# Approaches to improve and adapt maternal mortality estimations in low- and middle-income countries: a scoping review

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REVIEW ARTICLE

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# Approaches to improve and adapt maternal mortality estimations in low- and middle-income countries: A scoping review

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## Abstract

**Background:** In the absence of robust vital registration systems, many low- and middle-income countries (LMICs) rely on national surveys or routine surveillance systems to estimate the maternal mortality ratio (MMR). Although the importance of MMR estimates in ending preventable maternal deaths is acknowledged, there is limited research on how different approaches are used and adapted, and how these adaptations function.

**Objectives:** To assess methods for estimating maternal mortality in LMICs and the rationale for these modifications.

**Search Strategy:** A literature search with the terms "maternal death", "surveys" and "low- and middle-income countries" was performed in Medline, Embase, Web of Science, Scopus, CINAHL, APA PsycINFO, ERIC, and IBSS from January 2013 to March 17, 2023.

**Selection Criteria:** Studies were eligible if their main focus was to compare, adapt, or assess methods to estimate maternal mortality in LMICs.

**Data Collection and Analysis:** Titles and abstracts were screened using Rayyan. Relevant articles were independently reviewed by two reviewers against inclusion criteria. Data were extracted on mortality measurement methods, their context, and results.

**Main Results:** Nineteen studies were included, focusing on data completeness, subnational estimates, and community involvement. Routinely generated MMR estimates are more complete when multiple data sources are triangulated, including data from public and private health facilities, the community, and local authorities (e.g. vital registration, police reports). For subnational estimates, existing (e.g. the sisterhood method and reproductive-age mortality surveys [RAMOS]) and adapted methods (e.g. RAMOS 4+2 and Pictorial Sisterhood Method) provided reliable confidence intervals. Community engagement in data collection increased community awareness of

maternal deaths, provided local ownership, and was expected to reduce implementation costs. However, most studies did not include a cost-effectiveness analysis.

**Conclusion:** Household surveys with community involvement and RAMOS can be used to increase data validity, improve local awareness of maternal mortality estimates, and reduce costs in LMICs.

**KEYWORDS**

community participation, data collection, developing countries, maternal death, maternal mortality, quality indicators

## 1 | INTRODUCTION

### 1.1 | Background

Maternal death is defined by the World Health Organization (WHO) as "the annual number of female deaths from any cause related to or aggravated by pregnancy or its management (excluding accidental or incidental causes) during pregnancy and childbirth or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy".[1] In 2017, approximately 295 000 women died during and following pregnancy and childbirth.[2] The majority of these deaths (95%) occurred in low- and lower-middle-income countries.[2]

Sustainable Development Goal 3.1. aims to achieve a global maternal mortality ratio (MMR) of fewer than 70 deaths per 100 000 live births by 2030. As of 2017, however, the global MMR was 211 deaths per 100 000, representing only a 38% reduction from the level in 2000. As many countries do not have reliable civil registration and vital statistics (CRVS) systems to report on maternal deaths, the United Nations uses modeled estimates to report country-level MMRs.[3] Countries also rely on special studies including the Demographic Health Surveys (DHS), which are typically conducted every 5 years to generate national MMRs. Although these country-level estimates are useful to monitor national trends and relative performance across countries, they do not produce data with sufficient frequency or granularity to inform internal monitoring or to guide subnational programming—posing a further challenge for achieving Goal 3.1. Commonly used approaches for estimating MMR were extracted from Graham et al.[4] and are shown in Table 1.

In many low- and middle-income countries (LMICs), both empirical and analytical approaches are used to estimate MMR. A 2017 systematic review by Mgawadere et al.[5] described methods to estimate the MMR in LMICs. Methods used were grouped into two categories: those that calculate MMRs using existing data from sources such as civil registration, health facilities, and the census; and those that rely on special studies including population or household surveys, reproductive age mortality studies, and the sisterhood method (both direct and indirect). The strengths and limitations of these methods were described and the authors concluded that reproductive age surveys were a good option in LMICs until CRVS systems were able to routinely produce reliable MMR estimates.[5] However, the review by Mgawadere et al.[5] did not cover studies assessing the completeness of these MMR estimates, adaptations to existing methods, or novel estimate approaches.

Recognizing the importance of more explicitly linking information with action, most countries have expanded on their existing maternal death reporting and prevention efforts to implement comprehensive maternal death surveillance and response systems as introduced by WHO in 2013 and later expanded to include perinatal deaths.[6] Maternal and perinatal death surveillance and response (MPDSR) is the overall framework adopted by most LMICs to end preventable deaths.[7] The framework explicitly links approaches to identify deaths (e.g. maternal death surveillance) with efforts to understand the context of a woman's death to analyze, summarize, and share the information, to take action that addresses the challenges or missed opportunities contributing to the maternal death, and to monitor and refine the response. Identification and reporting of all maternal deaths require a fully scaled and optimized MPDSR system.[8,9] As countries vary in the maturity of their CRVS and MPDSR systems and related enabling characteristics, approaches to improve the quality and utility of maternal mortality estimation continue to be developed and piloted.[7]

### 1.2 | Objectives

The present review was designed to assess methods to estimate MMRs in LMICs and to understand the rationale for the approach used and the gaps the study implementers hoped to address.

## 2 | MATERIALS AND METHODS

The reporting of this scoping review is in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, Extension for Scoping Reviews (PRISMAScR)-statement (see Data S1).[10]

### 2.1 | Eligibility criteria

Studies were considered if their primary focus was maternal mortality estimation or measurement. We included studies reviewing, adapting,

**TABLE 1** Measuring and estimating maternal mortality—approaches, uses, strengths, and limitations.[a]

| Approach | Description | Current use | Strengths | Limitations |
|---|---|---|---|---|
| CRVS/SVRS | Registration of births, deaths, and cause of deaths | Reference standard in settings with robust systems | • Continuously collected<br>• Precision<br>• Comparability<br>• Reliability | • Most countries do not have adequate systems to capture all events<br>• Sustained investment required |
| Census | Official count of an entire population and deaths within the previous 12 months | Recommended by the UN in settings where death registration is not accurate as a way to estimate mortality | • Reliability<br>• Sampling-related biases are avoided<br>• National and subnational measures | • Frequency (usually only completed every 10 years)<br>• Additional questions typically needed to classify pregnancy-related death as a maternal death<br>• Resource intensive for a discrete time period |
| Direct sisterhood method | Questions regarding birth history of mother and details on all siblings | DHS and MICS | • Reliability<br>• Ability to capture non-facility deaths<br>• Point-estimates<br>• Estimates maternal death (vs pregnancy death) | • Wide confidence intervals<br>• Frequency (3–5 years)<br>• Retrospective measure (0–6 years)<br>• Greater data requirements and cost (vs indirect sisterhood method)<br>• Resource intensive |
| Indirect sisterhood method | Four questions asked regarding deaths of sisters | Used in settings with high fertility rates | • Reliability<br>• Ability to capture non-facility deaths<br>• Small sample size requirements relative to other methods | • Retrospective estimate of maternal mortality (10–12 years)<br>• Estimates pregnancy-related deaths vs maternal deaths, i.e. cause of death may not be related to an obstetrics-related cause |
| RAMOS | Data collection involving multiple data sources | Implemented to help improve completeness of maternal death estimation | Incorporates both facility and community-level information, including interviews and/or verbal autopsies to establish cause of death | • Resource intensive<br>• Retrospective measure |
| MADE-IN/MADE-FOR | Community-informant based identification of pregnancy-related deaths involving two groups of informants with 'capture-recapture' analysis | Used in study setting in Indonesia and Pakistan | • May be used in relatively small populations<br>• May raise community awareness<br>• Lower cost than large surveys | • Relies on existing community networks<br>• Certain deaths may be underreported (e.g. abortion) |
| Health facility-based information systems | Data captured on births and deaths from hospital-based records | Routinely used by hospitals for internal monitoring | • Real-time<br>• Localized information | • Deaths occurring outside facilities are not routinely captured<br>• Generally, do not include private or military health facilities |

Abbreviations: CRVS, civil registration and vital statistics; DHS, Demographic and Health Surveys; MADE-IN/MADE-FOR, Maternal Death from Informants/Maternal Deaths Follow-on Review; MICS, Multiple Indicator Cluster Surveys; MMR, maternal mortality ratio; RAMOS, reproductive-age mortality surveys; SVRS, sample vital registration system.

[a]Adapted from Graham et al.[4]

or comparing maternal mortality estimation methods, or aimed at strengthening their quality. Studies describing trends or associated factors without focusing on the data collection method were excluded. Also, entries describing MPDSR implementation, modeled data, or death reviews were considered to be outside the scope of this review. We only considered studies published after January 1, 2013, as we aimed to expand on the maternal mortality surveillance technical guidance by the WHO.[6] Inclusion and exclusion criteria are listed in Table 2.

**TABLE 2** Inclusion and exclusion criteria.

| | |
|---|---|
| Inclusion criteria | Measurement or estimation methods are the papers focus: e.g. sisterhood method, vital registration, community-based surveillance |
| | Methods to estimate maternal mortality are compared, reviewed, adapted, modified, piloted, assessed, or used as surrogates |
| | Reliability, discrepancies, or challenges with measurement of maternal mortality are discussed |
| | Interventions or approaches to strengthen the quality (e.g. completeness, reliability) of maternal mortality data |
| Exclusion criteria | Published before January 1, 2013 |
| | Full text not available in English |
| | Entries examining factors associated with or contributing to, or increasing risk of maternal mortality |
| | Entries describing maternal mortality trends, but do not focus on the indicators or data collection method (e.g. DHS analyses) |
| | Entries focusing on interventions with maternal mortality used as an outcome (e.g. programs to improve health outcomes) |
| | Entries describing MPDSR system implementation |
| | Entries describing modeled estimates |
| | Entries focusing on antenatal care, newborn or infant mortality, pregnancy, abortion, cesarean section, intimate partner violence |
| | Conditions or complications associated with maternal mortality (e.g. abortion, cesarean section) |
| | Death reviews, verbal, or social autopsy as primary study focus |

Abbreviations: DHS, Demographic and Health Surveys; MPDSR, Maternal and perinatal death surveillance and response.

### 2.2 | Information sources

A systematic search was executed in the following databases up to March 16, 2023 (by JK and MT): OVID/Medline, Embase.com, Clarivate Analytics/Web of Science Core Collection, Elsevier/Scopus, Ebsco/APA PscycINFO, Ebsco/ERIC, Proquest/International Bibliography of Social Sciences (IBSS), and Ebsco/CINAHL.

### 2.3 | Search strategy

The search included controlled terms and free text terms for synonyms of "maternal death", "surveys", and "low- and middle-income countries" (see Data S2). The search was performed without restrictions for methodology, date, or language. Duplicate articles were excluded using Endnote X20.0.1 (Clarivate Analytics™), following the Amsterdam Efficient Deduplication method per Otten et al. and Bramer et al.[11,12]

### 2.4 | Study selection

Three co-authors (MT, SZ, and OI) independently screened all potentially relevant articles through review of titles and abstracts using Rayyan.[13] Studies were included if they described methods to estimate maternal mortality, including articles that compared, adapted, or piloted approaches; and reported on efforts to assess or to improve the quality, including the completeness of maternal mortality measurement efforts. Articles were excluded if maternal mortality measurement was not the primary focus, if they described a program or intervention, or simply reported on MMR as an outcome of interest, or were descriptive papers describing MMR trends over time or factors associated with maternal mortality. Moreover, articles describing processes related to MPDSR implementation and review articles were excluded. Table 2 includes a detailed list of the inclusion and exclusion criteria used.

All articles that were rated relevant or that could not be excluded based on abstract review were independently reviewed by two reviewers against the inclusion criteria. Differences in judgment during full-text review were resolved through discussion with co-authors.

### 2.5 | Data extraction

Data were extracted on variables of interest including mortality measurement methods used, context, and results. Review and synthesis of extracted information was completed by all authors.

## 3 | RESULTS

The initial search returned a total of 24 689 references (Figure 1). After removing duplicates, 11 896 references remained. By screening titles and abstracts, 86 references were selected for full-text review. Of these 86, 67 did not meet the inclusion criteria and were excluded. The most common reasons for exclusion were the article being a review article, describing MPDSR implementation or factors associated with or interventions to reduce maternal mortality.

The 19 papers included in the scoping review describe efforts to estimate maternal mortality in 16 LMICs, including 12 papers from

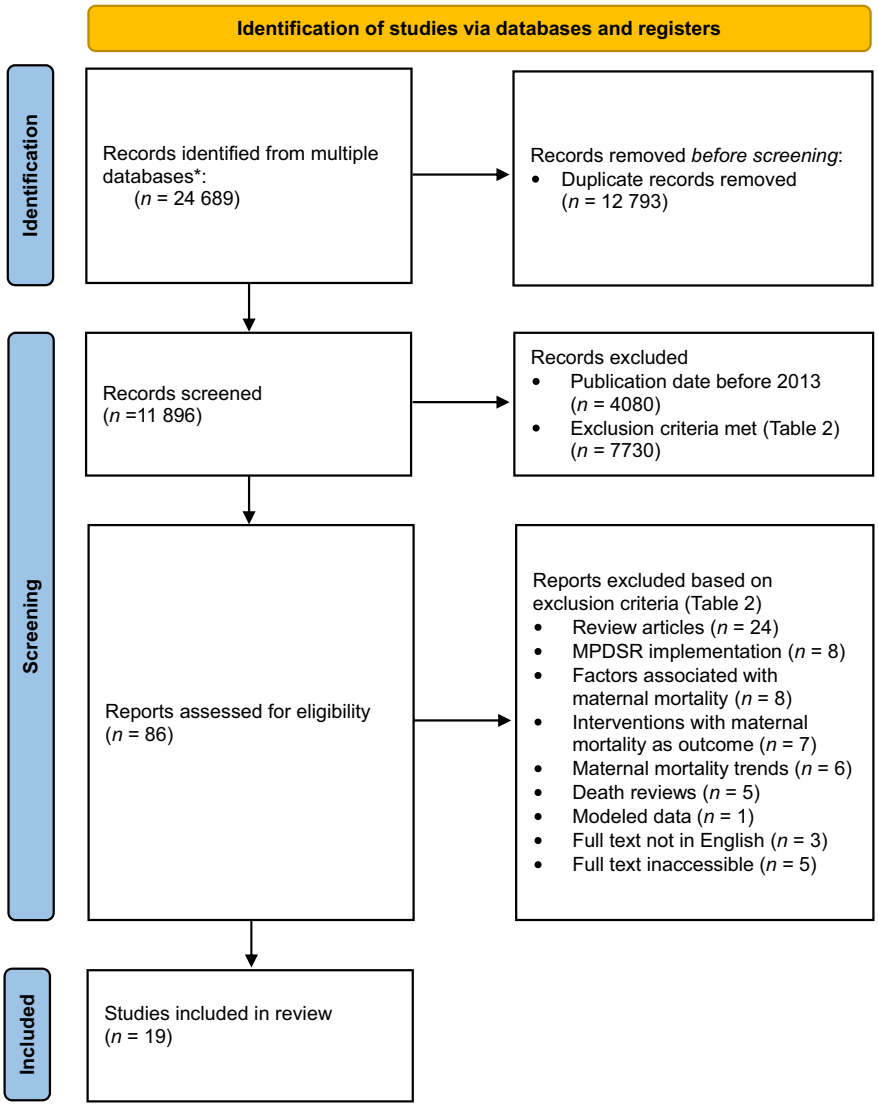


FIGURE 1 PRISMA flow diagram for search and selection process; *Medline, Embase, APA PsycINFO, CINAHL, IBSS, ERIC, Web of Science, and Scopus. MPDSR, maternal and perinatal death surveillance and response.

Africa, four from Asia, two from Central America, and one each from the Caribbean and Oceania (Table 3). Sixteen studies provided an MMR and compared their estimation method with (sub-)national routine estimation efforts (Table 4). Studies were categorized as efforts to assess and/or improve the completeness of MMR estimates, generating timely subnational MMR estimates or incorporating community engagement.

### 3.1 | Addressing completeness of maternal mortality estimates

Understanding the extent to which and the reasons behind whether routine reporting methods capture all maternal deaths, i.e. reporting evaluating the completeness of death reporting, was the focus of five publications included in Table 3.[14–18] This involves understanding the extent to which routine reporting methods capture all maternal deaths, and reasons for this.

In these studies, routine reporting channels were found to underestimate MMRs.[14–16] The reasons for underreporting of maternal deaths fell into two general categories: (1) challenges with finding a maternal death, e.g. administrative delays in reporting deaths, missing deaths that occurred outside a health faclity, poor coordination between reporting and recording entities;[15] or (2) difficulties with assigning a cause of death, e.g. misclassification or failure to correctly identify a maternal death given a lack of information on pregnancy status.[16]

Anwar et al.,[14] Abouchadi et al.,[15] and McCaw-Binns et al.[16] enhanced data collection by including different sources (e.g. data from private facilities, police reports, and local authorities) and demonstrated that routine reporting does not capture all deaths. McCaw-Binns et al.[16] and Abouchadi et al.[15] both worked with multiple data sources over fixed time periods to retrospectively identify and classify all maternal deaths. McCaw-Binns et al.[16] started with all reported deaths from vital registration records and incorporated data sources including police reports (e.g. transport accidents, suicides)

**TABLE 3** Summary table of included studies with study methodology and conclusion ($N = 19$).

| Author | Country | Study methodology | Conclusion |
|---|---|---|---|
| Addressing completeness of maternal mortality estimates ($n = 5$) | | | |
| Anwar et al. (2018)[14] | Pakistan | Prospective analysis through enhancement of a surveillance system capturing data from public health facilities, now expanded to include information from private facilities and the community. | Data collection from multiple sources and follow up of all pregnancies improves MMR accuracy and timeliness at (sub)district levels.<br>Its feasibility is unknown in areas with low community worker coverage.<br>Women living in very remote areas could not be completely covered. |
| Abouchadi et al. (2018)[15] | Morocco | Retrospective analysis using multiple data sources (e.g. health offices, local authorities) compared with nationwide maternal death surveillance system. | Communication and coordination regarding maternal death reporting were improved by using health offices and local authorities. |
| McCaw-Binns et al. (2015)[16] | Jamaica | Retrospective analysis using multiple death data sources (e.g. police reports, Ministry of Health records) compared to vital registration data alone. | In CVRS, underreporting of maternal deaths was common due to certification errors.<br>To ensure complete maternal death case ascertainment, multiple data sources should be included. |
| Lougue et al. (2013)[17] | Burkina Faso | Retrospective data quality assessment of census data: correct for missing data, address duplicates, adjustments of number of live births. | Authors concluded that the adjustment technique used to account for missing data and other inconsistencies was insufficient. |
| Mola et al. (2013)[18] | Papua New Guinea | Retrospective analysis using a facility-based survey, Health Information System data and a community-based survey.<br>MMR was compared with modeled MMRs from the United Nations. | Modeled MMR estimates may rely too much on gross domestic product per capita without using economic inequity or access to service measurement.<br>Recommendation to continue using local Health Information System data to inform local decision-making. |
| Estimating subnational maternal mortality ($n = 9$) | | | |
| Perry et al. (2023)[19] | Guatemala | Prospective study using vital registration, community-based reporting and follow-up verbal autopsy to estimate subnational MMR in the Department of Huehuetenango.<br>MMR was compared with data from CVRS. | Community-level information yields a higher MMR than facility-based reporting.<br>Education of the community improves maternal death reporting in quantity and quality.<br>Strong methodology with verbal autopsy within 2 weeks from reported death by experienced nurse. |
| Kea et al. (2023)[20] | Ethiopia | Cross-sectional study using a household survey and the WHO verbal autopsy tool to estimate subnational MMR in Sidama regional state.<br>MMR was compared with the national DHS estimate. | High MMR with significant district level variations.<br>Increased data validity by using data collectors from the study area and reviewing deaths independently by two public health officers. |
| Kea et al. (2022)[21] | Ethiopia | Cross-sectional study using the indirect sisterhood method to estimate subnational MMR in Sidama regional state.<br>MMR was compared with the national DHS estimate. | Compared with the direct sisterhood method, the indirect method lacks exact information and may overestimate MMR. |
| Onoja et al. (2020)[22] | Nigeria | Cross-sectional study using the indirect sisterhood method to estimate subnational MMR in six local areas of Ondo State.<br>MMR was compared with health facility-based estimates. | State MMR estimates are in accordance with UNICEF national MMR, but higher than state facility-based estimates. |
| Sharma et al. (2017)[23] | Nigeria | Cross-sectional study using the indirect sisterhood method to estimate subnational MMR in Jigawa State.<br>MMR was compared with the national DHS estimate. | Approach generated a high subnational MMR and localized information important for programming. |
| Godefay et al. (2015)[24] | Ethiopia | Cross-sectional study with a community-based household survey using the WHO verbal autopsy tool to estimate subnational MMR in Tigray Region.<br>MMR was compared with a regional modeled estimate. | This straightforward and feasible approach provided a subnational MMR and localized information important for programming. |
| Moseson et al. (2014)[25] | Liberia | Cross-sectional study using a modified direct sisterhood method to estimate subnational MMR in Bomi County. An additional question on the county of the maternal death was included.<br>MMR was compared with the national DHS estimate. | Was able to use a modified sisterhood method to estimate a subnational MMR for the County.<br>Limited by wide CI, which could be addressed by including neighboring counties or increase number of included households. |
| Leone (2013)[26] | Lesotho and Nicaragua | Used census data from two countries and estimated differential MMRs based on residence and education | While feasible, the authors concluded that estimate differential MMRs using census data was not recommended |
| Aminati et al. (2013)[27] | Nigeria | Cross-sectional study using the indirect sisterhood method to estimate MMR in Suleja of Niger state. | Interest in capturing community-level data given low facility birth rate. |

(Continues)

TABLE 3 (Continued)

| Author | Country | Study methodology | Conclusion |
|---|---|---|---|
| Engaging the community with maternal mortality estimates (n = 5) | | | |
| Qomariyah et al.[28] | Indonesia | MADE-IN/MADE-FOR approach using two groups of community informants (heads of neighborhood units, health volunteers) to identify maternal deaths in Banten Province. Maternal deaths were confirmed by verbal autopsy.<br>Deaths were compared with routine community-based reporting (district health offices). | Involvement of existing community networks improves data completeness and provide the possibility for subnational MMR estimates.<br>Intermittent implementation of MADE-IN/MADE-FOR may be used to evaluate completeness of routine maternal death reporting systems.<br>No MMRs were provided. |
| Roggeveen et al. (2016)[29] | Tanzania | Modified indirect sisterhood method which includes visuals (Pictorial Sisterhood Method) was served by illiterate traditional birth attendants to measure MMR in a rural population.<br>MMR was compared with the national DHS estimate and estimates of studies using the sisterhood method. | Involvement of illiterate community stakeholders increases local awareness of maternal death and local ownership.<br>Research facilitated collaboration between traditional and skilled birth attendants.<br>Small sample with large CI. Needs further evaluation. |
| Adomako et al. (2016)[30] | Ghana | Modified reproductive-age mortality survey (RAMOS 4 + 2) used by community health workers to estimate MMR in Bosomtwe district and to help with real-time MMR monitoring.<br>MMR was compared with facility-based MMR estimates. | RAMOS 4 + 2 instrument is an effective and efficient option to improve maternal surveillance for countries lacking complete vital registration data.<br>8% of positive RAMOS were found to be incorrect. |
| Mir et al. (2015)[31] | Pakistan | MADE-IN/MADE-FOR approach using community informants (village-based primary healthcare providers, village imams, councilors, nikah registrars) to identify maternal deaths in the Chakwal district. Maternal deaths were confirmed by verbal autopsy.<br>MMR was compared with rural DHS estimates. | Existing community-based networks could be used to capture maternal deaths.<br>Two separate groups of informants can provide a subnational MMR through capture-recapture method.<br>Lower cost approach and assists with local ownership and advocacy efforts. |
| Alam et al. (2014)[32] | Bangladesh | Survey with adult women in Dhaka to assess their knowledge on maternal deaths. MMR was compared with estimates from the health and demographic surveillance system. | Method can be used to supplement existing efforts and examine relative differences or changes in MMR between areas.<br>Challenge with overreporting; recent deaths being more accurately reported, deaths in different time frame, including pregnancy-related deaths. |

Abbreviations: CI, confidence intervals; CRVS, civil registration and vital statistics; DHS, Demographic Health Survey; MADE-IN/MADE-FOR, Maternal Death from Informants/Maternal Deaths Follow-on Review; MMR, maternal mortality ratio; RAMOS, reproductive-age mortality surveys.

and Ministry of Health records (maternal mortality surveillance) to refine the MMR estimate. Abouchadi et al.[15] identified deaths of women of reproductive age using civil and health registration offices, local authorities, and data from public and private hospitals. Qualitative information was obtained through household interviews to identify maternal deaths among deceased women of reproductive age. Both studies show that data from surveillance systems were incomplete and could be improved by implementing registries from local authorities instead of the larger health offices, and by questioning communities.

Anwar et al.[14] implemented a more expansive approach and focused on prospectively identifying and following the outcomes of all pregnant women using multiple information streams in both the community, and public and private sectors. Although MMR accuracy and timeliness were improved, the method relies heavily on community workers and its feasibility is unknown in areas with low community worker coverage.

Mola and Kirby[18] compared international modeled MMR estimates to data from a health facility-based information system and a community-based survey in Papua New Guinea. They estimated a national MMR based on the population distribution with women living in urban areas, rural areas with access to care, and rural areas inaccessible to care. They found international modeled MMRs to be much lower, probably because these models included wealth as an explanatory factor for maternal mortality, but did not account for the inequity in wealth distribution and access to health care. Despite only registering facility-based deaths, the authors recommend using local Health Information System data instead of modeled data.

Lougue et al.[17] found the MMR generated by the 2006 population census in Burkina Faso to be acceptable, as cleaning data from duplicated cases, adjustments of the number of live births, and estimation technique provided a similar MMR.[17]

## 3.2 | Estimating subnational maternal mortality

Nine papers described successful efforts to calculate more granular mortality estimates using empirical methods, such as verbal autopsy, indirect sisterhood, and a modified direct sisterhood method (Table 3).[19–27]

Citing wide variation in MMR levels, the need for localized information, and challenges with CRVS data, three papers from Nigeria used the indirect sisterhood method to calculate MMRs at administrative level 1 (i.e. state) or administrative level 2 (i.e. local government areas).[22,23,27] In Onoja et al.[22] and Sharma et al.,[23] the calculated MMRs were substantially higher than the most recent national DHS estimate, which further justified the rationale for

**TABLE 4** Maternal mortality ratio per method—comparison between routine and enhanced estimates ($N = 16$).

| | | MMR enhanced approach estimates | | | MMR routine approach estimates | | |
|---|---|---|---|---|---|---|---|
| **Author** | **Country** | **Description** | **Deaths per 100 000 live births** | **95% CI** | **Description** | **Deaths per 100 000 live births** | **95% CI** |
| Census (including enhanced approaches) | | | | | | | |
| Lougue et al. (2013)[17] | Burkina Faso | Enhanced census | 331 | 293–402 | Census | 307 | – |
| RAMOS (including enhanced and modified approaches) | | | | | | | |
| Anwar et al. (2018)[14] | Pakistan | RAMOS | 247 | 147–391 | Facility-based | 180 | 101–297 |
| Abouchadi et al. (2018)[15] | Morocco | RAMOS | 103 | – | MDSS | 43 | – |
| McCaw-Binns et al. (2015)[16] | Jamaica | RAMOS | 118 | 85–150 | CRVS | 28 | 12–48 |
| Mola et al. (2013)[18a] | Papua New Guinea | Facility-based and community survey | 545 | – | Modeling | 230 | 100–510 |
| Adomako et al. (2016)[30] | Ghana | Modified RAMOS | 357 | – | Facility-based | 128 | – |
| Community surveys with verbal autopsy (including MADE-IN/MADE-FOR) | | | | | | | |
| Kea et al. (2023)[20a] | Ethiopia | Household survey | 419 | 260–577 | DHS | 412 | 273–551 |
| Godefay et al. (2015)[24a] | Ethiopia | Household survey | 266 | 198–350 | Modeling | 420 | 240–720 |
| Mir et al. (2015)[31a] | Pakistan | MADE-IN/MADE-FOR | 309 | 266–358 | DHS, rural | 319 | – |
| Alam et al. (2014)[32] | Bangladesh | Household survey | 220 | 140–300 | HDSS | 183 | – |
| Direct sisterhood method (including modified approaches) | | | | | | | |
| Moseson et al. (2014)[25a] | Liberia | Modified direct sisterhood | 890 | 497–994 | DHS | 994 | – |
| Indirect sisterhood method (including modified approaches) | | | | | | | |
| Kea et al. (2022)[21a] | Ethiopia | Indirect sisterhood | 623 | 573–658 | DHS | 412 | 273–551 |
| Onoja et al. (2020)[22] | Nigeria | Indirect sisterhood | 950 | 584–1386 | Facility-based | 208 | – |
| Sharma et al. (2017)[23a] | Nigeria | Indirect sisterhood | 1012 | 898–1126 | DHS | 576 | 500–652 |
| Aminati et al. (2013)[27] | Nigeria | Indirect sisterhood | 400 | – | DHS | 545 | 475–615 |
| Roggeveen et al. (2016)[29a] | Tanzania | Modified indirect sisterhood | 689 | 419–959 | DHS | 556 | 446–666 |

Abbreviations: CI, confidence interval; CRVS, civil registration vital statistics; DHS, Demographic Health Surveys; HDSS, health and demographic surveillance system; MADE-IN/MADE-FOR, Maternal Death from Informants/Maternal Deaths Follow-on Review; MDSS, maternal death surveillance system; MMR, maternal mortality ratio; RAMOS, reproductive-age mortality surveys;

[a]As no subnational estimates are available, comparison was made with national maternal mortality estimates.

subnational calculations (Table 4).[22,23] In Aminati et al.[27] the estimated MMR was lower than the national DHS estimate, which was explained by the authors as the result of regional differences, with the north of Nigeria having higher MMRs.

In Western Guatemala, Perry et al.[19] collected data prospectively using volunteers and community members, such as traditional birth attendants and village health committee members. The subnational MMR was found to be three times the national MMR reported by DHS and twice the regional MMR reported by local authorities. Data quality was increased by having experienced local nurses conducting verbal autopsies of the identified deaths in 2 weeks from their report.

Three papers published from Ethiopia explored empirical approaches for subnational MMR estimation given the need for subnational information to facilitate local health programming and the interest in more frequent estimations.[20,21,24] Kea et al.[20,21] used two different methods for calculating regional MMRs: a household survey supplemented by verbal autopsy and the indirect sisterhood method. Both methods provided MMR estimates that were higher than DHS estimates. However, in the same region the indirect sisterhood method identified more deaths than were confirmed by the WHO verbal autopsy tool, which was attributed to the lack of exact information obtained by the indirect sisterhood method.[21] Godefay et al.[24] also used a community-based cross-sectional household survey for a straightforward and feasible approach to estimate subnational MMRs, plus acquiring local information important for policy-making.

Moseson et al.[25] implemented a modified direct sisterhood method in Liberia, adding one additional question regarding the location of the maternal death. The addition of this one question allowed for the calculation of subnational MMR estimates, although confidence intervals were wide.

### 3.3 | Engaging the community with maternal mortality estimates

Five studies described efforts to engage community members in maternal death estimation (Table 3).[28–32] Several existing methods were applied for community use, including the sisterhood method by Roggeveen et al.,[29] the reproductive-age mortality survey by Adomako et al.,[30] and the MADE-IN/MADE-FOR approach by Mir et al.[31] and Qomariyah et al.[28]

Making data collection tools more user friendly and acceptable by communities was described by Roggeveen et al.[29] and Adomako et al.[30] Roggeveen et al.[29] developed "the Pictorial Sisterhood Method", a modification of the indirect sisterhood method, to estimate maternal mortality in a closed-off Maasai community in Tanzania. The indirect sisterhood method involves four questions about the sisters of a woman in question, regarding the death of women of reproductive age during pregnancy, during childbirth, or in the 6 weeks after pregnancy (Table 1). The adapted method includes a form depicting sisters and their children, so that illiterate community stakeholders could be involved. This increased the local awareness of maternal death and gave community members ownership of information. Similarly, Adomako et al.[30] conducted a reproductive-age mortality survey using a simplified questionnaire involving six questions regarding whether a woman was pregnant when she died, the location, and presumed cause of death (RAMOS 4 + 2). The questions were used by community-based volunteers to identify pregnancy-related deaths in the Bosomtwe district in Ghana. The instrument was considered an effective option for maternal death surveillance in countries lacking complete vital registration. Both studies were conducted with a relatively small sample size and require further evaluation in larger populations.

Both Qomariyah et al.[28] and Mir et al.[31] used the Maternal Deaths from Informants/Maternal Death Follow on Review (MADE-IN/MADE-FOR) method in Indonesia and Pakistan, respectively. The MADE-IN/MADE-FOR method consists of two phases for data collection, with phase one involving identification of pregnancy-related deaths by community informants (MADE-IN) and phase two confirming these deaths through verbal autopsy and collecting additional information. Both studies used two separate groups of community-based informants covering the same geographical area, to identify what fraction of maternal deaths identified by the second group was also identified by the first. By doing so, the number of maternal deaths missed by both groups could be estimated using the "capture-recapture method".[28] In the Banten Province of Indonesia it was estimated that routine maternal death surveillance identified105 out of 184 (57%) maternal deaths, whereas MADE-IN/MADE-FOR captured 169/184 (92%).[28] In the rural Chackwal district in Pakistan, the MMR generated from the MADE-IN/MADE-FOR method was 309 maternal deaths per 100 000 live births, which was comparable to MMR in rural areas of 319 from the last Pakistan DHS.[31]

Alam and Townend[32] implemented a community-based survey directly involving adult women, asking them about nearby vital events in recent years among their neighbors in a rural area of Bangladesh. The reported maternal deaths were compared with the health and demographic surveillance system in the same area. Although the method was not able to provide absolute values of MMR because this requires the assumption that overreporting and underreporting are similar for live births and deaths, it provided an inexpensive option to monitor MMR relative differences between and change within an area. There were several maternal deaths reported by the adult women that could not be identified in the health and demographic surveillance system. These deaths could be unnoticed maternal deaths by routine surveillance or the result of a different definition of maternal death between the two methods (e.g. pregnancy-related death versus maternal death).

Table 5 provides an updated version of the previously discussed maternal mortality estimate approaches. Some existing methods may be used in a different way (indirect sisterhood method, modeling) or were adapted (census, direct sisterhood method, RAMOS). Also, new methods have been added (RAMOS 4 + 2, community surveys with verbal autopsy, Pictorial Sisterhood Method).

**TABLE 5** Measuring and estimating maternal mortality—updated, enhanced or alternative approaches.

| Approach | Used in | Description | Strengths | Limitations |
|---|---|---|---|---|
| CVRS/SVRS | Perry et al.[19] | Prospective registration of births, deaths, and cause of deaths in a predefined area.<br>Addition of intermittent community-surveillance in areas with high home birth rates.[a] | • Reference standard<br>• Prospectively collected<br>• Including deaths in and outside of facilities | • Most countries do not have adequate systems to capture all events<br>• Sustained investment required<br>• Community network required[a] |
| Enhanced census | Lougue et al.[17]; Leone[26] | Official count of an entire population and deaths within the previous 12 months.<br>Increase reliability by removing duplicates and adjustment of number of live births.[a] | • Reliable<br>• Sampling-related biases are avoided | • Frequency (only completed every 10 years)<br>• Additional questions typically needed to classify as pregnancy-related death<br>• Resource intensive<br>• Not preferred for subnational estimates[a] |
| Enhanced RAMOS | Anwar et al.[14]; Abouchadi et al.[15]; McCaw-Binns et al.[16] | Reproductive age mortality survey using multiple data sources: CVRS/SVRS, public and private facilities, police reports and local authorities.[a]<br>Verbal autopsies can be used to confirm maternal death.[a] | • Completeness<br>• Reliable<br>• Can assess completeness of routine measurements[a] | • Resource intensive<br>• Retrospective measure |
| RAMOS (4 + 2)[a] | Adomako et al.[30] | Modified easy-to-use reproductive age mortality survey involving six questions identifying pregnancy-related deaths. | • Simple<br>• Able to use by community volunteers | • Only tested in a small sample<br>• Pregnancy-related, not maternal deaths<br>• Needs to be followed by verbal autopsy |
| MADE-IN/ MADE-FOR | Qomariyah et al.[28]; Mir et al.[31] | Community-based informants identifying maternal deaths. If two separate groups covering one area are used, the capture-recapture method can estimate unidentified deaths. | • Can be used in relatively small populations<br>• Can raise community awareness<br>• Can capture non-facility deaths<br>• Can estimate unidentified maternal deaths[a]<br>• Can assess completeness of routine measurements[a] | • Relies on existing community networks |
| Community surveys with verbal autopsy[a] | Kea et al.[20]; Godefay et al.[24]; Alam et al.[32] | Community/household surveys identifying pregnancy-related deaths, followed by verbal autopsy. Ideally, identification of pregnancy-related deaths is performed by community members/existing community networks. | • Can capture non-facility deaths<br>• Can estimate subnational ratios<br>• Increasing local awareness of maternal deaths<br>• Community ownership of data<br>• Low costs compared with non-community member involvement | • Retrospective estimate<br>• Requires large sample for reliability<br>• Established community network needed |
| Modified direct sisterhood method | Moseson et al.[25] | Questions regarding birth history of mother and details on siblings.<br>Adding a question on location of sisters death.[a] | • Reliable<br>• Can capture non-facility deaths<br>• Can measure subnational estimates[a]<br>• Maternal, instead of pregnancy death | • Wide confidence intervals<br>• Retrospective measure (0–6 years)<br>• Greater data requirements and cost (vs indirect sisterhood method) |
| Indirect sisterhood method | Kea et al.[21]; Onoja et al.[22]; Sharma et al.[23]; Aminata et al.[27] | Four questions asked regarding deaths of sisters. | • Can be used in relatively small populations<br>• Can capture non-facility deaths<br>• Can estimate subnational ratios | • Retrospective estimate<br>• Pregnancy-related death, not maternal death |
| Pictorial sisterhood method[a] | Roggeveen et al.[29] | Modified indirect sisterhood method including visuals. | • See indirect sisterhood method<br>• Involvement of illiterate community members | • Only tested in a small sample |

Abbreviations: CRVS, civil registration vital statistics; MADE-IN/MADE-FOR, Maternal Death from Informants/Maternal Deaths Follow-on Review; RAMOS, reproductive-age mortality surveys; SVRS, sample vital registration system.

[a]New methods/statements compared with Table 1.

### 3.4 | Costs

Only 3 out of 19 studies mentioned reducing MMR estimation costs as a motivation for their proposed MMR estimation method. Godefay et al.[33] estimated that their survey in the Ethiopian Tigray region, including training of staff and field work, cost approximately $60 000. They covered 900 000 people and found 54 pregnancy-related deaths, providing a meaningful MMR and contributing factors for a population of five million people.[24] The authors argue that $0.012 per capita is a small price to provide such valuable information for running an effective healthcare system. Mir et al.[31] recorded 2001 deaths in women of reproductive age and calculated $0.12 per womn of reproductive age for their community-involved MADE-IN/MADE-FOR method. According to the authors, this would be lower than conducting a survey. Alam and Townend[32] aimed to use community knowledge on maternal deaths, without setting up a system of meetings, to reduce survey costs. Although they provide a method that is useful for detecting MMR differences, no costs were mentioned.

## 4 | DISCUSSION

In this scoping review, we presented different estimation practices to arrive at the MMR, their completeness, adaptations, and rationale behind such practices. Methods were implemented and adaptations were made for various reasons, such as increasing data accuracy and improving community awareness. No one method can be stated as best in every situation. The wide variety of methods and their success in specific settings highlight the need for local level and locally managed information. Our review indicated three areas of focus of the included studies: reporting on completeness of estimates, the need for calculating (sub)national MMR estimates, and integration of community engagement.

We reported active surveillance efforts combined with triangulating information from multiple data sources, including the community, public health facilities, and private health facilities, assisted with improvement in the completeness in maternal death reporting. Analyzing multiple data streams and introducing active data collection (which proactively seek to identify cases in contrast to passive efforts, which rely on routine reporting systems to identify cases) may be an option to improve the completeness of MMR estimates and to make use of existing data systems when faced with the alternative of waiting multiple years for a DHS survey or modeled estimate.[18]

The importance of local level data to help inform and guide Safe Motherhood efforts was frequently stated as the rationale for calculating subnational MMR estimates. The need to supplement national MMR estimates with subnational estimation was especially relevant for countries with regional heterogeneity in maternal mortality.[20–25,27] For these countries, including Nigeria and Ethiopia, an understanding of regional maternal mortality variation in combination with an understanding of local conditions, including infrastructure and healthcare availability, may help inform and guide resource allocation and relevant programming. The importance of subnational efforts, alongside national and global efforts, to realize change in maternal mortality outcomes is reflected in WHO's 2015 report, *Ending Preventable Maternal Mortality* (EPMM), indicating that subnational information is critical for programming and resource allocation, as well as accountability.[34] The EPMM Report includes 10 milestones to monitor progress, including 'Milestone 4: Date for Action', which highlights the need for national and subnational data. Ideally, the DHS would be powered to provide these estimates, but the cost to generate subnational estimates with sufficient precision is currently prohibitive.[35]

In addition to acknowledging the need for more granular information, included studies also highlighted the importance of community engagement—not only to improve the completeness of maternal death estimates through community surveillance, but also to facilitate ownership of the reporting and estimation process.[28–32] Both the Pictorial Sisterhood Method used in Tanzania and the MADE-IN/MADE-FOR used in Indonesia and Pakistan employed approaches adapted for community-level use and generated information that may inform community advocacy efforts for maternal health and support blame-free mortality reporting efforts.[28,29,31] A separate scoping review has delved further into the topic of community surveillance for maternal death reporting in LMICs and described the added value of this approach to capture maternal deaths and to complement nascent civil registration systems, while noting the unrealized potential of fully engaging community health workers with the death reporting, review and response process.[36] While engaging community members for informal and formal reporting and surveillance roles may enhance the completeness of maternal mortality estimates and community ownership, it is also important to consider the sustainability of such efforts and, ultimately, the formal integration of these individuals and their efforts into the mainstream health system.[37]

Different estimation methods have their own benefits and area of application, but the biggest limitation to their use is their costs. As maternal deaths are rare, a large sample of the population is needed to provide MMR estimates with meaningful confidence intervals. Detecting differences in MMR after an intervention is even more cumbersome. The current review is limited in its analysis into the costs of the proposed new methods, because most authors did not include an economic analysis. It is, however, very important to consider costs of the proposed methods, especially in low-resource settings, as $60 000 spent on a survey could have been invested in the healthcare system that it is trying to supplement. Methods that could reduce costs are use of existing data sets (e.g. census, local authorities), predictive models using more prevalent variables, or the use of existing community networks. Future studies should explore the relative cost implications of these approaches, i.e. triangulating multiple, existing data sources versus implementing a national Demographic and Health Survey, relative to the precision of the MMR estimates. This will assist policy-makers to prioritize resources to strengthen mortality reporting and estimations.

A limitation of the current review may be its focus on new or adapted estimation methods in LMICs, as it excludes attempts to improve maternal death reporting in high-income countries. Despite their CRVS, maternal deaths in high-income countries are also underreported. As an example, in five Italian regions between 2000 and 2007 only 37% of deaths were included in the official MMR of 4.4 per 100 000 live births, providing an actual MMR of 11.8.[38] Although there are many lessons to be learned from these studies, absolute MMRs are low compared with LMICs. We aimed to identify methods that could be distributed widely in LMICs and, by doing so, provide reliable estimations to reduce the largest burden of maternal deaths.[2]

Given that ending preventable maternal deaths is the ultimate goal, MMR estimates help stakeholders to understand where progress has been made and where additional emphasis is needed. National-level estimates and internationally generated modeled metrics inform global monitoring, but are less informative for locally led efforts to understand and address maternal mortality. Ensuring that MMR estimates derived from routine systems are as complete as possible, engaging the community to facilitate data completeness as well as local ownership, and generating information at a frequency and geographic level relevant for programming, all present pragmatic options to help strengthen estimation approaches. Additionally, to address challenges with the precision of maternal mortality estimates, regular surveillance of the primary causes of maternal mortality (e.g. postpartum hemorrhage, eclampsia, and sepsis) and morbidities may help to address needs in subnational or resource-limited settings and assist with efforts to end preventable maternal deaths.[34] Progress towards Goal 3.1 can only be measured accurately when MMR estimates are precise and reliable.

## AUTHOR CONTRIBUTIONS

Maya Tholandi is the first author and contributed to conceptualization of the review, analysis and interpretation of the included studies, and writing. Johannes Ket gave significant insight in setting up the search strategy and conducted the literature search. Siem Zethof and Onaedo Ilozumba were involved in data analysis and writing a first draft. Young-Mi Kim, Abera Kenay Tura, Merlin Willcox, and Thomas van den Akker helped to revise the initial draft, provided critical insight for data interpretation, and supervised the entire work. All authors reviewed and edited the final version of the manuscript, approved the final version to be published, and agree to be accountable for all aspects of the review.

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## CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest.

## DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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