Understanding Global Trends in Maternal Mortality

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CONTEXT: *Despite the fact that most maternal deaths are preventable, maternal mortality remains high in many developing countries. Target A of Millennium Development Goal (MDG) 5 calls for a three-quarters reduction in the maternal mortality ratio (MMR) between 1990 and 2015.*

METHODS: *We derived estimates of maternal mortality for 172 countries over the period 1990–2008. Trends in maternal mortality were estimated either directly from vital registration data or from a hierarchical or multilevel model, depending on the data available for a particular country.*

RESULTS: *The annual number of maternal deaths worldwide declined by 34% between 1990 and 2008, from approximately 546,000 to 358,000 deaths. The estimated MMR for the world as a whole also declined by 34% over this period, falling from 400 to 260 maternal deaths per 100,000 live births. Between 1990 and 2008, the majority of the global burden of maternal deaths shifted from Asia to Sub-Saharan Africa. Differential trends in fertility, the HIV/AIDS epidemic and access to reproductive health are associated with the shift in the burden of maternal deaths from Asia to Sub-Saharan Africa.*

CONCLUSIONS: *Although the estimated annual rate of decline in the global MMR in 1990–2008 (2.3%) fell short of the level needed to meet the MDG 5 target, it was much faster than had been thought previously. Targeted efforts to improve access to quality maternal health care, as well as efforts to decrease unintended pregnancies through family planning, are necessary to further reduce the global burden of maternal mortality.*

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Maternal mortality is a key indicator of international development, and its reduction has long been a challenge in low-income countries, despite the existence of effective interventions. The focus on maternal mortality as an important development measure dates back at least to the 1980s, when researchers first highlighted the role of complications related to pregnancy and childbirth in death rates among women of reproductive age and noted the inadequacy of attention paid to addressing these largely preventable deaths.[1–3] Also, in the mid-1980s, the World Health Organization (WHO) estimated that approximately half a million women died yearly from maternal causes.[4]

The 1987 Safe Motherhood Conference in Nairobi, which was the first of a series of international meetings that highlighted the worldwide problem of maternal mortality, called for reducing maternal mortality in developing countries by half in one decade. Strategies for achieving this goal included making family planning universally available, providing prenatal care and trained assistance at delivery, and ensuring access to emergency obstetric care.[5] Subsequent international conferences in the 1990s, including the World Summit for Children in 1990, the International Conference on Population and Development in 1994, and the Fourth World Conference on Women in 1995, also called for a substantial reduction in maternal mortality.

In September 2000, the UN General Assembly adopted the United Nations Millennium Declaration. The following year, the Millennium Development Goals (MDGs) were articulated. MDG 5 called for a three-quarters reduction between 1990 and 2015 in the maternal mortality ratio (MMR), the number of maternal deaths per 100,000 live births.[6] At the same time, it was acknowledged that it would be difficult to track progress toward achieving this target, since reliable data were lacking in the very countries thought to have the greatest burden. A second target of achieving universal access to reproductive health by 2015 was added in the subsequent reformulation of the MDGs.[7]

It has been challenging for many countries to produce timely and accurate data on levels of maternal mortality that would indicate the extent of their progress in reducing maternal deaths. To address the gap in data availability on maternal mortality, WHO and the United Nations Children's Fund (UNICEF) published, in 1996, the first interagency estimates of maternal mortality, including MMRs, numbers of maternal deaths and lifetime risks of death. The estimates, which referred to the year 1990, covered 174 countries. Of these countries, 77 had no direct or indirect estimates of maternal mortality, and their estimates were derived entirely from a statistical model. An additional 14 countries lacked data for predictor variables and thus had no estimate provided.

Subsequent rounds of interagency estimates were produced for the years 1995, 2000 and 2005 with the collaboration of additional UN agencies. Each round of estimates built on previous rounds but introduced improvements and innovations; thus, the estimates from the various rounds were not strictly comparable. In September 2010, an interagency exercise by WHO, UNICEF, the United Nations Population Fund (UNFPA) and the World Bank, led by an academic team at the University of California, Berkeley, produced trend estimates of the MMR and numbers of maternal deaths for the years 1990, 1995, 2000, 2005 and 2008, overriding the previously reported findings.[8] For the 2008 estimates, just 24 out of 172 countries lacked national-level data on maternal mortality, a major improvement since the first UN interagency exercise.

In this article, we describe briefly the data and methods used to produce the most recent estimates released by the UN interagency team. We then highlight the results of this exercise, focusing on global, regional and country-specific trends observed over the period 1990–2008. Using the new estimates, as well as complementary data from other reports on progress toward the MDGs, we attempt to understand better the factors contributing to the global progress in reducing maternal mortality observed over this period, as well as continued regional disparities in maternal mortality.

DATA AND METHODS

Various methods are available for collecting data on maternal mortality, including vital registration, household surveys (e.g., those that record recent household deaths or all deaths among respondents' sisters—the "sisterhood method"), surveillance systems, reproductive-age mortality studies and censuses. Also, there are various measures of maternal mortality, including the maternal mortality ratio (MMR), the maternal mortality rate, the adult lifetime risk of maternal mortality and the proportion of all deaths among women aged 15–49 that are maternal deaths.[9] Data on maternal mortality are generally collected at the national level and disseminated by national statistical offices. To produce global estimates, WHO maintains a centralized database of these observations. For the most current round of estimates, the database included 2,842 country-years of data (1,891 country-years from vital registration data, 819 from sisterhood survey–based data and 132 country-years from other sources).

Three types of adjustments were made to the maternal mortality data included in this database before they were used to estimate country-specific trends over the period 1990–2008. These adjustments are meant to correct for underreporting of maternal deaths, miscategorization of nonmaternal deaths as maternal deaths and miscategorization of HIV/AIDS-related deaths. Full details of the adjustments made are reported elsewhere.[10] We describe the adjustments briefly here to highlight some of the biases associated with these data.

To account for incomplete reporting or misclassification of maternal deaths, we generally adjusted data upward. This type of adjustment is needed, for example, to account for maternal deaths related to abortion that are not reported or maternal deaths (especially those occurring in early pregnancy) that are misclassified because pregnancy status is not known.

We adjusted downward any observations that reflected deaths during pregnancy, or the period following a pregnancy, that were not true maternal deaths. We defined a maternal death as "the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes."[11] Maternal deaths can be further classified into direct maternal deaths (deaths due to obstetric complications related to pregnancy) and indirect maternal deaths (deaths due to other diseases or conditions that have been aggravated by pregnancy).

Maternal mortality and HIV/AIDS are two of the leading causes of death among women of reproductive age worldwide, and there is evidence that HIV-positive women are at higher risk than women who are not HIV positive for dying of complications related to pregnancy and childbirth.[12] We sought to distinguish between AIDS-related deaths among pregnant women that were incidental to the pregnancy (i.e., would have occurred in the absence of a pregnancy) and deaths that were caused primarily by HIV infection, but in which pregnancy was a substantial aggravating factor. We refer to the latter category, classified as indirect maternal deaths according to the ICD-10 protocols (code O98.7), as AIDS-related maternal deaths.[13]

In sum, we divided all deaths that occurred during pregnancy or within 42 days of termination of pregnancy into the following categories: non–AIDS-related maternal deaths, AIDS-related maternal deaths, accidental or incidental deaths not related to AIDS, and deaths related to AIDS that were not aggravated by pregnancy. Only deaths in the first and second categories are represented in our results. Separating AIDS-related and non–AIDS-related maternal deaths gives us a sense of the impact of the AIDS epidemic on estimated trends in maternal mortality. If we included all AIDS deaths occurring among pregnant women in our estimate of maternal mortality, regardless of whether the pregnancy caused or contributed to the death, we would overstate the true risk of maternal mortality in recent years and would thus underestimate the rate of improvement in the MMR since 1990.[14,15]

In practice, there were a number of obstacles to identifying AIDS-related maternal deaths. We used estimates from the United Nations Joint Programme on HIV/AIDS for the number of AIDS deaths among reproductive-age women as an input to our estimation process.[16] Although those estimates are derived from simulations that do not explicitly account for interactions between pregnancy and HIV, they provide a reasonable baseline for tracking the potential impact of the AIDS epidemic on maternal mortality.

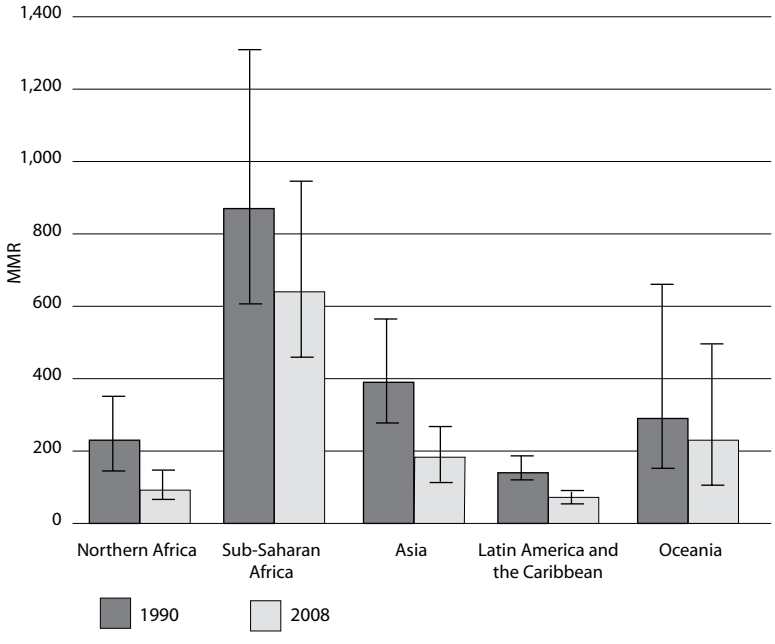
TABLE 1. Levels and rates of change in numbers of live births, the maternal mortality ratio (MMR), and numbers of maternal deaths, 1990 and 2008

Region	No. of maternal deaths (in 000s)				MMR*			No. of live births (in 000s)		
	1990	2008	Average annual decline (%)	Total absolute decline	1990	2008	Average annual decline (%)	1990	2008	Average annual decline (%)
World	546,000	358,000	2.3	188,000	400	260	2.3	137,000	136,000	0.1
Developed regions	2,000	1,700	1.1	300	16	14	0.8	12,000	12,000	0.3
CIS†	3,200	1,500	4.4	1,700	68	40	3.0	4,800	3,700	1.5
Developing regions	540,000	355,000	2.3	185,000	450	290	2.4	120,000	121,000	0.0
Africa	208,000	207,000	0.0	1,000	780	590	1.6	27,000	35,000	–1.5
Northern Africa	8,600	3,400	5.2	5,200	230	92	5.0	3,800	3,700	0.2
Sub-Saharan Africa	199,000	204,000	–0.1	–5,000	870	640	1.7	23,000	32,000	–1.8
Asia	315,000	139,000	4.6	176,000	390	190	4.0	82,000	74,000	0.5
Eastern Asia	29,000	7,800	7.2	21,200	110	41	5.5	26,000	19,000	1.7
Southern Asia	234,000	109,000	4.2	125,000	590	280	4.2	40,000	39,000	0.0
South-Eastern Asia	46,000	18,000	5.2	28,000	380	160	4.7	12,000	11,000	0.5
Western Asia	6,100	3,300	3.4	2,800	140	68	4.0	4,300	4,900	–0.7
Latin America and the Caribbean	17,000	9,200	3.4	7,800	140	85	2.9	12,000	11,000	0.4
Oceania	540	550	–0.1	–10	290	230	1.4	190	240	–1.4

*Maternal deaths per 100,000 live births. †Commonwealth of Independent States. *Notes:* Live births and maternal deaths are rounded to nearest 100 if the value is between 1,000 and 9,999 (in 000s) and to the nearest 1,000 if the value is equal or greater than 10,000 (in 000s). MMR values are not rounded if they are less than 100 (per 100,000 live births) and are rounded to the nearest 10 if they are between 100 and 999. Rates of average annual decline have been calculated using unrounded figures. *Sources:* MMR and maternal deaths—reference 8; births—reference 19.

Identifying non–AIDS-related and AIDS-related maternal deaths also required making certain assumptions about the relationship between HIV/AIDS and maternal mortality. Specifically, we had to make assumptions about the risk of AIDS-related death for a pregnant versus nonpregnant woman, as well as the proportion of AIDS deaths occurring during or soon after pregnancy that are truly maternal deaths. Despite the risk that pregnancy poses for HIV-positive women, we assumed that a pregnant woman's risk of dying from AIDS was less than that of a nonpregnant woman because women in later stages of the disease are not as likely to become pregnant as women in earlier stages of the disease and because, overall, HIV-positive women are not as likely to become pregnant as HIV-negative women.[17] A series of model-fitting exercises, coupled with inferences gained from the available empirical evidence, suggested a relative risk of 0.4.[10,18] With no empirical evidence available on the proportion of pregnancy-related AIDS deaths that are truly maternal, we assumed a value of 0.5. Given a possible range of 0–1, this choice minimizes the potential error.[10]

FIGURE 1. Estimates of the maternal mortality ratio (MMR) with 95% uncertainty intervals, developing regions, 1990 and 2008



Sources: MMR—reference 8; uncertainty intervals—reference 10.

Different methodological approaches were used to estimate country-specific trends between 1990 and 2008, depending on the type of data available. Countries fell into three categories: those with no nationally representative data on maternal mortality generated using standard methodologies (14% of countries, accounting for 4% of global births); those that have data available from sources such as surveillance systems, sample surveys and period censuses, but lack a complete civil registration system (49% of countries, accounting for 82% of global births); and those with a complete and reliable civil registration system (37% of countries, accounting for 15% of global births).

For the latter set of countries, whose registration systems met certain criteria for quality, the death registration data were used directly in the analysis to derive trends in the MMR. In contrast, for countries in which complete and reliable death registration systems were lacking, the core of our estimation strategy was a hierarchical or multilevel model. We considered several potential predictor variables, including measures of socioeconomic development, fertility and access to reproductive health services. The final model included the gross domestic product per

capita (GDP),* the general fertility rate, the ratio of live births to the number of reproductive-age women[19] and the proportion of deliveries for which a skilled birth attendant is present.[20]

Using the proportion of non–AIDS-related deaths among women aged 15–49 that are maternal deaths as the dependent variable, we estimated a multilevel regression model with random effects for both country and region; independent variables were the GDP, the general fertility rate and the proportion of deliveries for which a skilled birth attendant is present.† Predicted values of the regression equation were computed for five-year intervals centered around 1990, 1995, 2000, 2005 and 2008 for each country.

We used the proportion of all deaths among women aged 15–49 that are maternal deaths as the input to our estimation model because it is considered more robust and reliable than either the number of maternal deaths alone or maternal deaths in relation to live births. This decision was based on precedence, as well as on the results of our own analysis of alternative measures.[10,21] In describing our results, we focus on trends in the MMR, both with and without AIDS-related maternal deaths, because this measure quantifies the risk of maternal death per live birth and thus is an indicator of obstetric risk. Estimates were derived at the country level and then aggregated to the regional and global level. In this paper, most of the results are examined at the regional level using the United Nations MDG regional groupings. The figures reported are rounded (see note in Table 1); however, calculations made using the estimates and reported here are based on the unrounded underlying data.

The process of preparing the data and fitting the model was quite complex and required making several assumptions. Therefore, the point estimates derived from this process are uncertain. This uncertainty comes from many sources: any remaining bias in adjusted values for the proportion of all deaths among women aged 15–49 that are maternal deaths, imprecise knowledge of assumed values for certain model parameters, variability as reflected in the multilevel regression model, errors in data used for the AIDS adjustment or the conversion of the proportion of all deaths among women aged 15–49 that are maternal deaths to MMR estimates (i.e., the "envelope adjustment"‡) and alternative specifications of the model (e.g., choice of covariates). With the exception of alternative model specifications, we attempted to account for these various sources in the uncertainty intervals presented here. Further details on the statistical methods are available elsewhere.[10]

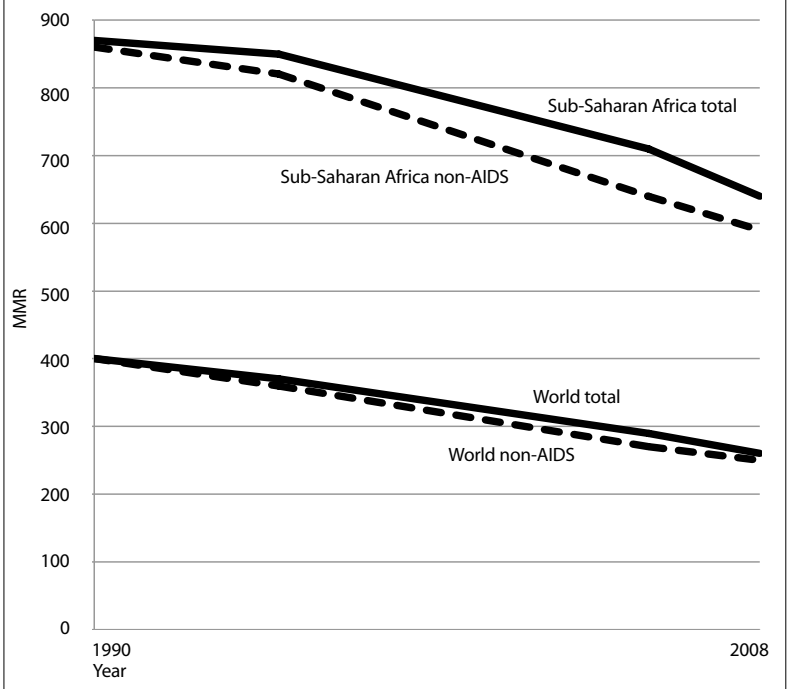
RESULTS

Global Trends in Maternal Mortality

The total number of maternal deaths observed annually fell from 546,000 in 1990 to 358,000 in 2008, a 34% decline over this period (Table 1). Similarly, the global MMR declined from 400 to 260 maternal deaths per 100,000 live births, a decline of 34% over the entire period and an average annual decline of 2.3%. As we will explain in more detail, the rates of decline in maternal deaths and MMR are similar because the global trend in births was essentially flat over the period 1990 to 2008. Although these estimates suggest progress in reducing maternal mortality at the global level, the decline is not rapid enough to achieve the MDG 5 target. Also, there are considerable regional disparities in reduction of maternal mortality.

All results presented here should be viewed with caution, given the considerable uncertainty surrounding these estimates. For example, while the median estimate of the total number of maternal deaths observed in 2008

FIGURE 2. Estimated levels of the maternal mortality ratio (MMR), with and without AIDS-related maternal deaths, world and Sub-Saharan Africa, 1990–2008



Source: MMR—reference 8.

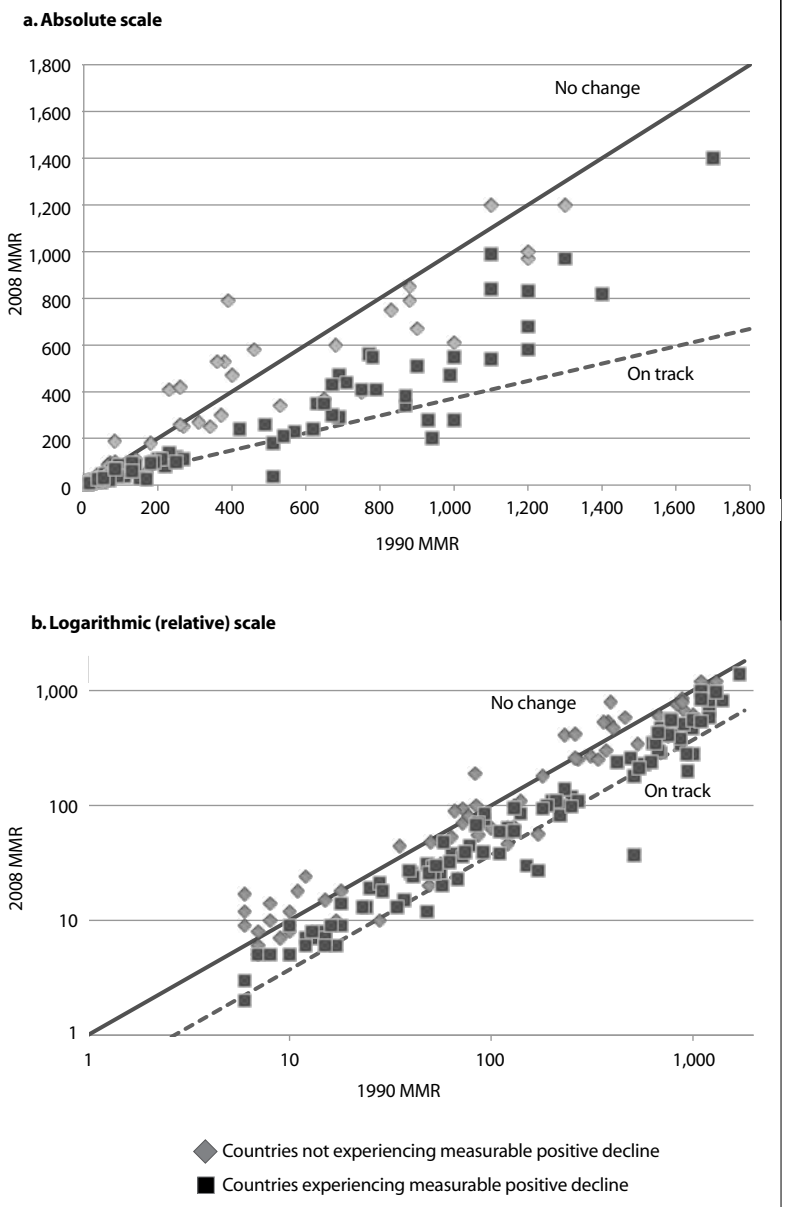
*Most data on GDP per capita were taken from a database maintained by the World Bank (source: World Bank, World Development Indicators database, 2012, <http://data.worldbank.org/data-catalog/world-development-indicators>, accessed Mar. 1, 2010.). For a limited number of countries, GDP data were taken from either the unpublished WHO National Health Accounts Series or the Penn World Tables (sources: Unpublished data from the WHO National Health Accounts Series; and Heston A, Summers R and Aten B, Penn World Table, version 6.3, Philadelphia: Center for International Comparisons of Production, Income and Prices, University of Pennsylvania, 2009, <http://pwt.econ.upenn.edu/php_site/pwt_index.php>, accessed June 1, 2010).

†Assuming that observation i refers to country j located in region k, PMna is the proportion of non-AIDS related deaths among women aged 15–49 that are maternal deaths, GFR is the general fertility rate and SAB is the proportion of deliveries for which a skilled birth attendant is present, the estimated regression model was as follows:

$$\log(PM^{na}) = 2.253 - 0.217\log(GDP_i) + 1.272\log(GFR_i) - 0.652\log(SAB_i) + a^{C}_{j[i]} + a^{R}_{k[i]} + e_i$$

‡The envelope adjustment estimates the total MMR by multiplying proportion of all deaths among women aged 15–49 that are maternal deaths by the ratio of the estimated number of deaths among all women aged 15–49 to the estimated number of live births.[19] This figure is then converted into units of maternal deaths per 100,000 live births. The total number of deaths was derived by multiplying UN age-specific estimates of the total number of women and WHO estimates of age-specific death rates (sources: reference 19 and WHO, Life tables for WHO member states, 2010, <http://www.who.int/healthinfo/statistics/mortality_life_tables/en/index.html>, accessed July 10, 2010).

FIGURE 3. Estimated levels of maternal mortality ratio (MMR) in 172 countries, 1990 vs. 2008



Note: Positive decline is indicated by a 95% uncertainty interval around the estimated rate of change over the period 1990 to 2008 (e.g., as noted earlier, the 95% uncertainty interval around the estimate of average annual decline in the global MMR of 2.3% is 1.8–2.8%, which indicates a measurable positive decline). *Sources:* MMR—reference 8; trend uncertainty intervals—reference 10.

is 358,000, the 95% uncertainty interval around this estimate extends from 265,000 to 503,000 deaths. Similarly, the 95% uncertainty interval around the estimated 2.3% average annual decline in the global MMR is 1.8–2.8%.

Regional Trends in Maternal Mortality

At the regional level, declines in the total number of maternal deaths during this time period were observed for all regions except Sub-Saharan Africa and Oceania. Whereas the estimated annual number of maternal deaths increased slightly in Sub-Saharan Africa (from 199,000 to 204,000) a profound decline in the total number of maternal deaths across Asia (from 315,000 to 139,000) drove global trends (Table 1). As a result of these divergent patterns, the largest share of the burden of maternal deaths shifted from Asia to Sub-Saharan Africa over this period. More specifically, in 1990, around 58% of maternal deaths worldwide occurred in Asia (43% of global maternal deaths occurred in Southern Asia) and 36% in Sub-Saharan Africa; in contrast, in 2008, 57% of global maternal deaths occurred in Sub-Saharan Africa and 39% in Asia (30% in Southern Asia).

Examining regional trends in MMR for the developing world, we observe growing disparities in the risk of maternal mortality over the period 1990–2008 (Figure 1, page 34). In 1990, Sub-Saharan Africa exhibited the highest MMR among the developing regions, 870 maternal deaths per 100,000 live births. The next highest MMRs were observed in Southern Asia (590) and Southeastern Asia (380). Disparities in MMR between Sub-Saharan Africa and other developing regions grew over the period 1990–2008, as the rate of decline in MMR in Sub-Saharan Africa, 1.7% per year (uncertainty interval, 1.1–2.1%), was slower than the declines observed in all other developing regions with the exception of Oceania, 1.4% per year (uncertainty interval, –4.5–7.2%). In Southern and Southeastern Asia, average annual declines in MMR over the period were much more rapid, at 4.2% (3.6–4.8%) and 4.7% (3.8–5.6%), respectively. The estimated absolute decline in MMR between 1990 and 2008 was largest in Southern Asia (590 to 280) and similar in Sub-Saharan Africa and Southeastern Asia (870 to 640 and 380 to 160, respectively).

The relative stagnation since 1990 in the decline in MMR observed for Sub-Saharan Africa, relative to other regions of the world, can be attributed partly to the HIV/AIDS epidemic. The MMR observed for Sub-Saharan Africa in 2008 was 640; if maternal deaths related to HIV/AIDS were excluded, this figure would be reduced to 580 (Figure 2, page 35). However, this adjusted figure is still much higher than those observed in Southern and Southeastern Asia (280 and 160, respectively).

It is important to note that, as is the case for the global estimates, there is considerable uncertainty surrounding regional MMR estimates in both 1990 and 2008 (Figure 1). Also, there is significant heterogeneity in country-specific trends within regions, which we discuss in the next section.

Country Trends in Maternal Mortality

The Maternal Mortality Estimation Inter-Agency Group considers countries to be "on track" to meet the MDG 5 target if the estimated rate of decline in the MMR has been 5.5% per annum or greater.[8] "Making progress" is defined by a rate of decline that is greater than or equal to 2.0% but less than 5.5%, "insufficient progress" by a rate of decline greater than or equal to 0% and less than 2.0%, and "no progress" by an MMR that is rising. Of the 88 countries in which the MMR was observed to be greater than or equal to 100 in 1990, estimates indicate that 10 are on track, 48 are making progress, 22 are making insufficient progress and eight are making no progress (Web Appendix Figure

1). Similar to inferences gained from our analysis of regional trends, these data suggest that the majority of countries showing no progress are concentrated in Sub-Saharan Africa; however, country-specific trends within this region are heterogeneous.

The growing disparities in MMR between Sub-Saharan Africa and other developing world regions raise the question of whether the countries with the highest initial MMRs are being left behind. To answer this question, we examine country-specific trends in MMR over the period 1990–2008. Countries with a higher initial MMR needed to have achieved higher absolute declines in MMR over the period 1990 to 2008 in order to be considered on track for achieving the MDG 5 target.

In Figure 3a, the distance between the solid "no change" line and the dotted "on track" line indicates the reduction in MMR between 1990 and 2008 that was necessary to be considered on track for meeting the MDG 5 target. Figure 3b shows the same information plotted on a logarithmic scale, and thus, the "no change" and "on track" lines are parallel. In both panels, we have shaded observations for which we estimated that there was a measureable positive decline in the MMR between 1990 and 2008 as indicated by a 95% uncertainty interval around the estimated rate of change over the period 1990 to 2008.

Countries with higher initial MMRs generally experienced greater absolute declines in MMR over the period 1990–2008 than did countries with lower initial levels. In addition, the data plotted on the logarithmic scale suggest that neither the estimated relative rate of change in the MMR observed over the period 1990–2008, nor our certainty that a positive decline in the MMR has actually occurred, appears to be tied to the initial MMR observed in 1990.

These results stand in contrast to the findings of Hill et al. (arrived at using a different method of analysis), which suggested that the decline in MMR over the period 1990–2005 for the group of countries with an initial level of MMR greater than 200 was not statistically significant.[22] Using country-specific uncertainty intervals around rates of change, our results suggest that statistically significant progress in reducing maternal mortality can be observed at varying initial levels of MMR.

Decomposing Changes in the Numbers of Maternal Deaths

The annual rate of decline in maternal deaths can be approximated by the sum of the annual rate of decline in births and the annual rate of decline in MMR. As the global trend in births was almost flat from 1990 to 2008, the decline in the total number of maternal deaths at the global level over this time period is attributable entirely to a decline in the MMR (Table 1).

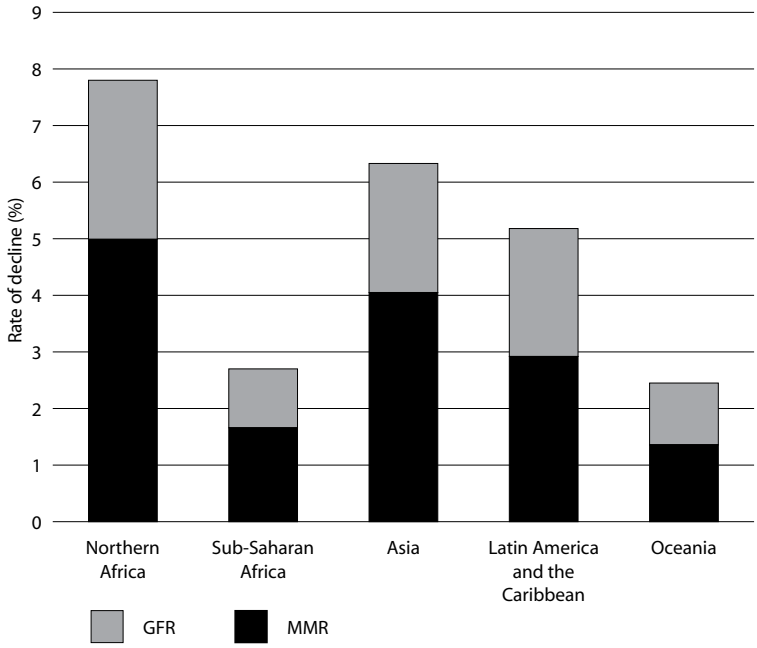
Declines in the MMR were not rapid enough to counterbalance the effect of increasing numbers of births in Sub-Saharan Africa and Oceania, and consequently the total number of maternal deaths increased over the period 1990–2008 in these two regions. In all other developing regions, annual declines in the MMR were more rapid and were generally coupled with declines in the total number of births. Thus, most developing regions experienced declining numbers of total maternal deaths (in Eastern Asia, especially, the decline in total births contributed substantially to the decline in maternal deaths). Similarly, in developed regions, as well as in the Commonwealth of Independent States, declines in both the MMR and the number of live births contributed to the decline in maternal deaths.

Decomposing Changes in Lifetime Risk of Maternal Death

Reductions in the MMR decrease the lifetime risk of maternal death directly, while reductions in the general fertility rate decrease the lifetime risk of maternal death by reducing the number of times women are exposed to pregnancy-related health threats.* An increase in the average woman's reproductive lifetime (due to reductions in mortality generally) will increase the amount of time a woman is exposed to the risk of pregnancy and subsequently to the risk of maternal death, and thus will increase the lifetime risk of maternal death.

In all developing regions, both the MMR and the GFR declined between 1990 and 2008, and the sum of the annual percentage change in these two measures approximates the annual percentage change in the lifetime risk of

FIGURE 4. Annual rate of decline in the lifetime risk of maternal death



Note: The sum of rates of the change in MMR and GFR approximates the rate of change in lifetime risk of maternal death. A third component, the rate of change in the average length of a woman's reproductive lifetime, is negligible. For this reason, and because it typically has a negative effect on the overall rate of decline, it is not shown here. *Sources:* MMR—reference 8; GFR—reference 19.

*Annual rates of change in the lifetime risk of maternal mortality can be decomposed into the changes in the MMR, the general fertility rate and the average length of a woman's reproductive lifetime, in accordance with the following formula:
% change in MMR + % change in GFR + % change in the average length of a woman's reproductive lifetime = % change in lifetime risk of maternal death

TABLE 2. Levels and trends in number of live births and in the proportion and number of births with skilled attendant present at delivery, 1990 and 2008

Region	No. of live births (in 000s)			% with skilled attendant			No. with skilled attendant (in 000s)		
	1990	2008	Average annual change (%)	1990	2008	Average annual change (%)	1990	2008	Average annual change (%)
Sub-Saharan Africa	23,000	32,000	1.8	41	46	0.6	9,400	15,000	2.4
Southern Asia	40,000	39,000	0.0	30	45	2.3	12,000	18,000	2.2
Southeastern Asia	12,000	11,000	–0.5	46	75	2.7	5,600	8,300	2.2

Notes: See note in Table 1 for information on rounding. The number of births with skilled attendant present at delivery was estimated by multiplying the number of live births by the proportion of births with a skilled attendant present. *Sources:* Births—reference 19; skilled birth attendance—reference 25.

maternal death (Figure 4, page 37). Changes in the average length of a woman's reproductive lifetime also contribute to the change in the lifetime risk of maternal death but were negligible relative to the other components of change and were typically in the opposite direction.*

The estimated annual rate of decline in the lifetime risk of maternal death varied across developing regions and was highest for Asia and Northern Africa and lowest for Sub-Saharan Africa and Oceania. On average, across all regions depicted in Figure 4, about 60% of the annual decline in lifetime risk was attributable to declines in the MMR and 40% to declines in the general fertility rate, illustrating that both interventions to improve maternal health care and interventions to reduce unwanted fertility can play important roles in reducing the likelihood of a maternal death over a woman's lifetime.

DISCUSSION

The results presented above highlight the role of population growth and HIV/AIDS in shifting the greatest part of the burden of maternal deaths from Asia to Sub-Saharan Africa over the period 1990–2008. In this section, we expand on these results and also explore the impact of trends in related indicators of maternal health.

When we compare the results of the decomposition analysis of lifetime risk of maternal death to the decomposition of trends in total maternal deaths, we note that despite declines in fertility, as measured by the GFR, the number of births in Sub-Saharan Africa increased over the period 1990–2008 due to population momentum (i.e., an increase in the number of women of reproductive age). In other regions, fertility declines were relatively more rapid and thus better able to counteract the effects of population momentum. Another decomposition analysis of these maternal mortality estimates, published by Ross and Blanc, specifically highlighted the role of fertility decline in reducing the number of global maternal deaths, despite a tremendous increase in the number of reproductive-age women across the globe.[23] According to their calculations, approximately 1.7 million maternal deaths over the period 1990–2008 were avoided as a result of fertility decline.

Although the impact of AIDS on trends in maternal deaths in Sub-Saharan Africa is substantial, population growth was the dominant factor in shifting the greatest share of the burden of maternal mortality from Asia to Sub-Saharan Africa. If trends in births had remained flat in Sub-Saharan Africa (i.e., 23 million births per year, as in 1990), while the MMR decreased at the same rate over the period 1990–2008 (870 to 640), there would have been roughly 56,000 fewer maternal deaths in 2008. Comparing this figure with the 18,000 estimated AIDS-related maternal deaths in Sub-Saharan Africa in 2008 suggests that population growth over the period 1990–2008 had roughly three times as much impact as HIV/AIDS on the number of maternal deaths occurring in that region. However, the result of this simple comparison should be interpreted with caution, given the limited empirical evidence on the relationship between HIV/AIDS and maternal mortality.

Trends in Related Reproductive Health Indicators

In addition to the target of reducing the MMR by 75% between 1990 and 2015, MDG 5 also calls for achieving universal access to reproductive health by 2015.[7] The two targets of MDG 5, reducing maternal mortality and achieving universal access to reproductive health, are synergistic. For instance, the proportion of deliveries at which a skilled attendant is present and the proportion of women who receive antenatal care from a skilled health worker at least once during their pregnancy represent the delivery of health services to women in the intrapartum and antenatal periods, respectively, and thus indicate efforts to decrease the risk of maternal death among pregnant women.

TABLE 3. Levels and trends in the proportion and number of women aged 15–49 receiving antenatal care from skilled health personnel at least once during pregnancy, 1990 and 2008

Region	% receiving antenatal care			No. receiving antenatal care (in 000s)		
	1990	2008	Average annual change (%)	1990	2008	Average annual change (%)
Sub-Saharan Africa	67	76	0.7	15,000	24,000	2.5
Southern Asia	48	70	2.1	19,000	28,000	2.1
Southeastern Asia	72	93	1.4	8,700	10,000	0.9

Notes: See note in Table 1 for information on rounding. The number of women receiving antenatal care was estimated by multiplying the number of live births by the proportion of women receiving antenatal care. *Sources:* Births—reference 19; antenatal care—reference 25.

*For instance, in Asia, where the maximum percentage increase in the average length of a woman's reproductive lifetime occurred, the change observed was an annual increase of 0.1%, whereas the MMR, the general fertility rate and lifetime risk of maternal death declined annually by 4.1%, 2.3% and 6.2%, respectively.

The proportion of women who are married or in union and have an unmet need for contraception is also related to the risk of maternal death indirectly, in that increasing the proportion of women whose contraceptive needs are met reduces the number of women exposed to the risk of maternal death as a result of an unintended pregnancy. Although interventions aimed directly at improving women's access to care during the intrapartum period (including by building and expanding health centers) are considered the best strategies for reducing high rates of maternal mortality, interventions targeting the antenatal period and reducing the risk of unwanted fertility and unsafe abortion are also important components of a comprehensive plan to reduce the global burden of maternal mortality.[24]

The highest MMRs in 1990 were found in Sub-Saharan Africa, Southern Asia and Southeastern Asia; as already noted, progress in reducing the MMR has been quite rapid in Southern and Southeastern Asia, but much more limited in Sub-Saharan Africa. Levels of use of skilled birth attendance and antenatal care were similar in Sub-Saharan Africa and Southern Asia in 2008: A skilled attendant was present for roughly 46% of births in Sub-Saharan Africa and for 45% of births in Southern Asia (Table 2).[25] In Sub-Saharan Africa, 76% of women received antenatal care at least once during their pregnancy, compared with 70% in Southern Asia (Table 3). Trends within these two regions over the period 1990–2008 were substantially different, however, with the proportion of deliveries at which a skilled attendant is present and the proportion of women who receive antenatal care increasing much more rapidly in Southern Asia (average annual change of 2.3% and 2.1%, respectively) than in Sub-Saharan Africa (0.6% and 0.7%). In 1990 and 2008, Southeastern Asia exhibited higher levels of both types of care, compared with the other two subregions. Between those years, Southeastern Asia also made faster progress in increasing the proportion of deliveries at which a skilled attendant is present (2.7%), and slightly less progress in increasing the proportion of women who receive antenatal care (1.4%), than did Southern Asia.*

Looking at these indicators and their trends in terms of proportions and rates of change, however, obscures a deeper demographic reality. If we consider the trends either in the absolute number of births for which a skilled attendant was present or the absolute number of women who received antenatal care at least once while pregnant, a different picture emerges.† Comparing the estimated number of births with a skilled attendant present in 1990 and 2008, we find that that number grew by 55% in Sub-Saharan Africa. By contrast, in Southern Asia and Southeastern Asia, this number grew by only 49%. Regarding changes in the number of pregnant women receiving antenatal care during the same period, interregional differences are even more striking, with the number of pregnant women receiving antenatal care increasing by 56% in Sub-Saharan Africa, 45% in Southern Asia and only 18% in Southeastern Asia.

It is encouraging that Sub-Saharan Africa has successfully expanded maternal health services and kept up with the growth of demand that has been driven by population increase over this period. Indeed, these services seem to be expanding more rapidly in Sub-Saharan Africa than in Southern or Southeastern Asia in terms of the absolute number of births covered. However, if the number of births in Sub-Saharan Africa were increasing less rapidly, it might be possible for maternal health services to reach a greater proportion of pregnant women.

One-quarter of women who are married or in union in Sub-Saharan Africa have an unmet need for contraception, which puts them at risk of an unintended pregnancy.[25] Unmet need in Sub-Saharan Africa is substantially higher than in Southern Asia or Southeastern Asia (15% and 11%, respectively, in 2007; not shown). In all three regions, limited progress was made in reducing unmet need over the period from 1990 to 2008, with the smallest percentage point reduction observed in Sub-Saharan Africa (1.7% vs. 3.5% in Southern Asia and 4.2% in Southeastern Asia). These figures suggest that there is still substantial progress that could be made in reducing unintended fertility in these developing regions, and the effect of satisfying demand for contraceptives on reducing maternal deaths could be quite large. A recent report issued jointly by the Guttmacher Institute and UNFPA, which is based partly on the maternal mortality estimates reported here, suggests that fulfilling unmet need for family planning in developing countries could result in 94,000 fewer maternal deaths annually, and in combination with expanded maternal and child health care, could avert 251,000 maternal deaths annually.‡[26,27]

Limitations

Trends for many countries are model-based because data are not routinely collected in many areas of the world. A number of developing countries lack nationally representative data on maternal mortality altogether, and data are sparse for many other countries across Sub-Saharan Africa and Asia. There is considerable uncertainty in the estimates presented here, as demonstrated in Figure 1 by the depictions of the uncertainty intervals around developing regions' MMR estimates for 1990 and 2008. This uncertainty comes from many sources, including the predictive model, which is a simplification of a complex reality; an additional source of uncertainty is the assumptions made in adjusting for definitional differences and underreporting, and in accounting for the relationship between HIV/AIDS and maternal causes of death. Beyond issues

*The result of the latter comparison may be attributable to the fact that the proportion of women receiving antenatal care in Southeastern Asia was already much higher than the proportion in Southern Asia in 1990.

†These numbers were calculated by multiplying each proportion by the annual number of births. For antenatal care, total births are taken as a proxy measure for the number of pregnant women, and in practice, survey questions about antenatal care are typically asked only of women who have had a live birth.

‡The cumulative effect of these two sets of interventions is not the sum of their impact in isolation.

with the data on maternal mortality, the reliability of the estimates presented here also depends on accurate estimates of the number of live births and the number of deaths among women aged 15–49. These estimates are also based on limited information and could be inaccurate and thus contribute to bias in estimates of maternal mortality.

Conclusions

Although our results suggest that the world is not on track to achieve the MDG 5 target, we estimate that the global MMR has declined by one-third between 1990 and 2008. The estimated rate of decline varied among regions, with substantial improvements across Asia and North Africa and less improvement in Sub-Saharan Africa. Differential trends in the pace of decline of the MMR and in the annual number of births shifted the global distribution of maternal deaths substantially over the period from 1990 to 2008, and Sub-Saharan Africa replaced Asia as the region where more than half of such deaths occur.

Despite Sub-Saharan Africa's higher numbers of maternal deaths and slower decline in MMR, compared with other developing regions, trends in use of skilled birth attendance and antenatal care between 1990 and 2008 indicate that maternal health services have been extended to reach increasing numbers of women in the region. Yet rapid growth in the annual number of births—and the resulting increase in demand for basic maternal care—means that Sub-Saharan Africa has simply kept pace with this growing demand; it has not been able to substantially increase the proportion of women these services reach.

Extending basic maternal health services, improving quality of care and eliminating unmet need for contraception are all key to reducing maternal mortality. A range of clinical interventions is available, and these have been proven effective at addressing all the main causes of maternal deaths; however, more research is needed to identify the determinants of successful campaigns to reduce maternal mortality in countries with heavy burdens, so that if contextually appropriate, these interventions can be applied in countries experiencing less progress. The challenge is to make sure that every woman in need receives these interventions in a timely fashion at each stage of her reproductive life: while planning pregnancies and during pregnancy, childbirth and the postpartum period. Meeting this challenge will require organized and persistent action at both the health services and community levels.

Reliable information is a necessary component of any strategy aimed at reducing maternal mortality. Although the availability of maternal mortality data has improved since the first set of UN interagency estimates was released in the mid-1990s, continued progress in data collection is key to more precisely estimating country-specific trends and to evaluating progress in reducing maternal mortality. Maternal mortality data are still relatively scarce across the developing world and will continue to be scarce until fully functioning vital registration systems become widespread.

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RESUMEN

Contexto: *A pesar del hecho de que la mayoría de las muertes maternas son prevenibles, la mortalidad materna sigue siendo alta en muchos países en desarrollo. La Meta A del Objetivo de Desarrollo del Milenio (ODM) 5 plantea reducir en tres cuartas partes la razón de mortalidad materna (RMM) entre 1990 y 2015.*

Métodos: *Derivamos estimaciones de mortalidad materna para 172 países durante el período 1990–2008. Las tendencias en la mortalidad materna se estimaron directamente a partir de datos de registros vitales; o bien, de un modelo jerárquico o de niveles múltiples, dependiendo de los datos disponibles para un país en particular.*

Resultados: *La cifra anual de muertes maternas en el mundo disminuyó en un 34% entre 1990 y 2008, de aproximadamente 546.000 a 358.000 muertes. La RMM estimada para todo el mundo también disminuyó en un 34% en este período, de 400 a 260 muertes maternas por 100.000 nacidos vivos. Entre 1990 y 2008, la mayor parte de la carga global de muertes maternas se desplazó de Asia a la región de África subsahariana. Las tendencias diferenciales en fecundidad, epidemia del VIH/SIDA y acceso a la salud reproductiva son factores clave asociados con el cambio de la carga de muertes maternas de Asia a la región de África subsahariana.*

Conclusiones: *Aunque la tasa anual estimada de disminución en la RMM global (2,3%) quedó por debajo del nivel requerido para alcanzar la meta del ODM 5, esta tasa estimada de reducción es mucho más rápida de lo que se había pensado. Los esfuerzos dirigidos a mejorar el acceso a la atención materna de calidad, así como los esfuerzos para reducir los embarazos no planeados a través de la planificación familiar, son necesarios para reducir aún más la carga global de mortalidad materna.*

RÉSUMÉ

Contexte: *En dépit du fait que la plupart des décès maternels sont évitables, la mortalité maternelle demeure élevée dans de nombreux pays en développement. La cible A de l'Objectif du Millénaire pour le développement (OMD) 5 préconise une réduction de trois quarts du taux de mortalité maternelle entre 1990 et 2015.*

Méthodes: *Nous avons dérivé les estimations de la mortalité maternelle de 172 pays sur la période de 1990 à 2008. Les tendances ont été estimées directement sur la base des données d'état civil, ou bien sur celle d'un modèle hiérarchique ou multiniveaux, suivant les données disponibles pour un pays donné.*

Résultats: *Le nombre annuel mondial de décès maternels a baissé de 34% entre 1990 et 2008, passant d'environ 546.000 à 358.000. Le taux de mortalité maternelle estimé à l'échelle mondiale a également diminué de 34% sur cette période, passant de 400 à 260 décès maternels pour 100.000 naissances vivantes. Entre 1990 et 2008, la charge mondiale des décès maternels est passée, pour la majorité, d'Asie en Afrique subsaharienne. Les tendances différentielles de fécondité, l'épidémie du VIH/sida et l'accès à la santé génésique sont les facteurs clés associés à ce déplacement régional.*

Conclusions: *Bien que le taux annuel estimé du déclin du taux de mortalité maternelle mondial (2,3%) soit inférieur au niveau requis pour satisfaire à la cible de l'OMD 5, ce taux est beaucoup plus rapide qu'on ne l'avait précédemment pensé. Des efforts ciblés d'amélioration de l'accès à des soins de santé maternelle de qualité et d'autres visant à réduire les grossesses non planifiées par le biais de la planification familiale sont nécessaires si l'on veut réduire davantage la charge mondiale de la mortalité maternelle.*

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