Estimates of maternal mortality worldwide between 1990 and 2005: an assessment of available data

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Summary

Background **Maternal mortality, as a largely avoidable cause of death, is an important focus of international development efforts, and a target for Millennium Development Goal (MDG) 5. However, data weaknesses have made monitoring progress problematic. In 2006, a new maternal mortality working group was established to develop improved estimation methods and make new estimates of maternal mortality for 2005, and to analyse trends in maternal mortality since 1990.**

Methods **We developed and used a range of methods, depending on the type of data available, to produce comparable country, regional, and global estimates of maternal mortality ratios for 2005 and to assess trends between 1990 and 2005.**

Findings **We estimate that there were 535 900 maternal deaths in 2005, corresponding to a maternal mortality ratio of 402 (uncertainty bounds 216–654) deaths per 100 000 livebirths. Most maternal deaths in 2005 were concentrated in sub-Saharan Africa (270 500, 50%) and Asia (240 600, 45%). For all countries with data, there was a decrease of 2·5% per year in the maternal mortality ratio between 1990 and 2005 ($p<0·0001$); however, there was no evidence of a significant reduction in maternal mortality ratios in sub-Saharan Africa in the same period.**

Interpretation **Although some regions have shown some progress since 1990 in reducing maternal deaths, maternal mortality ratios in sub-Saharan Africa have remained very high, with little evidence of improvement in the past 15 years. To achieve MDG5 targets by 2015 will require sustained and urgent emphasis on improved pregnancy and delivery care throughout the developing world.**

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Introduction

Maternal mortality—ie, the death of a woman during pregnancy or in the 42 days post partum due to causes directly or indirectly associated with the pregnancy—has been a priority area for the global health and development community at least since the Nairobi Safe Motherhood Conference in 1987. That conference, attended by representatives from 50 developing countries and from key development agencies, has been followed by numerous international forums at which safe motherhood was on the agenda. The 2000 Millennium Summit established the improvement of maternal health as Millennium Development Goal (MDG) 5.[1] The target of MDG5 is to reduce the maternal mortality ratio (defined as maternal deaths in a time period, usually 1 year, divided by the number of livebirths in the same period, and conventionally expressed per 100 000 livebirths) by 75% between 1990 and 2015; for a country to achieve this target requires an average decrease of 5·5% per year in the maternal mortality ratio.

Country estimates of maternal mortality are essential to inform national decisionmaking and resource allocation, to underpin advocacy efforts, and to stimulate research. Additionally, international development partners and donors rely on sound estimates to inform their own decisionmaking on resource allocation. Yet currently available country data vary greatly in quantity and quality and do not readily lend themselves to comparisons, either over time or between countries. The best way of reliably measuring maternal mortality is through a civil registration system that registers all deaths and provides medical certification of cause of death. However, even where such systems exist, vigilance is necessary to ensure that all maternal deaths are correctly classified; studies have shown maternal deaths to be under-reported.[2–6] In countries lacking complete recording of adult deaths—eg, most low-income countries—alternative approaches are needed. Researchers have developed a range of alternative measurement strategies and data availability has increased over the past 15 years. Yet in countries representing a quarter of global births there remains little empirical basis for estimating maternal mortality.

UNICEF, WHO, and the UN Population Fund (UNFPA) have previously developed global, regional, and country estimates of maternal mortality for the years 1990, 1995, and 2000.[7–9] In 2006 a new maternal mortality working group was established that included WHO, UNICEF, UNFPA, the UN Population Division, and the World Bank, as well as several outside technical experts, to develop new estimates of maternal mortality for 2005. As a starting point, this group reviewed a set of suggested improvements, prepared as part of an external review commissioned by WHO, to the methods that had been used for the 2000 estimates. In response to these suggestions and to questions posed by countries after the 2000 round of estimates, the working group agreed on ways to classify countries on the basis of data availability, on how to adjust data derived from different

Panel: Country groups, categorised by type of available data

- Group A: Countries with satisfactory civil registration data
- Group B: Countries with complete registration of deaths but excessive proportions of ill-defined causes
- Group C: Countries with direct sisterhood surveys
- Group D: Countries with reproductive age mortality surveys
- Group E: Countries with sample registration estimates
- Group F: Countries with population census based estimates
- Group G: Countries with other empirical bases
- Group H: Countries lacking appropriate empirical data (model used)

sources to enhance comparability across countries and across time, and on the specifications for the statistical model used to predict values for countries lacking appropriate data. Here, we describe the new methods used and present national, regional, and global 2005 estimates of maternal mortality. We also address the challenge of comparability of estimates over time and generate some broad conclusions about global and regional trends since 1990.

See Online for webtable 1

Methods

Our unit of analysis was the country. Countries have used a range of different data collection approaches to generate estimates of maternal mortality. Our analysis was restricted to nationally representative sources of data. Sources were identified in collaboration with countries through WHO, UNICEF, and UNFPA country representatives as well as from internationally coordinated survey programmes; our cutoff for the review of data sources was March, 2007. Different data sources require different analytical strategies to enhance comparability across countries and over time. As a result, we used different methods to obtain comparable country, regional, and global estimates of maternal mortality ratios for 2005 and for the analysis of trends between 1990 and 2005. Countries and territories with populations under 250 000 were excluded.

	Maternal mortality ratio (deaths per 100 000 livebirths)	Maternal deaths
Overall	402 (216–654)	535 900 (288 400–871 800)
Developed regions	9 (8–17)	960 (910–1950)
Countries of the Commonwealth of Independent States	51 (28–139)	1810 (1000–4930)
Developing regions	450 (242–730)	533 100 (286 400–864 900)
Africa	824 (414–1351)	276 100 (138 600–452 900)
Northern Africa	157 (85–286)	5660 (3050–10 300)
Sub-Saharan Africa	905 (453–1480)	270 500 (135 600–442 500)
Asia	329 (189–523)	240 600 (138 100–382 600)
Latin American and the Caribbean	132 (81–230)	15 500 (9470–26 900)
Oceania	427 (121–1169)	890 (250–2440)

Data are estimate (uncertainty bounds). Excludes countries with populations of less than 250 000 in 2005.

Table 1: **Maternal mortality estimates for 2005 by UN MDG regions**

Estimation of maternal mortality ratios

The challenge in producing comparable country estimates of maternal mortality ratios is to make maximum use of the strengths of recent (post-1995) empirical data while minimising the effects of the data weaknesses identified in previous global estimates.[7–9] A modelling strategy was required for countries without any reliable national level data for maternal mortality. We identified eight broad types of data availability (panel), and used different strategies to estimate or adjust reported maternal mortality ratios for each; we also estimated uncertainty bounds, intended to give a sense not of formal statistical significance but of plausible range. In most settings the magnitude of uncertainty is unclear; our approach to establishing uncertainty bounds was largely arbitrary. Studies in countries with high-quality data have revealed a widespread tendency to under-record maternal deaths in civil registration, on average by a third (webtable 1).[10–19] We assumed that in less good data collection settings the errors were likely to be at least as large, so we used an upward adjustment of maternal mortality ratios by 50% in many settings. Throughout we used UN Population Division estimates of 2005 births (the denominator of the maternal mortality ratio) for consistency. For countries in groups C, F, and H, we made use of the proportion of deaths of all women of reproductive age due to maternal causes (PMDF) because we believe it to be more accurately recorded than maternal mortality per se. However, the PMDF is affected by the HIV/AIDS epidemic: where adult female deaths have increased sharply, the PMDF has fallen. In many cases, the PMDF is observed for a year

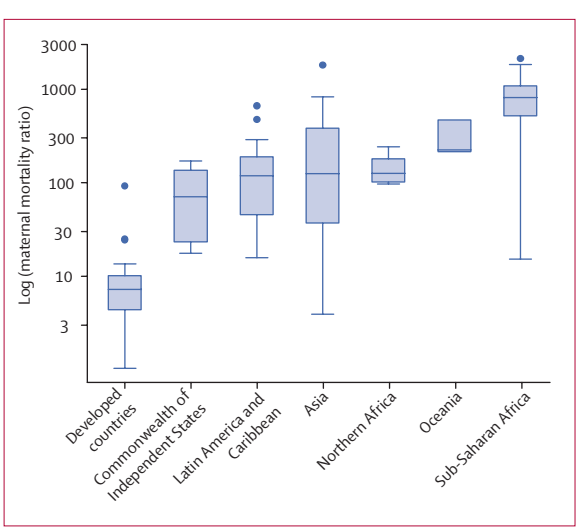

Figure: **Distribution of country estimates of maternal mortality ratios for 2005 by MDG regions**

Boxes represent 25th and 75th percentiles of the observations, with the middle bar representing the median, and the whiskers marking the upper and lower adjacent values. Dots represent extreme outliers.

other than 2005. To avoid bias due to excess HIV-related deaths, we calculated the proportion of deaths due to maternal causes among deaths of all causes except HIV, a proportion that we refer to as $PMDF^{non\text{-}HIV}$. One should note that expressing the proportion relative to non-HIV deaths does not mean that maternal deaths of women as a result of HIV are excluded.

In group A countries (n=59, 13% of global births in 2005), WHO estimates that at least 90% of deaths are registered, and there is medical certification of cause of death using International Statistical Classification of Diseases and Related Health Problems (ICD) standards, and where ill-defined cause of death codes appear on less than 20% of certificates.[20] For these countries, we calculated maternal mortality ratios by dividing the average number of maternal deaths for the three most recent years available (we averaged over 3 years to smooth out volatility resulting from small numbers; for countries with population size below half a million we averaged over 6 years) by the estimated number of births in 2005. On average about two-thirds of all true maternal deaths were identified as such in complete civil registration systems (webtable 1). However, national registration procedures vary, and a single adjustment factor (of around 1·5) cannot be generalised. Therefore, national estimates were used both as the lower limit of the country-specific uncertainty bound and as the point estimate; the upper uncertainty bound was obtained by multiplying the estimated maternal mortality ratio by two to account for uncertainty in the under-reporting of deaths due to maternal causes. Maternal mortality was so low in group A countries that any adjustments to their estimates would make essentially no difference to regional or global estimates.

In group B countries (n=6, 1% of global births), civil registration systems are judged by WHO to record at least 90% of deaths, but ill-defined cause of death codes appear on 20–30% of certificates.[21] Initial estimates of maternal mortality ratios for these countries were arrived at by proportionately redistributing female deaths of ill-defined causes among known causes. The adjusted estimates of maternal deaths averaged over the three most recent years available and estimated number of births in 2005 were used to estimate maternal mortality ratios for 2005. In view of the additional uncertainty of these estimates relative to group A, the point estimate was obtained by multiplying the initial estimate of the maternal mortality ratio by 1·5. The initial estimate was used as the lower uncertainty bound, and twice the initial estimate as the upper bound.

Group C countries (n=28, 16% of global births) have used direct sisterhood modules in nationally representative household surveys.[22] These modules collect information concerning all siblings born of the same mother: sex and age for living siblings; sex, age at death, and year of death for dead siblings. Additionally, for sisters who died at ages 15–49 years, information was collected as to whether the sister was pregnant or within 2 months of delivery when she died. Estimates of maternal mortality derived from sisterhood methods are usually calculated for a reference period of 0–6 years before the survey. Previous analyses have suggested that sisterhood data tend to under-estimate overall female

See Online for webfigure, webappendix and webtable 2

	Reference period of latest data or estimate*	Estimated maternal mortality ratio 2005 (deaths per 100 000 livebirths)
Group A*		
Australia	2003	4 (4–9)
Austria	2005	4 (4–7)
Bahamas	2000	16 (16–33)
Barbados	2000	16 (16–31)
Belarus	2003	18 (18–35)
Belgium	1997	8 (8–16)
Belize	2001	52 (52–100)
Bosnia and Herzegovina	2004	3 (3–6)
Bulgaria	2004	11 (11–22)
Canada	2003	7 (7–13)
Chile	2003	16 (16–32)
Costa Rica	2004	30 (30–60)
Croatia	2005	7 (7–15)
Cuba	2004	45 (45–90)
Cyprus	2005	10 (10–20)
Czech Republic	2005	4 (4–9)
Denmark	2001	3 (3–6)
Estonia	2005	25 (25–50)
Finland	2005	7 (7–15)
France	2003	8 (8–16)
Germany	2004	4 (4–9)
Hungary	2005	6 (6–11)
Iceland	2004	4 (4–8)
Ireland	2005	1 (1–2)
Israel	2003	4 (4–9)
Italy	2002	3 (3–6)
Japan	2004	6 (6–12)
Kuwait	2002	4 (4–8)
Latvia	2004	10 (10–19)
Lithuania	2005	11 (11–22)
Luxembourg	2005	12 (12–23)
Macedonia, Former Yugoslav Republic of	2005	10 (10–20)
Malta	2005	8 (8–17)
Mauritius	2003	15 (15–30)
Mexico	2003	60 (60–120)
Moldova	2004	22 (22–44)
Mongolia	2003	46 (46–93)
Netherlands	2005	6 (6–12)
New Zealand	2003	9 (9–18)
Norway	2003	7 (7–15)
Puerto Rico	2001	18 (18–36)
Romania	2005	24 (24–49)
Russia	2004	28 (28–55)

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Serbia and Montenegro	1997	14 (14–27)
Singapore	2003	14 (14–27)
Slovakia	2004	6 (6–12)
Slovenia	2005	6 (6–12)
South Korea	2004	14 (14–27)
Spain	2005	4 (4–9)
Suriname	2000	72 (72–140)
Sweden	2002	3 (3–7)
Switzerland	2004	5 (5–11)
Trinidad and Tobago	2000	45 (45–89)
Ukraine	2004	18 (18–36)
UK	2004	8 (8–15)
USA	2003	11 (11–21)
Uruguay	2001	20 (20–40)
Uzbekistan	2004	24 (24–49)
Venezuela	2002	57 (57–110)
Group B		
Argentina	2003	77 (51–100)
Bahrain	2001	32 (21–42)
Greece	2004	3 (2–4)
Poland	2004	8 (5–10)
Portugal	2003	11 (7–14)
Qatar	2004	12 (8–16)
Group C		
Bolivia	1998–2003	290 (160–430)
Burkina Faso	1994–98	700 (390–1000)
Cambodia	1999–2005	540 (370–720)
Cameroon	1998–2004	1000 (670–1400)
Chad	1998–2004	1500 (930–2000)
Congo	1999–2005	740 (450–1100)
Dominican Republic	1993–2002	150 (90–210)
Ethiopia	1999–2005	720 (460–980)
Gabon	1994–2000	520 (290–760)
Guinea	1996–2005	910 (590–1200)
Haiti	1995–2000	670 (390–960)
Indonesia	1998–2003	420 (240–600)
Kenya	1993–2003	560 (340–800)
Lesotho	1995–2004	960 (570–1400)
Madagascar	1999–2003	510 (290–740)
Malawi	1998–2004	1100 (720–1500)
Mali	1995–2001	970 (620–1300)
Mauritania	1995–2001	820 (480–1200)
Morocco	1994–2003	240 (140–350)
Mozambique	1994–2004	520 (360–680)
Namibia	1991–2000	210 (110–300)
Peru	1994–2000	240 (170–310)
Rwanda	2000–2004	1300 (770–1800)
Senegal	1999–2005	980 (590–1400)
Tanzania	1995–2005	950 (620–1300)
Togo	1993–98	510 (290–750)
Uganda	1992–2001	550 (350–770)
Zambia	1995–2001	830 (520–1200)

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mortality.[22–24] The webfigure compares a summary measure of female mortality (the probability of dying between the ages of 15 and 50 years) estimated from sister histories with independent estimates made by WHO based on careful assessments of all available data;[25,26] although there is a strong relation, in all but two cases the sister-based estimate is below the WHO estimate. The same studies have also suggested that the proportion of sister deaths reported as occurring during pregnancy or the immediate post-partum period (pregnancy-related deaths) provides a reasonable estimate of the true PMDF; theoretically, pregnancy-related deaths exceed true maternal deaths because of the inclusion of deaths from causes incidental to the pregnancy, but in practice this excess could be roughly balanced by a failure to report some deaths (eg, abortion-related deaths), as occurring during pregnancy.[27–29] Thus, for group C countries we based our estimate of maternal mortality ratios on WHO estimates of the number of deaths of women of reproductive age in 2005 combined with the survey estimates of PMDF. For each survey, we standardised our estimates of PMDF onto the age distribution of women in the survey population, because the age distribution of sisters is not the same as that of the female population itself. A further adjustment is required as a result of the dynamics of national HIV epidemics. The survey estimates of PMDF represent averages over the 7 years before the survey; thus for a survey taken at the end of 2002, the PMDF represents an average over the period 1996–2002. Since PDMF can change rapidly over time in a population with an HIV/AIDS epidemic, we calculated $PMDF^{non\text{-}HIV}$ over the period and then estimated maternal deaths for 2005 by applying this $PMDF^{non\text{-}HIV}$ to estimated non-HIV deaths of women of reproductive age in 2005. This estimate was then divided by the estimated number of births in 2005 to obtain the point estimate of the maternal mortality ratio. Lower and upper bounds for the estimates were calculated from a model that related published SE on 7-year sisterhood estimates[22] to the square root of the number of sister years of observation.

Group D countries (n=4, 5% of global births) are those that have done reproductive age mortality surveys. A true reproductive age mortality survey uses several sources of data on deaths of women of reproductive age to ensure that all such deaths are identified (triangulation) and are usually regarded as the gold standard for the estimation of maternal mortality ratios. However, some surveys are not nationally representative, and others fail to report their procedures clearly. We therefore took a conservative approach to estimates from such surveys. We used only those surveys that were nationally representative or had been adjusted for geographic selection, and used this estimate as the lower bound of the uncertainty range. The point estimate was obtained by multiplying the observed value by 1·5, and the upper bound by doubling it.

Group E countries (China and India, 32% of global births) have data from disease surveillance or sample registration systems. We assumed that these estimates at best were as uncertain and faced the same biases as group B countries; this could be a liberal assumption in view of possible issues related to number of deaths covered and how representative the systems were for the country as a whole. Accordingly, the observed value was accepted as the lower uncertainty bound, the point estimate was obtained by multiplying the observed value by 1·5, and the upper bound by doubling it.

Group F countries (n=5, 2% of global births) have population census data on household deaths with identification of pregnancy-related deaths. We treated these data in much the same way as sisterhood data: we multiplied the observed $PMDF^{all}$ by the WHO estimate of deaths for the respective census year to estimate the number of maternal deaths, and then expressed this as a percentage of WHO non-HIV deaths. This adjusted $PMDF^{non\text{-}HIV}$ was then applied to WHO-estimated non-HIV deaths in 2005. This number of maternal deaths, divided by estimated births in 2005, was used as the lower uncertainty bound; the point estimate was obtained by multiplying the observed value by 1·5, and the upper bound by doubling it.

Group G countries (n=6, 5% of global births) have estimates for maternal mortality ratios from special studies about which little information is available. For these countries, the observed value was taken to be the lower uncertainty bound; the point estimate was obtained by multiplying the observed value by 1·5, and the upper bound by doubling it.

Group H countries (n=61, 25% of global births) are those with no empirically based data sets or estimates for maternal mortality ratios in 1995 or more recently produced according to established methods. For these countries, it was not possible to develop correction factors; instead we had to predict maternal mortality values on the basis of statistical modelling. We adopted a strategy similar to that used for the 2000 estimates, involving a four-stage procedure. First, we developed a statistical model to estimate PMDFs for non-HIV/AIDS deaths (webappendix and webtable 2), using data from all countries with empirical data (ie, groups A to G, with the exception of group B). We used this model to estimate the $PMDF^{non\text{-}HIV}$ for each country in group H. We then multiplied the estimated $PMDF^{non\text{-}HIV}$ by the number of non-HIV/AIDS deaths of women aged 15–49 years, as estimated by WHO for 2005, to establish the number maternal deaths. Lastly, we derived estimates of the maternal mortality ratio by dividing the estimated maternal deaths by estimated 2005 livebirths. Lower and upper bounds were estimated from the SE of out-of-sample estimates from the PMDF model.

Estimation of trends in maternal mortality ratios

Few developing countries, especially low-income ones, have more than one national estimate of maternal

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Group D		
Brazil	2005	110 (74–150)
Egypt	2000	130 (84–170)
Jordan	1996	62 (41–82)
Turkey	2005	44 (29–58)
Group E		
China	2005	45 (30–60)
India	2001–2003	450 (300–600)
Group F		
Honduras	2001	280 (190–380)
Iran	1995–96	140 (95–190)
Nicaragua	2005	170 (120–230)
Paraguay	2002	150 (99–200)
South Africa	2001	400 (270–530)
Group G		
Bangladesh	2000	570 (380–760)
Burma	1999	380 (260–510)
Malaysia	1996	62 (41–82)
Saudi Arabia	2000	18 (12–24)
Sri Lanka	2004	58 (39–77)
Thailand	2005	110 (70–140)
Group H		
Afghanistan	2005	1800 (730–3200)
Albania	2005	92 (26–300)
Algeria	2005	180 (55–520)
Angola	2005	1400 (560–2600)
Armenia	2005	76 (23–250)
Azerbaijan	2005	82 (21–290)
Benin	2005	840 (330–1600)
Bhutan	2005	440 (160–970)
Botswana	2005	380 (120–1000)
Brunei	2005	13 (3–47)
Colombia	2005	130 (38–370)
Burundi	2005	1100 (480–1900)
Cape Verde	2005	210 (68–530)
Central African Republic	2005	980 (380–1900)
Comoros	2005	400 (150–840)
Côte d'Ivoire	2005	810 (310–1600)
Democratic Republic of the Congo	2005	1100 (480–1900)
Djibouti	2005	650 (240–1400)
Ecuador	2005	210 (65–560)
El Salvador	2005	170 (55–460)
Equatorial Guinea	2005	680 (210–1600)
Eritrea	2005	450 (180–850)
Fiji	2005	210 (55–720)
Gambia	2005	690 (250–1500)
Georgia	2005	66 (18–230)
Ghana	2005	560 (200–1300)
Guatemala	2005	290 (100–650)
Guinea Bissau	2005	1100 (500–1800)
Guyana	2005	470 (140–1600)
Iraq	2005	300 (110–600)
Jamaica	2005	170 (51–510)

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Kazakhstan	2005	140 (40–500)
Kyrgyzstan	2005	150 (43–460)
Laos	2005	660 (190–1600)
Lebanon	2005	150 (41–500)
Liberia	2005	1200 (520–2100)
Libya	2005	97 (28–300)
Maldives	2005	120 (42–260)
Nepal	2005	830 (290–1900)
Niger	2005	1800 (840–2900)
Nigeria	2005	1100 (440–2000)
North Korea	2005	370 (110–1200)
Oman	2005	64 (18–200)
Pakistan	2005	320 (99–810)
Panama	2005	130 (39–410)
Papua New Guinea	2005	470 (130–1300)
Philippines	2005	230 (60–700)
Sierra Leone	2005	2100 (880–3700)
Solomon Islands	2005	220 (65–580)
Somalia	2005	1400 (550–2700)
Sudan	2005	450 (160–1000)
Swaziland	2005	390 (130–980)
Syria	2005	130 (40–370)
Tajikistan	2005	170 (53–460)
Timor-Leste	2005	380 (150–700)
Tunisia	2005	100 (27–380)
Turkmenistan	2005	130 (37–400)
United Arab Emirates	2005	37 (10–130)
Vietnam	2005	150 (40–510)
Yemen	2005	430 (150–900)
Zimbabwe	2005	880 (300–2000)

Data are maternal mortality ratio (uncertainty bounds). Because of the very large uncertainty bounds around country point estimates, we have rounded estimates of maternal mortality ratios below 100 per 100 000 livebirths to the nearest unit, estimates between 100 and 1000 to 10 units, and estimates above 1000 to the nearest 100 units. *For groups A and B, year refers to the most recent year for which maternal deaths are available to WHO from civil registration.

Table 2: **Country estimates of maternal mortality ratios for 2005**

See Online for webtables 3 and 4

mortality. We therefore used two different approaches to explore trends in maternal mortality ratios.

The first approach was a random-effects time-series regression model of empirically based estimates of maternal mortality ratios compiled (and adjusted if necessary with the methods described above) by this and earlier WHO, UNICEF, and UNFPA exercises covering the period 1985 to the present, including estimates for high-income countries that had been excluded from the modelling exercise for group H countries. All estimates that were based on the models of PMDF (the equivalent in earlier exercises of the group H countries in 2005) were excluded from the analysis. The distribution by data source of the estimates included in the analysis is shown in webtable 3. The time-series regression model related the outcome variable (the estimated maternal mortality ratio) to the reference date of the estimate. Random-effects regression models were used because they are more appropriate to the structure of our data (multiple observations at irregular time points for some countries, single observations for others) than were standard time-series methods. The random effects model uses not only multiple observations within countries but also the patterns of change across countries; it therefore makes use of single country observations, but could provide biased results if countries are selected into the database differentially over time. To test for possible bias we re-estimated the models by use of fixed-effects models, which produced almost identical results (webtable 3).

The specific form of the random-effects regression model was as follows:

$$\ln(MMR_{i,t})=\beta_0+\beta_1(time_i)+v_i+\varepsilon_{i,t}$$

where $MMR_{i,t}$ is the maternal mortality ratio for country i at time t, $time_t$ is the reference year to which the estimate applies, v_i is a country-specific normally distributed term, and $\varepsilon_{i,t}$ is a random residual term. The coefficient β_1 on time can be interpreted as an estimate of secular trend in maternal mortality ratios. This regression equation was used for all 858 empirically based estimates of maternal mortality ratios, but we also examined differences in the estimated model parameters across MDG regions, level of income as determined by the World Bank,[30] and the initial maternal mortality ratio.

Our second approach was to re-estimate maternal mortality for all countries of the world for around 1990, by use of the same methods used for the 2005 estimates. For countries with some empirical basis for estimates of maternal mortality ratios around 1990, we replicated the methods used to estimate maternal mortality ratios for 2005 with data from the late 1980s and early 1990s. For countries lacking an acceptable basis for estimates around 1990, a model of the PMDF is used, the model having the same form as the 2005 model, but with coefficients re-estimated with data available for 1985–95. Webtable 4 compares the coefficients of the 1990 and 2005 models. Trends were then explored by examining the regional changes in maternal mortality ratios and numbers of maternal deaths between the 1990 and 2005 estimates.

Role of the funding source

Representatives of UNICEF and the World Bank-Netherlands Partnership Program participated in the Maternal Mortality Working Group and in data compilation, and made suggestions about our analysis. All participants in the working group had access to all the data. The corresponding author had final responsibility for the decision to submit for publication.

Results

We estimate that there were about 535 900 maternal deaths worldwide in 2005, and the maternal mortality ratio was about 402 maternal deaths per 100 000 livebirths (table 1). Most maternal deaths were concentrated in

	Number of countries	Number of observations	Coefficient β_1 on reference year
All	125	858	–0·025*
Countries classified by World Bank income level			
Low income	31	65	–0·017
Lower-middle income	36	155	–0·038*
Upper-middle income	24	272	–0·046*
High income	34	366	–0·002
Countries classified by data source type			
Vital registration	69	751	–0·023*
Sisterhood surveys	41	63	–0·002
Reproductive age mortality surveys	15	21	–0·071†
Other	8	23	–0·043*
Countries classified by initial maternal mortality ratio			
<200	81	785	–0·024‡
≥200	44	73	–0·021

Probability that the coefficient equals 0: *<0·001, †<0·05, ‡<0·01.

Table 3: **Random-effects model estimates of trends in the maternal mortality ratio by income region, data source type, and initial level of ratio**

sub-Saharan Africa (270 500, 50% of deaths worldwide) and Asia (240 600, 45% of deaths worldwide); almost half (48%) of maternal deaths worldwide in 2005 was concentrated in just five countries: India (117 100), Nigeria (58 800), the Democratic Republic of Congo (32 300), Afghanistan (26 000), and Ethiopia (22 200).

Variation in the maternal mortality ratio at the regional level was very large, from nine per 100 000 livebirths for developed countries to 905 per 100 000 livebirths in sub-Saharan Africa (table 1 and figure). Even within developing regions, the range is substantial—eg, the estimate for Latin America and the Caribbean is about a seventh of that for sub-Saharan Africa (table 1). Variation at the country level is even more dramatic than for regions, from a low of one per 100 000 livebirths in Ireland to 2100 per 100 000 livebirths in Sierra Leone (table 2).

Overall, the random-effects regression model was fitted to 858 observations from the late 1980s to 2005 for a total of 125 countries. Coefficients of the regression model fitted to all 858 observations from the late 1980s to 2005 are shown in table 3. The coefficient β_1 on reference date measures trends in maternal mortality ratios, and can be interpreted as the average annual rate of change in the ratio per year over the time period. For all countries, the coefficient for β_1 is –0·025 ($p<0·0001$) indicating that, over the period of observation, there was a 2·5% decline per year in the maternal mortality ratio in all countries with empirically based estimates of the ratio; the fixed effects results in webtable 5 show an almost identical rate of change across those countries with two or more observations.

See Online for webtable 5

Table 3 also shows results of the random-effects model fitted to observations for different World Bank income categories, countries classified by type of maternal mortality data source, and initial levels of maternal mortality ratios. The downward trend in maternal mortality ratios with time is only significant in lower-middle and upper-middle income countries. Decreases in the maternal mortality ratios are significant across all data source types except for those obtained from sisterhood studies; the decrease was largest for estimates of maternal mortality ratios from studies with complete registration of deaths but excessive proportions of ill-defined causes, which represent about 2% of the sample. An additional analysis of the trends in sisterhood-based estimates of maternal mortality ratios as reported by Demographic and Health Surveys, without adjustment for the WHO estimated numbers of deaths, produced similarly non-significant results (data not shown), confirming that the results in table 3 are not an artifact of our adjustment procedure. Countries with initial maternal mortality ratios below 200 deaths per 100 000 livebirths experienced declines of about 2·4% per year ($p<0·0001$), whereas countries with initial ratios of

	1990		2005		Change in maternal mortality ratio (%)
	Maternal mortality ratio (deaths per 100 000 livebirths)	Maternal deaths	Maternal mortality ratio (deaths per 100 000 livebirths)	Maternal deaths	
Overall	425	576 300	402	535 900	–5·4%
Developed regions	11	1330	9	960	–23·6%
Countries of the Commonwealth of Independent States	58	2780	51	1810	–12·5%
Developing regions	481	572 200	450	533 100	–6·6%
Africa	829	221 000	824	276 100	–0·6%
Northern Africa	246	8940	157	5660	–36·3%
Sub-Saharan Africa	921	212 000	905	270 500	–1·8%
Asia	410	329 100	329	240 600	–19·7%
Latin American and the Caribbean	179	21 100	132	15 500	–26·3%
Oceania	548	1050	427	890	–22·2%

Table 4: **Comparison of 1990 and 2005 regional and global estimates of maternal mortality ratios**

200 or more deaths per 100 000 livebirths experienced no significant decline between 1990 and 2005 (table 3).

Table 4 shows our re-estimation of maternal mortality ratios by MDG region around 1990, and compares them with those from 2005. These estimates indicate that the worldwide maternal mortality ratio fell by only 5·4% between 1990 to 2005, which equates with an average decrease of about 0·4% a year. In the same period, there was a 7% decrease in the number of maternal deaths worldwide. Decreases in maternal mortality ratios exceeded 20% in northern Africa, Latin America and the Caribbean, Oceania, and in developed countries, but were negligible in sub-Saharan Africa. Sub-Saharan Africa was the only MDG region in which the number of maternal deaths increased between 1990 and 2005, driven by increasing numbers of births and a negligible decline in maternal mortality ratios.

Discussion

Our results indicate that the worldwide maternal mortality ratio for 2005 is about 402 deaths per 100 000 livebirths, which represents about 535 900 maternal deaths in 2005. At the national level, estimated maternal mortality ratios range from below 10 deaths per 100 000 livebirths in most developed countries to as high as 2000 deaths per 100 000 livebirths in some developing countries. This huge difference in risk dwarfs differences for other commonly used health indicators, such as the infant mortality rate, and makes it likely that effective interventions to reduce maternal mortality exist but are not being widely implemented.

Reports of maternal mortality ratios in 1995 and 2000 strongly cautioned users against comparing the new country, regional, and global estimates with those from earlier exercises in terms of trends. Changes in data availability, data collection, and analysis methods rendered the results non-comparable. Here, we made an explicit attempt to estimate trends. Both methods we used indicated some decline in maternal mortality ratios between 1990 and 2005. The time-series analysis indicated an average decline of about 2·5% per year, but also indicated that such a decrease is largely restricted to middle-income countries and those countries with initial ratios below 200 deaths per 100 000 livebirths (table 3). Our re-estimation analysis showed a much smaller decline, of less than 1% a year, also restricted to countries in northern Africa, Asia, and Latin America; there is little evidence of any improvement for those countries in sub-Saharan Africa with high maternal mortality ratios (table 4). The substantial difference between the results of the two approaches is the result of differences in the composition of the country data sets included and of the methods of calculation. The time-series analysis used countries as the unit of analysis, irrespective of the number of births, whereas the re-estimation analysis weighted changes by numbers of births; births have increased in areas with high maternal mortality ratios such as sub-Saharan Africa where little progress has been made, but have declined in middle-income countries where progress has been made. The time-series random-effects model was only fitted to countries with empirical data, whereas the re-estimation analysis includes all countries. Since the countries with empirical data might plausibly have done better than those without, the time-series estimates should be viewed as upper bounds on the true trends. One should also note that the available data permit analysis for regional and global aggregates only and not for individual countries.

We estimated national maternal mortality ratios for 2005 by use of a broadly similar strategy to that used by the previous WHO, UNICEF, and UNFPA exercises for 1995 and 2000.[8,9] After an internationally coordinated exercise to identify and compile all available sources of nationally representative data concerning maternal mortality, we classified countries according to the type of data available. For most countries, the observed information is adjusted or recalculated in some way to address issues of non-comparability of data from different sources both over time and across countries. Only for countries representing about an eighth of global births were births and deaths completely recorded with generally good cause of death recording, and even in these supposedly ideal cases there was considerable uncertainty about the true maternal mortality ratio because of failure to identify maternal deaths as such on death certificates, or coding errors. Despite our efforts at data compilation, no suitable recent data were found for a third of the countries of the world. For these countries, a statistical model was used to predict the proportion of women of reproductive age who died because of maternal causes. Indeed, the maternal mortality database remains very weak, especially for those countries with the highest levels of risk; national estimates of maternal mortality ratios continue to have very wide uncertainty bounds. Major investment by the international community is needed to measure maternal mortality and to build country capacity so that we can assess and interpret such data more accurately.

In the context of MDG5, progress is slow. The yearly rate of decline required to achieve the MDG5 target of reducing national maternal mortality ratios by three-quarters between 1990 and 2015 is 5·5%, far faster than the 2·5% decrease per year estimated for the countries with data or even the 4·6% fall estimated for upper-middle income countries. Of great concern is that, although some regions have shown some progress since 1990 in reducing maternal deaths, maternal mortality ratios in sub-Saharan Africa have remained very high, with little evidence of improvement in the past 15 years. To achieve MDG5 targets by 2015 will need a huge and urgent emphasis on improved pregnancy and delivery care throughout the developing world. Identifying progress by 2015 will also require a major investment in data availability and data quality; advantage must be taken

of all possible sources of relevant information, such as including the necessary questions—eg, recent household deaths by age and sex with follow-up questions for death of women at ages 15–49 years about the timing of death relative to pregnancy—in forthcoming national population censuses.[31]

Contributors

KH oversaw the technical analysis, co-wrote the first draft, and edited subsequent drafts. KT contributed to compilation of data, did the statistical analysis and co-wrote the first draft. CAZ contributed to compilation and assessment of data, and advised on methodology and interpretation. NW contributed to methodological development and editing of revisions. LS contributed to the conception and planning of the study, identification and assessments of the primary data sources and maintenance of the database. MI contributed to the collection, compilation of data and estimation for countries with civil registration systems, carried out a literature review on the situation of reporting of maternal deaths in such systems and produced a summary table. ES contributed to methodology development, database maintenance, editing of revisions, and production of summary tables.

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Conflict of interest statement

We declare that we have no conflict of interest.

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