**Measuring Maternal Mortality: A systematic review of methods used to obtain estimates of the Maternal Mortality Ratio (MMR) in low- and middle-income countries**

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**Short Title:** Methods to estimate the maternal mortality ratio (MMR)

**Abstract**

**Background**

The new global target for Maternal Mortality (MMR) is a Ratio below 70 maternal deaths per 100 000 live births by 2030.We undertook a systematic review of methods used to measure MMR in low- and middle-income countries.

**Sources of data**

Systematic review of the literature; 59 studies included.

**Areas of agreement**

Civil registration (5 studies), census (5) and surveys (16), Reproductive-Age Mortality Studies (RAMOS) (4) and the sisterhood methods (11) have been used to measure MMR in a variety of settings.

**Areas of controversy**

Middle-income countries have used civil registration data for estimating MMR but it has been a challenge to obtain reliable data from low-income countries with many only using health facility data (18 studies).

**Growing points and areas for further research**

Based on the strengths and feasibility of application, RAMOS may provide reliable and contemporaneous estimates of MMR while civil registration systems are being introduced. It will be important to build capacity for this and ensure implementation research to understand what works where and how.

**Key words:** measuring, maternal mortality ratio, RAMOS, low- and middle-income countries

## Introduction

Reducing maternal mortality is one of the priority goals on the international agenda – the new global target is to reduce the Maternal Mortality Ratio (MMR) to less than 70 maternal deaths per 100 000 live births and country should reduce their maternal mortality ratio (MMR) by at least two thirds from the 2010 baseline and no country should have a MMR higher than 140 deaths per 100 000 live births by 2030.1,2 A cross-cutting priority for the post-2015 agenda is to move towards counting every birth, maternal death and perinatal death through the establishment of effective national registration and vital statistics systems in every country, as stated within the recommendations of the Commission for Information and Accountability.3

Reliable data are needed so that adequate resources can be allocated to maternal health programmes for countries (or regions in countries) that are not yet accelerating the annual reduction in maternal deaths. These data are also needed to monitor progress towards the targets set for the new Sustainable Development Goals (SDG). Assessing progress has been a challenge because less than 40% of countries currently have complete civil registration systems in place or other methods to provide accurate and contemporaneous MMR data. Similarly, although Maternal Death Surveillance and Review is promoted and being implemented in many settings, attribution and reporting of cause of maternal death is not yet systematically in place.4,5 Only two of the 49 least developed countries have more than 50% coverage with regard to death registration.1

The World Health Organization (WHO) publishes global estimates of MMR based on United Nations statistical models, including estimates for countries without reliable data.6 Most of these estimates are subject to greater or lesser degrees of uncertainty and this is a recognised limitation. There are, in addition to modelling, a variety of methods available to measure MMR including via censuses, household surveys, Reproductive Age Mortality Surveys (RAMOS) and using the Sisterhood methods. Each method has strengths and weaknesses. This may include cost of application of method, lack of in-country capacity to use the method and requirement for large sample sizes to be able to estimate MMR with reasonable accuracy. Although some of these methods have been used in a number of developing countries, there is a lack of knowledge and guidance regarding which method(s) are the be most appropriate and feasible to use in which settings (e.g. large or small population, national or sub-national application and type of data required to estimate MMR).

We, therefore, conducted a systematic review of the literature to identify which methods have been used to estimate MMR and reviewed their use and applicability to low- and middle-income countries. The specific research questions included: what are the type of data and data sources required, what are the strengths and weaknesses of each method; and which method(s) would be useful and applicable in low-and middle-income settings and able to provide reasonably accurate and contemporaneous data.

# Methods

We used the following databases SCOPUS, PUBMED and Institute for Scientific Information (ISI) and MEDLINE to search for studies which measured MMR in low- and middle-income countries. Publications of organisations and programmes such as the United Nations Population Fund (UNFPA), United Nations Children’s Fund (UNICEF), World Bank, WHO and the Initiative for Maternal Mortality Programme Assessment (IMMPACT) were included. Internet searches using the Google search engine were conducted to identify relevant literature not published in peer-reviewed journals and the references of all identified, relevant papers were hand-searched.

### Search terms used

Medical Subject Headings (MeSH) were searched to identify all relevant terms used to describe maternal mortality and measuring. Boolean operators such as “OR”were used to join keywords and MeSH terms defining the same concepts and different concepts were searched with “AND”to arrive at the final result. We used the search terms “maternal mortality OR maternal death OR pregnancy death OR motherhood death OR women deaths” in combination with “measure OR estimate” OR “estimation”. These were then combined using the Boolean operator “AND” with the following search terms: civil registration data, Census, Surveys, health facility data, sisterhood methods, RAMOS and low- and middle-income countries. Star truncation (\*) was used where multiple endings of terms were possible.

### Inclusion and exclusion criteria

We included papers published between 2000 and October 2016 from low- and middle-income countries as defined by the World Bank income categorisation.7 This time period was selected as many countries undertook to assess the MMR to evaluate the burden of maternal mortality and effect of implementation of interventions to achieve MDG5 at this time.8

Studies were included for estimates of MMR obtained either at national or sub-national level regardless of method used. We excluded studies assessing impact of one or more interventions on MMR; demographic health surveys (DHS) as they are included in the direct sisterhood methods and global estimates by WHO, UNICEF, UNFPA and the World Bank (published by the WHO and not countries which use statistical models that may have errors, use unreliable data sources and, in some cases, countries do not use them). We also excluded reviews, posters, editorials and discussion papers which did not include methodologies and estimates of MMR. DHS were excluded as these use the direct sisterhood method which is already included in the review. Global estimates were excluded when they employed statistical modelling.

### Data extraction

Two reviewers independently screened all titles and abstracts. When the information provided by title and abstract was insufficient to decide on inclusion or exclusion, full-text versions were retrieved and evaluated. All included papers were reviewed in full. Any discrepancies were resolved through discussion with a third researcher. A summary table was developed and agreed by all authors before full-text review was conducted and all included studies were then summarised. (Supplementary Table S1: Summary Table of included studies**)**

# Results

In total, 60 studies meet the inclusion criteria (Figure 1). Six methods by which MMR or relevant data are obtained in low- and middle-income countries were identified. These include use of existing opportunities which include: 1) civil registration data (5 studies), 2) health facility data (18 studies), 3) population census (5 studies), use of special studies which included: 4) population or household surveys (16 studies)), 5) direct and indirect sisterhood method (11 studies) and 6) RAMOS Studies (4 studies).

**Figure 1. PRISMA Diagram**



### 1) Civil Registration and vital statistics data

Civil registration (CR) is defined as the continuous, permanent, compulsory and universal recording of the occurrence and characteristics of vital events pertaining to the population as provided through decree or regulation in accordance with the legal requirements of a country.9 The data retrieved from CR systems are referred to as vital registration (VR) data. Complete coverage, accuracy and timeliness of civil registration are essential for quality vital statistics and are the ideal data to count maternal deaths. Civil registration is carried out primarily for the purpose of establishing the legal documents provided by the law. Additionally, registration of births and deaths generates information that has substantial policy utility, especially when the age of the mother giving birth, age and sex of the decedent and underlying cause of death are correctly specified.10 Ideally, civil registration systems with high coverage and good attribution of cause of death provide accurate data on the level of MM and the causes of maternal deaths. The drawback, however, relates primarily to the availability, reliability, completeness and coverage of the civil registration data.11 The number of maternal deaths and number of live births recorded are used to calculate MMR (number of MD per 100 000 live births).

Five papers reported using civil registration data to estimate maternal mortality. These studies were conducted in China, the Dominican Republic, Brazil, Egypt and Guatemala, all middle income countries.12-16 There were no studies from low-income countries using this method.12-16 In Guatemala, vital registration data were supplemented with additional information from medical charts and from public healthcare centres which improved the quality of data obtained. The study detected three times the number of maternal deaths compared to using the civil registry data only.15 However, to establish if the death of a woman of reproductive age (WRA) is a maternal death, information on pregnancy status at time of death is required. It was noted that information on pregnancy status was often either missing or unclear on the death certificates for studies conducted in China, the Dominican Republic, Brazil and Egypt. The authors note that this resulted in misclassification and possibly an underestimation of the number of maternal deaths.12,13,14,16 Deaths among women living in villages accessible only by foot were not registered in the study in the Dominican Republic.14

### 2) Health facility surveys

Health facility data remain the main, routine source of data on MM for many developing countries. Currently, health facility data are not used by academics and by agencies for compiling global mortality estimates, but they are widely used in many countries as they are locally generated and continuously available. Data sources include routinely reported records in health facilities or sentinel sites, reports from healthcare providers and health facility surveys.

Eighteen papers reviewed used health facility data to estimate MMR.17-34 Most studies were conducted in low- and middle-income African countries such as Nigeria, Cameroon, Malawi and Zambia. However, middle-income countries such as India, Pakistan and Turkey also estimated MMR using health facility data.18,23,27 It was noted that 15 studies were conducted in tertiary or teaching hospitals which are expected to have a significant proportion of high-risk obstetric cases although this proportion was not reported.17,19-23,27-29,31-34 Maternal deaths were identified from maternity ward records in 16 out of 18 facilities. Only two studies identified cases from other wards including the female or gynaecology ward and from operating theatre registers.21,31 Case notes for women who had died were noted to have been missing in some facilities and there were considerable inaccuracies in routine registers noted in most retrospective studies.20,25

### 3) Population Census

Greater interest has been shown in using data from population censuses to measure maternal mortality. A national census, with the addition of a small number of additional questions, can be used to obtain estimates of maternal mortality.35 This is a result of the endorsement of this method by the United Nations Principles and Recommendations for Population and Housing Censuses.36 The UN principles recommend two follow-up questions in cases where the household being interviewed reports a death during the past 12 months. After ascertaining the name, age and sex of the deceased person and date of death, the interviewer should inquire:

1) Was the death due to an accident, violence, homicide or suicide?

2) If the deceased was a woman aged 15 to 49, did the death occur while she was pregnant, during childbirth or during the six weeks after the end of pregnancy?

As a result, in the 1990s several countries included questions intended to ascertain if any WRA had died during pregnancy or within a defined period post-partum, usually 6 weeks. In principle, a census allows the identification of deaths in a household in a relatively short reference period (1–2 years) and thereby provides estimates of recent maternal mortality.

Population census data was used to estimate maternal mortality in five studies.37-41 Questions regarding the time of circumstance of death among women of reproductive age who died during pregnancy, labour and in the post-partum period (usually 6 weeks after delivery) were included during census data collection. The studies were conducted in Latin America (Honduras, Nicaragua and Paraguay), South Africa, Burkina Faso, Honduras (only) and Indonesia. A study conducted in Burkina Faso used this approach and obtained an estimate of the MMR, the results of which were similar to a previous study which had used the direct sisterhood method.41 In Latin America, there was a greater number of reported pregnancy-related deaths in census data when compared to the number reported during a household survey which was conducted at the same time.39 Similarly, in the Republic of South Africa, an increase in maternal death was observed.40 Narrow confidence intervals were obtained: MMR: 519 per 100 000 (95% CI: 454, 584)] in Damage and MMR: 353 per 100 000 (95% CI: 295, 411) in Orangey in Burkina Faso.41 Similarly, there was a greater number of reported pregnancy-related deaths using census data than obtained via sample surveys in Latin America.

### 4) Population or Household Surveys

Population or household surveys are one of the most important data capturing methods for maternal deaths in settings where routine information systems are weak or non-existent. These surveys are administered at the household level to collect information about maternal deaths. Names and residences are cross-checked to avoid double counting. Sometimes they are complemented with verbal autopsies where the family members or other people with knowledge about the death could be asked to describe the situation surrounding the death relatives. The WHO has devised a standard verbal autopsy tool to collect information on signs, symptoms, medical history and circumstances preceding death42 which countries can adapt according to their situation. In both population or household surveys and verbal autopsies, names and residences are cross-checked to avoid double counting. These methods are only appropriate for settings in which the sampling unit is a complete village and the geographical scope of the study is quite limited. Surveys, however, require a relatively large sample size to obtain statistically significant findings for occurrences that are relatively rare such as maternal deaths.35 Sixteen studies included in this review estimated the number of maternal deaths using population and/or household surveys.38,43-57 Out of the 16 studies, only five were conducted in Africa (Ethiopia, Kenya, Malawi, Senegal and Tanzania).44,52,52,56,57 Six were conducted prospectively (Colombia, Sri Lanka, Ethiopia, Indonesia, Jamaica and Pakistan).38,43,48,50,51,53 For cultural reasons, family members and birth attendants in Cambodia were reported to have felt ashamed of deaths that had occurred and, therefore, did not report all deaths. There were sampling problems in some of the studies and very wide confidence intervals were obtained for the MMR estimates.55,57 For example, in India, only a small area was covered because it was considered too expensive to conduct a household survey covering a bigger, geographical area.

### 5) Direct and indirect sisterhood methods

In sisterhood surveys, adult respondents report on the aggregate numbers of surviving sisters and of sisters who have died.58 There are two types of sisterhood methods, the indirect and the direct method. The original (indirect) sisterhood method was developed in the late 1980s by Graham et al.58 In the indirect sisterhood method, adult respondents are asked four questions pertaining to the survival (or not) of all their adult sisters born to the same mother. By inquiring about female siblings in a high fertility setting, one effectively expands the sample size with very little additional cost. The method also reduces the need for large sample sizes because there may be more than one respondent per household and more than one sister per respondent. The questions for which responses are required in the indirect sisterhood method are listed in the box below.

Indirect Sisterhood Questions

1. How many sisters (born to the same mother) have you ever had who reached age 15 (who were ever-married) including those who are now dead?
2. How many of these ever-married sisters are alive now?
3. How many of these are dead?
4. How many of these dead sisters died while they were pregnant, or during childbirth, or during the six weeks after the end of the pregnancy?

Source: World Health Organization, 1997. The Sisterhood method for estimating maternal mortality: guidance potential users. Available on <http://apps.who.int/iris/bitstream/10665/64007/1/WHO_RHT_97.28.pdf>. Accessed on 21st November 2016.

As this method identifies any death which occurs during pregnancy, childbirth or the postpartum period; the indirect sisterhood approach identifies pregnancy-related deaths rather than true maternal deaths. Overestimation of maternal mortality due to the inclusion of deaths that are coincidental and/or non-maternal deaths is likely. Conversely, abortion-related maternal deaths are often not captured. It has been suggested that the omission of induced abortions a compensate for the inclusion of non-maternal deaths. However, the extent of the compensation is unknown. Finally, estimates obtained using the indirect sisterhood method relate to the previous 10-12 years and are, therefore, not contemporaneous and cannot be used for evaluating the effectiveness or impact of an intervention programme.

Rutenburg and Sullivan proposed the direct sisterhood method,59 which has been widely used in DHS programmes. This is a variant of the indirect sisterhood method based on a detailed sibling history obtained from each respondent. The four questions listed above for the original indirect sisterhood method are expanded to 11 questions. In addition, the formulation of the original questions was altered. For example, the fourth question on timing of death in relation to pregnancy, childbirth and the postpartum period was changed to include three separate questions.

Direct Sisterhood Questions

1. How many children did your mother give birth to?
2. How many of these births did your mother have before you were born?
3. What was the name given to your oldest (next oldest) brother or sister?
4. Is (NAME) male or female?
5. Is (NAME) still alive?
6. How old is (NAME)?
7. In what year did (NAME) die? OR how many years ago did (NAME) die?
8. How old was (NAME) when she died?

For dead sisters only:

1. Was (NAME) pregnant when she died?
2. Did (NAME) die during childbirth?
3. Did (NAME) die within two months after the end of pregnancy or

Source: World Health Organization, 1997. The Sisterhood method for estimating maternal mortality: guidance potential users. Available on <http://apps.who.int/iris/bitstream/10665/64007/1/WHO_RHT_97.28.pdf>. Accessed on 21st November 2016.

The data requirements for the direct sisterhood method are considerably more demanding than those for the indirect approach. In the direct approach, a respondent is asked to provide the birth history of her mother, including the current age of all living siblings and the age at death and years since death for all deceased siblings. These data allow deaths and births to be placed in calendar time and, therefore, permit the calculation of sex and age-specific death rates for reference periods. 59 Unlike the indirect sisterhood method, the direct sisterhood method targets a more limited reference period for sister deaths: the previous 0-6 years compared to the previous 10-12 years for the indirect sisterhood method. Point estimates for maternal mortality are obtainable. The approach also allows for the calculation of rates/ratios for the reference period of interest and monitor trends. The direct sisterhood method is currently used during DHS. This method requires larger sample sizes than the indirect method. It also requires an additional 8-10 minutes per interview on average and additional training and supervision in the field.

Both methods measure the ICD-10 concept of pregnancy-related mortality rather than maternal mortality on the grounds that respondents would not be easily able to distinguish between maternal and pregnancy-related deaths.39 We did not find any peer-reviewed studies which use the direct sisterhood method apart from the DHS. An analysis of the quality of maternal health indicators for DHS studies is not part of this review and has been described elsewhere.60 Eleven included studies used the indirect sisterhood method to estimate MMR. Ten studies were conducted in Africa ((Liberia, Nigeria (2 studies), Mali, Tanzania (3 studies), Swaziland, Uganda and Ghana.61-69 One study was conducted in India.70 In Ghana and Uganda, the MMR estimates identified through the indirect sisterhood method were higher than those obtained as national estimates (modelling, UN global estimates) conducted at the same time.68,69 All studies registered pregnancy-related deaths and include death due to accidental or incidental causes (i.e. not maternal deaths). Cause of death is not determined and data collected refers to the previous 10-12 years.

### 6) Reproductive Age Mortality Studies (RAMOS)

A RAMOS has been identified as a relatively robust method which uses both active and passive data collection methods to estimate the MMR in countries without vital registration data and are often considered to be the gold standard.35 The approach involves retrospective or prospective identification and investigating the causes of all deaths of WRA in a defined area/population by using multiple sources of data such as existing records (civil registration and health facility data), census, surveys and surveillance. RAMOS are conducted in two phases. The first phase, involves identification of all deaths among WRA in a population. In the second phase, all deaths are investigated (using verbal autopsy, health facility reports or medical record reviews death certificates with medical cause and interview with household members and relatives) to ascertain if they are pregnancy-related or maternal deaths.71

Four studies conducted in Malawi, Sudan, Jordan and Ghana estimated MMR using the RAMOS method.72-75 Three studies were prospective and one study retrospective.73 A list of all deaths of WRA was collected using data collated at health facilities (e.g. admission and discharge books, death certificate books, death registers and mortuary logbooks) and individual case notes when necessary, available census data or any other relevant data e.g. the number of births from the most recent DHS and from the Health Management Information System (HMIS). Deaths that occurred in the community were identified by local key informants, traditional birth attendants and community workers. A study in Malawi used the existing health staff (nurses, doctors, medical assistants and community health workers known as health surveillance assistants) at both health facility and community level to identify and report all deaths of women of reproductive age. One study in Pakistan included interviews with graveyard caretakers as an additional source of data. In most studies, verbal autopsies where family members or other people with knowledge about the death were interviewed to describe the situation surrounding the death.

All RAMOS studies highlight that this method identifies more maternal deaths than obtained via any one of the existing reporting mechanisms alone (e.g. HMIS, facility death reports, etc.). Underreporting of maternal deaths (by 44% and 43%) documented via survey and civil registration was reported in Ghana and Malawi respectively.72,75 In Sudan and Jordan, the RAMOS study was conducted at state level, while in Malawi and Ghana the studies were conducted at district and city level, respectively.73,74 In Malawi, verbal autopsy was only done for deaths that were identified as maternal deaths. Maternal deaths were identified using the ICD-10 version 10 definition of MD.76

# Discussion

Accurate levels of maternal mortality are difficult to measure in a population for it is challenging to identify maternal deaths precisely, particularly in settings where routine recording of deaths is not complete within civil registration systems.6 The woman’s pregnancy status is usually missed even if such a death were recorded and may not be reported as a maternal death even if the woman were pregnant. Even in countries where routine registration of deaths is in place, maternal deaths may be unidentified due to misclassification of ICD-10 coding and identification of the true numbers of maternal deaths may require special investigations into the causes of deaths.59,77 This review shows that even in high-middle income countries such mechanisms are only now in process of being fully developed. A variety of other methods are used in low- and middle-income settings. Very often the only contemporaneous data available are health facility-based MMR estimates which do not apply to the whole population or estimates obtained via the sisterhood method which are not contemporaneous and report pregnancy-related rather than maternal deaths per se.

### Birth and death registration

For birth and death registration systems to provide data on the number of maternal deaths among all deaths of women of reproductive age (WRA), it is important that pregnancy status is known. Although a tick box has been included on the death notification from, underreporting of the number of maternal deaths and misreporting (misclassification of death of a WRA as a maternal death or not) has been identified as a problem of civil registration data.78,79 In this review, information on pregnancy status was often either missing or unclear in the identified deaths.12-16 Although countries such as Sweden, the Netherlands, the United Kingdom and United States of America, which have documented reduction in MMR over several decades, have relied on adequate civil registration systems, misclassification and underreporting exists.4,79 Revision of the death certificate to include information on pregnancy status improves the quality of data and helps to reduce misclassification of maternal deaths. Civil registration data can be compared with data obtained via other systems specific to the evaluation or audit of maternal deaths; countries such as the United Kingdom and South Africa have used the Confidential Enquiry into Maternal Deaths (CEMD) to ensure any death missed by the civil registration system are captured.2,80,81,82

### Health facility data

Valuable information can be obtained when maternal deaths that occur in a health facility are reviewed specifically to identify where the health system needs to improve.22,83 However, in low- and middle-income countries unless more than 95% of women give birth in a health facility (as opposed to at home), findings from hospital-based studies cannot be generalised to the entire population. However, the majority of the studies from developing country settings reported hospital-based MMR. These only apply to the hospital itself and reflects the type of services provided; large referral hospitals with a large proportion of referred and complicated cases (rather than uncomplicated deliveries) can expect the MMR to be higher than for lower level hospitals (from where patients who are severely ill will be referred out). Thus, facility-based MMR can only be used at the facility level to monitor trends over time and if the proportion of women with potentially life threatening obstetric complications is taken into consideration. It is also crucial that all deaths of WRA are identified and an assessment is made to classify them as maternal deaths or not. Unless a country has a healthcare system like Saudi Arabia, where almost all maternal deaths take place in the hospital or where all women are brought into hospital soon after death outside the facility, hospital-based data cannot be used to provide accurate estimates of MMR for the population.84

### Census and population or household surveys

The United Nations recommends the use of a population censuses for estimating MMR, without considering this a substitute for vital registration.85 Use of census data to calculate MMR is cost-effective as the data can be obtained as part of an already agreed country census. Census data should provide a complete picture of the whole population and results in an estimate with relatively normal confidence indicators due to the large samples sizes. However, a census is usually only conducted every ten years and cannot be used for routine monitoring. Furthermore, they identify pregnancy-related deaths (not maternal deaths). Early pregnancy deaths may remain under-reported if pregnancy status was not known and maternal mortality can be over-estimated where death was incidental and not due to the pregnancy. This is illustrated in a study conducted in the Republic of South Africa where an increase in maternal deaths was identified when census data were used as compared to a previous MMR estimate which was obtained using a survey method.40 Despite these limitations, census data still offer the opportunity to measure pregnancy-related mortality as a proxy for maternal mortality in countries with poor or no death registration systems in place.

When specific, planned surveys are used, capturing deaths and births is more complete than with routinely gathered statistics. However, survey methods require prohibitively large sample sizes to obtain statistically significant findings. Such surveys could, however, be used to estimate MMR in resource-limited countries in smaller subsets of populations where the other data sources are not available and/or RAMOS cannot be conducted.

### Sisterhood methods

The sisterhood method is cost-effective and easier to perform than prospective population-based methods. Specifically, with the indirect sisterhood method, the number of households that need to be visited in order to obtain information on large numbers of women who have reached reproductive age is relatively small.58 Given that questions are asked about the deaths of adult sisters, both methods actually measure pregnancy-related deaths rather than maternal deaths, on the grounds that respondents (sisters) would not easily be able to distinguish between maternal and non-maternal deaths and/or usually unable to assign cause of death with certainty. Both methods provide estimates of maternal mortality in orders of magnitude rather than precise ratios since both can have wide margins of error (wide confidence intervals). Neither method provides a current estimate for the year of the survey. For these reasons, sisterhood studies cannot be used to monitor changes in maternal mortality or to assess the impact of safe motherhood programmes in the short term. The sisterhood method has been recommended by the WHO for countries without other reliable source of data and this method is frequently used as part of the 5-year DHS in low- and middle-income countries.

### Reproductive Age Mortality Surveys (RAMOS)

In the absence of a civil registration system with/without additional data collection mechanisms such as a CEMD, the RAMOS approach probably provides the most complete and contemporaneous estimation of MMR because information regarding the number of maternal deaths is obtained from a variety of sources and each death among WRA is evaluated to assess whether the death is a maternal death or not. However, the RAMOS approach is difficult in the absence of a reasonably complete initial list of deaths. Inadequate identification of all deaths among WRA results in an underestimation of maternal mortality levels. For example, Surinam had a reliable registration system for deaths which made identification of deaths of WRA relatively easy.86 Similarly, during the prospective RAMOS in Pakistan, good population-based systems were in place for tracking deaths.48 This meant that the number of maternal death among deaths of WRA could be assessed. RAMOS studies can be expensive and time consuming when conducted on a larger scale.14 A RAMOS may, therefore, be considered to provide accurate MMR data for a sub-national population.

# Conclusion

To end preventable maternal deaths, it is crucial that countries develop systems and processes to ensure the ability to count every maternal death and identify the cause of death and contributing conditions. This will help identify where and how the availability or coverage as well as quality of care need to be improved. Ideally, MMR estimates should be obtained from civil registration data which provides both numerator and denominator data. This would also assist in monitoring any trends in MMR over time. Many low- and middle-income countries are in the process of introducing civil registration systems for births and deaths. For countries without reliable systems in place, a RAMOS can be an effective method that can be used to obtain recent data and provides better estimates of MMR.

A RAMOS approach can also help illustrate what is needed to support the introduction of a full-scale Maternal Death Surveillance and Response (MDSR) process**.** The MDSR builds on the principles of public health surveillance and response by collecting accurate information on cause of maternal deaths solessons can be learnt and actions taken to prevent similar deaths in the future and to improve quality of care.

**Conflicts of interest**

The authors are unaware of any potential conflicts of interest.

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**Supplementary Table 1: Summary Table for studies included in the systematic review**

| **No** | **Setting** | **Author** | **Year** | **Title** | **Methodology** | **Major findings** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1. **Estimates of MMR using Civil registration systems** | | | | | | | |
| 1 | China | Zhu et al. | 2009 | Comparison of maternal mortality between migrating population and permanent residents in Shanghai, China, 1996-2005 | All cases of maternal deaths identified from a central death register were reviewed by the Maternal Death Review Committee. | MMR in residents of Shanghai declined from 22.47/ 100 000 in 1996 to 1.64/100 000 live births in 2005 (p<0.01), while the MMR in the migrating population reduced moderately from 54.68/100 000 live births to 48.46/100 000 (p>0.05). | Migrating population were included with the permanent residents if they had resident permits. Therefore, the results do not show the real difference in deaths between the two groups. Information on pregnancy status was missing in some death registers. |
| 2 | Dominican Republic | Westhoff et al. | 2009 | Estimating maternal mortality in Monseñor Nouel Province, Dominican Republic | Estimated the MMR combining two methods of data collection - sample survey method and via vital registration. | The results showed a MMR significantly higher than other national estimates (348/100 000 live births versus 72-50/100 000). | Reported MMR did not portray the true magnitude because death certificates did not provide adequate data. There was lack of data from women living in villages accessible only by foot because their deaths were not registered. Another limitation was a small target population for the survey considering that maternal mortality is rare. |
| 3 | Brazil | Alves | 2007 | Maternal Mortality in Pernambuco, Brazil: What Has Changed in Ten Years | Used death certificates of women of child bearing age registered in the local information system, hospital records, autopsy services, in-depth interviews with relatives of the deceased and health workers from June 2003-September 2004. | Of the 1258 female deaths investigated, 54 maternal deaths were identified, corresponding to a MMR of 77/100 000 live births. Underreporting of 46% compared to previous studies was identified. | The study utilised reliable data from multiple sources to identify deaths. However, some records could not be located and others were incomplete which may have biased the results. Relatives could not identify or report abortion-related deaths. |
| 4 | Egypt | Hamza | 2005 | The Egyptian National Maternal Mortality Study | Used civil registration data. | The study estimates a dramatic drop of 52% in maternal deaths between the 1992-1993 and 2000 study. MMR estimate of 84/100 000. | Some registers incomplete and pregnancy status not indicated. |
| 5 | Guatemala | Kestler and Ramirez | 2000 | Pregnancy-related mortality in Guatemala, 1993-1996 | All death certificates of women of childbearing age (10-49 years old) issued from January 1, 1993 through 31 December 1996 were reviewed, medical charts and other information from public and private hospitals and from primary healthcare centres. Data for verbal autopsies were collected by interviewing traditional birth attendants and family members. Autopsy reports that had been prepared by hospitals and by the national coroner’s offices were also reviewed. | The MMR was 156.2/100 000 live births. Women 35 years of age and older had a higher risk of maternal death than younger women. Women between the ages of 35 and 39 years had a maternal death risk almost three times as high as women aged between 20 and 24. For women who were 40 or older, the risk was more than double that of women 20-24 years old. | Using multiple sources of information improved the quality of information. This study detected as many as three times the number of maternal deaths as via the national vital statistics registry only. The absence of detailed hospital data for all cases limited the ability to assign cause of death. |
| **2. Estimates of MMR using Census data** | | | | | | | |
| 1 | Honduras | Queiroz | 2011 | Estimating **maternal mortality** differentials using census data: experience in Honduras | Using national population censuses to **measure maternal mortality** and studyregional differentials inHonduras. | Adjusted pregnancy-related maternal mortality was 224/100 000 live births ranging from 200 in Region A to 274 in Region B. | Less than 50% of deaths were recorded in poor areas which resulted in an underestimate of the MMR. |

| **No** | **Setting** | **Author** | **Year** | **Title** | **Methodology** | **Major findings** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 2 | Indonesia | Qomariyah et al. | 2010 | An option for measuring maternal mortality in developing countries: a survey using community informants | Heads of neighbourhood units (RTs) and health volunteers (Kaders) were instructed to the list deaths of women of reproductive age; comparison of the two lists. | The RT network identified a higher proportion of pregnancy-related deaths (PRD) than the Kaders (estimated 0.85 vs. 0.71), but the latter was easier and cheaper to access. Assigned PRD status amongst identified deaths in women of reproductive age was more accurate for the Kader network, and seemingly for more recent deaths and deaths from rural areas. | Recent MMR estimates were obtained quickly and relatively cheaply using two independent informant networks. However, there could be recall bias as this method relies on informants’ memory and knowledge to record deaths. |
| 3 | Latin America | Hill et al. | 2009 | Estimating pregnancy-related mortality from census data: Experience in Latin America | Data was from more than one census in the same country.  Honduras 1988 & 2001  Nicaragua 1995 & 2005  Paraguay 1992 & 2002 | Evaluation of the data for Nicaragua and Paraguay showed over-reporting of adult deaths and downward adjustment of 20% to 30% was required. In Honduras, the number of adult female deaths required substantial upward adjustment. The number of live births needed minimal adjustment. The adjusted pregnancy-related maternal mortality estimates were consistent with existing estimates of maternal mortality from various data sources, though the comparison varied by source. | The advantage of using census data was that there was a greater number of reported pregnancy-related deaths than in sample surveys. Census data provide the necessary information for evaluating coverage. Census data can be used to measure pregnancy-related mortality as a proxy for maternal mortality in countries with reasonable registration systems in place and where literacy is high. |
| 4 | South Africa | Garenne et al. | 2008 | Maternal mortality in South Africa in 2001: from demographic census to epidemiological investigation | To estimate maternal mortality levels and identify the main sources of differentials through univariate and multivariate analysis. In the multivariate analysis, cases (maternal deaths) were compared with controls, defined as women who were present at the census and who delivered in the past 12 months. | MMR in 2001 was 542/100 000 live births. This level was much higher than previous estimates pre-HIV/AIDS. Higher risks in provinces were not necessarily associated with lower income, lower education or a higher proportion of home delivery but correlated primarily with the prevalence of HIV/AIDS. | The census data provided a complete picture of the whole population and therefore avoided issues of representativeness which often hampers estimates based on hospital data. The census also offered large numbers and small confidence intervals, in contrast to demographic surveys with a small sample size. However, only pregnancy-related deaths not maternal deaths were identified. |
| 5 | Burkina Faso | Bell et al. | 2008 | The epidemiology of pregnancy outcomes inrural Burkina Faso | A census was conducted in the two study districts, recording deaths among women aged 12-49 years in the household from 2001 to 2006. Questions on pregnancy outcome in the last five years for resident women of reproductive age were included and an additional method, direct sisterhood was added in part of the area. Adult female deaths were followed-up with verbal autopsy with household members. | The MMR was 441/100 000 live births (95% CI: 397-485) significantly higher in Diapaga [519/100 000 (95% CI: 454, 584)] than Ouargaye [353/100 000 (95% CI: 295, 411)]. | Narrow confidence intervals were obtained suggesting precise results. This study clearly explained the methodology used and can easily be replicated. However, the low literacy levels in this population may have affected the accuracy of reported timings of events such as births and deaths. For the MMR calculation, data on live births were only collected from women who were resident at the time of the survey and the number of births in the household could be under- or over-estimated. |
| **3. Estimates of MMR using Population or Household Surveys** | | | | | | | |
| 1 | Pakistan | [Mohammad](javascript:__doLinkPostBack('','ss~~AR%20%22Mir%2C%20Ali%20Mohammad%22%7C%7Csl~~rl','');) et al. | 2015 | Using Community Informants to Estimate **Maternal Mortality** in a Rural District in Pakistan: A Feasibility Study | Used 4 community networks to identify deaths in women of reproductive age in the past two years in Chakwal district, Pakistan. The deaths recorded by the informants were followed up using verbal autopsy. | This study identified 2001 deaths in women of reproductive age. 1424 deaths were followed up with verbal autopsies conducted with the relatives of the deceased. 169 pregnancy-related deaths were identified from all reported deaths. **Maternal mortality**in Chakwal district was estimated at 309/100 000 live births. | Evidence shows reliable information on deaths among women of reproductive age can be obtained at a reasonably low cost via community-based networks and surveys using religious leaders. |
| 2 | Sri Lanka | Agampodi et al. | 2014 | **Maternal mortality** revisited: the application of the new ICD-MM classification system in reference to **maternal deaths** in Sri Lanka | Extracted and analysed data from the **maternal death** surveillance system in Sri Lanka for the period of 2005 to 2011, in order to identify the implications of this new classification on **maternal mortality** estimates. Causes of **deaths** were extracted and coded using ICD-10 reclassified according to new ICD-MM for **maternal deaths.** | Of the 118 deaths, 53 (44.9%) were maternal deaths. The estimated MMR in the study area based on the new classification during the years 2009, 2010 and 2011 was 115, 103 and 88/100 000 live births, respectively. These 53 included one d**eath** due to suicide, out of 21(17.8%) suicide **deaths** among 118 reported **deaths.** | Application of the new ICD-MM allowed inclusion of suicide deaths, this resulted in a 56.6% increase in number of **maternal deaths** in the province. |
| 3 | Argentina, Guatemala, India,  Kenya,  Pakistan and Zambia | Saleem et al. | 2014 | A prospective study of **maternal**, fetal and neonatal **deaths** in low- and middle-income **countries** | A prospective study of pregnancy outcomes was performed in 106 communities at seven sites in Argentina, Guatemala, India, Kenya, Pakistan and Zambia. Pregnant women were enrolled and followed to six weeks postpartum. | Between 2010 and 2012, 214 070 of the 220 235 enrolled women (97.2%) completed follow-up. The **MMR** was 168/100 000 live births, ranging from 69/100 000 in Argentina to 316/100 000 in Pakistan. Overall, 29% (98/336) of **maternal deaths** occurred around the time of delivery: most were attributed to haemorrhage (86/336), pre-eclampsia or eclampsia (55/336) or sepsis (39/336). | Enrolment began at 16 weeks’ gestation. Some maternal deaths may have been missed that occurred early in gestation before the pregnancy had been recognised. |
| 4 | Ethiopia | Prata et al. | 2012 | An innovative approach to **measuring maternal mortality** at the community level in low-resource settings using mid-level providers: a feasibility study in Tigray, Ethiopia | Community-based sentinel surveillance in which priests, traditional birth attendants and community-based reproductive health agents were responsible for locating and reporting all births and deaths in their designated areas. | MMR of 467/100 000 live births. These data were compared the most recent maternal mortality ratio for Ethiopia (2008), estimated by WHO, was 450/100 000 live births. | One limitation of the study was the small sample size (four maternal deaths). This did not allow for statistically meaningful assessment. |
| 5 | Indonesia | Qomariyah et al. | 2010 | Mortality in developing countries: a survey using community informants: An option for measuring maternal morality | Community surveywhich **used** village **informant** networks to capture deaths of women. Two village **informant** networks were used; heads of neighbourhood units (RTs) and health volunteers (Kaders). | Reports pregnancy-related deaths (PRD) The RT network identified a higher proportion of PRDs than the Kaders (estimated 0.85 vs. 0.71), but the latter was easier and cheaper to access. Assigned PRD status amongst identified deaths in women of reproductive age was more accurate for the Kader network, and seemingly for more recent deaths and deaths from rural areas. Assuming information on live births from an existing source to calculate the MMR, the survey cost only US$0.10 per women-year risk of exposure, substantially cheaper than alternatives. | Assigned PRD status amongst identified deaths among women of reproductive age was more accurate for the Kader network, and seemingly for more recent deaths and for death**s** from rural areas. |
| 6 | Pakistan | Jafarey et al. | 2009 | Verbal Autopsy of Maternal Deaths in two Districts of Pakistan - Filling Information Gaps | Examination of different sources of data during the study year, 2007 (prospective) and the previous two years, 2005 and 2006 (retrospective) to identify gaps in information and analyse maternal deaths that occurred at the community or health facility levels in two districts in Pakistan. A verbal autopsy questionnaire was administered to households where a maternal death had occurred. | No single source had complete data on maternal deaths. Risk factors identified among 128 deceased women were: low socioeconomic status, illiteracy, low-earning jobs, parity and bad obstetric history. These were similar to the findings of earlier studies. | No additional maternal deaths were identified by caretakers of grave­yards. The caretakers of the majority of graveyards were not educated and, thus, could not document or keep records Although records of female deaths were available at the union councils, there was no information as to whether the deaths were maternal or not. |
| 7 | Turkey | Karabulut et al. | 2010 | Maternal Mortality in Denizli Region: Three Years Evaluation | From January 2006, maternal deaths were evaluated by a board formed within the Directorate of Health. Information was gathered from primary healthcare centres, hospital and from the family. This was evaluated by the commission and cause of death was recorded. | The MMR was 22.8/100 000 live births lower than the national estimates. Thirty-three percent of patients died of postpartum haemorrhage, 33.3% due to amniotic fluid embolism, 22.2% due to pulmonary emboli and 11.1% died of complications secondary to hypertension. The most frequent cause for indirect maternal deaths was cardiac problems. | The strength of this prospective study was that it was easy to track the deaths. Combining results with retrospective data strengthened the study. However, it was expensive due to the follow-ups which were done. No confidence intervals were presented. |
| 8 | Kenya | Ziraba et al. | 2009 | Maternal mortality in informal settlements of Nairobi City:What do we know | Data from verbal autopsies conducted on nearly all female deaths aged 15-49 years between January 1, 2003 and December 31, 2005. Data from a healthcare facility survey conducted in 2006 to assess maternal health experiences as captured by the health management information system (HMIS) in healthcare facilities during 2004-2005 was also included. The healthcare facilities were identified from reports provided by women who participated in the household survey component of the project. | The MMR for the two Nairobi slums was higher than the national estimates. MMR was 706/100 000 live births. There were 22 late maternal deaths (maternal deaths between 42 days and one year of pregnancy termination) most of which were due to HIV/AIDS and anaemia. | The verbal autopsy tool seems to have captured more abortion-related deaths compared to healthcare facility records. Up to 14% of all female deaths did not have a verbal autopsy and about 47% of the healthcare facility medical records were incomplete. This could have potentially introduced bias in the estimates. Due to incomplete healthcare facility records and lack of a defined catchment population (and hence denominator), the healthcare facility survey data could not be used to inform the estimate of MMR. |
| 9 | Cambodia | Chandy et al. | 2008 | Comparing two survey methods for estimating maternal and perinatal mortality in rural Cambodia | Two survey methods were applied in two separate sectors: a community-based survey gathering data from public sources and a household survey gathering data direct from primary sources. | The community-based survey registered a total of 4482 deliveries in 2004. Of these, 20 mothers died during delivery or within 42 days after termination of the pregnancy giving a MMR of 446/100 000 live births (95% CI: 0.25%-0.64%). The household survey reported 14 dead mothers in a total of 3152 deliveries, a MMR of 444/100 000 (95% CI: 0.24%-0.74%). | For cultural reasons, family members and birth attendants felt ashamed of the fatalities and did not tell their stories to outsiders. Comparing the two survey methods was inaccurate because the surveys were conducted in different populations. The authors note that surveys can be used but they require large sample sizes. |
| 10 | India | Singh et al. | 2007 | House-to-house survey for capturing maternal deaths in India: A search for a cost-effective method | House-to-house survey was conducted to enumerate live births and maternal deaths. Snowball sampling was adopted for capturing maternal deaths in addition to the house-to-house survey. | 94 maternal deaths were captured through snowball technique compared to 83 through house-to-house survey. The estimate of MMR for the five states combined was 356/100 000 live births, as compared to the national estimate of 400/100 000 live births for the country as a whole. The relative standard error for the estimate was 10%. | The methodology used was appropriate for the study. However, the study covered only a small area and the results could not be generalised. |
| 11 | Jamaica | McCaw-Binns et al. | 2008 | Maternal mortality surveillance in Jamaica | Continuous maternal mortality surveillance was introduced in 2003. The number of deaths notified was compared with the number of independently identified deaths for each period and region studied and key informants reported on their experience of the surveillance process. | A decline in total hospital mortality, from 115 to 95/100 000 live births (p=0.047), but a significant reduction in direct mortality, from 99 to 66/100 000 live births. This reduction was due to fewer cases of gestational hypertension, haemorrhage and puerperal infection. | Multi-source strategies provide the best options for achieving near-complete reporting on cases of maternal deaths. However, addresses given at hospital registration were sometimes incomplete or inaccurate. Relatives were reluctant to share information regarding violent deaths for fear of reprisal. When the death resulted from an abortion, relatives were often unaware of the pregnancy. |
| 12 | India | Barnett et al. | 2008 | A prospective key informant surveillance system to measure maternal mortality - findings from indigenous Jharkhad and Orissa populations in India | Paid key informants identified all births and deaths among women of reproductive age, prospectively, over a period of 110 weeks Most key informants were traditional birth attendants (TBAs). They were paid an incentive of 30 rupees (USD0.65) for every accurate birth or death identification. | A MMR of 722/100 000 live births (CI: 591-882) was identified. Four additional pregnancy-related and four late maternal deaths were identified (17%). | The system provided valuable and reliable data on maternal mortality in a given population. Most maternal mortality data for developing countries are estimates, derived retrospectively. The use of an incentive driven system could bias findings as identifiers could over report the deaths to get more money. |
| 13 | Pakistan | Farooq et al. | 2006 | An assessment study of maternal mortality ratio in five districts of North Western Frontierprovince in Pakistan | Quantitative cross-sectional study from 2001 to 2002 using records and maternal mortality statistics from the public health sector. | The MMR was Haripur 0.168 and 0.173, Mansehra 00 and 00, Battagram 00 and 00, Swat 0.051 and 0.524 and Swabi 00 and 0.968/1000 live births. | The data bank provided an estimate of MMR. The limitation was that some data was incomplete and some case files were missing. |
| 14 | Malawi | van den Broek et al. | 2003 | Reproductive health in rural Malawi: a population-based | A descriptive population-based study using interviews with women in 20,649 households using structured questionnaires. | The MMR was reported at 413/100 000 live births (95% CI: 144-682). | This was a population-based study which yielded a better maternal mortality estimate than the national estimate. However, population-based studies have proved to be expensive. |
| 15 | Senegal | Ba et al. | 2003 | Verbal autopsy to measure maternal mortality in rural Senegal | Data were collected through two sources: a questionnaire filled out by data collectors during the demographic survey and a complementary survey done by an epidemiologist among families. In addition, information from the registers of health facilities was used. For all female deaths (15-49 years), the detailed sequence of events leading to the death were obtained via verbal autopsy. All the cases were submitted to two independent obstetricians for analysis. | The demographic surveillance led to a complete registration of female deaths and an analysis of all female deaths helped to measure maternal mortality during the observed time period. | Verbal autopsy is an attractive method for ascertaining cause of death in settings where the proportion of people who die in health facilities is low. Language barriers were noted to limit information obtained using verbal autopsy. A lack of precision in data collection because of lack of experience of the interviewers was also noted. |
| 16 | Tanzania | Olsen et al. | 2002 | Maternal mortality in northern rural Tanzania: assessing the completeness of various information sources | Maternal deaths in the study area in 1995 were identified from hospital records, health centres, dispensaries and registration by village leaders, follow-up of an antenatal cohort and a household survey. Data from some of these sources were also obtained in 1996. | Estimates based upon official reports showed substantial underreporting. | The study was comprehensive using both hospital- and population-based sources of information. On the other hand, completeness of different sources of information was a challenge especially for hospital-based data. |
| **4. Estimates of MMR using Reproductive age mortality studies (RAMOS)** | | | | | | | |
| 1 | Malawi | Mgawadere et al. | 2016 | Identification of maternal deaths, cause of death and contributing factors in Mangochi District, Malawi: a RAMOS study. | To assess the feasibility of conducting a RAMOS study in a low-income setting. | Out of 424 deaths of women of reproductive age, 151 were maternal deaths giving a MMR of 363/100 000 live births (95% CI: 307-425). Only 86 maternal deaths had been reported via existing reporting mechanisms representing an underreporting of 43%. The majority of maternal deaths (62.3%) occurred in a health facility and were the result of direct obstetric causes (74.8%) with obstetric haemorrhage as the leading cause (35.8%), followed by pregnancy-related infections (19.4%), hypertensive disorders (16.8%) and pregnancy with abortive outcome (13.2%). Malaria was the most frequently identified indirect cause (9.9%). | Verbal autopsy not done for all women of reproductive age who died. |
| 2 | Sudan | Mohammed et al. | 2011. | Maternal mortality in Kassala State - Eastern Sudan: community-based study using reproductive age mortality survey (RAMOS) | RAMOS to study maternal mortality in Kassala State. The study consisted of a retrospective community-based survey with two phases of data collection: death identification and interviews of respondents from the deceased household using a standard verbal autopsy questionnaire. | Maternal mortality rates and ratios were 80.6/100 000 in women of reproductive age and 713.6/100 000 live births, respectively. There was a wide discrepancy between urban and rural maternal mortality ratios (369 and 872/100 000 live births, respectively). Direct obstetric causes were responsible for 58.4% of deaths. Severe anaemia (20.3%) and acute febrile illness (9.4%) were the major indirect causes of maternal death whereas obstetric haemorrhage (15.6%), obstructed labour (14.1%) and puerperal sepsis (10.9%) were the major obstetric causes. | This was a population-based study using a RAMOS in Sudan at the state level. RAMOS studies can be expensive if carried out on a larger scale. |
| 3 | Jordan | Amarin | 2010 | National maternal mortality ratio for Jordan, 2007-2008 | RAMOS of maternal deaths among women aged 15-49 years in Jordan in 2007-2008. | Among 1406 identified deaths of women of reproductive age, 76 maternal deaths were identified out of 397 588 live births, giving a MMR of  19.1/100 000 live births. This was a remarkable decrease compared with the estimated MMR of 41.1 for 1995-1996. | The study aimed to identify all deaths in women of reproductive age and later isolate maternal deaths. However, categorising maternal deaths as due to direct or indirect obstetric causes or due to accidental or incidental events was a challenge because of a lack of information on cause of death. |
| 4 | Ghana | Zakariah et al. | 2009 | Reproductive age mortality survey (RAMOS) in Accra, Ghana | RAMOS was carried out in Accra over one year using multiple sources such as admission and discharge books, death certificate books, death registers, mortuary logbooks and individual case notes. Pathologists carried out post-mortem examinations in some hospitals. | The RMAOS approach captured more deaths than the routine reporting alone. However, this did not provide adequate information on the number of live births. | Most deaths that occurred in a health facility or at home were identified. Post-mortems helped to classify the deaths. The limitation was possible omission of pregnancy or childbirth status in mortuary logbooks. The approach relied on the assumption that (virtually all) women in Accra are buried and therefore need a death certificate. This was not always the case. In areas where there are no pathologists to carry out post-mortem examination for deaths taking place outside the hospital environment, such deaths could not be classified and this led to gross underreporting of cases of maternal death. |
| **5. Estimates of MMR using Sisterhood methods** | | | | | | | |
| 1 | Liberia | Moseson et al. | 2014 | Estimation of **maternal** and neonatal **mortality** at the subnational level in Liberia | Direct sisterhood **method** was modified to account for place and time of **maternal death in a** population of 1985to enable calculation of subnational estimates. | Of 71 reported **deaths** of sisters, 18 (25.4%) were due to pregnancy-related causes and had occurred in the past 3 years in Bomi County. The estimated **MMR** was 890/100 000 live births (95% CI, 497-1301). | The implementation of a modified version of the direct sisterhood method enabled the location of maternal deaths and area-specific estimates to be subsequently calculated. Limitation with precision. |
| 2 | Nigeria | Adegoke et al | 2013 | Community Study **of maternal mortality** in South West Nigeria: how applicable is the Sisterhood Method | This study used a multi-stage sampling design with stratification and clustering in 3028 selected households. | There was a high incidence of maternal mortality in the study setting: 1324/6519 (20.3%) sisters of the respondents had died with 1139 deaths reportedly related to pregnancy, childbirth or the puerperium. The MMR was 7778/100 000 live births (95% CI 7326-8229). Adjusted for a published Total Fertility Rate of 6.0, the MMR was 6525/100 000 live births (95% CI 6144-6909). | Overestimation of maternal deaths might have resulted in this very high MMR. This might have also occurred from collecting information of the same dead sisters from siblings. This means that a single death may be counted several times, depending on how many of the siblings were interviewed. |
| 3 | Nigeria | Oye-Adeniran et al | 2011 | The use of the sisterhood method for estimating MMR in Lagos state, Nigeria | The aim of this study was to obtain a population-based estimate of maternal mortality in Lagos State, Nigeria using the indirect sisterhood method in 2008. | The estimated MMR was 450/100 000 live births with a 95% CI of 360 and 530. Out of 111 reported deaths, 35 (31.5%) occurred during pregnancy, 49 (44.1%) occurred during delivery and 27 (24.3%) within 6 weeks of delivery. | The sample size of 4315 households was sufficient for the sisterhood method, as it was large enough to detect an MMR of 250-500 with an error margin of 20% and a 95% confidence level recommended was in order of 4000 households or less according to Hanley et al 1996. However, the maternal mortality figures recorded here may be subject to limitations that are inherent in a verbal autopsy approach to maternal mortality as no details on the causes were investigated. |
| 4 | Mali | Aa et al. | 2011 | High maternal mortality estimated by the Sisterhood Method in a rural area of Mali | The objective was to estimate the MMR in Kita, rural Mali using the indirect sisterhood method. | This study from rural Mali documented a MMR of more than 3000/100 000 live births. This MMR was much higher than the latest national estimates which estimated the MMR in Mali to be 1000/100 000 live births. | These study results refer to the prevailing MMR around 8 years before data collection and could not provide the most recent MMR for the study area. Deaths due to abortions and ectopic pregnancies may have been misclassified as very few deaths were reported. |
| 5 | Tanzania | Mbaruku et al | 2003 | Estimates of Maternal Mortality in Western Tanzania by the Sisterhood Method | The indirect sisterhood method was carried out. | The overall estimated MMR in Sigma Region was 606/100 000 live births (95% CI 518-695). In urban areas, the MMR was 447 (95% CI 262-635), compared to 638 (95% CI 539-737) in rural areas. The highest MMR of 757 was found in Kigoma rural district, the most isolated part of the region (95% CI 599-916). | The method underestimated early pregnancy deaths due to abortions and ectopic pregnancies as most sisters did not talk about the two. |
| 6 | Swaziland | Lech & Zwane | 2002 | Survey on maternal mortality in Swaziland using the Sisterhood Method | Indirect sisterhood method. | The study revealed the estimated MMR to be 229 and the lifetime risk of maternal death was 1 in 69. These values were probably low and stable throughout the 6- to 7-year period before the study. | The low MMR could be as a result of the high level of migration which took place in the country reducing the likelihood that all surviving siblings were interviewed. |
| 7 | Tanzania | Olsen | 2000 | Estimates of maternal mortality by sisterhood method in rural Northern Tanzania: a householdsample and antenatal clinic sample | The indirect sisterhood method was used; 2043 men and women aged 15-60 from a household survey and 4172 women aged 15-59 from an antenatal clinic survey. | The number of maternal deaths was 362/100 000 live births (95% CI 269-456) and 444/100 000 live births (95% CI 371-517) for the household and antenatal clinic surveys, respectively. The MMR in this area was comparatively high, but substantially lower in this survey than in previous surveys in Tanzania. | The sisterhood method may overestimate maternal mortality since it may register all pregnancy-related deaths, including those due to accidental or incidental causes. It may also underestimate the MMR because early pregnancies, abortions and ectopic pregnancies are not likely to be identified. |
| 8 | India | Bhat | 2002 | Maternal Mortality in India: An Update | Two indirect procedures, the sisterhood method and a regression method involving sex differentials in adult mortality were used and compared with estimates available from other sources. | The MMR using the sisterhood method was 15% lower than using the regression method. | The sisterhood method has been criticised for lacking precision which is essential for trend analysis. The MMR reflected a period roughly 12 years before the survey. |
| 9 | Tanzania | Font et al. | 2000 | Maternal mortality in a rural district of south eastern Tanzania: an application of the sisterhood method | The indirect sisterhood method was used in a rural district in the Morogoro Region of South Eastern Tanzania and the main causes of maternal death were studied. | The MMR was 448/100 000 live births (95% CI: 363-534). | The method was useful for small areas where specific health information did not exist, such as the Kilombero valley. Furthermore, it accounted for sampling variability. |
| 10 | Uganda | Orach et al. | 2000 | Maternal mortality estimated using the Sisterhood method in Gulu district, Uganda | A random selection of 27 parishes of five counties in the district were included. A total of 5522 adult respondents randomly selected from each parish were interviewed for this sample. | The MMR was 662/100 000 deliveries (95% Cl: 421-839). The MMR was found to be 1.3 times higher than the estimated national MMR of 500/100 000 deliveries. | A community-based retrospective maternal mortality study using the sisterhood method. An adequate sample was used for the study. The study was done when there was a war in Uganda. |
| 11 | Ghana | Smith et al. | 2001 | Estimates of the maternal mortality ratio in two districts of the Brong-Ahafo region, Ghana | Estimates of the maternal mortality ratio in two districts of the Brong-Ahafo region, Ghana. | The MMR was estimated to be 269/100 000 live births for both districts combined, a figure higher than the national figure. | Bias during analysis could occur because of the sampling techniques used in the survey and the adjustments used; variance of the total fertility rate (TFR) and TFR value used to calculate MMR estimates. |

| **No** | **Setting** | **Author** | **Year** | **Title** | **Methodology** | **Major findings** | **Comments** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **6. Estimates of MMR using Health facility data** | | | | | | | |
| 1 | Orissa and Rajasthan (India) | Aggarwal et al. | 2015 | Estimates of the **maternal mortality** ratio and the associated medical causes in Orissa and Rajasthan States - a cross sectional study | Conducted from October 2010-June 2012 on a sample of 13 Primary Health Centres (PHCs) in Orissa and 15 PHCs in Rajasthan using the snowball technique. | The MMR was 252/100 000 live births in Orissa (95% CI: 246-259) and 209/100 000 live births in Rajasthan (95% CI: 207-211). Main causes of maternal death were postpartum haemorrhage, anaemia and septicaemia. More than 25% **maternal deaths** could be attributed to indirect causes including suicide, accident and infectious diseases. | Covered a small area, based upon only health facility deaths. |
| 2 | Rwanda | Rulisa et al | 2015 | Maternal near miss and mortality in a tertiary care hospital in Rwanda | A cross-sectional study of all women admitted to the tertiary care University Hospital in Kigali with severe “near miss” maternal morbidity and mortality during a one-year period using the WHO criteria for “near miss” and maternal mortality. | The prevalence of severe maternal outcomes was 11/1000 live births. The maternal near miss ratio was 8/1000 live births. The majority of severe obstetric morbidity and mortality resulted from: sepsis/peritonitis (30.2%) primarily following caesarean deliveries, hypertensive disease (28.6%) and haemorrhage (19.3%). | There was limited information for patients who died on wards other than maternity wards. |
| 3 | Pakistan | Malik et al 2015 | 2015 | Retrospective analysis of **maternal mortality** at a tertiary care hospital in Peshawar, Pakistan. | To determine the frequency of**maternal mortality**and identify cause by age group in a tertiary care hospital in Peshawar, Pakistan. Retrospective review of validated records of hospital registers from January 1, 2009 to December 31, 2011. Convenience sampling used to access the records. | A total of 277 **maternal**deaths in three years. Haemorrhage remains the leading cause with 27.07% (CI=0.66, SD=5.65) followed by eclampsia 15.88 % (CI=0.60, SD=5.13), ruptured uterus 10.83% (CI= 0.51, SD=4.35) and sepsis 10.10% (CI=0.47, SD=4.04). The highest number of **maternal**deaths (33.57%) reported in the 26-35 year age group, followed by 26.71% in 15-25 years, 23.10% in 36-45 years and 3.24% in 45-55 years. | Convenience sampling used to access the records; records may have been missed. |
| 4 | Tanzania | Li et al. | 2014 | **Maternal** **mortality** among HIV-infected pregnant women in Tanzania | Data were collected for all patients enrolled in an HIV/AIDS care and treatment programme between November 2004 and September 2011. | 363 maternal deaths occurred, giving a MMR of 1729/100 000 live births (95% CI 1553-1905). Being wasted [odds ratio (OR) 3.38, 95% CI 2.58-4.45] or anaemic (OR 2.26, 95% CI 1.70-3.00) was associated with a higher risk of maternal mortality. Women who were initiated on antiretroviral therapy before their pregnancy had a 55% decreased risk of maternal mortality (95% CI 0.29-0.70) compared with women who were not. | Only HIV-infected women were included in the study. |
| 5 | India | [Mundkur](javascript:__doLinkPostBack('','ss~~AR%20%22Anjali%20Mundkur%22%7C%7Csl~~rl','');) [& Vanya Rai](javascript:__doLinkPostBack('','ss~~AR%20%22Lavanya%20Rai%22%7C%7Csl~~rl','');) | 2013 | Prepare and prevent rather than repair and repent: study of **maternal mortality** in a tertiary care hospital | Retrospective study. All **maternal deaths** in a tertiary care referral centre from January 2007 to September 2012 were studied for their demographic profile and causes of **death**. | 62 maternal deaths out of 18 458 deliveries, giving a MMR of 335/100 000 live births. All were referred from other healthcare units. 29 died within 24 hours of admission and 33 women died after 24 hours of admission, 34 due to direct obstetric causes and of 26 patients due to indirect obstetric causes. Two deaths were due to accidental causes. Sepsis was found to be the most common cause of **maternal mortality** followed by haemorrhage. | This high level of maternal mortality can be attributed to the fact that the study was conducted in the tertiary care referral centre. Mortality rates were considered to be 2-10 times higher compared to field surveys as most of the seriously ill patients were referred to the tertiary care centres. |
| 6 | Nigeria | Igwegbe et al. | 2011 | Improving maternal mortality at a university teaching hospital in Nigeria | A retrospective survey of case notes of maternal deaths recorded at a University Teaching Hospital between January 1, 2004 and December 31, 2010. The main outcome measures were yearly maternal mortality ratio (MMR), relative risk (RR) of maternal mortality and presentation-intervention interval. | There were 4916 live births and 54 maternal deaths during the study period, giving an MMR of 1098/100 000 live births. Pre-eclampsia/eclampsia was the most common direct cause (25.0%), followed by haemorrhage (18.8%) and sepsis (8.3%). Anaemia (12.5%) was the most common indirect cause. | These were facility-based MMR which did not include maternal deaths that occurred in the community. Authors noted the lack of information in routine health facility registers and some case notes were missing. |
| 7 | Ghana | Gumanga et al. | 2011 | Trends in Maternal Mortality in Tamale Teaching Hospital, Ghana | Retrospective descriptive review of maternal deaths at Tamale Teaching Hospital between 2006 and 2010. | The MMR at the health facility dropped from 1870/100 000 live births in 2006 to 493/100 000 live births in 2010. | Non-availability of some of audit reports and/or patient folders and records for patients who suffered maternal deaths in the hospital between 2006 and 2007 could have led to underestimation of maternal deaths. |
| 8 | Tanzania | Bergsjø et al. | 2010 | Recording of maternal deaths in an East African university hospital | Descriptive study identifying maternal deaths through the facility birth registry and separate manual tracing of all case records. | There was considerable under-reporting of deaths in the medical birth registry. Twenty of the 119 mothers died before 23 weeks' gestational age, most of them from unsafe abortion. | Facility data yielded valuable information especially as the facility had systems in place for registering all births. However, there were problems concerning identification of cases due to missing files and use of single hospital-based medical birth registries may lead to underestimating the MMR. |
| 9 | Nigeria | Agan et al. | 2010 | Trends in maternal mortality at the University of Calabar Teaching Hospital, Nigeria, 1999-2009 | Retrospective review of obstetric service delivery records of all maternal deaths over an 11-year period (January 1, 1999 to December 31, 2009). All pregnancy-related deaths of patients managed at the hospital were included in the study. | MMR of 1513.4/100 000 live births. In the last two years, there was a downward trend in maternal deaths. Most (63.3%) of the deaths were in women aged 20-34 years, 33.3% had completed at least primary education and about 55.4% were unemployed. | The teaching hospital tried to keep accurate data and provided information on cause of maternal deaths which made classification easier. On the other hand, as a teaching hospital, the facility dealt with high-risk obstetric cases and so more maternal deaths were recorded. |
| 10 | Nigeria | Olopade & Lawoyin | 2010 | Maternal Mortality in a Nigerian Maternity Hospital | Case control study where case files of all maternal deaths that occurred in the hospital during the 2-year period were retrieved and data extracted into a study pro forma. Each maternal death was matched with three controls who delivered the same day and lived around the same area of Ibadan. | Facility MMR was higher than the national estimate for Nigeria. However, it was lower than what was obtained in other studies from teaching hospitals around the nation. | The study was carried out in a secondary health facility which does not have as high a selection of complicated cases as tertiary or teaching hospitals and receives referred cases through the primary healthcare system. However, the case-control method could not be applied for deaths in the 42 days following delivery or later. Selection of controls was difficult and needs to be carefully done to avoid bias. |
| 11 | Nigeria | Omo-Aghoja | 2010 | Maternal mortality and emergency obstetric care in Benin City South-south Nigeria | Service delivery records of all maternities over two years at a teaching hospital were analysed. Emergency care facilities in the hospital were physically verified and 10 senior medical/midwifery staff were interviewed. | MMR higher than the national average. | The study provided an estimate of facility-based MMR, but there could be selection bias since the study concentrated on the use of records for women who attended the health facility. |
| 12 | Pakistan | Iftikhar | 2009 | A study of maternal mortality | A retrospective study of 30 mothers who died over a period of five years in a tertiary care hospital. Case summaries of all maternal deaths were reviewed to examine causes of maternal mortality. | Facility-based MMR noted to be higher than the previous years. | As many women delivered at home in this setting, the MMR is facility-based only. |
| 13 | Nigeria | Okeh | 2009 | Statistical analysis of the **maternal death** rate at the Ebonyi State University Teaching Hospital, Abakaliki, for the year ending 31st December 2007 | Data from case notes of all **maternal deaths** that occurred at the University Teaching Hospital between January 1 and December 31, 2007 form the basis of this study. | MMR of 2735.6/100 000 live births. Fifteen (37.5%) unbooked primigravida were found to have died of severe pre-eclampsia/eclampsia. A total of 1645 mothers were noted to have delivered babies, of whom 1472(89.5%) were booked and 173 (10.5%) unbooked, with the hospital. Severe pre-eclampsia/eclampsia, haemorrhaging and sepsis were the major causes of **death**. A high **maternal** **mortality** rate was found to be common among the unbooked primigravida, who often presented late with pre-eclampsia/eclampsia. | Data were obtained from the registers kept in the labour and isolation wards only. |
| 14 | Nigeria | Onakewhor & Gharoro | 2008 | Changing trends in maternal mortality in a developing country | A 5-year review of the MMR in the largest centrally located Mission Hospital in Benin City. Cases identified from the labour ward registers; the antenatal, postnatal, female ward and theatre registers. Case notes and midwifery/nurses' reports were also examined. Copies of the death certificates were examined. | The MMR increased progressively from 325 in 1996 to 765 in 1999 (p<0.0001) with an insignificant drop in 1998 (p>0.06). It was lowest in 2000 (241) (p<0.0001). As the number of deliveries decreased progressively from 1530 per annum in 1996 to 1247 in 2000, the MMR increased progressively from 327/100 000 in 1996 to 675/100 000 in 1999. | Hospital-based MMR calculated. Deaths identified across all wards not only the maternity areas. |
| 15 | Cameroon | Tebeu et al. | 2007 | Maternal mortality in Marouunia Provincial Hospital | Descriptive and historical cohort study done using delivery room and death registers between 1st January 2003 and 31st December 2005. Any death identified over the 3-year period was matched with three controls (women who had a safe delivery). | MMR was high, 1266/100 000 live births and the leading causes of death were hypertension (17.5%), obstetric infections (14.3%), uterine rupture (14.3%), anaemia (12.7%) and complications of HIV/AIDS (9.5%). | The paper has clearly explained the methodology used and the study can easily be replicated. Selection of controls could not be reliable because “safe delivery” is not clearly defined. Hospital records noted to be unreliable with inadequate and poor documentation. |
| 16 | Turkey | Malatyalioglu et al. | 2006 | Maternal mortality in the last eight years: A university-based study from Turkey | Retrospective study and review of hospital records. | 27 related deaths were identified and facility MMR decreased from 822.2/100 000 to 412/100 000. Pregnancy induced hypertension was the most common cause of death. | Hospital MMR estimated. |
| 17 | Malawi | Lema et al | 2005 | Maternal Mortality at the Queen Elizabeth Central Teaching Hospital in Blantyre Malawi | A retrospective descriptive survey to identify the social, demographic and reproductive profiles of women who died between January 1, 1999 and December 31, 2000. | The facility-based MMR was noted to be higher, 1027.2/100 000 than the national figure of  807/100 000 for the same time period. | The study concentrated on maternal deaths at a very busy, high volume tertiary hospital. Not all case files could be identified during the review and some files were incomplete. |
| 18 | Nigeria | Sule-Odu | 2000 | Maternal deaths in Sagamu, Nigeria | A review of maternal deaths at a State University Teaching Hospital in Nigeria over a 10-year period. | Hospital-based MMR was higher than the national. | The figures presented were hospital-based. Over 60% of deliveries in this setting take place at home or at traditional birth attendants’ clinics and churches. Such deliveries are not properly supervised and most maternal deaths resulting from these deliveries are not reported. It was noted that presumed deaths from clandestine abortion were not reported or “hidden” by patients and relatives. |