Estimates of maternal mortality for 1995

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Objective To present estimates of maternal mortality in 188 countries, areas, and territories for 1995 using methodologies that attempt to improve comparability.

Methods For countries having data directly relevant to the measurement of maternal mortality, a variety of adjustment procedures can be applied depending on the nature of the data used. Estimates for countries lacking relevant data may be made using a statistical model fitted to the information from countries that have data judged to be of good quality. Rather than estimate the Maternal Mortality Ratio (MMRatio) directly, this model estimates the proportion of deaths of women of reproductive age that are due to maternal causes. Estimates of the number of maternal deaths are then obtained by applying this proportion to the best available figure of the total number of deaths among women of reproductive age.

Findings On the basis of this exercise, we have obtained a global estimate of 515 000 maternal deaths in 1995, with a worldwide MMRatio of 397 per 100 000 live births. The differences, by region, were very great, with over half (273 000 maternal deaths) occurring in Africa (MMRatio: >1000 per 100 000), compared with a total of only 2000 maternal deaths in Europe (MMRatio: 28 per 100 000). Lower and upper uncertainty bounds were also estimated, on the basis of which the global MMRatio was unlikely to be less than 234 or more than 635 per 100 000 live births. These uncertainty bounds and those of national estimates are so wide that comparisons between countries must be made with caution, and no valid conclusions can be drawn about trends over a period of time.

Conclusion The MMRatio is thus an imperfect indicator of reproductive health because it is hard to measure precisely. It is preferable to use process indicators for comparing reproductive health between countries or across time periods, and for monitoring and evaluation purposes.

Keywords: Maternal mortality/statistics; Statistics/methods; Models/statistical (*source: MeSH*).

Mots clés: Mortalité maternelle/statistique; Statistique/méthodes; Modèle statistique (*source: INSERM*).

Palabras clave: Mortalidad materna/estadística; Estadística/métodos; Modelos estadísticos (*fuente: BIREME*).

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Introduction

Maternal mortality is notoriously difficult to measure (*1*). The most widely used measure, the Maternal Mortality Ratio (MMRatio), expresses maternal deaths per 100 000 live births, but MMRatios rarely exceed 1000 or 1 per 100 live births. Maternal deaths are thus relatively rare events and they are also hard to identify precisely, both of which limit the applicability of sample survey measurement methods. In countries with well-developed statistical services, the conventional source of information about maternal mortality is the civil registration system, which records both live births and deaths, by cause, on a continuous basis. Even in such settings, however, maternal deaths are invariably found to be under-recorded in official statistics owing to misclassification of the cause of death (*2–4*). In countries with less well developed statistical services, the outright omission of deaths contributes an additional source of error.

Despite the difficulties in measuring maternal mortality, interest in obtaining estimates has increased. The MMRatio varies by a factor of over 100 between the highest and lowest mortality settings, making it the health outcome with the largest gap between developed and developing countries. Interest has also increased because one of the main targets of the Programme of Action, which was developed at the International Conference on Population and Development in Cairo in 1994 (*5*), is reproductive health. One specific goal of the

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Programme of Action called for quantified reductions in maternal mortality. However, although the goal was phrased in terms of a 1990 baseline, no global estimates of the situation in 1990 were available. To try to bridge the gap between the need for reliable data and the quality of conventional data sources, alternative approaches to measurement have been explored.

In 1996, WHO and UNICEF prepared model-based estimates of maternal mortality for about the year 1990 in developing countries, for which adequate empirical information had not been identified (*6, 7*). The model caused considerable controversy, particularly in countries which did have relevant information and for which the model-based estimates were often substantially higher than the existing figures. The resulting controversy, however, had at least three positive outcomes: 1) it increased general awareness of the problems surrounding the measurement of the MMRatio; 2) it drew attention to the various strengths and weaknesses of the different measurement approaches; and 3) it brought to light relevant data hitherto unavailable to the international community, or stimulated new data collection, or both. This paper updates the 1996 exercise using a revised methodology, incorporating new data as available, and presents the maternal mortality estimates, by countries and regions, for 1995.

The basis of the estimates

The estimation strategy was developed in response to concerns in three major areas, which were expressed in international forums about the 1996 exercise: 1) failure to use country data where they were available and which are believed to be of good quality; 2) concern about the choice of a dependent variable in the statistical model; and 3) rigidities in the model that limited the range of possible values of estimates of maternal mortality (*8–11*).

For the present estimation exercise, every attempt was made to use country data where available and of adequate quality. Using the available data, countries, areas, and territories were placed in one of the following six categories, according to whether they had:

(a) complete death registration data, with generally good cause of death attribution;
(b) complete death registration data, but uncertain cause of death attribution;
(c) information from a survey on deaths of sisters, with timing of death related to pregnancy;
(d) recent results from a Reproductive Age Mortality Study (RAMOS);
(e) other available relevant data;
(f) no relevant data available for a recent period.

Different strategies were used to arrive at estimates for the countries in each category, taking advantage of the stronger elements of the data while minimizing the distortions resulting from data errors.

Despite increased data availability, estimates for countries in categories (b) and (f) still require a statistical model to estimate the MMRatio. The model is fitted to country observations deemed to be of very high quality, using predictor variables that are available for almost every country, and is then used to predict estimates for countries that lack high quality information.

Choice of a dependent variable for the statistical model

A model using the proportion of deaths of women of reproductive age due to maternal causes (*PMDF*), rather than the MMRatio, has several advantages. First, the estimated *PMDF* is bounded by 0 and 1, so that its logit ($\ln\{PMDF/(1\text{-}PMDF)\}$) can be modelled without risk of the predicted values falling outside that range. The predicted *PMDF* can then be applied to an "envelope" of deaths of women of reproductive age, obtained either from death registration data or from special tabulations of deaths, by age and sex, provided by the United Nations Population Division (UNPD) from the 1998 revision of World Population Prospects (*12*), to estimate the number of maternal deaths. Thus, the estimates have to be consistent with other demographic information about the population in question. Second, the *PMDF* estimate makes full use of limited data. For example, in category (b) countries with good overall death registration but uncertain cause-of-death reporting, a model-based estimate of *PMDF* can be applied to the "envelope" of registered female deaths, modelling only the distribution of such deaths by cause, not their number.

Third, sisterhood data, the most frequently available type of information about maternal mortality in high-mortality settings, are likely to provide more robust measures of the *PMDF* than of the MMRatio. A large majority of nationally representative data sets on sister survival, mostly collected under the auspices of the Demographic and Health Surveys (DHS) programme, have used sibling history to collect the basic data. Each of a respondent's siblings is listed, and survival status is recorded. For sisters who died at age 12 or older, further questions are asked as to whether she was pregnant, or giving birth, or within two months of the end of a pregnancy when she died. These questions are used to identify possible maternal deaths; strictly speaking, it is a time-of-death (pregnancy-related) definition, not a cause-of-death (maternal) definition. Some non-maternal deaths are included, but some true maternal deaths are likely to be excluded because the respondent may not be aware of a sister's pregnancy at the time of death. The extent to which these two errors cancel out is not known with certainty (*13, 14*), but it is unlikely that the net error is large. Consequently, the *PMDF* can be expected to be estimated with reasonable accuracy.

Sisterhood estimates of the MMRatio, on the other hand, depend both on the classification of

deaths as pregnancy related or otherwise and on the completeness of reporting of the sisters' deaths. Certain features of the data raise questions about this completeness. The sibling history format allows the calculation of mortality rates for defined time periods before the survey. In an analysis of 15 DHS data sets (*15*), the estimates of female mortality between the ages of 15 and 50 years were higher for the period 0–6 years before the survey than for the period 7–13 years before the survey in a large majority of countries. These increases were not paralleled by increases in mortality in other age ranges, such as under the age of 5 years. Thus the sisterhood data indicated implausible recent increases in adult female mortality in most of the countries studied. Despite these differences in mortality level, the *PMDF* remained remarkably stable across time periods. A more likely explanation than rising mortality is data error, either an omission of sister deaths that occurred further back in the past, or misdating of such deaths and transferring them into a more recent period. Either way, one can have little confidence that the level of mortality for the period 0–6 years before the survey is accurate. This conclusion is reinforced by a comparison of sisterhood estimates with estimates from other sources. For most countries, there are no alternative sources of estimates, but in four cases (Guatemala, the Philippines, Senegal and Zimbabwe) it has been possible to compare the sisterhood estimates of adult mortality with independently validated alternative estimates. In all four, sisterhood data underestimated recent adult mortality, by amounts ranging from 15% to 60% (*16*).

These findings suggest that sisterhood data tend to underestimate overall mortality, particularly for periods further back in the past, and that, in the absence of counterbalancing errors, the MMRatios from sisterhood estimates are likely to be too low. The nature of these possible biases in the sisterhood estimates argue for using such data in the form of *PMDF*s rather than MMRatios.

One technical problem has to be addressed before using the sisterhood *PMDF*s. The *PMDF* shown in DHS country reports is calculated as the number of pregnancy-related deaths of sisters divided by the overall number of sister deaths. However, the distributions of sister deaths and of sister-years of exposure by age are not the same as the corresponding distributions in the actual population (*17*). For example, the sisters of reproductive age of respondents aged 15–19 years are likely to be, on average, older than the respondents (they cannot be younger than 15, but they can be 20 or older), whereas the sisters of reproductive age of respondents aged 45–49 years are likely to be generally younger. Years of exposure of sisters are thus concentrated in the central ages of the reproductive period at the expense of the extremes. However, it is also in the central ages that most births, and therefore most maternal deaths, are likely to occur. Thus, the reported *PMDF* is likely to be higher than the true *PMDF* would be for a group of women distributed by age in the same way as the actual population. In order to allow for this effect, age-standardized *PMDF*s were calculated, which can appropriately be applied to the number of deaths of women of reproductive age to estimate the number of maternal deaths.

The use of information from RAMOS studies also argues for the use of the *PMDF* rather than the MMRatio in the modelling exercise. RAMOS studies typically use a variety of data sources to try to get as complete a count of the number of deaths as possible, and of the maternal deaths among the deaths. However, RAMOS studies do not typically go to great lengths to check the numbers of births to use as the denominator of the MMRatio. Thus RAMOS studies, even though they tend to report their results in terms of the MMRatio, are by design more likely to obtain unbiased estimates of the *PMDF*.

Choice of independent variables

The choice of independent variables is constrained by the need to use only variables that are available for the vast majority of countries in the world around the year 1995. Given the nature of the dependent variable, the first predictor variable that has to be included is an indicator of fertility: the higher fertility (for a given maternal mortality risk per birth), the higher the number of maternal deaths, and the higher the *PMDF*. Since *PMDF* is calculated on the basis of the age distribution of women aged 15–49 years, the appropriate fertility measure is the General Fertility Rate (*GFR*).

Socioeconomic variables are constrained by their limited availability, but it was possible to include both female literacy and per capita income in purchasing power parity terms. Neither variable retained significance, however, once other variables were included, although colinearity was high.

As an indicator of the role of health services, *TRATT*, the percentage of deliveries assisted by a skilled attendant — i.e. a physician, nurse, or professionally-trained midwife) was included in the model. Given the widespread consensus that maternal mortality will not be significantly reduced if the appropriate management of obstetric complications is absent, this variable comes closest to capturing such access while being widely available from DHS and other surveys, and compiled into a database by WHO and UNICEF.

The HIV/AIDS epidemic can be expected to have important effects. A major increase in female adult mortality resulting from the epidemic would tend to reduce the *PMDF* by increasing the other causes of death (and perhaps by reducing fertility). Failure to take this epidemic into account would thus result in a model that would overestimate *PMDF* in countries badly affected by the epidemic, and would tend to underestimate the *PMDF* elsewhere. Country-specific estimates of HIV prevalence for 1995 (*HIVAIDS*) from UNAIDS were therefore incorporated in the model.

A variety of variables reflecting data quality were tried, but the variable ultimately used was a dummy variable identifying a country with death registration reported to the United Nations to be complete (*goodVR*). Two dummy variables for region, one identifying countries of formerly socialist Europe (*FSE*) and the other identifying countries of Latin America, Africa, West and South Asia (*LASSAME*) were also included.

Selection of cases for model fitting

National estimates of maternal mortality were carefully reviewed on a case-by-case basis, and only adequately documented estimates, backed by clear descriptions of acceptable methodology, were included in the data set to which the model was fitted. In some cases, adjustments were made to the dependent variable before fitting the model. For countries with documented assessments of completeness of recording of maternal deaths (Argentina, Costa Rica, Finland, France, Mexico, the Netherlands, New Zealand, and the United Kingdom), that estimate of the coverage was used to inflate the observed values. *PMDF*s for other statistically developed countries with registration-based estimates were inflated by a uniform factor of 1.5[a] (*7*). Estimates of *PMDF* derived from sisterhood data were age-standardized as noted above. Estimates derived from RAMOS studies were not adjusted. Independent variables were also carefully reviewed where possible. In particular, estimates of the proportion of deliveries assisted by medically-trained professionals were reviewed country by country.

In all, the model was fitted to 73 contemporary observations, 30 of which were for industrialized countries or countries of formerly socialist Europe. The data set, excluding variables that did not prove to be significant, is shown in Annex Table 1 (available on our web site: http://www.who.int/bulletin).

The final model

The final model, fitted using a robust regression approach that underweights the observations with large residuals,[b] is shown below. Values in parentheses under the coefficients show the *t*-values; all except the *HIVAIDS* variable were significant at the 1% level or better. The *HIVAIDS* variable was close to statistical significance at the 10% level, and its coefficient had the expected sign. Including this variable in the model was judged the most appropriate way of avoiding possible prediction bias that might result from inflated numbers of non-maternal HIV-related deaths The robust regression does not provide a direct R^2 for this model, but Ordinary Least Squares regression gave very similar parameter estimates with an R^2 of 0.919 and a Root Mean Square Error of 0.51. A plot of predicted values of *PMDF* plotted against observed values (not shown) does not indicate departure from the standard assumptions of regression analysis.

$$\ln\{PMDF/(1-PMDF)\} = \underset{}{-8.289} \underset{(-4.54)}{-0.0141 * TRATT} \underset{(-2.96)}{+1.386 * \ln GFR} \underset{(3.91)}{+0.682 * FSE} \underset{(3.19)}{+0.719 * LASSAME} \underset{(2.93)}{-0.684 * goodVR} \underset{(-3.16)}{-0.0197 * HIVAIDS} \underset{(-1.36)}{}$$

[a] The value of 1.5 was arrived at by averaging the results of studies of underreporting of maternal deaths in France, the United Kingdom, and USA.

[b] The *rreg* command in STATA was used.

Estimates of maternal mortality for 1995

Maternal mortality estimates for countries with a population of 300 000 or more are shown as MMRatios in Tables 1(a) to 1(f) on the basis of data source, following the typology described earlier. The ways in which final values were arrived at vary from one country to another according to the country's data availability category, as follows.

- For the 48 countries in category (a), the MMRatios were based on the reported values adjusted by a factor that was in most cases 1.5. These estimates, with the actual adjustment factors used, are shown in Table 1(a).
- For the 18 countries in category (b) — based on complete death registration but questionable cause of death data — the *PMDF* was estimated from the model, and applied to the appropriate "envelope" of female deaths to estimate the number of maternal deaths; the MMRatio was obtained by dividing by the registered number of live births. The results for these countries are shown in Table 1(b).
- The 28 countries in category (c) — based on direct sisterhood estimates — are listed in Table 1(c). Each age-standardized *PMDF* from the sisterhood data was applied to the number of deaths among females aged 15–49 years, indicated in the United Nations Estimates and Projections (1998 Revision) (*18*) for the year 1995. There were two exceptions to this treatment. For Zimbabwe, a review of data on household deaths by age from the 1992 Population Census suggested that the data were of good quality; the sisterhood *PMDF* was therefore applied to the Census estimate of the numbers of deaths of women of reproductive age. The second exception concerns countries with sisterhood estimates and with substantial AIDS mortality. The sisterhood *PMDF*s apply to a time period earlier than 1995. For the United Republic of Tanzania, for example, the *PMDF* covers a period from 1987 to 1996. The number of female deaths in this country rose steeply in the early 1990s as a

Table 1(a). **MMRatios in 48 countries with good registration systems and relatively good attribution of cause of death**

Country	Year	Reported MMRatio	Adjustment factor	Adjusted MMRatio	No. of live births (Demographic Yearbook)
Argentina[a]	1995	44	1.9	84	658 735
Australia	1993	4	1.5	6	256 190
Austria	1995	7	1.5	11	88 669
Belarus	1996	22	1.5	33	101 144
Belgium	1989	5	1.5	8	115 638
Bosnia and Herzegovina	1990	10	1.5	15	43 415[b]
Bulgaria	1992–94	15	1.5	23	71 967
Canada	1993	4	1.5	6	378 011
Costa Rica[a]	1994	29	1.2	35	80 306
Croatia	1995	12	1.5	18	50 182
Cyprus	1993	0	1.5	0	9869
Czech Republic	1995	9	1.5	14	96 097
Denmark	1995	10	1.5	15	69 771
Estonia	1995	52	1.5	78	13 560
Finland[a]	1993–95	6	1.03	6	63 067
France[a]	1992–94	10	2.0	20	729 609
Germany	1994–95	8	1.5	12	765 221
Greece	1993–95	1	1.5	2	101 495
Hungary	1995	15	1.5	23	112 054
Ireland	1990–92	6	1.5	9	48 530
Israel	1992–95	5	1.5	8	116 461
Italy	1990–92	7	1.5	11	526 064
Japan	1992–94	8	1.5	12	1 187 064
Latvia	1994	45	1.5	68	21 595
Lithuania	1996	18	1.5	27	41 180
Luxembourg	1994	0	1.5	0	5421
Malta	1994	0	1.5	0	5003
Mauritius	1996	30	1.5	45	20 604
Netherlands[a]	1993–95	7	1.4	10	190 513
New Zealand[a]	1994	15	1.0	15	57 795
Norway	1991–93	6	1.5	9	60 292
Poland	1994–96	8	1.5	12	433 109
Portugal	1993–95	8	1.5	12	107 184
Puerto Rico	1991	20	1.5	30	64 325[c]
Republic of Moldova	1996	42	1.5	63	56 411
Romania	1997	41	1.5	62	236 640
Russian Federation	1996	49	1.5	74	1 363 806
Singapore	1993–95	6	1.5	9	48 635
Slovakia	1995	9	1.5	14	61 427
Slovenia	1995–96	11	1.5	17	18 980
Spain	1990–92	5.5	1.5	8	363 469
Sweden	1993–95	5	1.5	8	103 326
Switzerland	1993–94	5	1.5	8	82 203
The former Yugoslav Republic of Macedonia	1995–96	11	1.5	17	32 154
Ukraine	1996	30	1.5	45	492 861
United Kingdom[a]	1992–95	7	1.4	10	732 049
USA	1990–95	8	1.5	12	3 899 589
Yugoslavia	1995–96	9.7	1.5	15	140 504

[a] National adjustment factors.

[b] Births from UN Population Division estimates.

[c] 1994 births.

result of the AIDS epidemic. Applying the 1987–96 *PMDF* to the 1995 deaths would therefore overestimate the number of maternal deaths. For all countries with substantial numbers of AIDS deaths, the United Nations estimates of non-AIDS and AIDS deaths for 1985–90 and 1990–95 were used to estimate the proportion, p, of all deaths of females of reproductive age that were due to AIDS

Table 1(b). **Vital registration data from 18 countries with good death registration systems but uncertain attribution of cause of death**

Country	Year[a]	Deliveries assisted by a skilled attendant (*TRATT*) %	General Fertility Rate (*GFR*)[b]	Model-based *PMDF*	No. of deaths of women of reproductive age (Demographic Yearbook)	No. of live births (Demographic Yearbook)	Estimated MMRatio[d]
Albania	1991; 1996	99	87.0	0.0294	635	60 696	31
Armenia	1994	96	57.7	0.0176	838	51 143	29
Barbados	1991; 1995	100	48.0	0.0127	90	3473	33
Brunei Darussalam	1992; 1996	98	92.0	0.0320	53	7633	22
Cape Verde	1991; 1992	54	137.3	0.1781	102	9671	188
Chile	1995	100	82.3	0.0278	3329	279 928	33
Fiji	1995; 1994	100	99.3	0.0178	215[c]	19 358	20
Georgia	1996; 1995	100	46.2	0.0123	1007	56 341	22
Kazakhstan	1996; 1995	100	73.2	0.0229	9455	277 006	78
Kuwait	1994; 1995	98	117.2	0.0458	224	41 169	25
Kyrgyzstan	1995	98	114.4	0.0429	2153	117 340	79
Panama	1995	86	102.4	0.0848	18	61 939	98
Qatar	1994	98	107.8	0.0782	55	10 561	41
Tajikistan	1994	79	153.2	0.0808	2477	162 152	123
Trinidad and Tobago	1995	98	65.7	0.0208	624	19 258	67
Uruguay	1993; 1995	96	86.8	0.0314	897	55 664	51
Uzbekistan	1994	98	119.7	0.0456	8499	657 725	59
Venezuela	1991; 1995	97	99.5	0.0370	5995	520 584	43

[a] Reference year of deaths and births; where two years are given, the first is for deaths, the second for births.

[b] Number of births per 1000 women of reproductive age.

[c] Deaths from UN Population Division estimates.

[d] [(Column v * column vi)/column vii] * 100 000.

over the period of time covered by the sisterhood *PMDF* (assuming a linear trajectory for AIDS deaths). The United Nations estimate of non-AIDS deaths in 1995 was then divided by $(1-p)$ to approximate the number of deaths (both AIDS and non-AIDS) there would have been in 1995, had the AIDS deaths equalled their average proportion over the period covered by the sisterhood *PMDF*. The observed *PMDF* was then applied to this adjusted number of 1995 deaths.

- Seventeen countries in category (d) — based on RAMOS-type studies — are shown in Table 1(d), the observed MMRatio being assumed to be correct. The estimated numbers of live births for 1995, generally taken from United Nations estimates, were used to obtain the number of maternal deaths for calculation of regional summaries.
- Among the four countries in category (e) — based on miscellaneous data sources — shown in Table 1(e), India carried out a major household survey, the National Family Health Survey (NFHS), in 1992–93 in collaboration with the Demographic and Health Surveys programme. The NFHS collected information on household deaths in the two years before the survey, and used the time of death relative to pregnancy to identify maternal deaths. The NFHS report (*19*) does not give enough information to evaluate the resulting MMRatio in detail, but the reported value was consistent with other sources and was used. Iran carried out a national census in 1996 which included questions on household deaths in the year before the interview. Households reporting a death of a woman of reproductive age were revisited and the results of a verbal autopsy were used, in conjunction with information from local health facilities, to identify maternal deaths. Evaluation of the information on deaths suggested substantial omissions, but the proportion of maternal deaths among the reported female deaths should be of RAMOS-type quality. Thus the reported *PMDF* was applied to the United Nations estimate of deaths of women of reproductive age in 1995 to arrive at an estimate of maternal deaths, from which the MMRatio was estimated using the United Nations estimate of live births in 1995. In the case of Mexico, an evaluation of death registration and cause-of-death reporting carried out by the Ministry of Health provided an estimate of the MMRatio. For Morocco, the 1998 PAPCHILD survey included questions on deaths in the household in the year before the survey, and further questions concerning the time of death relative to pregnancy for deaths of women of reproductive age. Detailed data from the survey are not available to the authors at present, but the estimated level of overall female adult mortality appears surprisingly low, so the reported *PMDF* was applied to the United Nations estimates of deaths in 1995, following the same procedure as for Iran.

Table 1(c). **MMRatios in 28 countries based on sisterhood estimates**

Country	Year	Reported MMRatio[a]	Observed (age-standardized) *PMDF*	No. of deaths of women of reproductive age (UN estimates 1995)	No. of live births (UN estimates 1995)	Estimated MMRatio[d]
Benin	1989–96	498	0.321	6294[c]	228 631	884
Bolivia	1989–96	390	0.211[b]	6659	255 500	550
Brazil	1983–96	161	0.107	82 549[c]	3 375 742	262
Cameroon	1989–98	430	0.232	16 375[c]	527 341	720
Central African Republic	1989–95	1451†	0.240	6354[c]	126 579	1205
Chad	1991–97	827	0.387	11 719[c]	302 903	1497
Côte d'Ivoire	1989–95	597	0.248	24 369[c]	508 601	1188
Ecuador	1988–94	159	0.123[b]	51 77[c]	307 971	207
Eritrea	1986–95	998	0.326	4755[c]	137 012	1131
Guatemala	1990–95	190	0.152	6592[c]	375 718	267
Indonesia	1988–94	454†	0.146	151 023[c]	4 666 710	472
Kenya	1992–98	590	0.289	44 814[c]	967 340	1339
Madagascar	1990–97	488	0.221	15 602[c]	590 952	583
Malawi	1986–92	752†	0.198	14 051[c]	483 395	576
Mali	1989–96	577	0.315	9638[c]	481 990	630
Namibia	1983–92	395†	0.145	1432[c]	56 397	368
Nepal	1990–96	539	0.232	27 291[c]	766 879	826
Niger	1986–92	672†	0.313	13 668[c]	463 490	923
Peru	1990–96	265	0.135[b]	10 722[c]	617 139	235
Philippines	1987–93	208†	0.137	35 309[c]	2 036 763	238
Senegal	1986–92	566†	0.343	11 982[c]	343 194	1198
Sudan	1983–89	569†	0.329	40 009[c]	906 250	1452
Togo	1993–98	478	0.203	8446[c]	174 408	983
Uganda	1986–95	506	0.140	72 881[c]	966 276	1056
United Republic of Tanzania	1987–96	529	0.260	50 763[c]	1 246 857	1059
Yemen	1988–97	351	0.383	15 876[c]	715 417	850
Zambia	1990–96	649	0.126	24 330[c]	353 629	867
Zimbabwe	1988–94	393†	0.143	15 396[c]	361 454	609

[a] From ref. *15* where indicated with †; otherwise from country reports.

[b] Imputed from non age-standardized value.

[c] Number of deaths in 1995 have been adjusted to reflect the proportion of AIDS deaths over the time period covered by the *PMDF*.

[d] [(Column iv * column v)/column vi] * 100 000.

Table 1(d). **MMRatios in 17 countries based on reproductive age mortality studies (RAMOS)**

Country	Year	Reported MMRatio	No. of live births (UN estimates 1995)
Belize	1995	139	6970
China	1995	62	20 973 560
Cuba	1996	24	147 170[a]
Egypt	1992–93	174	1 719 971[b]
Guinea Bissau	1989–90	914	46 429
Honduras	1989–90	221	199 148
Jamaica	1986–87	115	57 607[a]
Jordan	1995–96	41	202 849
Lao People's Democratic Republic	1989–91	653	198 496
Malaysia	1994	39	538 994
Maldives	1992–94	385	7780[c]
Republic of Korea	1995–96	20	704 590[a]
Saudi Arabia	1997	23	636 215
Sri Lanka	1996	62	343 224[a]
Suriname	1991–93	226	8700
Thailand	1995–96	44	1 016 153
Tunisia	1994	69	186 416[a]

[a] 1995 live births from the Demographic Yearbook.

[b] 1994 live births from the Demographic Yearbook.

[c] 1993 live births from the Demographic Yearbook.

- The 55 countries in category (f), which were lacking an acceptable basis for a national estimate of maternal mortality, are listed in Table 1(f). The general procedure for these countries was to use the regression model to predict *PMDF*, which was then applied to the deaths of women of reproductive age in 1995 to estimate the number of maternal deaths. The MMRatio was then obtained by dividing the number of maternal deaths by an estimate of the number of births in 1995. In almost all cases, the overall numbers of births and deaths were obtained from the United Nations estimates.

Exceptions to the general procedure were made for two countries, Rwanda and Liberia, which were affected in the early 1990s (but not around 1995) by civil strife. For these countries the annual deaths during the civil strife were abnormally high, and the number of maternal deaths would be only slightly inflated, if at all. Accordingly the model-estimated *PMDF* was applied to an estimate of deaths in the absence of strife. For both these countries, deaths in the absence of strife were assumed equal to the annual deaths between 1995 and 2000.

Table 1(e). **MMRatios in 4 countries based on other information sources**

Country	Year	Reported *PMDF*	No. of deaths of women of reproductive age (UN estimates 1995)	No. of live births (UN estimates 1995)	Estimated maternal deaths	Estimated MMRatio
India[a]	1992–93	N/A[d]	632 864	25 194 100	N/A	437
Iran (Islamic Republic of)[b]	1996	0.0718	28 994	1 596 070	2082	130
Mexico	1995	N/A	29 071	2 347 659	N/A	67
Morocco[c]	1998	0.1862	13 858	663 234	2580	390

[a] Based on National Family Health Survey 1992–93: deaths and maternal deaths in the 2 years before the survey.

[b] Derived from Proportion Maternal among deaths of women aged 15–49 in years before the 1996 census.

[c] Derived from Proportion Maternal among deaths of women aged 15–49 in years before the 1998 PAPCHILD survey.

[d] N/A = not available.

The results presented in Tables 1(a) to 1(f) are summarized in Table 2. On the basis of this exercise, the estimated number of maternal deaths in 1995 for the world was 515 000. Of these deaths, over half (272 500) occurred in Africa, about 41% (217 500) occurred in Asia, about 4% (22 000) in Latin America and the Carribean, and less than 1% (2700) in Europe and North America. In terms of the MMRatio, the world figure was estimated to be 397 per 100 000 live births. By region, the MMRatio was highest for Africa (1006), followed by Asia (276), Latin America (190), Oceania (119), Europe (28), and North America (11).

The country with the highest estimated number of maternal deaths was India (110 000), followed by Ethiopia (46 000), Nigeria (45 000), Indonesia (22 000), the Democratic Republic of the Congo (20 000), Bangladesh (20 000), the United Republic of Tanzania (13 000), Sudan (13 000), China (13 000), and Kenya (13 000). These ten countries account for 61% of all maternal deaths. To be included in this list, however, is partly a function of having many births, since the number of maternal deaths is the product of the numbers of births and the risk per birth. On a risk-per-birth basis, the countries with the highest MMRatios were all in Africa; the top ten, in rank order, were Rwanda, Sierra Leone, Burundi, Ethiopia, Somalia, Chad, Sudan, Côte d'Ivoire, Equatorial Guinea, and Burkina Faso. In all, there were 22 countries in sub-Saharan Africa with MMRatios in excess of 1000. Apart from Haiti, no country elsewhere in the world has a value in excess of 900.

Uncertainty bounds

The estimates of MMRatio presented in Tables 1(a) – 1(f) have a wide margin of uncertainty. Even in countries with highly developed statistical systems, the MMRatios are thought to be underestimates by a substantial margin, and they have been inflated by 50% in the present study. However, we do not know if 50% is correct — the true figure could be higher or lower. The other categories of estimates also have their margins of uncertainty — e.g. sampling errors for RAMOS studies and DHS estimates of *PMDF*, and prediction errors for the modelled *PMDF*s. For each data category, we have attempted to determine the uncertainty boundaries around the estimated value, within which the true figure is likely to lie. These are not confidence intervals in the statistical sense, because there are errors involved that cannot be quantified in a rigorous probabilistic manner. However, they do give a sense of the magnitude of the possible errors involved. Each data category was treated differently.

For the countries with well-developed statistical systems in category (a), the lower confidence bound on the MMRatio is the official figure, and the upper confidence bound is twice the official figure. The point value usually lies halfway between.

For countries in category (b), with complete death registrations but uncertain cause of death classification, the upper and lower confidence bounds were based on plus or minus two standard errors of the model prediction of the logit of the *PMDF*.

For countries in category (c), based on sisterhood data, the survey estimate of the 95% confidence intervals around the recorded *PMDF* (*15*) was generally used. In a subset of cases, no survey estimate was available, and had to be estimated on the basis of the sample size of the survey and the relation between sample size and standard error observed for surveys with the necessary data. These estimates actually have additional errors, not quantifiable and not included in the confidence bounds, around the United Nations estimates of female deaths and births.

For countries in category (d), based on RAMOS studies, the published standard errors around the point estimate of the MMRatio were used where possible, and guesstimates derived from the reported sample size were used when no published figure was available. Actual errors were probably higher than those published, because of error in the estimates of live births used.

For countries in category (e), based on miscellaneous sources, the published confidence intervals were used where available; where they were not available, the uncertainty bounds were approximated from published information on sample size.

Table 1(f). **Estimates of maternal mortality in 55 countries, areas, and territories where accurate information is lacking**

Country, area, or territory	Year	Deliveries assisted by a skilled attendant (*TRATT*) %	General Fertility Rate (*GFR*)[a]	Predicted *PMDF*	No. of deaths of women of reproductive age (UN estimates 1995)	No. of live births (UN estimates 1995)	Predicted number of maternal deaths[b]	Predicted MMRatio[c]
Afghanistan	1995	8	209	0.2695	29 294	964 198	7895	819
Algeria	1995	77	121	0.1181	10 575	841 719	1249	148
Angola	1995	17	229	0.4207	16 922	544 133	7119	1308
Azerbaijan	1995	99	75	0.0240	2264	148 841	54	37
Bahrain	1995	98	98	0.0361	133	12 733	5	38
Bangladesh	1995	8	113	0.1359	144 488	3 292 008	19 636	596
Bhutan	1995	15	176	0.2085	1748	72 581	364	502
Botswana	1995	78	144	0.0931	2665	51 607	248	481
Burkina Faso	1995	42	215	0.2952	22 833	488 771	6740	1379
Burundi	1995	24	189	0.3086	16 445	269 859	5075	1881
Cambodia	1995	31	147	0.1351	15 750	360 358	2128	590
Colombia	1995	85	95	0.0784	15 010	990 693	1177	119
Comoros	1995	52	161	0.2204	589	22 673	130	573
Congo	1995	52	195	0.2408	5210	113 200	1255	1108
Democratic People's Republic of Korea	1995	100	75	0.0238	7092	478 257	169	35
Democratic Republic of the Congo	1995	45	211	0.2947	67 358	2 113 805	19 850	939
Djibouti	1995	79	152	0.1274	914	22 379	116	520
Dominican Republic	1995	96	98	0.0687	3186	199 137	219	110
East Timor	1995	40	178	0.1495	1564	27 585	234	848
El Salvador	1995	87	111	0.0927	3202	162 462	297	183
Equatorial Guinea	1995	5	186	0.3963	600	16 936	238	1404
Ethiopia	1995	8	208	0.3851	120 145	2 513 722	46 268	1841
Gabon	1995	80	163	0.1516	1622	39 837	246	617
Gambia	1995	44	171	0.2482	2003	46 398	497	1071
Ghana	1995	44	169	0.2447	16 328	682 042	3995	586
Guinea	1995	31	184	0.3057	11 838	295 542	3619	1224
Guyana	1995	95	83	0.0559	527	19 478	29	151
Haiti	1995	21	138	0.2426	11 454	247 573	2779	1122
Iraq	1995	54	163	0.2190	12 719	759 359	2786	367
Lebanon	1995	89	92	0.0718	1328	74 800	95	127
Lesotho	1995	50	149	0.1818	2009	69 086	365	529
Liberia	1995	58	195	0.2402	4497	106 313	1080	1016
Libyan Arab Jamihiriya	1995	94	125	0.0993	1700	143 752	169	117
Mauritania	1995	40	181	0.2811	3014	96 884	847	874
Mongolia	1995	100	100	0.0350	1107	61 953	39	63
Mozambique	1995	44	193	0.2359	31 340	758 341	7393	975
Myanmar	1995	56	79	0.0449	34 139	931 016	1533	165
Nicaragua	1995	65	160	0.1890	2166	166 091	409	246
Nigeria	1995	31	174	0.2814	158 551	3 953 232	4616	1129
Oman	1995	93	186	0.1623	563	79 780	91	115
Pakistan	1995	18	167	0.1899	54 638	5 158 185	10 376	201
Papua New Guinea	1995	53	137	0.0979	5572	140 827	545	387
Paraguay	1995	61	138	0.1675	1618	157 864	271	172
Reunion	1995	100	92	0.0323	158	12 940	5	39
Rwanda	1995	26	230	0.3429	18 505	273 783	6345	2318
Sierra Leone	1995	25	211	0.3592	11 816	205 532	4244	2065
Solomon Islands	1995	85	163	0.0809	100	13 820	8	59
Somalia	1995	2	244	0.5041	13 990	445 804	7052	1582
South Africa	1995	82	107	0.0736	48 427	1 045 432	3564	341
Swaziland	1995	56	155	0.1501	852	34 159	128	374
Syrian Arab Republic	1995	67	139	0.1576	5587	450 962	881	195
Turkey	1995	76	85	0.0365	21 281	1 384 060	777	56
Turkmenistan	1995	96	122	0.0474	1639	123 896	78	63
United Arab Emirates	1995	86	91	0.0619	211	43 195	13	30
Viet Nam	1995	79	98	0.0463	38 693	1 859 481	1791	96

[a] Number of births per 1000 women of reproductive age.

[b] [Column v * column vi].

[c] [Column viii/column vii] * 100 000.

Table 2. **Estimates of MMRatios for 1995, with lower and upper uncertainty bounds**

Area	No. of live births (x 1000)	No. of maternal deaths (x 1000)	MMRatio per 100 000 live births	Lower uncertainty bound on MMRatio	Upper uncertainty bound on MMRatio
Africa	27 081	272.5	1006	544	1644
Asia	78 609	217.0	276	180	430
Europe	7605	2.2	28	18	38
Latin America and the Caribbean	11 376	21.7	190	114	308
North America	4278	0.5	11	8	15
Oceania	488	0.6	119	42	308
Small countries, areas, and territories (<300 000 population)	136	0.2	126	65	245
World total	**129 573**	**514.5**	**397**	**234**	**635**

For countries in category (f), a model based on estimates of *PMDF* applied to United Nations estimates of the numbers of deaths, the standard error of the prediction of the logit of the *PMDF* was used to obtain the uncertainty bounds, as in the case of category (b) countries. The uncertainty bounds only reflect the errors in the model predictions; they do not take into account possible errors in the United Nations estimates.

Annex Table 2 (available on our web site: http://www.who.int/bulletin) shows for each country, area, or territory the category into which it falls, the point estimate of the MMRatio, and the upper and lower uncertainty bounds. Summaries (shown in Table 2) were obtained simply by averaging individual country values. It is likely, however, that compensating errors at the area level make the point estimates by area more precise than individual country estimates.

The uncertainty bounds are extremely wide. At the global level, the lower uncertainty bound is for a MMRatio of 234, with an annual total of some 303 000 maternal deaths, and the upper uncertainty bound is for a MMRatio of 635, with an annual total of some 822 000 maternal deaths. For countries with high point estimates derived from the model, the spread between the low and the high bounds is very wide. For example, the range for Rwanda, the country with the highest point estimate of 2318, is from 977 to 4171. Countries with low point estimates derived from the model have an even wider relative range; for example, the United Arab Emirates has a point estimate of 30, but the range is from 10 to 84. Country comparisons need to be made very cautiously, taking into account the very large range of uncertainty around the point estimates.

Discussion

The maternal mortality estimates presented in this paper are, for the most part, based on directly relevant country-specific information. Table 1(f), which lists the countries with the weakest empirical basis, represents only 55 countries (with 26% of the total of world births in 1995) out of the 170 countries with populations of over 300 000 for which estimates were made. Basic data have also been adjusted for countries in other data categories, however. For countries with highly developed statistical systems (see Table 1(a), with a total of 48 countries contributing 11% of total world births), the recorded maternal deaths were typically inflated by 50%. For countries with good coverage of deaths, but uncertain quality concerning attribution of the cause of death (see Table 1(b), with 18 countries accounting for 2% of total world births), the model-predicted *PMDF* applied to registered deaths inflated the recorded MMRatio by a factor of up to five, although, on average, the adjustments were much smaller. For countries with direct sisterhood data (Table 1(c), with a total of 28 countries accounting for 17% of total world births) and for the Islamic Republic of Iran and Morocco (Table 1(e)) with direct observations of *PMDF*, the observed age-standardized *PMDF*s were applied to the United Nations estimates of deaths for 1995, with the result that the estimated MMRatios were substantially higher than the original sisterhood estimates, in many cases more than double; in only one case, Paraguay, did the estimated MMRatio fall below the sisterhood value. Only for countries with RAMOS studies (Table 1(d), with a total of 18 countries accounting for 21% of world births) and for New Zealand and India was an observed MMRatio used without adjustment.

The estimates of MMRatio given in Tables 1 and 2 are expressed per 100 000 live births. However, at least for high values, the accuracy is substantially less than the number of digits shown. There are a number of sources of potential error in the estimates.

First, the model may be incorrect, affecting the results in Tables 1(b) and 1(f). The data points to which the model is fitted have wide confidence intervals, and rather arbitrary adjustments have been made to many of the points. However, it is encouraging that the model fits the observations well, and is robust for the inclusion or exclusion of different types of observation.

Second, extrapolation of the model beyond the range of observations to which it is fitted to

populations with more extreme values of the independent variables may be inappropriate.

Third, there may be variables missing from the model which influence the outcome, or the fact that countries have enough data to be part of the estimation data set may be associated with the outcome.

Fourth, the observed values of independent variables used to predict *PMDF*s may be incorrect.

Fifth, the "envelope" to which the *PMDF* is applied, deaths of women of reproductive age, may be incorrect, particularly if derived from United Nations estimates and projections.

Finally, the number of births used as the denominator of the MMRatio may also be wrong.

The exercise does, however, confirm that maternal mortality is a major problem in many areas. It is unlikely that there are fewer than 303 000 maternal deaths globally a year, or that the average worldwide MMRatio is less than 234. It is also unlikely that there are more than 822 000 maternal deaths globally a year, or that the average worldwide MMRatio is more than 635. Maternal mortality is a particularly serious problem in sub-Saharan Africa, which includes 22 of the 23 countries with national MMRatios estimated to be 1000 or more.

The wide margins of error inherent in all the estimates of MMRatio presented here, regardless of the statistical sophistication of the country, indicate that comparisons of this indicator between countries or across time are not necessarily valid. In particular, the results of the present and the 1996 exercise should not be compared on a country basis, and no conclusions should be drawn about trends, since both the methodology and the base data have changed since the 1996 exercise. Apart from the data and methodology changes, the uncertainty bounds around point estimates are so wide that even large apparent changes may not be statistically significant. In the absence of comprehensive and high quality registration of vital events, the MMRatio is too hard to measure to be programmatically useful. Greater effort should be directed to developing indicators of maternal health that can be monitored regularly and compared across populations and over a period of time. A number of process indicators have been proposed (*20*), such as coverage of essential obstetric care, the proportion of births by Caesarean section, or the proportion of deliveries assisted by skilled attendants. These measures are of value for programme design and monitoring in their own right, and are also, to the extent that they are correlated with maternal mortality, indirect indicators of outcome. Though each measure has its own problems, the judicious use of breakdowns into subpopulations and the use of locally appropriate definitions and standards offer opportunities for monitoring at the programme level which the MMRatio cannot match. ■

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Résumé

Estimations de la mortalité maternelle pour 1995

Objectif Présenter des estimations de la mortalité maternelle dans 188 pays, zones et territoires pour 1995 en utilisant des méthodes visant à améliorer la comparabilité.

Méthodes Pour les pays qui possèdent des données directement applicables à la mesure de la mortalité maternelle, diverses procédures d'ajustement peuvent être utilisées selon la nature des données. Pour les pays qui manquent de telles données, les estimations peuvent être réalisées au moyen d'un modèle statistique ajusté sur les informations des pays qui disposent de données jugées de bonne qualité. Ce modèle ne permet pas d'estimer directement le taux de mortalité maternelle mais il donne une estimation de la proportion de décès parmi les femmes en âge de procréer qui sont dus à des causes maternelles. On obtient une estimation du nombre de décès maternels en appliquant cette proportion au meilleur chiffre disponible du nombre total de décès chez les femmes en âge de procréer.

Résultats Cet exercice a conduit à une estimation mondiale de 515 000 décès maternels en 1995, avec un taux mondial de mortalité maternelle de 397 pour 100 000 naissances vivantes. Il existe de très grandes différences d'une région à l'autre, plus de la moitié des décès maternels (273 000) survenant en Afrique (taux de mortalité maternelle : >1000 pour 100 000), contre 2000 seulement en Europe (taux de mortalité maternelle : 28 pour 100 000). On a également réalisé une estimation des limites inférieure et supérieure d'incertitude d'où l'on a pu déduire que le taux mondial de mortalité maternelle n'était probablement pas inférieur à 234 ni supérieur à 635 pour 100 000 naissances vivantes. Ces limites et celles des estimations nationales sont si larges qu'il faut être très prudent lorsqu'on compare les données d'un pays à l'autre, et il n'est pas possible de tirer des conclusions valables quant aux tendances sur une période déterminée.

Conclusion Le taux de mortalité maternelle est donc un indicateur imparfait de la santé génésique car il est difficile de le mesurer avec précision. Il est préférable d'utiliser des indicateurs de processus pour comparer la santé génésique d'un pays à l'autre ou au cours du temps et à des fins de surveillance et d'évaluation.

Resumen

Estimaciones de la mortalidad materna para 1995

Objetivo Presentar estimaciones de la mortalidad materna en 188 países, zonas o territorios para 1995 empleando metodologías concebidas para mejorar la comparabilidad.

Métodos Para los países que disponen de datos directamente pertinentes para la medición de la mortalidad materna, pueden aplicarse varios procedimientos de ajuste en función de la naturaleza de los datos empleados. En cuanto a los países que carecen de datos pertinentes, se pueden realizar estimaciones empleando un modelo estadístico ajustado a la información de los países que poseen datos considerados de buena calidad. Más que estimar la Razón de Mortalidad Materna (RMM) directamente, este modelo estima la proporción de defunciones entre las mujeres en edad reproductiva que se deben a causas maternas. El número de defunciones maternas se estima entonces aplicando esa proporción a la mejor cifra disponible del número total de defunciones entre las mujeres en edad reproductiva.

Resultados Mediante esta forma de proceder, hemos obtenido una estimación mundial de 515 000 defunciones maternas en 1995, con una RMM mundial de 397 por 100 000 nacidos vivos. Las diferencias entre regiones fueron muy considerables, registrándose más de la mitad de los casos (273 000 defunciones maternas) en África (RMM = > 1000 por 100 000), frente a un total de sólo 2000 defunciones maternas en Europa (RMM = 28 por 100 000). Se estimaron asimismo los límites de incertidumbre inferior y superior, determinándose a partir de ese intervalo que era improbable que la RMM mundial estuviese por debajo de 234 o por encima de 635 por 100 000 nacidos vivos. Estos límites de incertidumbre y los de las estimaciones nacionales son tan amplios que hay que ser cautelosos a la hora de hacer comparaciones entre países, y no es posible extraer conclusiones válidas sobre las tendencias a lo largo de un periodo.

Conclusión Así pues, la RMM es un indicador imperfecto de la salud reproductiva, ya que es difícil medirlo con precisión. Es preferible emplear indicadores de procesos para comparar la salud reproductiva entre países o a lo largo de periodos y con fines de vigilancia y evaluación.

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