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11624380/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: There is **NO** Competing Interest.

A global analysis of the contribution of maternal mortality to lifetime uncertainty

Ursula Gazeley[1], Jesús Daniel Zazueta-Borboa[1], Wen Su[1], and José Manuel Aburto[2,3]

[1] Leverhulme Centre for Demographic Science, Nuffield Department of Population Health, Nuffield College, University of Oxford, Oxford, United Kingdom

[2] London School of Hygiene & Tropical Medicine, London, United Kingdom

[3] Max Planck Institute for Demographic Research (MPIDR), Rostock, Germany

Correspondence:

Ursula Gazeley, Leverhulme Centre for Demographic Science, Nuffield Department of Population Health, University of Oxford, Oxford, United Kingdom.
Ursula.gazeley@ndph.ox.ac.uk

José Manuel Aburto, London School of Hygiene & Tropical Medicine, London, United Kingdom. Jose.aburto@lshtm.ac.uk

Abstract

Preventable maternal mortality remains a major cause of premature death, particularly in sub-Saharan Africa. Maternal mortality reduces women's life expectancy, yet its contribution to variation in the age of death has not been quantified globally. Using Global Burden of Disease mortality estimates, we provide the first global estimates of its contribution to life expectancy and lifetime uncertainty. In most regions, maternal mortality makes a small contribution to both measures. Sub-Saharan Africa remains the exception. In the highest-burden countries, eliminating maternal mortality may substantially reduce lifetime uncertainty and increase life expectancy from age 10 onwards. Potential reductions in uncertainty exceed gains in life expectancy. Across the maternal mortality transition, the contribution of maternal mortality to both measures declines systematically. These findings reveal an overlooked dimension of inequity in maternal health outcomes: maternal mortality imposes a double burden on women's survival by shortening lives and making the timing of death less predictable.

Introduction

Maternal deaths are largely preventable. Yet an estimated 260,000 women died from maternal causes in 2023, with approximately 70% of these deaths occurring in sub-Saharan Africa.[1] Preventable maternal mortality remains an important indicator of human development and health system functioning, reflecting persistent health system failures and wavering political commitment to save women's lives during pregnancy and childbirth.[2] Inequity continues to characterise maternal survival, and vulnerable populations affected by humanitarian and environmental crises, poverty, and fragile health systems bear a disproportionate burden.[1,3,4]

Maternal mortality occurs in otherwise healthy adult ages when there are few other competing causes of death.[5] At the population-level, these premature deaths reduce reproductive age life expectancy and the potential gains from their elimination remain substantial in sub-Saharan Africa.[6] However, life expectancy captures only one dimension of mortality. As an average measure of age at death, it does not describe how deaths are distributed across a population. Two populations may have comparable life expectancy but differ substantially in their variability of ages at death.[7–9]

Lifetime uncertainty measures variation in the timing of death within a population, capturing a distributional dimension of mortality that is complementary to life expectancy.[7–9] Whereas life expectancy describes average survival, lifetime uncertainty describes the heterogeneity in survival and inequities in premature mortality. Premature deaths typically lower both life expectancy and increase lifetime uncertainty.[7–9] These dynamics mean that maternal mortality may therefore impose a double burden on women's survival by both shortening average length of life and increasing uncertainty in the timing of death.

Although lifetime uncertainty is measured at the population level, the mortality environment it characterises may have consequences for individuals, families and communities.[10–12] Individuals may internalise their surrounding mortality conditions when forming expectations about their own survival and making life course decisions.[11] Evidence from populations exposed to elevated premature mortality risk, including armed conflict and HIV before increased access to antiretrovirals, suggests that the perceived mortality environment can influence demographic and health behaviours, including reproductive choices.[13–15] These perceptions may shorten individuals' time horizons and reduce incentives for investments whose returns accrue in the future, including investments in education and preventive health,[16–20] while also potentially increasing risky behaviours.[21] Premature maternal mortality

and greater uncertainty in reproductive age-survival may therefore impose behavioural responses beyond the individuals and families directly affected by maternal deaths.

Finally, at the societal level, uncertainty in survival during the reproductive ages may make population health needs harder to predict, complicating health-system planning and resource allocation.

Despite its importance, how maternal mortality affects lifetime uncertainty has received little attention. Globally, maternal mortality is among the strongest predictors of overall lifespan inequality.[22] Yet no comparative analysis has quantified the contribution of maternal mortality to lifetime uncertainty across countries. As countries progress through the maternal mortality transition – from high to low maternal mortality, and direct to indirect obstetric causes of maternal death[23,24] – its contribution to lifetime uncertainty would be expected to decline. However, whether this hypothesis holds, how and where it declines across the maternal mortality transition remains unknown.

We present the first cross-country comparative estimates of the contribution of maternal mortality to both life expectancy and lifetime uncertainty. By quantifying how maternal deaths affect average length and variation in women's lifespans, we provide a more comprehensive assessment of global maternal mortality and its contribution to health inequality.

Results

Global and regional estimates in 2023

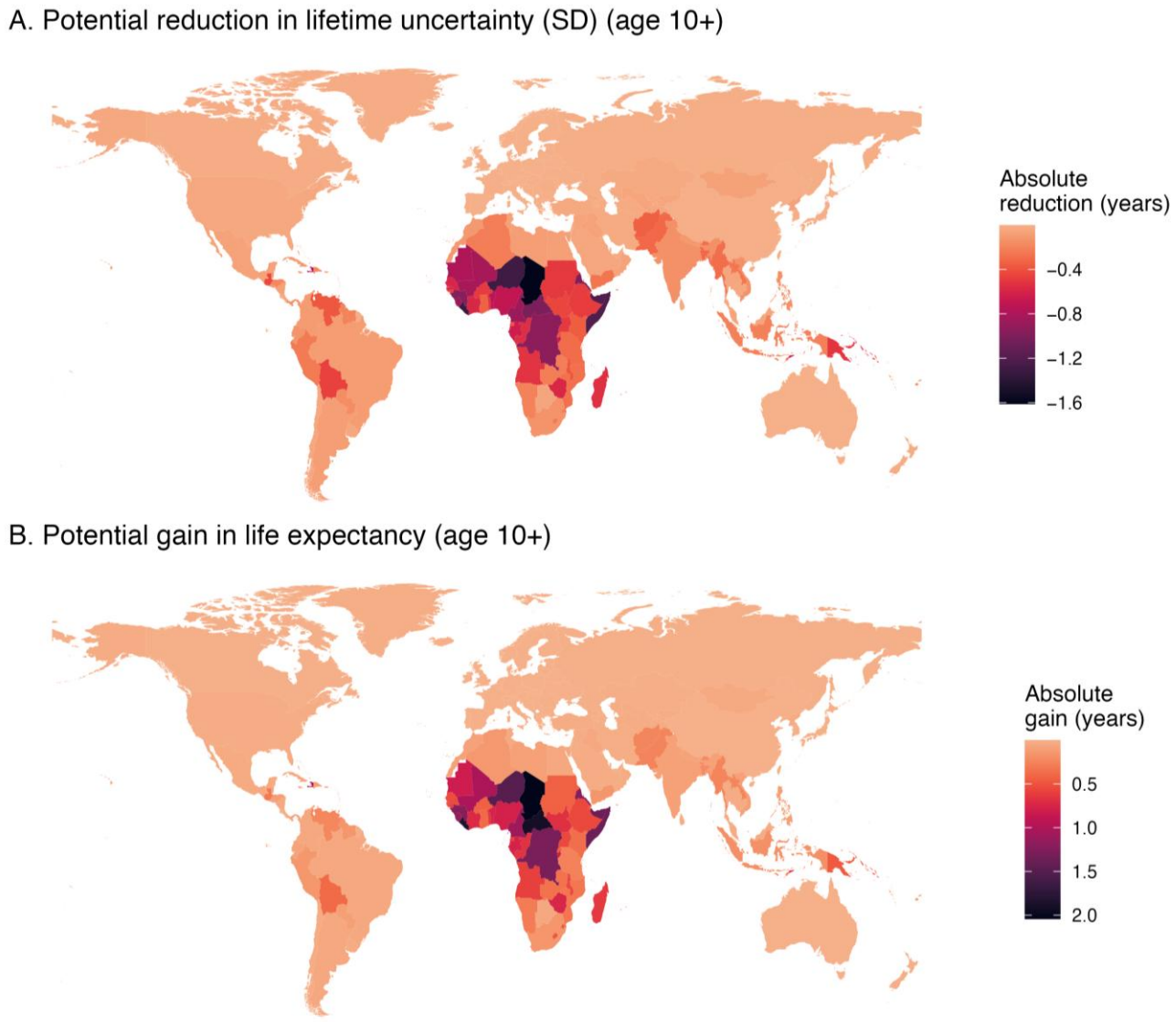
Figure 1 presents global estimates of the impact of maternal mortality on life expectancy and lifetime uncertainty (standard deviation of age at death) from age 10 and above in 2023. Full country-level results are provided in Table S1 (appendix pp.2-6). Panel A shows the absolute potential gains in life expectancy and reductions in lifetime uncertainty that would result from the elimination of maternal causes of death, while relative changes are presented in Figure S1 (appendix p.7). Across countries, the contribution of maternal mortality to life expectancy and lifetime uncertainty were highly correlated, with countries experiencing the largest gains in life expectancy also showing the greatest reductions in lifetime uncertainty.

The potential gain in life expectancy from eliminating maternal mortality was greatest in Chad, with an estimated 2 years, equivalent to a 3.6% increase from age 10 and above. In total, 11 countries had an estimated potential gain in life expectancy exceeding one year, all of which are in sub-Saharan Africa. 35 countries had estimated gains of at least 0.5 years, all located in sub-Saharan Africa except Haiti (Latin America and the Caribbean), Timor-Leste and the Solomon Islands (Southeast Asia, East Asia, and Oceania).

The largest potential reduction in lifetime uncertainty was again observed in Chad, where eliminating maternal mortality would reduce lifetime uncertainty from age 10 and above by 1.6 years, corresponding to an 8.5% reduction. In total, five countries had an estimated potential reduction in lifetime uncertainty of at least one year, and 28 countries had a potential reduction exceeding half a year, all in sub-Saharan Africa, except Haiti, Timor-Leste, and Papua New Guinea. Relative reductions in lifetime uncertainty exceeded 5% in Chad, Liberia, Niger, Somalia, and the Central African Republic, while 39 countries had potential reductions of at least 2.5%, 31 of which are in sub-Saharan Africa.

Results by GBD super region are presented in Table 1. In 2023, the contribution of maternal mortality to life expectancy is small in all regions except Sub-Saharan Africa, where its elimination would result in a potential gain of 0.72 years, equivalent to approximately 9 months of life expectancy from age 10 years. Its elimination would reduce lifetime uncertainty by an estimated 0.62 years, or over 3% of total variation in ages of death from age 10.

Figure 1. Absolute potential change in life expectancy and lifetime uncertainty with the elimination of maternal mortality, 2023



Note: no GBD data for Western Sahara

Table 1. Potential gains in life expectancy and reductions in lifetime uncertainty with elimination of maternal mortality by GBD super region

GBD super region	MMR[a]	Life expectancy (age 10+)			Lifetime uncertainty (SD[b], age 10+)		
		Observed	Maternal mortality eliminated	Difference (relative change)	Observed	Maternal mortality eliminated	Difference (relative change)
Central Europe, Eastern Europe, and Central Asia	14	69.93	69.95	0.01 years (0.02%)	13.26	13.24	-0.02 years (-0.16%)
High-income	20	74.11	74.13	0.01 years (0.02%)	12.68	12.65	-0.03 years (-0.22%)
Latin America and Caribbean	120	70.49	70.61	0.11 years (0.16%)	14.58	14.39	-0.18 years (-1.26%)
North Africa and Middle East	80	67.19	67.28	0.09 years (0.13%)	13.24	13.10	-0.14 years (-1.07%)
South Asia	138	65.15	65.28	0.13 years (0.20%)	14.43	14.25	-0.19 years (-1.30%)
Southeast Asia, East Asia, and Oceania	89	71.41	71.47	0.06 years (0.09%)	13.36	13.24	-0.12 years (-0.89%)
Sub-Saharan Africa	396	60.91	61.63	0.72 years (1.18%)	18.68	18.06	-0.62 years (-3.33%)

[a] MMR = Maternal mortality ratio

[b] SD = Standard deviation

1

2

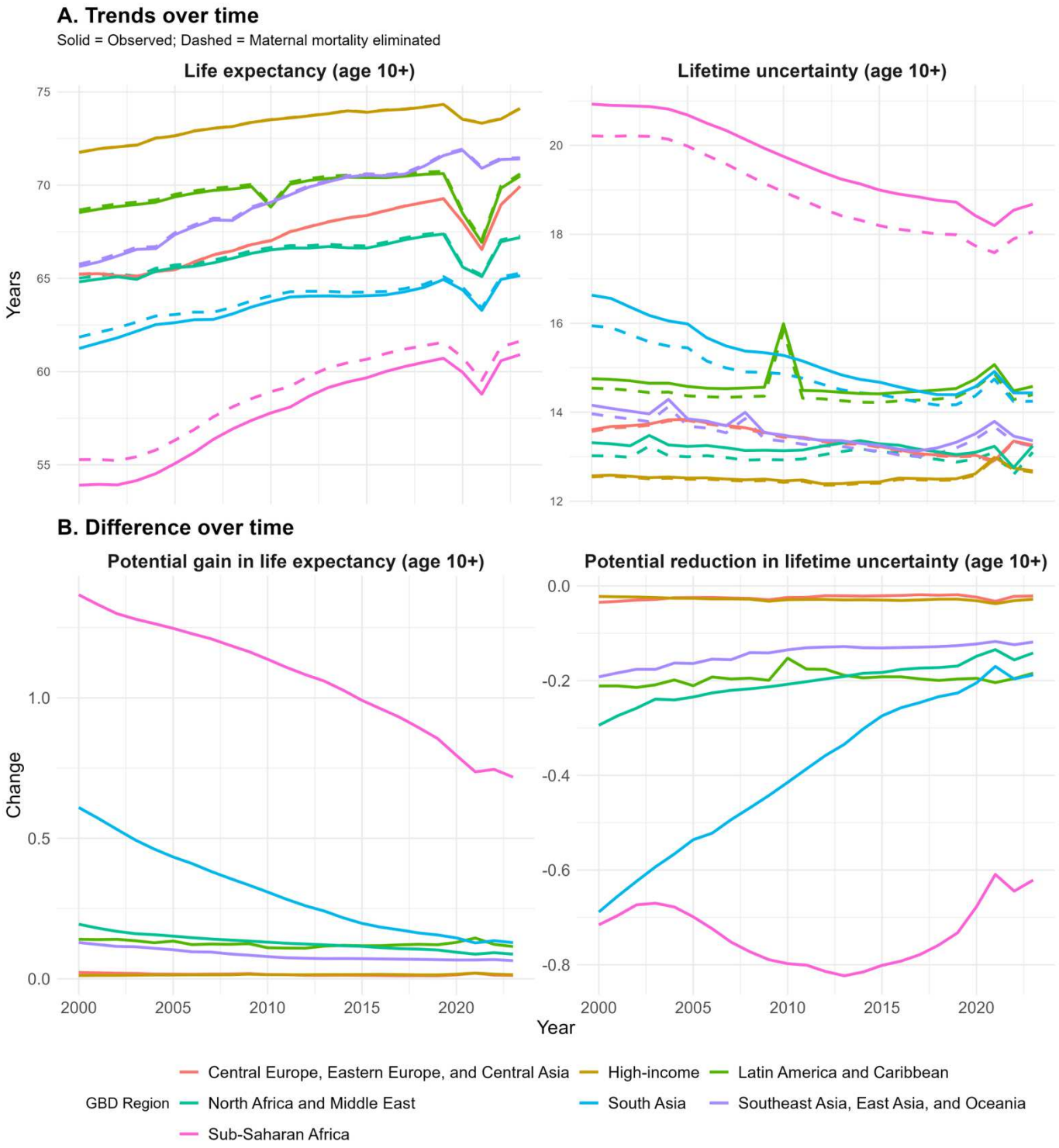
Regional trends from 2000 to 2023

Figure 2 shows the potential impact of eliminating maternal mortality on life expectancy and lifetime uncertainty from age 10 between 2000 and 2023 across GBD super regions.

Panel A presents observed trends (solid lines) alongside a counterfactual scenario in which maternal mortality is eliminated (dashed lines). Across all regions, the observed and counterfactual trajectories converge over time, reflecting the declining contribution of maternal mortality to overall reproductive age mortality. In almost all regions, life expectancy declined and lifetime uncertainty increased in 2020 and 2021, before starting to rebound.

Panel B quantifies the corresponding gains in life expectancy and reductions in lifetime uncertainty associated with eliminating maternal mortality. In all regions except sub-Saharan Africa, these potential improvements declined over the study period as maternal mortality fell. By 2023, most regions exhibited only modest remaining gains in both outcomes. In contrast, sub-Saharan Africa saw a larger potential reduction in lifetime uncertainty between 2003 and 2013 than previous period. Although this declined thereafter, eliminating maternal mortality in 2023 would still produce a substantial reduction in lifetime uncertainty.

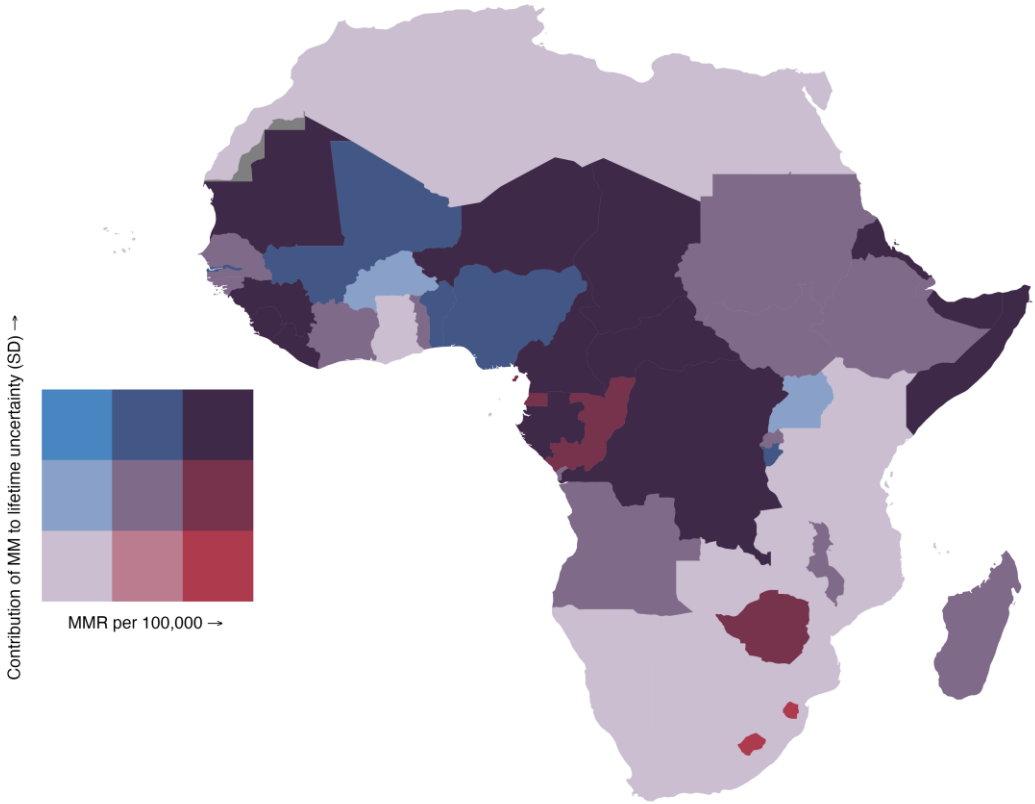
Figure 2. Life expectancy and potential gains, lifetime uncertainty and potential reductions, from the elimination of maternal mortality by GBD super region, 2000-2023



Dynamics of the maternal mortality transition

Figure 3 shows the relationship between the maternal mortality ratio (MMR) and the potential reduction in lifetime uncertainty that would result from eliminating maternal mortality across African countries. Countries are classified into tertiles for each measure. For most countries, the two measures are concordant: countries with higher MMRs tend to have larger potential reductions in lifetime uncertainty from eliminating maternal mortality. However, important differences emerge in some countries. Countries shown in red, including Eswatini, Lesotho, Zimbabwe, and the Republic of the Congo have relatively high MMRs but smaller potential reductions in lifetime uncertainty. Conversely, countries shown in blue, including Mali, Burkina Faso, Benin, Nigeria, and Uganda, have relatively low MMRs but larger potential reductions in lifetime uncertainty.

Figure 3. Relationship between maternal mortality ratio (MMR) and the potential reduction in lifetime uncertainty from eliminating maternal mortality in Africa, 2023.

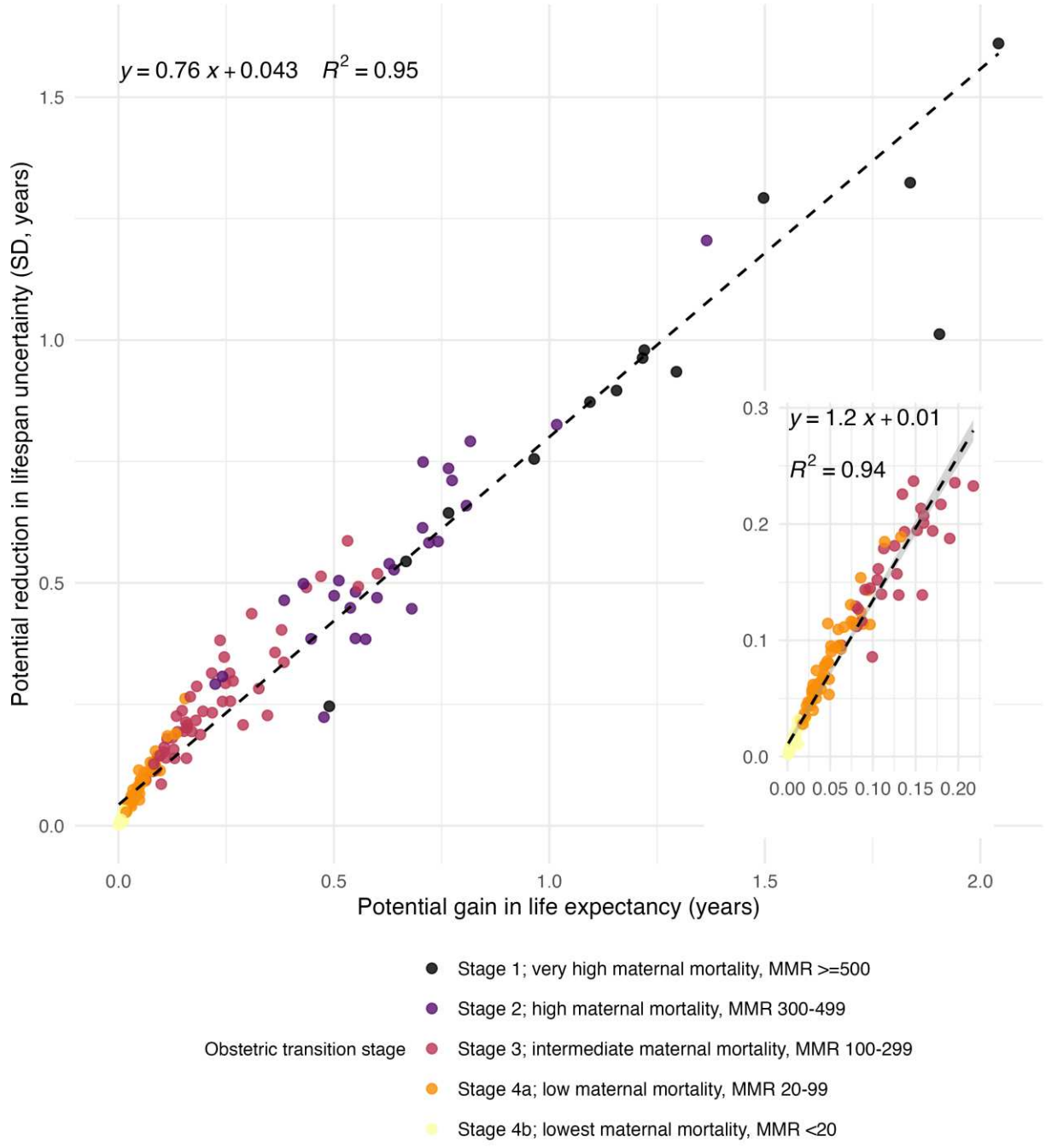


Notes: no GBD data for Western Sahara. MM = maternal mortality; SD = standard deviation; Tertiles were defined separately for the maternal mortality ratio (MMR) (low, <290; medium, 290–440; high, >440 deaths per 100,000 live births) and the potential reduction in lifetime uncertainty with the elimination of maternal mortality (low, <0.36; medium, 0.36–0.59; high, >0.59 years).

Figure 4 shows the relationship between the potential contribution of eliminating maternal mortality to life expectancy and lifetime uncertainty from age 10, with countries classified by their stage in the maternal mortality transition according to MMR.[23,24] There is a strong, approximately linear positive association between potential gains in life expectancy and reductions in lifetime uncertainty. Countries in stages 1 and 2, characterised by the highest MMRs, exhibit the largest potential gains in life expectancy and the greatest reductions in lifetime uncertainty from eliminating maternal mortality. As countries advance through the maternal mortality transition and the MMR declines, these potential benefits diminish, reflecting longer average lifespans and lower uncertainty in the timing of death from age 10 and above.

Relative changes are shown in Figure S2 (appendix p.8). Across all stages of the maternal mortality transition, the elimination of maternal deaths results in a potential relative reduction in total lifetime uncertainty which exceeds the relative gain in life expectancy.

Figure 4. Absolute potential gain in life expectancy and potential reduction in lifetime uncertainty (age 10+) by countries' stage in maternal mortality transition.



Finally, Table 2 summarises countries by stage of the maternal mortality transition, together with the mean potential gains in life expectancy and potential reductions in lifetime uncertainty that would result from eliminating maternal mortality. Countries in stage 1 of the transition (MMR >500), comprising 13 countries in sub-Saharan Africa in 2023, would gain, on average, 1.24 additional years of life expectancy (95% CI 0.95–1.53) and experience a reduction in lifetime uncertainty of 0.93 years (95% CI 0.72–1.14) if maternal mortality were eliminated. These potential benefits decline progressively across the transition. In stage 2, the corresponding gains are 0.63 years of life expectancy and a 0.55-year reduction in lifetime uncertainty, falling to 0.22 and 0.25 years, respectively, in stage 3. By stage 4b (MMR <20), the remaining potential gains in both life expectancy and lifetime uncertainty from the elimination of maternal mortality are small at the population-level.

Table 2. Potential gain in life expectancy and reduction in lifetime uncertainty from eliminating maternal mortality across stages of the maternal mortality transition

Maternal mortality transition stage	Potential gain in life expectancy from age 10+, mean years (95% CI)	Potential reduction in lifetime uncertainty from age 10+ (SD[c]) mean years (95% CI)	Countries
Stage 1; very high maternal mortality, MMR >=500	+1.24 (0.95–1.53)	−0.93 (0.72–1.14)	Cameroon, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Eritrea, Gabon, Guinea, Haiti, Lesotho, Liberia, Niger, Sierra Leone
Stage 2; high maternal mortality, MMR 300-499	+0.63 (0.54–0.72)	−0.55 (0.47–0.63)	Benin, Bhutan, Bolivia (Plurinational State of), Burundi, Côte d'Ivoire, Djibouti, Equatorial Guinea, Eswatini, Ethiopia, Gambia, Guinea-Bissau, Madagascar, Malawi, Mali, Mauritania, Nauru, Nigeria, Northern Mariana Islands, Rwanda, Solomon Islands, Somalia, South Sudan, Sudan, Timor-Leste, Togo, Zimbabwe
Stage 3; intermediate maternal mortality, MMR 100-299	+0.22 (0.18–0.26)	−0.25 (0.22–0.29)	Afghanistan, Algeria, American Samoa, Angola, Antigua and Barbuda, Bahamas, Bangladesh, Burkina Faso, Dominica, Dominican Republic, Fiji, Ghana, Grenada, Guam, Guatemala, Guyana, India, Indonesia, Kenya, Kiribati, Lao People's Democratic Republic, Libya, Marshall Islands, Micronesia (Federated States of), Morocco, Mozambique, Myanmar, Namibia, Niue, Pakistan, Palau, Papua New Guinea, Paraguay, Peru, Philippines, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Sao Tome and Principe, Senegal, South Africa, Suriname, Tokelau, Tonga, Trinidad and Tobago, Tuvalu, Uganda, United Republic of Tanzania, United States Virgin Islands, Venezuela (Bolivarian Republic of), Zambia
Stage 4a; low maternal mortality, MMR 20-99	+0.05 (0.04–0.06)	−0.08 (0.07–0.10)	Argentina, Bahrain, Barbados, Belize, Bermuda, Botswana, Brazil, Brunei Darussalam, Cabo Verde, Cambodia, Chile, Colombia, Comoros, Costa Rica, Cuba, Democratic People's Republic of Korea, Ecuador, Egypt, El Salvador, Georgia, Greenland, Honduras, Iran (Islamic Republic of), Iraq, Jamaica, Jordan, Kyrgyzstan, Lebanon, Malaysia, Maldives, Mauritius, Mexico, Mongolia, Nepal, Nicaragua, Oman, Panama, Puerto Rico, Saint Lucia, Samoa, Saudi Arabia, Seychelles, Sri Lanka, Syrian Arab Republic, Thailand, Tunisia, Türkiye, United States of America, Uruguay, Uzbekistan, Vanuatu, Viet Nam, Yemen
Stage 4b; lowest maternal mortality, MMR <20	+0.01 (0.00–0.01)	−0.01 (0.01–0.01)	Albania, Andorra, Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, China, Cook Islands, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Kazakhstan, Kuwait, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands, New Zealand, North Macedonia, Norway, Palestine, Poland, Portugal, Qatar, Republic of Korea, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, Tajikistan, Turkmenistan, Ukraine, United Arab Emirates, United Kingdom

[a] Maternal mortality ratio (MMR); [b] Confidence interval (CI); [c] Standard deviation (SD)

Age-specific contribution of eliminating maternal mortality

Figure S3 shows the contribution of maternal deaths in each age group to the potential gains in life expectancy and reductions in lifetime uncertainty following the elimination of maternal mortality, by GBD super region (appendix p.9). Age patterns were remarkably consistent across super regions, despite substantial differences in the absolute magnitude of the gains. In all regions, the largest contributions came from maternal deaths occurring at ages 15–19 years, followed by ages 10–14 and 20–24 years. Although maternal mortality rates are relatively low among the youngest age groups, deaths at these ages contribute disproportionately to potential gains in life expectancy and reductions in lifetime uncertainty, reflecting the large number of years of life lost when maternal deaths occur at younger ages.

Sensitivity results

Sensitivity analyses produced broadly consistent results. First, using WHO rather than GBD maternal mortality level estimates yielded similar results for most countries. The maximum difference was 9% in Afghanistan in the relative change in lifetime uncertainty with the elimination of maternal mortality between two data sources, but in most places was below 1%. (Table S2, appendix pp.10-14). Discrepancy was generally higher in countries in high burden MMR settings, where CRVS data are weak and maternal mortality estimates are primarily model driven. Second, results were robust to the choice of lifetime uncertainty measure, with similar country-level patterns using the standard deviation, life disparity, and coefficient of variation (Table S3, appendix pp.15-22). Third, conditioning on survival to age 15 rather than age 10 produced very similar results (Table S4, appendix pp.23-27). Finally, applying reductions in maternal mortality consistent with Ending Preventable Maternal Mortality (EPMM) targets rather than complete elimination produced similar patterns, although the potential reduction in lifetime uncertainty if the EPMM targets were achieved was slightly smaller than with complete elimination of maternal deaths in countries with high MMRs (Table S5, appendix pp.28-32).

Discussion

Most maternal deaths are preventable and occur among women of reproductive age, a period of the life course when the overall hazard of mortality is otherwise relatively low. This is the first study to quantify, across all countries and regions, the potential contribution of eliminating maternal mortality to both gains in life expectancy and reductions in lifetime uncertainty. Our findings reveal a previously overlooked double burden: in settings where maternal mortality remains high, premature maternal deaths not only shorten women's lives but also make the length of life less predictable.

In most world regions, maternal mortality now makes only a small contribution to life expectancy and lifetime uncertainty. Sub-Saharan Africa remains the clear exception. In 2023, eliminating maternal mortality across the region would result in a potential increase in life expectancy at age 10 of almost nine months, and reduction in lifetime uncertainty of over seven months. These regional estimates, however, mask substantial country-level heterogeneity. The largest effects were estimated in Chad, where eliminating maternal mortality would result in potential reductions of lifetime uncertainty by up to 1.6 years (8.5% relative reduction) and increase life expectancy at age 10 by 2 years (3.6% relative increase). Potential reductions in lifetime uncertainty exceeded 0.5 years in 28 countries, 25 of which were in sub-Saharan Africa; potential gains in life expectancy exceeded 0.5 years in 35 countries, 32 of which were in sub-Saharan Africa.

The substantial country-level variation in the contribution of maternal mortality is consistent with heterogeneity in life expectancy and lifetime uncertainty trajectories across sub-Saharan Africa.[25] Moreover, in most countries in sub-Saharan Africa, the relative reduction in lifetime uncertainty following elimination of maternal mortality was greater than the relative increase in life expectancy. This indicates that maternal mortality disproportionately affects the predictability of age at death relative to average longevity. Considering lifetime uncertainty alongside life expectancy therefore captures an important dimension of the mortality burden of preventable maternal deaths that longevity alone may obscure.[7,9,26]

The magnitude of these effects is substantial for a single level 2 cause category.[27] For comparison, between 1990 and 2021, reductions in enteric infections contributed up to 1.9 years to gains in life expectancy in sub-Saharan Africa, while reductions in ischaemic heart disease contributed around 1.8 years in high-income settings.[28] The relative contribution of maternal mortality to lifetime uncertainty in the highest burden countries is comparable to the contribution of homicides to male lifetime uncertainty in several African countries.[12] That maternal disorders can have effects of this magnitude is notable because maternal deaths

account for a relatively small share of deaths, even in high-burden settings. This illustrates that a cause need not account for a large share of deaths to make a significant contribution to lifetime uncertainty because its contribution also depends on the ages at which deaths occur and the age structure of the population.[29] The concentration of maternal deaths at younger adult ages may therefore help explain the magnitude of these effects.

Our findings advance the maternal mortality transition framework by showing how declining maternal mortality is accompanied by changes in both the length and predictability of life. The maternal mortality transition has been characterised by the long-term shift from high to low levels of maternal mortality and from predominantly direct to increasingly indirect obstetric causes of death.[23,24,30] As countries progress through the transition, the MMR declines, as does the contribution of maternal mortality to lifetime uncertainty and life expectancy. The consistency of these patterns across settings suggests that changes in lifetime uncertainty and life expectancy represent complementary characteristics of the maternal mortality transition, alongside changes in the level of maternal mortality and its cause composition.

Substantial improvements do not require the complete elimination of maternal mortality. Among high-burden countries with an MMR above 420 maternal deaths per 100,000 live births in 2010, reducing the MMR to below 140 in line with the existing EPMM target for these settings[31,32] would yield gains in life expectancy and reductions in lifetime uncertainty comparable in magnitude to those estimated under a scenario of complete elimination. Achieving existing global commitments to improve maternal survival could therefore substantially improve both the length and predictability of women's lives, particularly in sub-Saharan Africa.

Yet many high-burden countries remain significantly off track to reach the global SDG target 3.1 and their national maternal mortality targets by 2030.[1,2] Despite more than a decade of global efforts, the potential gains in life expectancy in sub-Saharan Africa for 2023 remain comparable to those reported before the start of the SDG era.[6] Our findings show that this stalled progress in maternal survival also leaves potential reductions in lifetime uncertainty unrealised, revealing a dimension of reproductive health inequity that life expectancy alone does not capture. This is relevant beyond SDG 3.1, including to commitments to universal health coverage under SDG 3.8 and reducing inequalities under SDG 10.[33] Against a backdrop of contracting global health financing and growing threats to maternal health, these findings reinforce the importance of sustained political and financial commitment to maternal health programmes and the data systems required to monitor progress.[34–36]

Finally, discrepancies in our estimates of lifetime uncertainty and life expectancy when using GBD and WHO maternal mortality estimates are greatest in high MMR settings with limited empirical input data where modelled estimates are primarily covariate driven. This emphasises the urgent and continued need to strengthen CRVS systems in low resource settings. Vital registration remains the gold standard for identifying maternal deaths, but sustained investment and capacity-building are needed to improve the completeness of CRVS systems, reduce the misclassification of maternal deaths, and ensure consistent application of ICD-11 coding standards.[34,37–39] Improving the availability and quality of empirical data is essential for reducing uncertainty in estimates of maternal mortality and, consequently, in estimates of its contribution to broader mortality dynamics.

An important strength of this study is the global scope, including all countries and GBD regions, with standardised and comparable estimates of the contribution of maternal mortality to life expectancy and lifetime uncertainty. We also compared several indicators of lifetime uncertainty, and the results are robust to the choice of measure. Ours is also one of the first papers to emphasise substantial lifetime uncertainty across women's lives, with most existing work highlighting greater lifetime uncertainty for men.[12]

However, this study also has several limitations. First, our estimates are only so good as the input data. Age-specific all cause and maternal mortality rates from GBD are primarily modelled for many low-income countries with poor CRVS systems and limited input data. This underscores the need to strengthen CRVS systems, including the registration of deaths and medical certification of the cause of death.[38,40] Second, the GBD estimates of the MMR are not consistent with the ICD-11 definition, which includes deaths only up to 42 days postpartum. Third, life expectancy and lifetime uncertainty are period measures, assuming current mortality levels remain constant, and do not reflect the survival of a real cohort of women. Fourth, cause-deleted life tables assume that women whose maternal deaths are prevented subsequently experience the same age-specific mortality risks as other survivors. If these women remain at elevated risk of death from other causes, our estimates may overstate potential gains. Conversely, they may understate gains if preventing maternal deaths also reduces subsequent mortality, for example through improved detection, treatment or continuity of care.

Conclusion

Maternal mortality continues to impose a substantial burden on women's survival in sub-Saharan Africa, shortening lives while increasing uncertainty in the age of death. By quantifying lifetime uncertainty alongside life expectancy, our findings reveal persistent global health inequity and an overlooked dimension of the maternal mortality transition.

Methods

All analyses were conducted using R and are fully reproducible from open data. All code is available at: https://osf.io/2rxy3/overview?view_only=7dcfecd193a24557812d41df1c0022a3

Data

We used publicly available, open-access age-specific estimates of all-cause mortality and mortality from maternal disorders for 204 countries and territories from the Global Burden of Diseases (GBD) study, produced by the Institute of Health Metrics and Evaluation (IHME).[27] Regions were grouped according to the seven GBD Super Regions (High Income; Central Europe, Eastern Europe, and Central Asia; Latin America and the Caribbean; North Africa and the Middle East; South Asia; Southeast Asia, East Asia and Oceania, and sub-Saharan Africa).

These analyses required age-specific estimates on all-cause and maternal mortality. GBD provides the only globally comparable, standardised age-specific estimates of maternal mortality between the ages 10-54 years, whereas WHO estimates are available only for the combined reproductive age range.[1] Estimates are primarily covariate driven in low resource settings with weak civil registration and vital statistics systems (CRVS) where input data are scarce. A summary of the GBD modelling approach for deaths from maternal disorders, which is particularly relevant for results pertaining to low resource settings, is available elsewhere,[41] along with further details on the GBD methodology.[27] Comparison and cross-validation of WHO and GBD maternal mortality estimates highlight key differences in estimates arise from how input data are adjusted for bias, how deaths among HIV-positive pregnant women are classified, and the specifications of statistical models.[37,42] Nonetheless, we assessed the sensitivity of our results to the choice of global estimates (see Sensitivity Table S2).

GBD include 10 sub-categories within "maternal disorders": (1) maternal haemorrhage; (2) maternal sepsis and other maternal infections; (3) maternal hypertensive disorders; (4) maternal obstructed labour and uterine rupture; (5) maternal abortion and miscarriage; (6) ectopic pregnancy; (7) other direct maternal disorders; (8) indirect maternal deaths; (9) maternal deaths aggravated by HIV/AIDS; (10) late maternal deaths. These subcategories do not correspond directly with the International Classification of Diseases-Maternal Mortality (ICD-MM) grouping schedule.[43] Most notably, the GBD maternal disorders category includes late maternal deaths in the overall maternal mortality ratio (MMR) estimate, whereas these are excluded from the ICD definition of maternal death and hence also the WHO definition of the MMR.[24] However, to quantify the contribution of maternal mortality to life expectancy and lifetime uncertainty, including maternal deaths occurring within 42 days as well as late

maternal deaths from 43 days to one year postpartum is a more comprehensive approach than limiting to deaths occurring up to 42 days postpartum.

Measures of lifetime uncertainty

Lifetime uncertainty is reflected in the variation in the age-at-death distribution, derived from a life table. We chose the standard deviation conditional on surviving to age 10 as the main indicator of uncertainty because it is expressed in years which aids interpretability alongside life expectancy. Several other measures of uncertainty exist that are highly correlated but differ in their sensitivity to deaths occurring at different ages. [7,44,45] We also replicated all results with life disparity (absolute measure) and the coefficient of variation (relative measure) to assess the robustness of the results to our choice of lifetime uncertainty indicator (see Sensitivity Table S3).

Estimation of life expectancy and lifetime uncertainty from age 10

We estimated the potential contribution of eliminating maternal mortality to life expectancy and lifetime uncertainty conditional on survival to age 10, the youngest age at which the GBD study estimates deaths from maternal disorders. Conditioning on survival to age 10 improves cross-country comparability by excluding variation in early-childhood mortality, allowing differences in the measure to more clearly reflect maternal rather than childhood mortality. .[6,46] Although maternal deaths occur during the reproductive years, they affect survival and lifetime uncertainty in the age-at-death distribution throughout the remainder of women's lives, not only up to the end of the reproductive period. We test the sensitivity of our results to conditioning on survival to age 10 versus age 15, which is the lower bound of maternal mortality used in WHO estimates (see Sensitivity Table S4).

Statistical methods

GBD mortality rates are provided in five-year age. We used natural cubic splines to estimate single-year age-specific death rates, providing greater resolution of the age-at-death distribution.[47,48] We subsequently constructed life tables by country and GBD super regions using standard methods.[49] From these, we derived life expectancy and indicators of lifetime uncertainty. Estimates based on smoothed single-year death rates closely reproduced the temporal trends and spatial patterns observed using five-year age groups.

We used a cause-deleted life table approach to quantify the effect of the elimination of maternal mortality to life expectancy and lifetime uncertainty. We constructed a counterfactual mortality age-profile where maternal mortality has been eliminated from the all-cause mortality. We compare the resulting life expectancy and lifetime uncertainty estimates with their respective values using observed all-cause mortality rates. From this

comparison, we estimate the absolute and relative change in life expectancy and lifetime uncertainty resulting from the elimination of maternal mortality by country and by GBD super region. The cause-deleted life-table approach assumes that eliminating maternal causes of death does not alter mortality rates from other causes.[50] Our estimates therefore represent hypothetical gains under cause elimination rather than predicted effects of an intervention, which may also affect the risk of death from other causes.

Counterfactual scenarios

For our primary analyses, we estimated the potential contribution of the complete elimination of preventable maternal mortality to life expectancy and lifetime uncertainty. Complete elimination represents an aspirational scenario not yet achieved by any country (maternal mortality transition stage 5; see below). We therefore conducted an additional analysis using the national-level Ending Preventable Maternal Mortality (EPMM) targets developed to support achievement of the Sustainable Development Goal (SDG) global target, to define scenarios based on established policy targets (see Sensitivity Table S5). EPMM commitments are as follows: (1) For countries with MMR less than 420 in 2010: reduce the MMR by at least two thirds from the 2010 baseline by 2030; (2) For all countries with baseline MMR greater than 420 in 2010: no country has an MMR greater than 140; (3) For all countries with low baseline MMR in 2010: achieve equity in MMR for vulnerable populations at the subnational level.[31] Hence, based on countries' estimated MMR in 2010, we used the counterfactual target of 140 for high-MMR countries, unless they had already achieved an MMR below 140 by 2023, in which case, we assigned their counterfactual as one-third of their 2010 MMR because assessing subnational inequity (EPMM 3) was not possible.

Dynamics of maternal mortality transition

We examined how maternal mortality's contribution to life expectancy and lifetime uncertainty varies across the maternal mortality transition. First, we compared the magnitude of changes in life expectancy and lifetime uncertainty according to countries' stage, classified as follows: stage 1 very high maternal mortality: MMR >500; stage 2 high maternal mortality: MMR 300-499; stage 3 intermediate maternal mortality: MMR 100-299; stage 4a low maternal mortality: MMR 20-99; and stage 4b lowest maternal mortality: MMR <20. No countries have reached the hypothetical stage 5, such that all preventable maternal mortality has been eliminated (MMR=0).[23] Second, given the central role of MMR in monitoring progress towards SDG 3.1, we compared its geographical distribution with that of the potential reduction in lifetime uncertainty from eliminating maternal mortality, classifying high-burden African countries into low, medium and high tertiles for each measure.

Ethics

These analyses used publicly available secondary, aggregated data fully available in the public domain and was therefore exempt from ethical approval as per the University of Oxford's ethical review protocol.

Declarations

Contributors

UG conceived the idea of the study and drafted the initial manuscript. UG, JDZB and WS developed the code and built the code repository. JDZB, WS and JMA contributed to the interpretation of results and revised the article. UG, JDZB, and WS accessed and verified the data. All authors had full access to the data in the study and had final responsibility for the decision to submit for publication.

Data sharing

IHME Global Burden of Disease data are available from: https://vizhub.healthdata.org/gbd-results/

WHO UN Joint Agency maternal mortality estimates are available from: https://www.who.int/publications/i/item/9789240108462

All code is available at: https://osf.io/2rxy3/overview?view_only=7dcfecd193a24557812d41df1c0022a3

Declaration of interests

We declare no competing interests.

Funding

UG was supported by UK Research and Innovation (EP/Y031172/1). WS and JDZB were supported by the European Research Council (ERC-2021-CoG-101002587 (MORTAL)). UG, WS, and JDZB were supported by the Leverhulme Trust (RC-2018-003) for the Leverhulme Centre for Demographic Science. JMA was supported by the Wellcome Trust (07859/Z/23/Z).

References

1. World Health Organization. Trends in maternal mortality estimates 2000 to 2023: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division [Internet]. Geneva; 2025 [cited 2025 Apr 24]. Available from: https://iris.who.int/bitstream/handle/10665/381012/9789240108462-eng.pdf?sequence=1

2. Khalil A, Samara A, O'Brien P, Coutinho CM, Quintana SM, Ladhani SN. A call to action: the global failure to effectively tackle maternal mortality rates. The Lancet Global Health. 2023 Aug 1;11(8):e1165–7. doi:10.1016/S2214-109X(23)00247-4 PubMed PMID: 37474218.

3. Graham W, Woodd S, Byass P, Filippi V, Gon G, Virgo S, et al. Diversity and divergence: the dynamic burden of poor maternal health. The Lancet. 2016 Oct;388(10056):2164–75. doi:10.1016/S0140-6736(16)31533-1

4. United Nations Secretary General. The road to dignity by 2030: ending poverty, transforming all lives and protecting the planet. Synthesis report of the secretary-general on the post-2015 agenda [Internet]. New York: United Nations; 2014 [cited 2026 Jul 28]. Available from: https://www.un.org/disabilities/documents/reports/SG_Synthesis_Report_Road_to_Dignity_by_2030.pdf

5. Nove A, Matthews Z, Neal S, Camacho AV. Maternal mortality in adolescents compared with women of other ages: evidence from 144 countries. The Lancet Global Health. 2014 Mar 1;2(3):e155–64. doi:10.1016/S2214-109X(13)70179-7

6. Canudas-Romo V, Liu L, Zimmerman L, Ahmed S, Tsui A. Potential Gains in Reproductive-Aged Life Expectancy by Eliminating Maternal Mortality: A Demographic Bonus of Achieving MDG 5. PLOS ONE. 2014 Feb 13;9(2):e86694. doi:10.1371/journal.pone.0086694

7. Aburto JM, Villavicencio F, Basellini U, Kjærgaard S, Vaupel JW. Dynamics of life expectancy and life span equality. Proceedings of the National Academy of Sciences. 2020 Mar 10;117(10):5250–9. doi:10.1073/pnas.1915884117

8. Seligman B, Greenberg G, Tuljapurkar S. Equity and length of lifespan are not the same. Proceedings of the National Academy of Sciences. 2016 Jul 26;113(30):8420–3. doi:10.1073/pnas.1601112113

9. United Nations Department of Economic and Social Affair. Statistics Division. On the importance of monitoring inequality in life expectancy. Poolicy Brief No. 1456. [Internet]. 2022. Available from: https://social.desa.un.org/sites/default/files/publications/2023-03/PB_145.pdf

10. Dormont B, Samson AL, Fleurbaey M, Luchini S, Schokkaert E. Individual Uncertainty About Longevity. Demography. 2018 Oct;55(5):1829–54. doi:10.1007/s13524-018-0713-4 PubMed PMID: 30242662.

11. Nepomuceno MR, Cui Q, van Raalte A, Aburto JM, Canudas-Romo V. The Cross-sectional Average Inequality in Lifespan (CAL†): A Lifespan Variation Measure That Reflects the Mortality Histories of Cohorts. Demography. 2022 Feb 1;59(1):187–206. doi:10.1215/00703370-9637380 PubMed PMID: 34851396.

12. Aburto JM, di Lego V, Riffe T, Kashyap R, van Raalte A, Torrisi O. A global assessment of the impact of violence on lifetime uncertainty. Science Advances. 2023 Feb 3;9(5):eadd9038. doi:10.1126/sciadv.add9038

13. Thiede BC, Hancock M, Kodouda A, Piazza J. Exposure to Armed Conflict and Fertility in Sub-Saharan Africa. Demography. 2020 Dec;57(6):2113–41. doi:10.1007/s13524-020-00923-2 PubMed PMID: 33067758; PubMed Central PMCID: PMC8141372.

14. Hayford SR, Agadjanian V, Luz L. Now or Never: Perceived HIV Status and Fertility Intentions in Rural Mozambique. Stud Fam Plann. 2012 Sep;43(3):191–9. doi:10.1111/j.1728-4465.2012.00317.x PubMed PMID: 23185862; PubMed Central PMCID: PMC3662548.

15. Ainsworth M, Filmer D, Semali I. Chapter 5. The Impact of AIDS Mortality on Individual Fertility: Evidence from Tanzania in From Death to Birth: Mortality Decline and Reproductive Change (1998) National Academies of Sciences, Engineering, and Medicine. 1998. From Death to Birth: Mortality Decline and Reproductive Change. [Internet]. Washington (DC); [cited 2026 Sep 16]. Available from: https://www.nationalacademies.org/read/5842/chapter/6

16. Jayachandran S, Lleras-Muney A. Life Expectancy and Human Capital Investments: Evidence From Maternal Mortality Declines [Working Paper] [Internet]. National Bureau of Economic Research; 2008 [cited 2026 Sep 16]. (Working Paper Series). Available from: https://www.nber.org/papers/w13947 doi:10.3386/w13947

17. Hansen CW. Life expectancy and human capital: evidence from the international epidemiological transition. J Health Econ. 2013 Dec;32(6):1142–52. doi:10.1016/j.jhealeco.2013.09.011 PubMed PMID: 24157844.

18. Oster E, Shoulson I, Dorsey ER. Limited Life Expectancy, Human Capital and Health Investments. American Economic Review. 2013 Aug;103(5):1977–2002. doi:10.1257/aer.103.5.1977

19. Picone G, Sloan F, Taylor D. Effects of Risk and Time Preference and Expected Longevity on Demand for Medical Tests. Journal of Risk and Uncertainty. 2004 Jan 1;28(1):39–53. doi:10.1023/B:RISK.0000009435.11390.23

20. Scott-Sheldon LAJ, Carey MP, Vanable PA, Senn TE. Subjective Life Expectancy and Health Behaviors among STD Clinic Patients. Am J Health Behav. 2010;34(3):349–61. doi:10.5993/ajhb.34.3.10 PubMed PMID: 20001192; PubMed Central PMCID: PMC2920613.

21. Ciancio A, Delavande A, Kohler HP, Kohler IV. MORTALITY RISK INFORMATION, SURVIVAL EXPECTATIONS AND SEXUAL BEHAVIOURS. Econ J (London). 2024 May;134(660):1431–64. doi:10.1093/ej/uead116 PubMed PMID: 38707864; PubMed Central PMCID: PMC11065140.

22. Clark R, Kara S. A Cross-National Analysis of Lifespan Inequality, 1950–2015: Examining the Distribution of Mortality Within Countries. Social Indicators Research. 2020 Apr;148(3):705–32. doi:10.1007/s11205-019-02216-7

23. Souza JP, Day LT, Rezende-Gomes AC, Zhang J, Mori R, Baguiya A, et al. A global analysis of the determinants of maternal health and transitions in maternal mortality. The Lancet Global Health. 2024 Feb 1;12(2):e306–16. doi:10.1016/S2214-109X(23)00468-0 PubMed PMID: 38070536.

24. Souza J, Tunçalp Ö, Vogel J, Bohren M, Widmer M, Oladapo O, et al. Obstetric transition: the pathway towards ending preventable maternal deaths. BJOG: An International Journal of Obstetrics & Gynaecology. 2014;121(s1):1–4. doi:10.1111/1471-0528.12735

25. Mejía-Guevara I, Gazeley U, Nabukalu D, Aburto JM. Evolution of Life Expectancy and Lifespan Variation in Sub-Saharan Africa [Internet]. medRxiv; 2025 [cited 2026 Oct 1]. p. 2025.05.20.25328051. Available from: https://www.medrxiv.org/content/10.1101/2025.05.20.25328051v1 doi:10.1101/2025.05.20.25328051

26. Seligman B, Greenberg G, Tuljapurkar S. Equity and length of lifespan are not the same. Proc Natl Acad Sci U S A. 2016 Jul 26;113(30):8420–3. doi:10.1073/pnas.1601112113 PubMed PMID: 27402750; PubMed Central PMCID: PMC4968733.

27. Hay SI, Ong KL, Santomauro DF, A B, Aalipour MA, Aalruz H, et al. Burden of 375 diseases and injuries, risk-attributable burden of 88 risk factors, and healthy life expectancy in 204 countries and territories, including 660 subnational locations, 1990–2023: a systematic analysis for the Global Burden of Disease Study 2023. The Lancet. 2025 Oct 18;406(10513):1873–922. doi:10.1016/S0140-6736(25)01637-X PubMed PMID: 41092926.

28. Naghavi M, Ong KL, Aali A, Ababneh HS, Abate YH, Abbafati C, et al. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. The Lancet. 2024 May 18;403(10440):2100–32. doi:10.1016/S0140-6736(24)00367-2 PubMed PMID: 38582094.

29. Permanyer I, Vigezzi S. Cause-of-Death Determinants of Lifespan Inequality.

30. Boerma T, Campbell OMR, Amouzou A, Blumenberg C, Blencowe H, Moran A, et al. Maternal mortality, stillbirths, and neonatal mortality: a transition model based on analyses of 151 countries. The Lancet Global Health. 2023 Jun 20;11(7):e1024. doi:10.1016/S2214-109X(23)00195-X PubMed PMID: 37349032.

31. World Health Organization. Strategies towards ending preventable maternal mortality (EPMM) [Internet]. Geneva; 2015 [cited 2022 Oct 14]. Available from: http://www.everywomaneverychild.org/images/EPMM_final_report_2015.pdf

32. World Health Organization. Ending Preventable Maternal Mortality (EPMM): A renewed focus for improving maternal and newborn health [Internet]. 2021. Available from: https://cdn.who.int/media/docs/default-source/mca-documents/maternal-nb/ending-preventable-maternal-mortality_epmm_brief-230921.pdf?sfvrsn=f5dcf35e_5

33. THE 17 GOALS | Sustainable Development [Internet]. [cited 2025 Jul 28]. Available from: https://sdgs.un.org/goals

34. Gazeley U, Filippi V, Campbell OMR, Graham WJ. The re-emergence of a data desert for maternal survival is a serious risk amid global health funding cuts. BMJ Glob Health. 2026 May 21;11(5). doi:10.1136/bmjgh-2025-020852 PubMed PMID: 10.1136/bmjgh-2025-020852.

35. Gibson RM, Wise PH, Dieleman JL, Yotov YV, Kirilakha A, Darmstadt GL, et al. The impact of aid sanctions on maternal and child mortality, 1990–2019: a panel analysis.

The Lancet Global Health. 2025 May 1;13(5):e820–30. doi:10.1016/S2214-109X(25)00058-0 PubMed PMID: 40120594.

36. Stover J, Sonneveldt E, Tam Y, Horton KC, Phillips AN, Smith J, et al. Effects of reductions in US foreign assistance on HIV, tuberculosis, family planning, and maternal and child health: a modelling study. The Lancet Global Health. 2025 Oct 1;13(10):e1669–80. doi:10.1016/S2214-109X(25)00281-5

37. AbouZahr C. New estimates of maternal mortality and how to interpret them: choice or confusion? Reproductive Health Matters. 2011 Jan 1;19(37):117–28. doi:10.1016/S0968-8080(11)37550-7 PubMed PMID: 21555092.

38. AbouZahr C, de Savigny D, Mikkelsen L, Setel PW, Lozano R, Nichols E, et al. Civil registration and vital statistics: progress in the data revolution for counting and accountability. Lancet. 2015 Oct 3;386(10001):1373–85. doi:10.1016/S0140-6736(15)60173-8 PubMed PMID: 25971224; PubMed Central PMCID: PMC7753937.

39. World Health Organization. Maternal mortality measurement: guidance to improve national reporting. Geneva; 2022.

40. Sankoh O, Dickson KE, Faniran S, Lahai JI, Forna F, Liyosi E, et al. Births and deaths must be registered in Africa. The Lancet Global Health. 2020 Jan 1;8(1):e33–4. doi:10.1016/S2214-109X(19)30442-5 PubMed PMID: 31839137.

41. Institute for Health Metrics and Evaluation. Global Burden of Disease Methods Maternal Disorders [Internet]. 2020. Available from: https://www.healthdata.org/sites/default/files/files/policy_report/2022/GBD_2020_methods_maternal_disorders.pdf

42. Kassebaum NJ, Lopez AD, Murray CJL, Lozano R. A comparison of maternal mortality estimates from GBD 2013 and WHO. The Lancet. 2014 Dec 20;384(9961):2209–10. doi:10.1016/S0140-6736(14)62421-1 PubMed PMID: 25625393.

43. World Health Organization. The WHO application of ICD-10 to deaths during pregnancy, childbirth and the puerperium: ICD-MM. [Internet]. Geneva, Switzerland: World Health Organization; 2012 [cited 2022 Oct 14]. Available from: https://apps.who.int/iris/bitstream/handle/10665/70929/9789241548458_eng.pdf

44. van Raalte AA, Caswell H. Perturbation analysis of indices of lifespan variability. Demography. 2013 Oct;50(5):1615–40. doi:10.1007/s13524-013-0223-3 PubMed PMID: 24043610.

45. Martin J, Aburto JM, Permanyer I. Dynamics of the coefficient of variation of the age at death distribution.

46. Edwards RD, Tuljapurkar S. Inequality in Life Spans and a New Perspective on Mortality Convergence Across Industrialized Countries. Population and Development Review. 2005;31(4):645–74. doi:10.1111/j.1728-4457.2005.00092.x

47. McNeil DR, Trussell TJ, Turner JC. Spline interpolation of demographic data. Demography. 1977 May 1;14(2):245–52. doi:10.2307/2060581

48. Smith L, Hyndman RJ, Wood SN. Spline interpolation for demographic variables: The monotonicity problem. Journal of Population Research. 2004 Mar 1;21(1):95–8. doi:10.1007/BF03032212

49. Preston S. Wiley.com [Internet]. 2000 [cited 2026 Oct 1]. Demography: Measuring and Modeling Population Processes. Available from: https://www.wiley.com/en-us/demography-measuring-and-modeling-population-processes-p-9781557864512

50. Andersen PK, Canudas-Romo V, Keiding N. Cause-specific measures of life years lost. Demographic Research. 2013 Dec 5;29:1127–52. doi:10.4054/DemRes.2013.29.41

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendixlifetimeuncertainty1.docx