OXFORD UNIVERSITY PRESS | Health Policy and Planning

A review of methodology and tools for measuring maternal mortality in humanitarian settings

Journal:	*Health Policy and Planning*
Manuscript ID	HEAPOL-2018-Jan-0025.R2
Manuscript Type:	Review
Country of Expertise:	Afghanistan, Asia, Central America, Middle East
Keywords:	conflict, aid, capacity building, developing countries, health systems research, maternal health, maternal mortality, mortality, non-governmental organizations, obstetrics

ABSTRACT

Estimation of maternal mortality ratio (MMR) in humanitarian settings (*'settings of conflict, displacement, and natural disaster')* is challenging, particularly where communities have dissolved and geographical areas are inaccessible. During humanitarian events, the reproduction of maternal mortality figures by the media is common, and are often based on inaccurate reports. In light of such uncertainties and challenges, the aim of this paper was to review and appraise the methodology and data collection tools used to measure MMR in humanitarian settings. A critical review of both grey and peer-review publications was conducted, focussing on articles published from January 1995 until December 2016. In the final review, articles that provided an estimate of MMR from a humanitarian setting were included. The assessment of study quality was based on an adapted framework for the quality of mortality studies in humanitarian settings. Overall 13 peer-review publications and one grey publication were included in the final review. These were grouped according to settings: camp, clinic, household and census. Studies varied in their definition of MMR, and few studies objectively defined the humanitarian setting. Household-based studies were based on retrospective designs and on the recall of surviving family members. Although many studies attempted to purposively sample the populations afflicted, there was substantial evidence of selection bias; few studies were able to confirm the maternal deaths through medical certificates, or attempted to visit homes to re-inquire about deaths using verbal autopsy. The variation in methods and tools applied suggest that maternal mortality estimates are more likely to be markedly different from the true unknown level. The implications are that a standardized methodology and tools are necessary: that are consistent in definition, use a representative sample where possible, attempt to triangulate and validate data sources, and reconfirm deaths through household visits with informant interviews.

Abstract word count: 295 words

Background

Maternal mortality estimates from humanitarian settings are frequently disseminated through the media to highlight the impact of the humanitarian disaster on women's health. Where there is a need to ensure that valid, reliable and timely estimates are made available to the relevant stakeholders, inaccurate reporting is considered problematic to the scientific community, policy and decision makers, donor and relief agencies. According to recent claims, '60% of preventable maternal deaths' occur in humanitarian settings (Nordenstedt and Rosling 2016; World Health Organisation 2015). This estimate cites data on maternal mortality in countries with the highest OECD fragility score – however, and does not correspond to maternal deaths in *'settings of conflict, displacement, and natural disaster,'* the commonly used description of humanitarian settings. The true estimate of maternal mortality in humanitarian settings is unknown.

The challenge of undertaking research within humanitarian settings is attributed to the inaccessibility of geographical areas, security, mass migration, displacement, breakdown in infrastructure and communication; and commonly, a lack of expertise and capacity. Methods for measuring mortality in humanitarian settings depend on active approaches; where cases are found through surveys, census or surveillance within the population. (Graham et al 2008) These include, but are not limited to, the single round approach, the multi-round approach, survivorship methods and enumeration of household members. These approaches have various limitations, however. For instance, the multi-round approach is time-consuming, and particularly challenging in humanitarian settings; where household dissolution is more likely, the security risk is high, and the population is very mobile. (Cairns et al 2017) Survivorship methods, which depend on interviewing surviving family members, are difficult to achieve as families may have lost touch.

Maternal mortality is also considerably difficult to measure. Even in countries where civil registration systems have been established, maternal deaths may be under-reported due to misclassification. (Graham et al 2008; Mathers et al 2005) In 1995, the UN agencies (UNFPA, UNICEF, and WHO) developed model estimates of maternal mortality; by providing estimates for developing countries where adequate empirical information had not yet been identified. (Stanton et al 1995) However these estimates had limitations, precluded by the lack of available data in countries. In response, a revised model was later developed by the UN agencies, improving on their earlier model for estimating maternal mortality in developing countries, by using the proportion of deaths of women of reproductive age due to maternal causes (PMDF) .

Towards a unified definition of maternal death

Another hurdle in producing reliable estimates is the lack of consensus on, and implementation of, the definition of maternal mortality. According to the latest ICD- 11 definition, maternal mortality is defined as *'the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, from any cause related to or aggravated by the pregnancy or its management but not from accidental or incidental causes.'* (WHO 2018) However, in low resource settings, the cause of death is commonly unreported, meaning that accidental or incidental causes may not be excluded. Furthermore, events early in pregnancy, such as unsafe induced abortion, are prone to underreporting by family members; and may not be recorded in health records. In reality, the definition is hard to actualise through available data sources, leading to misclassifications and underreporting. The commonly applied definitions on maternal deaths are presented in Figure 1.

[Insert Figure 1 around here]

To date there have been no previous reviews on methods used to measure maternal mortality in humanitarian settings. In light of inaccurate reporting of maternal mortality estimates, the aim of this paper was to review the methodology and data collection tools used to measure maternal mortality in humanitarian settings; to compare and contrast approaches, highlighting the common strengths and weaknesses of each approach, and to offer suggestions and recommendations for better measure of maternal mortality in different humanitarian settings.

Methods

Inclusion criteria

Routine data clinic-based studies, population-based cohort and cross-sectional studies, and mixed quantitative and qualitative studies were included in the review. To coincide with the advances made to the measure of maternal mortality in developing countries, articles published from January 1995 up until December 2016 were assessed for inclusion. Studies that (i) reported an estimate of maternal mortality, and provided evidence to support claims that (ii) the estimate was taken from a humanitarian setting, were eligible for inclusion.

Search strategy

The following electronic databases were searched with no language restrictions: Amed, EMBASE, CINAHL, Geobase, IBSS, Medline (Ovid), Pubmed, and Scopus.

Definition of the humanitarian setting: According to a recent United Nations working group, objectives of humanitarian action are *'to save lives, alleviate suffering and maintain human dignity during and in the aftermath of man-made crises and natural disasters, as well as to prevent sand strengthen preparedness for the occurrence of such situations.'* (Global Humanitarian Assistance 2016) The scope of natural disasters may include those arising from *geophysical, meteorological, hydrological, biological, climatological and extra-terrerestial* sources. Although man-made crises commonly include crises brought on by war and conflict, the Centre for Research on the Epidemiology of Disasters (CRED) also include disasters that are *technological.*

To correctly identify articles related to estimating maternal mortality within the humanitarian context, search terms included *camps, catastrophe, conflict, displacement, earthquake, epidemic, eruption, Ebola, famine, fire, humanitarian, natural disaster, outbreak, rebel attack, refugees, starvation, tsunami, war and wildfire.* Abstracts were screened and articles reporting maternal mortality estimates were selected for further review. Several grey literature publications were identified through online search engines; providing further information on the key agencies, such as NGOs and research groups, working in humanitarian settings. Based on these findings, several key experts were identified and contacted for further information to support the review.

Quality assessment of included studies

To our knowledge there are currently no tools for critically appraising maternal mortality studies in humanitarian settings. Where possible, the review assessed each article on the criterion considered of importance to meet the study aims and against the criteria of quality outlined in a recent systematic review of mortality in Iraq, which drew on findings from a methods workshop. (Tapp et al 2008) In addition to assessing the articles on the quality criteria set out in this review, each article was assessed for criteria related to the maternal mortality literature, to include: (i) a definition of maternal mortality (ii) recall period or time period, in which the mortality figures were being reported for; and the (iii) data collection tools and analytical methods used to estimate the maternal mortality. Each article was also assessed on bias, coverage, completeness and accuracy. A summary of the recommended quality indicators, and their rationale, is shown in Table 1.

[Insert Table 1 around here]

The studies were undertaken in a variety of settings, used different data sources, and applied various methods to estimate maternal mortality. Therefore to establish grounds for comparability, the publications were summarised according to data type (primary and secondary) as well as different settings: camp, clinics, and household.

Results

Overall, 14 articles met the inclusion criteria and were reviewed. Of these 14 articles, 13 were peer-review publications (Bartlett et al 2002; Bouchghoul et al 2015; Brentlinger et al 2005; Cutts et al 1999; Djafri et al 2015; Hudic et al 2011; O'Hare and Southall 2007; Hynes et al 2002; Hynes et al 2012; Jones et al 2016; Schaider et al 1999; Simetka et al 2007; Zolala 2011) and one was a grey literature publication. (Freyermuth 2002)

Only three papers included objective definitions to determine their setting as *humanitarian*; for example, whether it was currently (or recently) in a state of conflict, war, complex emergency. For example, one paper defined a *conflict* country by the presence of 'at least 1000 conflict-related deaths per annum.' (O'Hare and Southall 2007) By contrast, another paper defined the state of a *complex emergency* as the 'presence of one or more deaths out of 10,000 persons per day.' (Hynes et al 2002) Most studies described the humanitarian setting, although this was based on the researchers own subjective observations. Only one study used a more systematic approach, and consulted several experts and sources in order to define their humanitarian setting. (Brentlinger et al 2005)

The definitions used to measure maternal mortality are outlined in Table 2. Second to 'not including a definition', the most commonly used definition was the earlier ICD-10 definition of maternal mortality. (WHO 2008)

[Insert Table 2 around here]

Primary data studies

All primary data studies are summarised in Table 3.

Camp

There were three studies undertaken within a camp setting. Hynes et al. (2012) used UNHCR health information system (2008-2010) of up to 25,000 individuals. To establish maternal death and cause, they used maternal death review reports and qualitative case histories through surviving members; and maternal cause of death was based on WHO guidelines e.g. direct, indirect or contributory causes. Bouchghoul et al. (2015) examined the clinical data of women visiting camps, over a 6 month period. Hynes et al. (2002) used a retrospective cross-sectional design, for deaths over a 12 month period; using mixed methods and confirming deaths through death certificates.

Clinic

There were four studies undertaken in clinical settings; in terms of populations served, two studies had been affected by conflict, one by an earthquake, and one was affected by the Ebola outbreak. The studies conducted an estimation of maternal mortality from clinics which served populations affected. Hudic et al. (2011) used a database from over a 20 year period (1986 – 2001), which was consulted for the medical histories of pregnant women treated at the gynaecology-obstetrics clinic, and to determine number of maternal deaths and cause (based on clinical diagnoses) due to direct and indirect causes. Simetka et al. (2007) identified data retrieved from surgical logbooks, medical records and short interviews with women attending clinic. Djafri et al. (2015) selected healthcare centres affected by the earthquake at two levels: and included all 20 community clinics as well as six hospitals (out of a possible 28) Jones et al. (2016) included 13 clinics providing comprehensive emergency obstetric care and 65 (out of 67) facilities providing basic emergency obstetric care across Sierra Leone during the Ebola epidemic.

Household

Four articles drew their population from the household-level (Bartlett et al 2002; Brentlinger et al 2005; Cutts et al 1999; Schaider et al 1999). All household based studies were retrospective surveys, depended on the recall of maternal deaths by household members, and were carried out at as single round surveys i.e. interviewed surviving members at a single point in time. All studies estimated the maternal mortality based on maternal deaths reported by surviving members.

Unlike other studies, the study undertaken in Afghanistan used a two-staged cohort approach, in which the four provinces were purposively selected to represent different levels of remoteness (Bartlett et al 2002). For each province, villages were randomly selected – with an equal number of village per province. The overall study involved two stages: (i) the identification of deaths in households (individuals sharing a

cooking area), and (ii) and identification of whether the deaths were due to maternal complications. Once a death had been identified, verbal autopsy interviews were carried out in households reporting deaths, by using the WHO questionnaire (WHO 1995) and case histories were developed.

Brentlinger et al. 2005 applied cluster sampling in the household survey, which was conducted in Chiapas, Mexico, and used a mixed methods approach to estimate maternal mortality and utilisation of health services at the household level (Brentlinger et al 2005). The study sampled women of reproductive age (13 – 49 years) who had been pregnant in the past two years (1999 – 2001). The household survey used purposive sampling to select regions and municipalities most affected by the conflict – identified through experts and sources, including Mexican newspapers, human rights organisations and academic institutions.

[Insert Table 3 around here]

Secondary data analysis studies

Census/ National or Provincial

Three studies have used census or routine data to report maternal mortality estimates and are summarised in Table 4. For example, one study used the estimates provided by the United Nations Maternal Mortality Estimates Interagency Group to examine maternal mortality ratios (MMR) in Sub-Saharan African countries experiencing recent conflict (1990 – 2004) and defined conflict countries as those that experienced 'at least 1000 conflict-related deaths per annum' to the entire population, not just related to MMR (O'Hare and Southall 2007). Another study in Iran examined MMR before and after the Bam earthquake using both civil registration statistics and provincial statistics. (Zolala 2011) Given that the number of live births recorded at the local level were inaccurate, they used *'the number of children who received their first polio vaccination'* as a proxy for the number of live births. One grey literature publication in Chiapas, Mexico estimated MMR based on the Census on Vital Statistics (1990-1999), the information database for health of the Abierta Population from the Secretary of Health in 2002 and the Government Report of Chiapas (2002). The MMR calculated ranged from 60 – 190 per 100,000 live births. Little information was given on the limitations of these estimates. (Freyermuth 2002)

[Insert Table 4 around here]

Comparison of maternal mortality figures to historic estimates

Table 5 compares the maternal mortality estimates reported in studies *versus* the most historical national estimates of maternal mortality available. Compared to their most historical national estimates, *household* studies based in humanitarian settings generally yielded higher estimates of maternal mortality. There were two exceptions, including the study based on indirect sisterhood methods, and the study conducted in Angola, where traditional birth attendants had attended the births. By contrast, studies undertaken in *camp* settings had lower maternal mortality estimates compared to historical national estimates. Estimates of maternal mortality within *clinics*, on the other hand, varied considerably.

[Insert Table 5 around here]

Discussion

This methodological review presents maternal mortality estimates from a variety of settings. Both camp and clinic-based estimates were based on either retrospective or prospective estimates of clinic surveillance data. Household-based studies included retrospective studies interviewing surviving members, the tools for which ranged from: simple questionnaires using traditional birth attendants to household surveys. Census-based estimates were largely based on vital registries.

Camp populations and clinics, providing humanitarian assistance, had considerably lower maternal mortality ratios compared to national historical estimates. One study found reproductive health outcomes in internally displaced camps to be better than those of their respective country of origin, suggesting that estimates of maternal mortality produced from camp settings may not provide an accurate representation of the humanitarian context (Hynes et al 2002). By contrast, clinics directly affected by war (through loss of workers and access to supplies) had higher maternal mortality ratios during the humanitarian period (Hudic 2011). Likewise, household estimates of maternal mortality, from areas affected, were higher than the national historical estimates of maternal mortality.

The studies varied considerably in terms of their methodology and tools used, which have been briefly discussed here, highlighting their different strengths. First, for camp and clinic-based estimates, deaths were confirmed through clinical notes and death certificates; therefore estimates were not subjected to recall bias. By contrast, the majority of household and census-based estimates were dependent on self-report and reported statistics, respectively. Second, many of the household surveys used stratified cluster sampling to select regions representing the humanitarian context; which may have led to less selection bias compared to other sources. By contrast, there was evidence of selection bias in camps; for example,

in one study, the camp maternity unit could not cater for high risk pregnancies and such women were excluded. (Bouchghoul et al 2015) Third, reconfirmation of maternal deaths was attempted in two studies: the triangulation of three separate data sources (the family unit at Kerman Medical University, the statistics unit at Kerman Medical University and the civil registry) to confirm maternal deaths was used in one census study (Zolala 2011); whilst one household-based study revisited the households to confirm findings of maternal deaths.

Overall there were several methodological challenges. First, recall bias was commonly discussed in the limitations of household studies. Second, for studies that reported the definition of MMR, the majority required 'number of live births' as their denominator, which may not have been accurate due to lack of registries or reporting methods. One study, however, overcame this by using 'number of polio vaccines adminstered' as a proxy indicator (Zolala 2011). Third, there was a lack of consensus on the definition of maternal mortality. The most common definition was that cited in the International Classification of Disease or ICD-10. (WHO 2008) The measured timing of maternal death varied, however. One paper defined maternal mortality as a death from any cause related to pregnancy or its management within one year. (Bartlett et al 2002) This definition measures maternal death over a longer time period (beyond the 42 days) to include *late maternal deaths* (See Figure 1). However, the 42 day post-partum period, as suggested by the ICD-10 (and latest ICD-11) may not be sufficient enough to capture all maternal deaths, particularly in developing countries where pregnancy-related morbidity (such as pregnancy-related anaemia) may occur for longer. Fourth, few studies attempted to address the cultural context of study – by using supplementary qualitative data or culturally specific data collection methods, such as interviewing 'household heads' or 'community leaders.' Finally, census studies did not report the recall period for maternal death, nor an estimation of missing data.

Implications and proposals for further work

To improve the evidence base, there is a need for a standardized methodology to estimate maternal mortality in humanitarian settings. Based on the quality criteria used in this review, household-based surveys are considered to provide a more representative, and hence reliable estimate of the humanitarian population, compared to other settings. However there may still be limitations in accessibility and refusal to participate, which may lead to biased results if households with certain characteristics are more/less likely to refuse. Future developments of the household-based approach may consider the use of informants to identify maternal deaths within the community (Made-In), and a verbal autopsy to verify the circumstances and

cause of death (Made-For) (Qomariyah et al 2010). In conjunction with this approach, a stratified cluster random sample survey may serve to estimate the live births and risk factors related to maternal death. The advantage of a one-off survey is that it can produce precise local estimates, and is considerably less costly than demographic health surveys which are commonly used to estimate live births. Furthermore, estimates should be accompanied with a measure of reliability by including 95% confidence intervals. We further recommend using a consistent definition of maternal mortality that potentially counts maternal deaths (within the 42 day period) and late maternal deaths (≥43 days up to one year) independently to allow comparisons with the ICD definition, which appears to be the most commonly used definition across studies. For household surveys, a definitive recall period should be used, considering that longer recall periods, such as more than two years, will result in lower sensitivity. (Roberts et al 2010) Finally, where possible, studies should attempt to confirm deaths through triangulation with separate data sources and/or revisit the household to reconfirm deaths. (Qomariyah et al. 2010)

Clearly a more robust method need to be consolidated, and a more standardized approach is necessary to ensure that maternal mortality estimates reflect the true population level. True estimates of maternal mortality are needed to inform resource allocation and health system strengthening during the period of crisis and its aftermath. Recent discourse in health in humanitarian crisis suggest that a dedicated interagency service for public health information may facilitate, and indeed be in instrumental in assuring, the uptake of standardised procedures and methods related to obtaining such estimates (Checchi et al. 2017).

[Figure 1 caption: Commonly applied definitions of maternal death, according to time period and causes (indirect, direct, unspecified and coincidental)]

References

Bartlett, L.A., Mawji, S., Whitehead, S., Crouse, C., Dalil, S., Ionete, D., and Salama, P. (2002) "Where giving birth is a forecast of death: maternal mortality in four districts of Afghanistan." *The Lancet* 365: 864-870.

Bouchghoul, H., Hornez, E., Duval-Arnould, X., Philippe, H.J., and Nizard, J. (2015) "Humanitarian obstetric care for refugees of the Syrian war. The first 6 months of experience of Gynecologie Sans Frontieres in Zaatari Refugee Camp (Jordan)." *Acta Obstet Gynecol Scand.* 94: 755-759.

Brentlinger, P. E., Sanchez-Perez, H. J. Cedeno, M. A., Morales, L. G., Hernan, M. A. Micek M. A., and Ford, D. (2005) "Pregnancy outcomes, site of delivery, and community schisms in regions affected by the armed conflict in Chiapas, Mexico." *Social Science & Medicine.* 61(5): 1001-1014.

Cairns, K. L., Woodruff, B. A., Myatt, M., Bartlett, L., Goldberg, H., and Roberts, L. (2017) "Cross-sectional survey methods to assess retrospectively mortality in humanitarian emergencies." *Disasters* 33(4): 503-521.

Checchi, F., Warsame, A., Treacy-Wong, V., Polonsky, J., van Ommeren, M., and Prudhon, C. "Public health information in crisis-affected populations: a review of methods and their use for advocacy and action." (2017) *The Lancet* 390(10109): 2297-2313.

Cutts, F. T., Dos Santos, C., Novoa, A., David, P., Macassa G., and Soares, A.C. (1996) "Child and maternal mortality during a period of conflict in Beira City, Mozambique." *International Journal of Epidemiology.* 25(2): 349-356.

Djafri D., Chongsuvivatwong, V., Geater, A. (2009) Effect of the September Sumatra Earthquake on Reproductive Health Services and MDG5 in the City of Padang, Indonesia. *Asia Pacific Journal of Public Health. 27*: NP1444 - NP1456

Freyermuth, G. (2009) Chiapas: Mortalidad materna en Los Altos de Chiapas. ¿Una realidad postergada o una realidad negada? Accessed online: http://fundar.org.mx/mortalidad-materna-el-los-altos-de-chiapas-una-realidad-postergada-o-una-realidad-negada/ on 05th December 2016.

Global Humanitarian Assistance (2016) Global Humanitarian Assistance Report. Accessed online at http://devinit.org/wp-content/uploads/2016/06/Global-Humanitarian-Assistance-Report-2016.pdf

Graham, W. J., Foster, L. B., Davidson, L., Hauke, E., and Campbell, O. M. (2008) "Measuring progress in reducing maternal mortality." *Best Pract Res Clin Obstet Gynaecol.* 22(3): 425-445 on 06th December 2016.

Hudic, I., Radoncic, F., and Fatusic, Z. (2011) "Incidence and causes of maternal death during 20-year period (1986-2005) in Tuzla Canton, Bosnia and Herzegovina." *J Matern Fetal Neonatal Med.* 24(10): 1286-1288.

Hynes, M., Sakani, O., Spiegel, P., and Cornier, N. (2012) "A study of refugee maternal mortality in 10 countries, 2008-2010." *International perspectives on sexual & reproductive health* 38(4): 205-213.

Hynes, M., M. Sheik, H. G. Wilson and P. Spiegel. (2002) "Reproductive health indicators and outcomes among refugee and internally displaced persons in postemergency phase camps." Jama 288(5): 595-603.

Jones, S.A., Gopalakrishnan, S., Ameh, C.A., White, S., van den Broek, N.R. (2016) 'Women and babies are dying but not of Ebola': the effect of the Ebola virus epidemic on the availability, uptake and outcomes of maternal and newborn health services in Sierra Leone *BMJ Global Health*; 1:e000065.

Laurenti, R., Buchalla, C.M. (1997) "Maternal and child health indicators: implications of the tenth revision of the International Classification of Diseases." *Revista Panamericana de Salud Pública* 2: 13-17.

Mathers, C.D., Fat, D.M., Inoue, M., Rao, C., Lopez, A.D. (2005) Counting the dead and what they died from: an assessment of the global status of cause of death data. *Bulletin of the World Health Organization.*83(3):171–177.

Nordenstedt, H. and Rosling, H. (2016) "Chasing 60% of maternal deaths in the post-fact era." *The Lancet* 388(10054): 1864-1865.

O'Hare, B. A. M. and Southall, D. P. (2007) "First do no harm: the impact of recent armed conflict on maternal and child health in Sub-Saharan Africa." *Journal of the Royal Society of Medicine*. 100(12): 564-570.

Qomariyah, S. N., Braunholtz, D. Achadi, E. L., Witten, K. H. Pambudi, E. S., Anggondowati, T., Latief, K., and Graham, W. J. (2010) "An option for measuring maternal mortality in developing countries: a survey using community informants." *BMC Pregnancy and Childbirth.* 10(1): 74.

Roberts, B., Morgan, O. W., Sultani, M. G., Nyasulu, P., Rwebangila, S., Myatt, M., Sondorp, E., Chandramohan, D., and Checchi, F. (2010) "A new method to estimate mortality in crisis-affected and resource-poor settings: validation study." *International Journal of Epidemiology* 39(6): 1584-1596.

Schaider, J., Ngonyani, S., Tomlin, S., Rydman R., and Roberts, R. (1999) "International maternal mortality reduction: outcome of traditional birth attendant education and intervention in Angola." *Journal of Medical Systems* 23(2): 99-105.

Simetka, O., Reilley, B., Joseph, M., Collie, M., and Leidinger, J. (2007) "Obstetrics during Civil War: six months on a maternity ward in Mallavi, northern Sri Lanka." *Medicine, Conflict & Survival.* 18(3): 258-270.

Stanton C., AbouZahr, C., & Wardlaw, T. (1995) Modelling Maternal Mortality in the Developing World. Unpublished background paper prepared for WHO and UNICEF.

Tapp, C., Burkle, F. M., Wilson, K., Takaro, T., Guyatt, G. H., Amad, H., and Mills, E.J. (2008) "Iraq War mortality estimates: A systematic review." *Conflict and Health*. 2(1): 1.

World Health Organisation. (1995) Verbal autopsies for maternal deaths. Report of a WHO Workshop. Geneva, Switzerland. Accessed online at: http://apps.who.int/iris/bitstream/10665/61029/1/WHO_FHE_MSM_95.15.pdf

World Health Organisation. (2008) ICD-10 online versions. Accessed online via WHO website: http://www.who.int/classifications/icd/icdonlineversions/en/"International statistical classification of diseases and related health problems, 10th Revision." on 15 December 2016.

World Health Organisation. (2015) The Abu Dhabi Declaration. Accessed online via WHO website: http://www.who.int/pmnch/media/news/2015/abudhabi_declaration.pdf

World Health Organisation, UNICEF, UNFPA, World Bank Group and the United Nations Population Division. (2015) *Trends in maternal mortality: 1990 to 2015. Estimates by WHO, UNICEF, UNFPA, World Bank Group and the United Nations Population Division*. Accessed online at: http://www.who.int/reproductivehealth/publications/monitoring/maternal-mortality-2015/en/ on 12 September 2018.

.

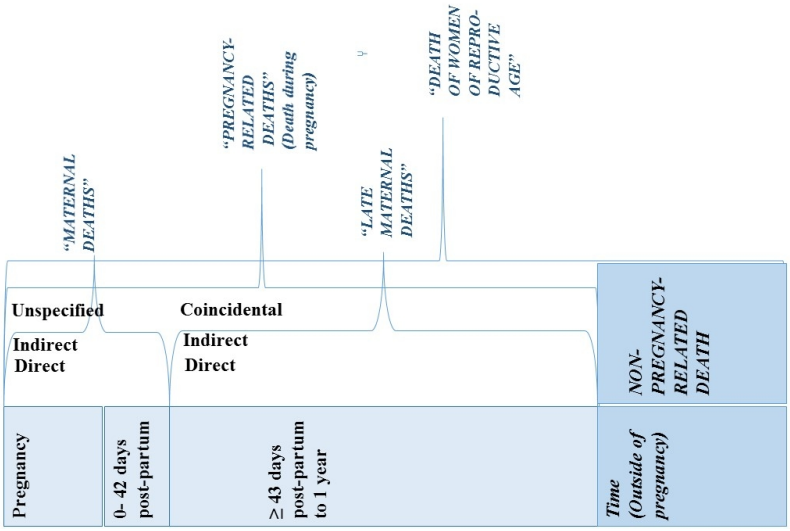
World Health Organisation. (2018) ICD-11 online versions. Accessed online via WHO website: https://icd.who.int/dev11/content/refguide.ICD11_en/html/index.html#2.29.3to2.29.6MaternalMortality| maternal-mortality| on 19 September 2018.

Zolala, F. (2011) "Evaluation of the usefulness of maternal mortality ratio for monitoring long-term effects of a disaster: case study on the Bam earthquake." *Eastern Mediterranean Health Journal.* 17(12): 976-980.

	Criterion	Rationale
a	Inclusion of definition of maternal mortality	Did the study investigators include a definition of maternal mortality?
b	(i) Sufficient coverage or representativeness of the underlying population affected by humanitarian setting; and the (ii) Characteristics of the household described - if applicable	This criterion determines whether the households or settings visited represent populations affected.
c	No evidence of selection bias	As some populations will be more, or less affected, study investigators should make efforts to reduce bias in sampling the population. The most common method to reduce bias is random selection of participating households or clinics.
d	Evidence that the response rate/ degree of missingness was reported	The response rate provides inferences on how likely the population sampled may represent the overall population. Is there reason to believe that those that did not respond are systematically different than those that did respond?
e	Efforts were made to confirm deaths	Did the study investigators aim to confirm deaths through corresponding evidence, eg. death certificates or verbal autopsy
f	Households (or families) were revisited to confirm findings	Did the study investigators revisit a random sample of study households or settings to re-inquire about deaths and did they find the same results?
g	Recall, or time period, for which the maternal deaths were being reported for	Did the study investigators specify and record the recall period that were used?
h	Data collection tools and analytic methods used to measure maternal mortality	Did the study investigators describe validated and/or pre-existing tools and

		analytical methods?

Table 1: Quality assessment criteria and rationale, for maternal mortality estimate studies in humanitarian settings



Commonly applied definitions of maternal death, according to time period and causes (indirect, direct, unspecified and coincidental)

338x190mm (96 x 96 DPI)

Table 2: A summary of maternal mortality definitions by publication.

Definitions of Maternal Mortality	Publication(s)
Maternal mortality ratio as *death from any cause related to pregnancy or its management within 1 year of pregnancy outcome, irrespective of duration or site. (Laurenti and Buchalla, 1997)*	Bartlett et al 2002
Maternal mortality ratio as *death occurring during pregnancy or labour, or within 42 days of birth or miscarriage, as a direct or indirect result of pregnancy complications (per 100,000 live births). (WHO, 2004)(ICD-10)*	Brentlinger et al 2005 ; Hynes et al 2012; O'Hare and Southall 2007; Hynes et al 2002
Maternal mortality ratio (indirect) as *proportion of sisters exposed to risk of childbearing who died during pregnancy, childbirth, abortion or miscarriage, or within 6 weeks after birth.*	Cutts et al 1999
Maternal mortality ratio as *number of maternal deaths per 100,000 live births.*	Jones et al 2016 Zolala 2011
Maternal mortality ratio as *number of maternal death per 10,000 live births*	Freyermuth 2002
No definition included	Bouchghoul et al 2015; Djafri et al 2015; Hudic et al 2011; Schaider et al 1999; Simetka et al 2007.

Table 3: Primary data studies on maternal mortality; by setting (a) camps (b) clinics and (c) households

Authors	Study design; Location	Criteria Assessment								Strengths/ Weaknesses
		a) Definition	*b) Sufficient coverage or representation of underlying population*	*c) No evidence of selection bias*	*d) Response rate reported*	*e) Deaths confirmed e.g. through death certificates or verbal autopsy*	*f) HH revisited to confirm findings*	*g) Time/ Recall period*	*h) Tools/ Analytical Methods used*	
(a) Camps										
Bouchghoul et al. (2015)	Prospective study of clinical data; Maternity Unit, Zaatari camp in Jordan	×	×	×	×	✓	×	Over 6 month	Estimate of maternal death and cause from clinical notes	**Strengths:** Prospective so no re bias; verification of cause of dea from clinical data **Weaknesses**: Small samples dependant on women visiting ca camp could not cater for high ri pregnancies which may have le under-estimation
Hynes et al. (2002)	Cross sectional retrospective cohort study (mixed methods); Post-emergency phase camps in Thailand, Myanmar, Nepal, Ethiopia, Uganda, Tanzania, Democratic Republic of Congo	✓	✓	× not all camps visited	×	✓	×	12 month period	Standardised data collection form; qualitative interviews with key informants; Monte Carlo stimulation used to calculate confidence intervals	**Strengths:** Comparability of da across sites; **Weaknesses:** Representative of populations only; underreportin deaths and live births
Hynes et al. (2012)	Cross-sectional study and qualitative case reviews;	✓	×	×	×	✓	×	Not reported	Estimate of MMR and maternal deaths using UNHCR Health Information	**Strengths:** Comparability of da across sites; **Weaknesses:** High missing data particularly of women who died in pregnancy or at home

	Refugee camps in 10 countries (Bangladesh, Chad, Ethiopia, Kenya, Nepal, Rwanda, Sudan, Tanzania, Uganda, Zambia)								System; qualitative coding of case histories to check for consistencies	
(b) Clinics										
Djafri et al. (2015)	Retrospective study of official health data and review at selected clinics; Padang, Indonesia	×	✓	×	×	✓	×	Not reported	Retrospective study of official health data and review at selected clinics	**Strengths:** Estimates over a fiv period **Weaknesses:** Potential for unde reporting and reporting biases; cause of death given
Hudic et al. (2011)	Retrospective study of clinical data; Clinic in Tuzla, Bosnia and Herzegovina	✓	×	×	×	✓	×	20 year period	Retrospective study of clinical data	**Strengths:** Data available over time period; verification of caus death from clinical data **Weaknesses:** Representative of population only; no population-adjustment used to account for variations in clinic population d period
Jones et al. (2016)	Retrospective study of clinical data; 13 facilities across Sierra Leone	✓	×	×	×	✓	×	22 months	Retrospective study of clinical data	**Strengths:** Data available over time period; verification of caus death from clinical data; compa of Ebola vs. non Ebola cases **Weaknesses:** Only larger healt facilities included and not lowe village-level facilities. MM esti based on small numbers in som districts.
Simetka et al. (2007);	Prospective study with qualitative interviews Maternity ward in Mallavi, Sri Lanka	×	×	×	×	✓	×	Over 6 months	Prospective study with qualitative interviews	**Strengths:** Prospective so no re bias; verification of death from clinical data **Weaknesses:** Small samples dependant on women visiting cl
(c) Households										

Bartlett et al. (2002)	Two staged retrospective cohort using verbal autopsies ; Four Provinces (Kabul, Laghman, Kandahar, Badakshan) in Afghanistan	✓	✓	✓ (purposive selection at regional level)	✓	✓	✓	3 years	Identification of deaths, verification of death and identification of cause using verbal autopsies (WHO questionnaire)	**Strengths:** Verbal confirmation deaths and type; **Weaknesses:** Used purposive sampling so not representative o whole population affected by conflict; needs large sample size
Brentlinger et al. (2005)	Cross-sectional retrospective household survey with semi-structured interview; Chiapas, Mexico	✓	× (clusters refused to participate)	✓	✓	✓	×	2 years	Household survey and questionnaire to establish maternal deaths	**Strengths:** Used stratified clust sampling; efforts made to verify death and cause **Weaknesses:** Randomly selecte cluster omitted due to refusal to participate - meant that samplin could have resulted in bias; nee large sample sizes
Cutts et al. (1996)	Retrospective randomised cluster survey using indirect sister method; Beira city, Mozambique	✓	×	✓	×	✓	✓	2 years	Cluster selected using expanded programme on immunisation sampling method; screening questionnaire used to register eligible women; indirect sisterhood method used	**Strengths:** Can be used with sm sample size; efforts made to ver death and cause; cluster samplin **Weaknesses:** Recall bias leadin under-reporting; maternal morta estimates not representative of geographic population due to in migration
Schaider et al. (1999)	Retrospective questionnaire conducted by traditional birth attendants; Kwanza Sul, Huambo and Luena; Angola	×	×	✓	✓	✓	×	4 years	Registration of maternal death from registration forms	**Strengths:** Response rate provi on maternal mortality (83%) **Weaknesses:** No confirmation cause of death; under-reporting deaths by birth attendants

Table 4: Secondary data: Census/ National or Provincial Statistics

Authors	Study design; Location	Criteria Assessment								Strengths/ Weaknesses
		a) Definition of MM	*b) Sufficient coverage or representation of underlying population*	*c) No evidence of selection bias*	*d) Response rate reported*	*e) Deaths confirmed e.g. through death certificates or verbal autopsy*	*f) HH revisited to confirm findings*	*g) Time/ Recall period*	*h) Data collection tools and analytical methods*	
Freyermuth (2002)	Cross sectional study of government and health statistics; Chiapas, Mexico	✓	×	×	×	×	×	×	Estimate of MMR from census and health statistics	**Strengths:** - **Weaknesses:** Under-reporting; no efforts to verify death and cause; population estimates may not have be representative of humanitarian population
O'Hare & Southall (2007)	Cross sectional study of WHO statistics; Data from 42 countries	✓	unclear	unclear	×	×	×	×	Use of adjusted maternal mortality estimates (due to underreporting and misclassification of deaths) from WHO	**Strengths:** Comparability of data; **Weaknesses:** Population estimates m not have been representative of humanitarian population; low respon rates; no efforts to confirm death and cause; mis-classification of deaths
Zolala (2015)	Cross sectional study of civil registry and provincial statistics; Bam, Iran	✓	✓	×	×	✓	×	×	Estimate of maternal deaths from provincial statistics. Use of proxy to estimate live births (polio vaccination)	**Strengths:** Use of three data sources confirm notification of death **Weaknesses:** Under-reporting; no efforts to verify death and cause; mis classification of deaths

Table 5: A comparison of maternal mortality estimates (study) with national maternal mortality estimates (historical)

Study Authors	Setting	**Maternal Mortality per 100,000 live births** (range given if across sites or years)	**National Maternal Mortality per 100,000 live births based on Estimation of Interagency Group, unless stated otherwise** (Year, most historical*)
Bartlett, Mawji et al (2002)	Household	418 – 6507	1100 (2000)
Bouchghoul, Hornez et al (2015)	Camp	0	59 (2010)
Brentlinger et al (2005)	Household	607	90 (1990)
Cutts, Dos Santos et al (1999)	Household	410	&411 (1980)
Djafri et al (2015)	Clinic	85	446 (1990)
Freyermuth (2002)	Household (Census/ National)	25 - 115 (1990 - 1994) 20 - 140 (1995 - 1999)	90 (1990)
Hynes, Sheik et al (2002)	Camp	Ranged from 76 (Burundians in Tanzania) to 730 (Somalians in Tanzania) amongst camp populations	$800 Democratic Republic of Congo 1400 Ethiopia 230 Myanmar 540 Nepal 530 Tanzania 44 Thailand 510 Uganda
Hynes, Sakani et al (2012)	Camp	Ranged from 43 (Tanzania) to 235 (Bangladesh)	319 Bangladesh (2005) 1500 Chad (2005) 743 Ethiopia (2005) 728 Kenya (2005) 444 Nepal (2005) 567 Rwanda (2005) 440 Sudan (2005) 687 Tanzania (2005) 504 Uganda (2005) 372 Zambia (2005)
Hudic et al (2011)	Clinic	49 (pre-war period) 87 (during war period) 50 and 23 (post-war period)	28 (1990, pre-war) 22 (1995, during war) 17 (2000, post war)
Jones et al (2016)	Clinic	Across all facilities: 3097 (Ebola affected) 1962 (Not Ebola affected)	3700 (2010)
O'Hare and Southall (2007)	Household (Census/ National)	1000 (median adjusted in countries with conflict)	690 (median adjusted in countries without conflict)
Schaider, Ngonyani et al (1999)	Household	293	1160 (1990)
Simetka, Reilley et al (2007)	Clinic	14	70 (1995)
Zolala (2015)	Household (Census/ National)	390 (civil registry) 62 (family unit), for year of earthquake	51 (2000)

Notes: *Most historical estimates from date study first started - from Maternal Mortality Inter-Agency group (World Health Organisation et al 2015);

& Global Burden of Disease Study estimate; no estimate by Maternal Mortality Inter- Agency group was available;

$ based on included national estimates within paper