

Maternal and neonatal mortality in rural south Ethiopia:

Comparing mortality measurements and assessing obstetric care

Yaliso Yaya Balla



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Dedication

To mothers who die during pregnancy and childbirth in resource-limited settings without accessing essential obstetric services.

“Pregnancy is not a disease but a normal physiological process that women must engage in for the sake of humanity. Whereas the elimination or eradication of disease is a rational and laudable endeavour, the same strategy cannot be applied to maternal mortality. There is no pathogen to control, no vector to eradicate. Women will continue to need care during pregnancy and childbirth as long as humanity continues to reproduce itself. Failure to take action to prevent maternal death amounts to discrimination because only women face the risk.” Carla AbouZahr (2003)

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Summary

Introduction: The aim of the Millennium Development Goals (MDG 4 and 5) is to substantially reduce maternal and child mortality in the world. However, information is limited in low-income countries to help oversee progress towards the MDG targets. In developed countries, quality data are obtained through routine vital registrations. Unfortunately, registry-based data are lacking or incomplete in most developing countries, and Ethiopia is no exception. As such, we had a scarcity of information on the level of maternal and neonatal mortality, as well as the coverage and quality of obstetric services in south Ethiopia. The information is important because the target for MDGs in 2015 and the preparation for the Sustainable Development Goals (SDGs) are fast approaching.

Objective: The aim of the thesis was to measure and compare maternal and neonatal mortality and obstetric services through community- and facility-based methods in southern Ethiopia.

Methods: We used four different methods to measure maternal mortality, and in one of these methods assessed one-year obstetric services in all health centres and hospitals in Gamo Gofa (population 1.8 million in 2010) in south Ethiopia. The methods were: 1) Between January and December 2010 health extension workers prospectively registered births and birth outcomes in 75 rural villages in three districts in south Ethiopia (population of 421,639 people) (Paper I); 2) In February 2011, we conducted a survey in 6,572 households that reported pregnancy and birth outcomes in the previous five years (2006-2010) out of a total of 11,920 households in 15 out of 30 randomly selected rural villages in the district of Bonke (Paper II); 3) Using the sisterhood method, we estimated the lifetime risk of pregnancy-related deaths and MMR through interviewing 8,503 adult siblings from the 15 kebeles where the survey for Paper II was conducted in Bonke (Paper III); and 4) We reviewed one-year institutional records on births, birth outcomes (maternal deaths), and signal functions of emergency obstetric care in all 63 health centres and three hospitals in Gamo Gofa. We then calculated the population coverage of obstetric care, the rate of skilled birth attendance, and the quality of obstetric service against the UN's minimum standards (Paper IV).

Results: In 2010, we recorded 10,987 births and 53 maternal deaths (an MMR of 489 per 100,000 LBs, with 83% (44/53) of maternal deaths occurring at home. The MMR was associated with the education level of the father of the baby, access to driveable roads, and sickness of the mother during pregnancy (Paper I). In the household survey (Paper II), we enumerated 11,762 births and 49 maternal deaths (an MMR of 425 per 100,000 LBs), and of the maternal deaths, 87% (43/49) occurred at home. The poorest households and those with illiterate household heads had a higher MMR. We also found 308 neonatal deaths (an NMR of 27 per 1,000 LBs). Neonatal mortality was associated with household wealth, a residence far from a driveable road (≥ 6 km), and narrowly spaced births in the households. We estimated a lifetime risk (LTR) of 1 in 10 pregnancy-related deaths with a corresponding MMR of 1,667 per 100,000 LBs by interviewing 8,053 siblings (brothers and sisters). Because of the indirect nature of the method, the estimate refers to the year 1998 (12 years before the survey).

In the facility review (Paper IV), we recorded 4,231 pregnancy- and birth-related admissions (6.6% of an estimated 64,413 births in the area in the same year), and found 79 maternal deaths in the institutions. This resulted in a quarter of the MMR being measured through the birth registry (120 vs. 489 per 100,000 LBs). Out of the studied 66 health institutions, only three met the basic-, and two satisfied the comprehensive emergency obstetric care standards. The coverage and quality of emergency obstetric care (EmOC) was below the UN's recommended minimum of five basic and one comprehensive EmOC facility for every 500,000 people. The rate of institutional delivery was very low (on average, 3.7% between 2006 and 2010, and 6% in 2010) in rural villages. Three studies consistently showed that more than two-thirds of maternal deaths occurred at home (Papers I, II, IV).

Conclusion: Community-based measurement methods (birth registry and household survey) provided comparable results of the MMR, which was high with most of the deaths occurring at home. The proportion of skilled birth attendance and EmOC was low. It is possible to conduct birth registries in rural communities where functional system of community health workforce is available and use it as a tool to measure birth outcomes.

List of original papers

The thesis is based on the following original research papers that will be referred by their respective Roman numerals.

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- Paper I** *Yaliso Yaya, Tadesse Data and Bernt Lindtjørn.* Maternal mortality in rural south Ethiopia: Outcomes of community-based birth registration by health extension workers. *PLoS ONE* (2015), 10(3): e0119321
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- Paper II** *Yaliso Yaya, Kristiane Tislevoll Eide, Ole Frithjof Norheim and Bernt Lindtjørn.* Maternal and neonatal mortality in south-west Ethiopia: Estimates and socio-economic inequality. *PLoS ONE* (2014), 9(4):e96294
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- Paper III** *Yaliso Yaya and Bernt Lindtjørn.* High maternal mortality in rural south-west Ethiopia: Estimate by using the sisterhood method. *BMC Pregnancy and Childbirth* (2012),12:136
-
- Paper IV** *Meseret Girma, Yaliso Yaya, Ewenat Gebrehanna, Yemane Berhane, and Bernt Lindtjørn.* Lifesaving emergency obstetric services are inadequate in south-west Ethiopia: A formidable challenge to reducing maternal mortality in Ethiopia. *BMC Health Services Research* (2013),13:459
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Abbreviations

EmOC	Emergency obstetric care
CI	Confidence interval
CSA	Central Statistical Authority
HEW	Health extension worker
HH	Household
LB	Live birth
LTR	Lifetime risk
MMR	Maternal mortality ratio
MOH	Ministry of Health
NMR	Neonatal mortality rate
OR	Odds ratio
PCA	Principal component analysis
REK	Regionale Komiteer for Medisinsk og Helsefaglig Forskningsetikk (Norwegian)
RR	Relative risk
SBR	Stillbirth rate
SD	Standard deviation
SES	Socio-economic status
SNNPRS	Southern Nations Nationalities and Peoples Regional State
TFR	Total fertility rate
UN	United Nations
UNFPA	United Nations Population Fund
UNICEF	United Nations Children's Fund
VHP	Volunteer health promoters
WHO	World Health Organization

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1 Introduction

1.1 Background on maternal mortality (the problem)

Maternal mortality is still one of the biggest health and societal challenges in the 21st century in resource-limited countries. For many decades, the number of maternal deaths was over 500,000 per year in the world [1]. In 2013, an estimated 293,000 mothers died in the world in the process of pregnancy or childbirth, with the maternal mortality ratio (MMR) per 100,000 live births ranging from a high of 957 in south Sudan to a low of 2 in Iceland [2]. The lifetime risk of maternal death for Sweden is 1 in 30,000, whereas in Sierra Leone it is 1 in 6 [3]. In fact, the difference in the rates of maternal mortality is considered to be the greatest of all health-related disparities between developed and developing countries [4]. In recent decades, global maternal deaths dropped by 47% (from 543,000 in 1990 to 287,000 in 2010) [5]. However, 99% of the current maternal deaths are in developing countries, especially in sub-Saharan Africa and south Asia [6]. More than 90% of these deaths are preventable with solutions currently available; particularly in relation to skilled care during labour, at delivery, and a few days during the postpartum period. Yet, in 2008, 50% of maternal deaths in the world only occurred in six countries (Ethiopia, Nigeria, Congo DRC, India, Pakistan and Afghanistan) [7].

Following the initiation of Safe Motherhood Initiatives (SMIs) and Millennium Development Goals (MDGs), access to interventions improved, and a reduction in maternal mortality has been observed, even in some low- and middle-income countries [7]. However, in many sub-Saharan countries, the rate of reduction has not been as planned for the MDG target [8]. In some of these countries, even previous gains were reversed because of the HIV epidemic [9, 10]. This presents a great challenge in Africa to reducing the MMR (the number of maternal deaths per 100,000 live births) by 75% in 2015 from the level in 1990 [7]. The reason behind this is the limited access to and utilization of skilled care during pregnancy, childbirth and postpartum compounded with the low socio-economic status of women in these settings [11-13]. As such, many mothers deliver and die out of a health facility, which makes it difficult to both prevent the unnecessary deaths and identify these deaths in settings where information is poor.

In contrast, strong and accountable health systems have a great potential to substantially decrease the adverse pregnancy and childbirth outcomes [14]. At the individual level, identifying and classifying an adult woman's death as maternal or non-maternal is a serious challenge because of the complex nature of defining the cause of death (medical diagnosis) and determining the pregnancy status during the death, especially deaths during early pregnancy [15]. This constraint is a particular concern in low-income settings without vital registration and where maternal mortality is greatest [16].

1.2 Definitions, causes, time, and indicators of maternal mortality

1.2.1 Definitions of maternal mortality

A clear understanding and universal application of maternal death definitions are crucial for monitoring progress and comparisons across geographic areas, as the differential use of definitions may present substantial implications on the credibility of estimates. The definitions of maternal mortality have changed over time, which resulted in inconsistencies in measurements and presents problems to oversee trends in maternal mortality. For example, in Sweden the change of the maternal mortality definition from ICD-8 to the subsequent ICD-9 and ICD-10 editions caused an increase in rates [17]. In addition, the introduction of the definition of "pregnancy related deaths" instead of "maternal death" has been a source of measurement variation. For instance, a study from Bangladesh reported 15% more pregnancy-related deaths compared to maternal deaths [18]. Moreover, clarity on the definition of life-threatening maternal complications is also important because for every mother who dies, there are many (30 or more) others who develop lifelong complications and disabilities known as a "maternal near-miss" [19]. Two basic elements for a definition of maternal mortality are the cause and the time of death in relation to pregnancy. The current working definitions of maternal mortality are as follows [20]:

Table 1: Maternal mortality and complication related definitions

Term	Definition	Requirement	ICD
Maternal deaths	Death of a woman while pregnant or within 42 days of the end of pregnancy, from any cause related to- or aggravated by the pregnancy or its management, but not from incidental or accidental causes.	Time-of-death and cause-of-death	ICD-9
Fortuitous (incidental) deaths	Death from unrelated causes that happen to occur in pregnancy or puerperium	Cause-of-death	ICD-9
Pregnancy-related deaths	Deaths occurring in women while pregnant or with 42 days of the termination of pregnancy, irrespective of the cause of the death	Time-of-death	ICD-10
Late maternal deaths	Deaths in women occurring between 43 days and 1 year after termination of pregnancy (abortion, miscarriage, or delivery)	Time-of-death	ICD-10
Maternal near-miss* (severe complication)	A woman who nearly died but survived a complication that occurred during pregnancy, childbirth, or within 42 days of termination of pregnancy (“nearly dying, but surviving”).	Severity and disability	ICD-10

Note: ICD is an international classification of diseases and health-related problems provided by the World Health Organization (WHO); * a maternal near-miss is well described elsewhere [19].

1.2.2 Causes of maternal mortality

Several distant and immediate factors determine the survival of a woman from pregnancy and childbirth-related deaths. However, health services are mainly concerned with medical (direct and indirect) causes. Direct causes are medical complications that primarily occur because of pregnancy, child birth or the managements during these periods and account for about 80% of maternal deaths [21]. The direct causes are bleeding (haemorrhage), infection, hypertensive disorders, unsafe abortion, and obstructed labour, with bleeding the leading cause of maternal deaths in developing countries; particularly in sub-Saharan Africa [22]. The combination of the three dominant direct medical causes of maternal death (bleeding, infection and hypertensive conditions) caused the largest proportion of MMR per 100,000 live births (500

in sub-Saharan Africa, 300 in south Asia, 100 in Latin America, and four in developed countries in 2005) [3, 23]. This shows the relative importance of interventions targeting these problems to reduce maternal deaths.

Indirect medical causes of maternal deaths are conditions that are not unique to pregnancy, which include anaemia, malaria, HIV, tuberculosis, heart diseases and other existing medical conditions aggravated by pregnancy to cause a maternal death. They are responsible for approximately one-fourth of global maternal deaths, with HIV being the leading indirect cause in countries highly affected by the epidemic [9, 21]. However, the quality of information on the indirect causes of deaths is particularly problematic because of difficulties in attributing deaths to these causes [24]. In some areas, targeting the key indirect causes of maternal deaths may be as crucial as the focus on direct causes. Furthermore, the prevention of maternal deaths from causes such as malaria [25, 26], anaemia [27] or HIV needs a strategic investment of resources on the primary and secondary prevention of these causes to substantially decrease maternal mortality.

Incidental and accidental causes such as suicide, violence (murders) and accidents, while pregnant or within 42 days, has received little attention in maternal death statistics. Nonetheless, evidence suggests that these deaths may be related to pregnancy [28-30]. For example, domestic violence was the second common cause of deaths in pregnancy in India [29]. In Matlab, Bangladesh, suicide caused 20% of deaths of unmarried pregnant women, although only 5% among married pregnant women, while the risk of violent death was three-fold among pregnant girls compared to non-pregnant girls [28, 30]. Though difficult to measure, these findings suggest that ignoring the number of deaths due to both incidental and accidental causes might lead to an under-estimation of maternal mortality.

The causes of maternal mortality may vary because of variations in the quality of the health system in a given country or region as the direct causes of maternal death (obstetric risks) are particularly sensitive indicators of the level of obstetric services in an area. In other words, in a country that has quality health service and most women access to services, maternal deaths from bleeding and infection can be substantially reduced [23]. One cannot expect the same in areas where most women deliver at home because of poor services and low access to health care.

Still, experts regularly estimate the proportion of the causes of maternal death for global and regional comparisons. For example, infection caused a five times higher maternal deaths rates in sub-Saharan Africa compared to developed countries (2.1% vs. 9.7%), whereas bleeding caused 34% of all maternal death in Africa and 13% in developed countries in 2006 [23]. Over time, the proportion of maternal deaths caused by bleeding declined to 25% in sub-Saharan Africa and increased to 16% in developed countries in 2013 [31]. This denotes that when the health system is strengthened, the share of preventable deaths can decrease. Consequently, when the number of deaths from a particular cause decreases, the proportion of other unchanged causes increases despite the number of deaths from the latter not having changed. The WHO provides the estimates of the causes of maternal deaths for each geographic area [23, 31].

1.2.3 Time of maternal death

Predicting the time of maternal complications and fatal conditions during pregnancy is difficult, but most maternal deaths occur during labour, delivery, and shortly after birth [32-34]. Over 50% of maternal deaths that occur in the postpartum period occur in the first 24 hours after delivery, and over 80% occur in the first week after birth or abortion [35]. Thus, skilled follow-up is needed during this critical period.

A conventional definition of maternal mortality considers deaths between pregnancy and 42 days after birth [36]. However, data show that some deaths due to maternal causes occur after 42 days, especially in the period up to six months postpartum [33, 34]. Accordingly, a new category of definition, “late deaths”, was proposed to include deaths within a year following the termination of pregnancy [36].

1.2.4 Indicators of maternal mortality (statistics)

Maternal mortality is a major public health problem, but in terms of absolute numbers, it is rare, which makes maternal mortality a challenging health outcome for statistical measurement. Hence, several ways of describing the magnitude have been proposed and used. These indicators are absolute numbers, maternal mortality ratio (MMR), maternal

mortality rate (MMrate), a lifetime risk of maternal mortality (LTR), and the proportion of maternal deaths among reproductive age female deaths (PMDF). Even so, the meanings carried by each of these indicators permit slight variations.

A. Number of maternal deaths

This is the method for reporting the number of maternal deaths in a geographic area during a certain period, commonly per year. As such, absolute numbers in maternal mortality is an important means of informing and alarming actors in the field. Some scholars expressed these numbers in a powerful way, including as follows, by Dr Malcolm Potts in the WHO Interregional Meeting on the Prevention of Maternal Mortality, November 1985 to express 250 maternal deaths very four hour in the world [37]: *"Every four hours, day in, day out, a jumbo jet crashes and all on board are killed. The 250 passengers are all women, most in the prime of life, some still in their teens. They are all either pregnant or recently delivered of a baby. Most of them have growing children at home, and families that depend on them"*, Richard Horton, editor of The Lancet, expressed global maternal deaths as: *"the number that has challenged the maternal health community is 500,000"* to reflect the number of maternal deaths per year in the world over the decades [1]. In fact, the number of maternal deaths has become the key report of the maternal mortality indicator in global maternal mortality estimations [2, 5, 7]. Therefore estimating and reporting the number of maternal deaths that could occur in a country or an area is powerful information, even without complex statistics.

B. Maternal mortality ratio (MMR)

MMR is the number of maternal deaths during a given time period per 100,000 live births during the same period. It is widely regarded as the conventional measure of maternal mortality, and measures the risk associated with each pregnancy (obstetric risk) [3]. A calculation of the MMR can be possible from different sources of measures [38]:

$$\frac{\text{Number of maternal deaths}}{\text{Number of livebirths}} \times 100,000$$

Or

$$\text{MMR} = \text{MMRate} / \text{General fertility rate (GFR)}$$

$$\text{MMR} = \text{MMR} = 1 - (1 - \text{LTR})^{1/\text{TFR}}$$

Where LTR= lifetime risk

C. Maternal mortality rate (MMRate)

This is the number of maternal deaths over a given time period per 100,000 women of reproductive age (15-49) [39]. It measures both the obstetric risk and the frequency with which women are exposed to this risk [40]. The MMRate can be calculated as follows [38]:

$$\frac{\text{Number of maternal deaths}}{\text{Number of women aged 15 – 49}} \times 100,000$$

Or

$$\text{MMRate} = \text{MMR} \times \text{General fertility rate}$$

$$\text{MMRate} = 1 - (1 - \text{LTR})^{1/35}$$

D. Lifetime risk (LTR) of maternal death

This measure accounts for both the probability of becoming pregnant and the probability of dying from pregnancy-related causes, and the risk is accumulated across a woman's reproductive year. Consequently, LTR indicates the probability of maternal death throughout a woman's reproductive life [40]. It takes into account the fertility probability and obstetric risk together and the likelihood is expressed in odds, example, e.g. one in 10 in a defined area [38].

$$\text{LTR} = 1 - (1 - \text{MMrate})^{35}$$

$$\text{LTR} = 1 - (1 - \text{MMratio})^{\text{TFR}}$$

Sometimes approximated as $\text{LTR} = 35 \times \text{MMRate}$

E. Proportion of maternal deaths among female deaths (PMDR)

This measures maternal deaths as a proportion of all female deaths of reproductive age (usually 15-49 years) for a given time period [38]. In countries and areas with poor obstetric care, the proportion of maternal deaths among reproductive female deaths is expected to be high compared to settings where there is effective obstetric care:

$$\frac{\text{Number of maternal deaths in a period}}{\text{Number of deaths among women 15 – 49 in the same period}} \times 100,000$$

Note: the formula boxes are obtained from the works of Graham WJ et al; reference [38]

1.3 Measurement methods for maternal mortality

1.3.1 Measurement backgrounds

The efforts of measuring maternal mortality have a long history pointing back to the 17th century in developed countries [41]. However, critical data to guide policy and interventions for reductions of avoidable maternal deaths is still limited in developing countries. In fact, all agree on the need for quality data to oversee changes in maternal mortality [16]. Similarly, the challenges in measuring maternal mortality are universal, and no country in the world can give a confident, reliable and valid national estimate of its maternal mortality [42]. Thus, there is an understanding that maternal mortality is difficult to measure compared to other health outcomes such as child mortality and fertility [43]. The reason behind this difficulty is that capturing maternal deaths (finding and counting) at the population level, and then when found, ascertaining a woman's death as maternal (confirming the cause of death as a maternal cause), are challenging [44].

Realizing the challenges in measuring maternal mortality as an outcome, some have used process indicators such as skilled birth attendance, financial commitments and policy approval [45, 46]. However, the main MDG5 indicator to assess the goal of 75% reduction in MMR requires measuring maternal mortality. Accordingly, there is a need to continuing the effort to find out improved ways of measuring maternal mortality, in addition to the process indicators [47].

In developed countries, maternal deaths in the population are captured through routine vital registrations (data sources that regularly record births, deaths, marriages, and divorces). Autopsy (also referred as post-mortem examination) is an ideal method used to identify the underlying and immediate causes of a maternal death [48]. Nevertheless, measuring maternal mortality at population level is a problem, even in settings where sophisticated systems are in place [49]. As a result, supplementary methods such as a confidential enquiry of maternal deaths (using different sources of tracking data such as professionals, confidential enquiry committees, news source) have been used to supplement data from registries [50-52]. In

resource-limited countries, which is where most of the people in the world live, both a routine registration of deaths and medical autopsies to confirm the deaths are lacking [53].

The weakness of measuring maternal mortality in less developed countries has been widely recognized since the 1980s; which has been further stimulated by stimulated by the initiation of safe motherhood programme [54]. The subsequent MDG declarations also helped to put maternal health and its measurement at the centre of development agendas [55]. The central aim of these international efforts is to galvanize actions for the reduction of maternal mortality, e.g. MDG5 to reduce the MMR by three-quarters in 2015 from its 1990 level. Meanwhile, monitoring progress towards these targets needs quality data, as “*what you count is what you target*” [56].

1.3.2 Measurement options (empirical measurements vs. analytical estimates)

Acknowledging a serious demand for information in developing countries where maternal mortality matters most, several alternative data acquisition methods were proposed. Some of these methods are empirical (direct searches for primary data), whereas others are analytical (statistical derivations to reach at estimates) [39].

Empirical methods depend on the collection of first-hand data including:

- A) Routine sources that rely on passive data collection based on reports from family or a health facility. These routine methods are: 1) death registrations (civil registrations), 2) sample vital registrations, 3) sample vital registrations with verbal autopsy, 4) health facility statistics, and 5) decennial census.
- B) Special opportunities (surveys and surveillances): surveys capture data at a single point in time, with such methods including direct and indirect sisterhood methods, household surveys, and sampling at service sites such as antenatal care. Regular surveillances makes continuous and repeated household visits to note changes in vital events [demographic surveillance sites (DSS) and active surveillance of reproductive age female deaths (RAMOS)] [39]. Unfortunately, these passive-routine methods are incomplete or non-existent in many developing countries. In addition, many of the survey and surveillance methods classified under special opportunities need a large sample size that demand a high cost, and are often subject to sample biases.

Analytical methods (modelling to estimate MMR, capture-recapture methods to correct for under-reporting, and birth-death linkages to find maternal deaths) apply statistical techniques to reach estimates of maternal mortality from the values of other proxy variables. Statistically modelled estimates (especially that of the UN and the Institute of Health Metrics at Washington University) have been the main sources of information for global and national figures that can be compared across countries [5, 7]. The information has influenced international organizations and national governments in low-income countries for planning resources and actions. However, inconsistencies and controversies using these methods resulted in calls for responsible estimations [57].

The advantages and shortcomings of these alternative methods is well described by Graham and colleagues [39], and there are many works on measuring maternal mortality in resource-limited settings [15, 16, 38, 39, 44]. Furthermore, realizing the shortcomings of the routine and active data collection methods for maternal mortality, modification of the national census is proposed as a feasible and efficient opportunity [16]. The proposal suggested the inclusion of additional questions in the census that ask about maternal mortality in the previous 12 months before the national census [58]. Consequently, some countries have used the census with maternal death questions, and estimates have been released [59].

However, there are no standardized methods that can be universally applied to monitor maternal mortality in all settings. As such, the methods can be weighed based on the purpose of the data, time urgency, and feasibility [38]. For example, knowing how mothers die from bleeding in an area may need a case-by-case assessment of these deaths. Yet, a study to improve the quality of obstetric health facilities can review maternal deaths and disabilities that occurred in health institutions. Moreover, aiming to measure the magnitude and differentials of maternal mortality at the national, regional, or district level requires community-based studies. The ultimate goal should be routine and complete vital registration to measure maternal deaths [60]. Figure 1 below summarizes the methods for measuring maternal mortality.

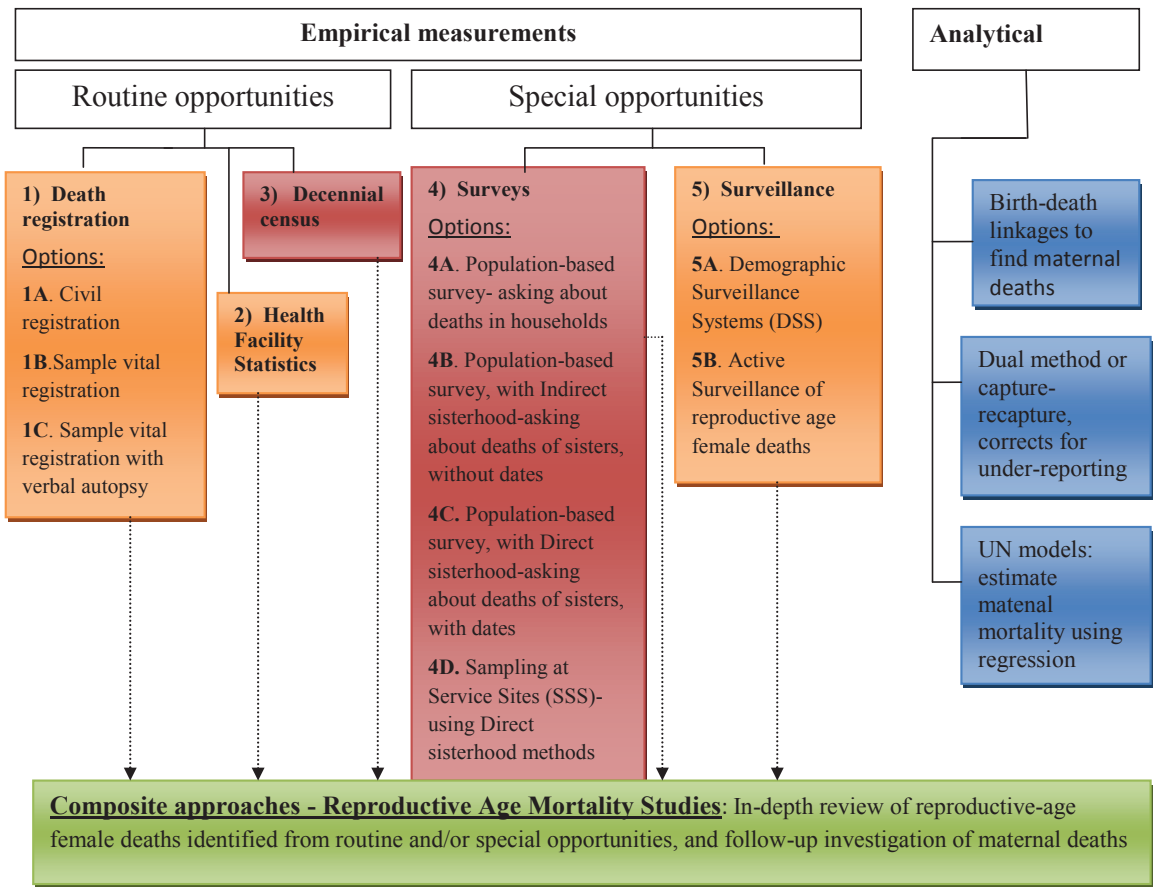


Figure 1: Options (methods) for measuring maternal mortality in developing countries.

Source: Graham *et al.* *BMC Medicine* 2008 6:12, doi:10.1186/1741-7015-6-12 [39]

1.4 Historical overview of policy and progress in maternal mortality

1.4.1 Early experiences and lessons learned

Evidence shows that even before modern medical interventions such as antibiotics, blood transfusions, and caesarean sections were available, effective measures were in place that reduced maternal mortality in northern European countries such as Sweden, Norway, Denmark, and the Netherlands. For example, in 1900, the MMR in Sweden was 230 per 100,000 live births, compared to 700 in the US and 400 in England and Wales [61]. In Sweden, individual health data (births, deaths, marriages, and migrations) have been registered since 1749, building on pre-existing registrations of births and deaths through churches. The Swedish Health Commission issued the first national maternal mortality report in 1751: an MMR of 900 per 100,000 live births. This information system enabled a recognition for the possibility of avoiding 400 out of every 651 maternal deaths (“avoidable maternal death”) if trained midwives were available for pregnancy and birth care [62]. As a result, the Swedish Government responded by training and deploying midwives in every village, thereby strengthening the information system. This resulted in an MMR of 230 per 100,000 births in 1900. Other developed countries learned that the good experience in Sweden was the result of an availability of midwives, and subsequently implemented midwifery training and licensing.

Consequently, in most developed countries the years 1950-1960 marked a uniformly low level of MMR (<100 per 100,000 live births) [61]. The decline in that period was associated with the invention of modern medical technologies such as antibiotics, blood transfusions, and caesareans in addition to a focus on midwifery care. Still, technologies have not been the only factors responsible for the effective decline in maternal mortality, as other important elements have helped these countries. On the one hand, there were social movements that constituted medical professionals and women’s rights groups that seriously campaigned to bring maternal health into the focus of governments.

For example, in England, confidential inquiries into every maternal death and subsequent improvements helped to see substantial reductions in maternal deaths [63]. On the other hand, the availability of information, professional commitments, and policy and technical supports

for maternal health have helped bring an early reduction of maternal mortality in some developed countries, while causing delays in others [54]. The governments of northern European countries were successful because of their timely response to the information they had, as well as the public pressures they faced for a reduction of maternal mortality [64].

1.4.2 The 1980s to the present: from Alma Ata to the MDGs

In developing countries, a high maternal mortality continued for decades in part because of a lack of information until the late 1980s when the international community began to understand the problem. Accordingly, in 1978, the WHO and UNICEF sponsored the International Conference on Primary Health Care (PHC) in Alma Ata [65]. Countries made statements to address the social, economic, and political causes of ill health, in addition to health service delivery. The aim was to provide basic health services that were affordable, accessible, acceptable, and useful for poor people. However, this novel initiative later shifted to selective interventions that depended on technological solutions such as child immunization, growth monitoring, and family planning [66].

The shift resulted in “vertical” programmes such as family planning, and lacked a meaningful intervention that addressed obstetric (clinical) causes of maternal deaths. As a response to a lack of information, the WHO, with funding from UNFPA, supported the first community-based study in 1985 on maternal mortality. The findings of the study and information from vital registration estimated that approximately 500,000 maternal deaths occur each year in the world, of which 99% was in developing countries [67]. Halfdan Mahler, the then WHO director-general, explained that the “*main reason for such a striking gap of maternal mortality rate between developed and developing countries was that until lately the size of the problem was not known*”. Subsequently, he explicitly called for the importance of information as “*sound estimates based on new data are thus the foundations for our current understanding of the concern*” [4].

In 1987, the WHO, UNFPA, and the World Bank jointly sponsored the first international safe motherhood conference in Nairobi, Kenya. The conference marked the formal initiation of the Safe Motherhood Initiative (SMI), aiming to reduce maternal mortality by 50% in 2000 [68]. At that time, people perceived that maternal mortality was a “neglected tragedy” compared to attention given to child health, in which Allan Rosenfield and Deborah Maine produced a powerful article entitled “*Where is the M in MCH?*” (the M refers to “maternal”

in MCH, maternal and child health) [69]. In 1989, the heads of states and representatives of influential organizations attended the World Summit for Children in New York, in contrast to the small amount of attention given to the maternal conference in Nairobi. In the New York conference, maternal health was addressed in the context of helping child survival as opposed to the independent agenda for the mothers [54].

Meanwhile, maternal health advocates considered maternal mortality as a human rights issue, and campaigned for government accountability and proposed broader approaches such as reproductive health and rights [54]. Even so, because of the donors' need to see the measured effects of the money spent, two components of safe motherhood elements (antenatal screening and TBA training for delivery attendance) got more attention in the first decade following the SMI initiation [70]. Nevertheless, in subsequent years it was widely recognized that both of these strategies had little effect on reducing maternal mortality, and diverted attention from midwifery care and hospital emergency obstetric services [70-73]. The reason why antenatal screening and TBA delivery had little effect was that the risks of maternal mortality are concentrated around labour and delivery, in which antenatal screening cannot capture these risks. In addition, TBAs had limited skills and technologies to tackle major killers such as bleeding, eclampsia, infection, and obstructed labour [68]. For this reason, the 500,000 global maternal mortality rates remained for a long period of time. In the meantime, experts argued for skilled attendance at birth and emergency obstetric care as a critical strategy to reducing maternal mortality [74, 75], which was later adopted as a key strategy for MDG5. However, as positive contributions, the SMI helped to increase the commitments of organisations of health professionals such as nurses, midwives, and gynaecologists for maternal health [54]. Additionally, non-governmental organizations also contributed and learned important lessons by working with communities in developing countries [76].

Subsequent to this, the 2000 MDG declaration was considered to be the greatest political attention that maternal mortality has received, in which 189 heads of states agreed on eight Millennium Development Goals (MDGs), of which the MDG5 was committed to a reduction of maternal mortality [77]. The goal of winning global policy attention was to motivate resource (financial) commitments and health systems strengthening. Yet, studies showed that there is a large resource gap between what is needed and what is available to help reduce maternal mortality [78-80]. One study suggested a an annual average increase of 3.9 billion USD over 10 years to meet combined maternal and new-born health needs [80].

Unfortunately, maternal mortality reduction was not a priority agenda for years in many developing countries [81], so the general feeling among the maternal health community was that maternal mortality instead remained an orphan agenda [82-84]. As such, although general estimates show that global MMR has been declining, the pace is slow and there is no concrete evidence of acceleration, which runs the risk MDG5 being the least likely achieved MDG goal by 2015, especially in sub-Saharan Africa [85].

Shiffman and Smith summarize the determinants for a relatively low amount of attention being given to safe motherhood [86]:

- 1) Actor power — the power of individuals and organizations that deal with maternal problems;
- 2) Idea power — the way the problem is understood and portrayed to the public and policy makers;
- 3) Political context — the political environment in which the actors operate; and
- 4) Issue characteristics — the feature of the problem (magnitude, severity, easy solutions).

Maternal mortality received less attention because of a relative rarity in absolute numbers compared to the high number of deaths from tuberculosis, malaria, AIDS, and child diseases that compete for policy attention and resources. In addition, it also lacked powerful actors (leaders) and convincing ways of delivery of message about the problem [86].

1.5 Determinants of maternal mortality

1.5.1 Theoretical framework

The survival of a pregnant woman depends on a diversity of complex factors, and not merely health services. It starts from the conditions in the time of her own birth to the environment she was brought up in including nutrition, diseases, culture, education, and mental satisfaction. Whether her pregnancy is wanted and healthy or not, also affect the outcome. Furthermore, the socio-economic factors are also important determinants of maternal health because maternal mortality is associated with factors such as education, economic backgrounds, and sex discrimination (a lack of reproductive autonomy) [87]. Poor women are less likely to have a formal education, less power on economic decisions, and are less likely to receive maternal care [88].

James McCarthy and Deborah Maine [89] give the theoretical framework for the determinants of maternal mortality in three categories:

- 1) **Distant (socio-economic and cultural) factors** such as woman's status in the family and community, her family's status in the community, and the development of her community
- 2) **Immediate determinants** such as a woman's health status, reproductive status (age, parity, marriage), access to health services, and utilization behaviour
- 3) **Pregnancy outcomes** (complications)

Thus, efforts to reduce maternal mortality need to focus on: 1) reducing the chances of a woman becoming pregnant; 2) reducing the probability of a pregnant woman developing complications; and 3) improving the outcomes for women with complications [89].

Figure 2 below describes the relationship between the three determinants of maternal mortality:

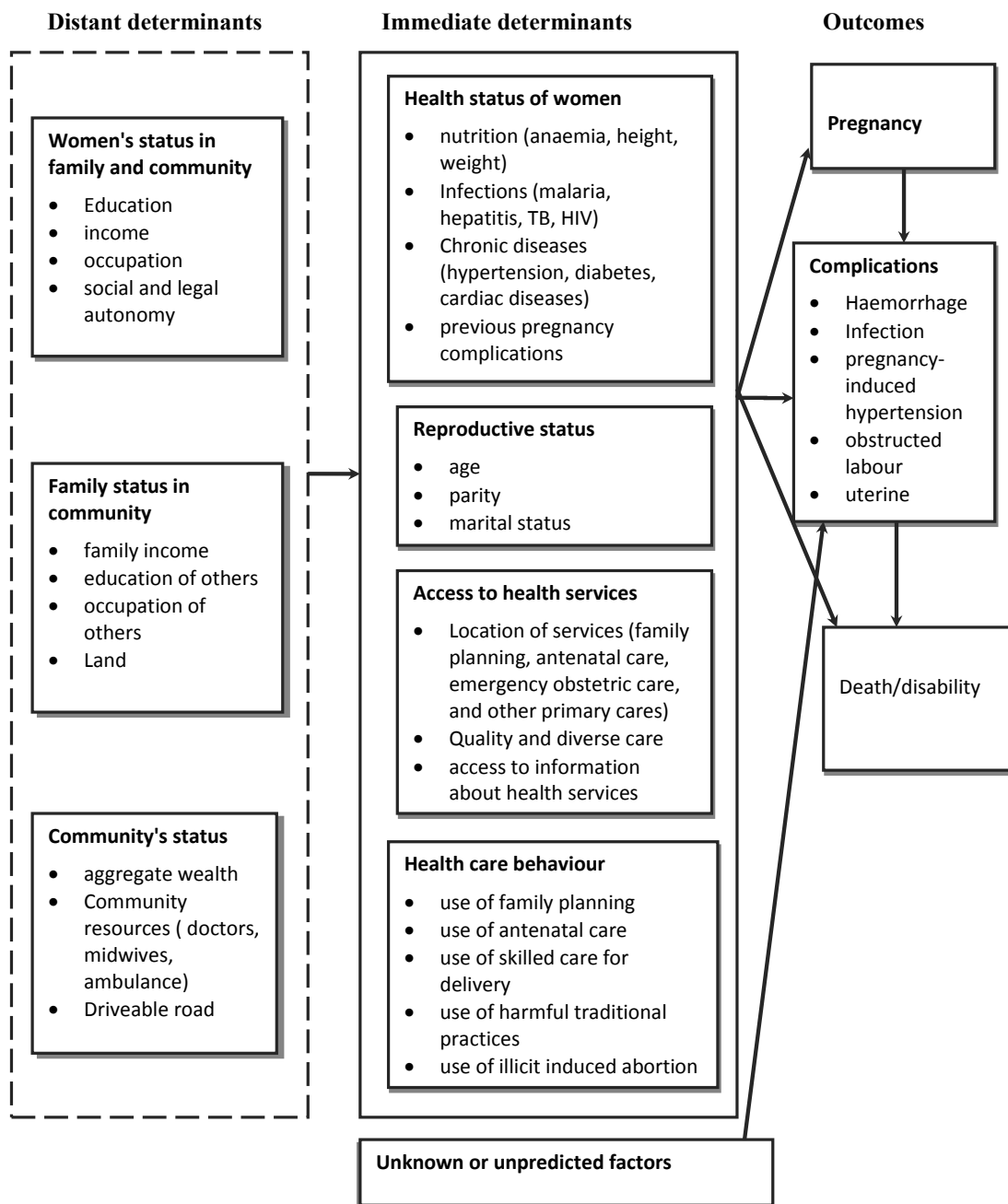


Figure 2: A framework for analysing the determinants of maternal mortality and morbidity.

Source: McCarthy J, Maine D (1992), reference [89]

1.5.2 Access to health care or poverty: Which matters most for maternal mortality?

Research findings demonstrate the links between poverty and maternal mortality, i.e. maternal mortality is higher among women in lower socio-economic classes [90]. Nevertheless, poverty does not always explain the level of maternal mortality. Historic evidence from western countries suggest that the overall standard of maternal care is more important than poverty in determining the level of maternal mortality [91]. There were exemplary community-based house-to-house maternal care services, which remarkably reduced maternal mortality in people of a low socio-economic condition in developed countries. These services include the midwifery service of the “Queen’s Institute of Nursing” in England and Wales from 1920s to the 1940s, and US midwives in the “Kentucky Frontier Nursing Service” from the 1920s to the 1930s [91]. In the communities where these services are provided, maternal mortality exhibited a marked decline compared to mortality levels in better-off social classes who received hospital services given by physician services (MMR of 66 vs. 800-900) [61, 91].

As such, mere access to health services in which modern technologies are available, does not guarantee good maternal outcomes. Other evidence also shows that in Britain in the years from 1870 to the 1940s, interference of labour by physicians in terms of an overuse of forceps and chloroform has been suggested to have caused higher maternal mortality rates among higher social classes [92].

In some developing countries as well, better commitment to health service provision resulted in good outcomes. Evidence from developing countries showed that despite an equally low level of economic development, some countries achieved a low level of maternal mortality, while others with a similar economy had up to 10 times a higher mortality. For example, in the 1990s the gross national product (GNP) in terms of purchasing power parity (PPP) for Vietnam, Lesotho, Central African Republic, and Nepal was between 1,000 and 1,200 USD (almost similar), although their MMR varied from 160 in Vietnam to 1,500 in Central African Republic (CAR) [61].

In general, poverty plays an important role by denying availability and access to health services that put poor mothers at a greater risk of death without any prioritized action to make health services accessible to the poor [93]. Consequently, a study done in over 50 countries

shows that more than 80% of births for the richest women is attended by skilled assistants, while only 34% of poorest women received the similar service [94]. In conclusion, access and utilization of standard maternal care have the potential to reduce maternal mortality, irrespective of household or national poverty levels.

1.6 Interventions for maternal mortality reduction

The knowledge of what works in reducing maternal mortality has two components: first, the knowledge of what interventions work to prevent a particular woman from dying (single intervention or packages of interventions for a single woman) and second, what strategies work to distribute these proven interventions to the public to help reduce maternal mortality at the population level [47].

1.6.1 Single or packages of interventions

Interventions proven to increase the survival of individual mothers include: infection prevention, antibiotics, blood transfusions, anticonvulsants, drugs that enhance the uterine contraction to reduce bleeding, and operative interventions (caesarean sections and repair of a ruptured uterus) [95]. Packages of interventions used to save the life of a woman suffering from severe bleeding include skills such as the manual removal of retained products, administering oxytocic drugs, blood transfusions, and caesarean sections. Because of this, the introduction of successful interventions (especially antibiotics, caesarean sections, and blood transfusions), and an effective public health strategy (midwifery care), helped to reduce maternal MMR from more than 1,000 to less than 10 per 100,000 live births in developed countries [96].

1.6.2 Strategies to distribute proven interventions to the public

There is no single strategy to supply these proven interventions to many mothers who need them. In addition, translating what works in one place to another is complex because of the diverse nature of area contexts and the multiple determinants of maternal health. Thus, merely ensuring the availability of essential maternal care at health facilities may not

guarantee the reduction of maternal mortality. Other factors such as a low utilization of the services and over-medicalization (iatrogenic factors) may also play a role [97].

Maternal mortality reduction will work by using strategies that combine proven interventions with distribution mechanisms that achieve a high coverage in the community [96]. To achieve a high coverage, a given intervention should be distributed through several strategies, e.g. contraceptive pills through health facilities, community health workers, social marketing, misoprostol for severe bleeding through community health workers and health facilities instead of restricting these to only health institutions. Instead of sticking to only facility-based care [96], skilled intrapartum care at home, health centres, and hospitals, are some of the mix of distribution strategies for a better achievement.

Accordingly, some developing countries that implemented effective distribution strategies for these interventions have rapidly reduced their maternal mortality [98]. For instance, Thailand, Malaysia, and Sri Lanka halved their MMR in less than 25 years [98-101]. In other developing countries a fast reduction of MMR has been registered over the period of less than a decade; Egypt reduced its MMR by 50% between 1992/93 and 2000 [102], whereas Honduras decreased by 40% between 1990 and 1997 [103].

However, some strategies used in developing countries to reduce maternal mortality were less effective and had a limited impact. Examples include community-based primary care, such as antenatal screening and the use of traditional birth attendants (TBAs). Primary care strategies can help to treat acute child diseases such as acute diarrhoea by oral rehydration, but it is still difficult to manage obstructed labour or severe the bleeding at the remote area [104]. No amount of antenatal screening can predict bleeding, infection, and high blood pressure that will occur during labour and delivery, and TBAs are not able to manage these acute conditions [105]. Community strategies that provide emergency obstetric care, such as health centre-based intrapartum midwifery care backed by comprehensive care at hospitals, is currently underscored [106].

1.6.3 Skilled birth attendance (SBA) and emergency obstetric care (EmOC)

The current globally recommended strategy to reduce maternal mortality is to provide access to basic emergency obstetric care. These are primarily intrapartum care strategies focusing on health centre-based skilled attendance at birth backed by a referral mechanism to connect to comprehensive obstetric care at hospitals. The World Health Organization (WHO), the International Confederation of Midwives (ICM), and the International Federation of Gynaecology and Obstetrics (FIGO) jointly define a skilled birth attendant as follows: “*A skilled attendant is an accredited health professional — such as a midwife, doctor, or nurse — who has been educated and trained to proficiency in the skills needed to manage normal (uncomplicated) pregnancies, childbirth, and the immediate postnatal period, and in the identification, management, and referral of complications in women and newborns*” [74].

Using skilled attendants, health centres are required to provide seven signal functions of basic emergency obstetric care (BEmOC) recommended by the WHO [107].

These signal functions are:

- 1) Assisted vaginal delivery;
- 2) Manual removal of the placenta;
- 3) Giving uterotonic drugs such as parenteral oxytocin, ergometrine and misoprostol (medicines that make uterus contract and prevent bleeding);
- 4) Administration of anti-consultants such as magnesium sulphate for women diagnosed with pre-eclampsia and eclampsia;
- 5) Removal of retained products using manual vacuum (MVA) aspiration or dilatation and curettage (DIC);
- 6) Administration of parenteral antibiotics; and
- 7) Newborn resuscitation.

In addition, hospitals should be available for referrals, and be able to provide comprehensive emergency obstetric care (CEmOC). CEmOC is the provision of all the seven functions mentioned above as well as two advanced functions:

- 1) Caesarean section (operative delivery); and
- 2) Blood transfusion.

An accessible health centre that consistently provides these signal functions, using professionals with midwifery skills backed by referral systems to CEmOC, can help reduce maternal mortality [96].

Misoprostol is another important intervention proposed for the prevention and treatment of postpartum haemorrhage (PPH) in remote areas. Studies have shown that the drug is clinically non-inferior to oxytocin (the current standard treatment), and can be distributed to mothers using community health workers [108, 109]. Moreover, misoprostol has two important advantages over oxytocin for use in rural areas: first, it does not require refrigeration for storing; and second, it has oral and sublingual forms that do not need a skilled person to administer unlike injections [110]. However, the fear of its potential abuse for purposes such as abortion and induced labour limits misoprostol's wider use for PPH [111].

1.6.4 Access (availability, acceptability, and affordability) to obstetric services

Strategies designed to distribute emergency obstetric services to a larger community of people in the rural areas of developing countries are problematic and often achieve low coverage. The principal factors are a shortage of skilled staff and equipped facilities for the large proportion of the population [112, 113]. Furthermore, the experience by women of services provided during facility delivery can define their future use [114]. As such, because of a low acceptability of services to the community, existing services are not effectively used. Women do not like to receive facility delivery services that are disrespectful, and in which their privacy concerns are not addressed [114]. In some places, mothers and the community perceive delivering at home as normal, and may not see the importance of going to a facility for childbirth [115].

Moreover, transportation is limited, and in many places getting to health facilities may be "too far to walk" [116], in addition to financial constraints [117-119]. Financial barriers are not only the fees for services, but also include a demand for side costs (non-facility costs). Such costs outside of the health service may become as high as half the cost of normal delivery, and introducing fee-free delivery service cannot change these non-service costs [76,

120]. Therefore, accessing and utilizing maternal services is affected by several factors, such as an availability of service, acceptability of the standard (quality and ethical handling) of service, and whether the users can afford to pay. Consequently, these access barriers may lead to either a delay in seeking skilled care or abandoning the services.

1.6.5 The three delays

Timely and quality treatment has the potential to avoid most maternal deaths. However, in resource-limited settings, delays before receiving health services are common. The three delays related to maternal health service utilization are [116]:

- 1) Delay at home before making decision to seek health care. This depends on an awareness of the benefits of service, the availability of financial sources, and family care.
- 2) Delays on the way before arriving at health facilities (between the decision and reaching the health facility), in which transport access and road conditions determine the speed.
- 3) Delays in health institutions before receiving adequate care (health provider delay), in which the availability of supply, staff attitude, and rules and procedures determine timely care.

1.7 Neonatal mortality and its relation to maternal outcomes

Neonatal mortality (newborn deaths in the first four weeks after birth) is a major public health problem, and its reduction depends on the quality of the health-care system. In 2009, an estimated 3.3 million neonates died in the world. Africa had the highest rate of death, and the slowest progress in terms of reduction [121]. The aforementioned amount is a sign of decline in neonatal mortality from 4.6 million in 1990. Nonetheless, because of a slow decline in neonatal deaths compared to an overall decrease in child mortality, the proportion of child deaths during the neonatal period has increased in all parts of the world. For instance, the neonatal share of child mortality increased from 37% in 2000 to 41% in 2008 [122].

Most newborn deaths (75% in 2008) occur in the first week of life, with the largest proportion taking place within 24 hours following birth (also known as early neonatal death). This highlights the critical importance of clinical care for the survival of the high-risk

newborn babies [122]. The main causes of neonatal mortality are preterm birth, severe infections, asphyxia, and neonatal tetanus [123]. Fortunately, there are effective solutions such as antibiotics, oxygen and assisted respiration, and incubation techniques that help tackle these deaths. The main challenge here is how to make available these proven interventions to the poor people in developing countries. For example, access to incubation and infection prevention and treatment techniques that help the survival of at-risk babies in advanced countries are limited in developing countries.

The health of newborn babies is also associated with the well-being of their mothers, which determines the level of feeding and the overall care the babies receive [124]. The implication of the association between maternal health and neonatal survival is that an integrated approach for the care of mothers and newborns is critical.

2 Maternal and neonatal health in Ethiopia

2.1 Ethiopia: The country

Ethiopia is a large country, with a total area of 1.1 million square kilometres in the eastern part of Africa. It shares borders with Sudan, south Sudan, Kenya, Somalia, Djibouti, and Eritrea. Ethiopia has the second largest population (88 million in 2014), after Nigeria [125], and the country is one of the ancient civilizations and is the oldest independent country in Africa. Even so, most of the population live in rural areas where health and other services are difficult to access. Economically, agriculture is the base of the economy (47% of the GDP share in 2013), which accounts for 85% of employment. Currently, there are pushes for diversifying the economy into manufacturing, textiles, and hydropower energy [126]. In recent years, the country has achieved a fast economic growth. However, according to the 2014 reports of the Human Development Index (HDI) [127] and the Multi-dimensional Poverty Index (MPI) [128], Ethiopia remains among the poorest countries in the world.

2.2 Health services in Ethiopia

Medical treatment was introduced to the country during the reign of Emperor Libne Dingel (1508-40) through foreign missionaries and travellers [129]. Later, Menelik II and Emperor Haile Sellassie promoted treatment in the same way. Haile Sellassie established the Ministry of Health, the first national health service, in 1947, and subsequent to this, the College of Public Health was opened at Gondar Town in 1952 with support from the WHO, UNICEF, and US-AID [129]. The Gondar Public Health College started to train a team of the first Ethiopia health professionals, which was comprised of public health officers at the degree level and community nurses and sanitarians at the diploma levels, and assigned in teams to health centres throughout the country.

Following the military overthrow of the Haile Sellassie government in 1974, the overall economic and social conditions deteriorated, and the plan to expand primary health care principles to the rural majority mostly failed. In 1991, the current Ethiopian Peoples' Revolutionary Democratic Front (EPRDF) government came to power and devised a new health policy that promoted a priority to health promotion, disease prevention, and equitable health service distribution to the areas with poor health service [130].

The current Ethiopian health service delivery system has four tiers (primary health-care units, district hospitals, zonal hospitals, and referral hospitals) [131]. The primary health-care unit is a combination of five satellite health posts and a health centre. Health posts are the lowest level, two-room buildings, which serve as offices and treatment places constructed in villages for an average population of 5,000 people, and are staffed by HEWs. Health centres provide curative and preventive services for approximately 25,000 people, with staff composition of health officers (people with four-year clinical and preventive health education at a university), nurses, midwives, laboratory technicians, and pharmacy technicians. Hospitals have medical doctors, in addition to other professionals with the specialty depending on the status of the hospital.

The Ministry of Health follows the work of Regional Health Bureaus and specialized referral hospitals. Regional Health Bureaus supervise regional referral hospitals and zonal health

departments; Zonal health departments follow zonal hospitals, district hospitals, and district health offices, while district health offices are responsible for the proper functioning of primary health-care units.

Since 2003, the year the Health Extension Program (HEP) was implemented, the outcome of the current policy has been widely appreciated. The HEP is based on placing two women, trained for one year in general health, in every village (with an average population of 1,000 households) in the country. As a result, Ethiopia made remarkable reductions in child mortality, and achieved an MDG4 target in 2012 [132]. What makes Ethiopia's HEP unique from community health worker systems in other countries is that the HEP receives an important amount of attention from the government. Approximately 30,000 rural HEWs (38,000 HEWs, including the urban version that followed later), were trained and deployed in five years. The government pays a salary, in addition to an established system of training, career, and supervision [133].

Furthermore, two other strategies of public mobilization linked to the HEP play an important role. The first strategy is a model family initiative, in which HEWs identify, train, and graduate families assumed to have adopted a healthy living behaviour. The second is the creation of the Health Development Army (HDA), a network of women who volunteer to identify bottlenecks in the use of essential health services within the community, and find local solutions for the problems by coordinating the efforts of the people [133].

2.3 Maternal and child health programmes in Ethiopia

According to the UN organizations (WHO, UNICEF, and UNFPA) and the World Bank joint estimate, MMR in Ethiopia decreased to 350 in 2010 from estimated 950 per 100,000 live births in 1990 [134], while the mortality ratio of children under-five years of age was reduced by two-thirds, from 204 to 68 per 1,000 live births between 1990 and 2012 [135]. However, the maternal mortality reports often conflict with each other and have wide confidence intervals, hence causing difficulty in observe the progress. For example, the DHS reported an MMR per 100,000 live births of 671 in 2005 and 676 in 2010, which is an unchanged rate. Moreover, according to the 2008 global maternal mortality estimate by the Institute of

Health Metrics and Evaluation (IHME), Ethiopia is one of the six countries that contributed to more than half of the maternal deaths in the world; the other countries were Afghanistan, Pakistan, India, Nigeria, and Democratic Republic of Congo [7].

Promisingly, however, the Ethiopian government puts a strong emphasis on the reduction of maternal mortality in its strategic health sector development plan (HSDP-IV), which is the fourth phase for 2010-2015 out of a 20-year vision [136]. The aim of the strategic plan was to strengthen skilled birth attendance, family planning, antenatal and postnatal cares, and emergency obstetric care. Emphasized interventions include an accelerated training of midwives, and improving the capacity of health extension workers. The accelerated training of midwives was comprised of two parts: Many who join regional health science colleges for three-year midwifery diploma training, and other who join universities for a four-year midwifery education. In addition, recognizing the skill gap of the HEWs for intrapartum care, the Ministry of Health began to upgrade HEWs to diploma level, with additional one-year training in midwifery, starting 2011.

Moreover, the implementation of a plan to accelerate the expansion of district hospitals to provide comprehensive emergency surgery is currently taking place. The new expansion aims to build 800 district hospitals, one for every district of 100,000 to 150,000 people. To respond to human resource shortages, two new programmes have been started: 1) Speciality training in surgery for non-physician clinicians (NPCs) who are health professionals with a bachelor's degree before joining the programme for three years 2) Four-year accelerated training of health professionals with bachelor's degree as medical doctors. In addition, there is an increased specialization of medical doctors.

Through these efforts, the Ministry of Health aims to cut the MMR per 100,000 live births to a level between 100 and 260 in 2025, further reducing this to a range of 45 to 53 in 2035 from an assumed MMR of 420 in 2014 [137].

2.4 Rationale of the study (the study in context)

Studies consume resources, and should be assessed for their importance (relevance). In other words, we should be able to answer questions such as: Is the topic of investigation really a problem?, Are there solutions to the problem?, Is the information obtained useful for any short- or long-term effects of the problem?, Can the study be applied in places other than the particular study setting? Regarding the aforementioned concerns, this thesis attempts to look into two key issues related to MDG5 targets. These are: 1) measuring the level of maternal mortality (the agreed indicator of progress towards the goal) and 2) assessing emergency obstetric services (the strategy emphasized to attain the goal). We conducted the studies under this thesis in areas in Ethiopia where information on these subjects was not well documented.

Maternal mortality is a great problem in developing countries; especially sub-Saharan Africa where Ethiopia is no exception. The reasons for high mortality are: 1) limited information about the problem for policy makers to give a priority to reducing the problem; and 2) a poor quality and low utilization of existing health services for pregnancy and childbirth care. The aim of MDG5 is to reduce the 1990 level of maternal mortality by 75% in 2015. Towards that end, the internationally emphasized strategy is emergency obstetric care. Unfortunately, with a few years remaining for the deadline of the MDG target when we conducted the studies, there was no sustainable community-based, real-time data to oversee progress in the level of maternal mortality and the status of skilled obstetric care in Ethiopia in general, and in south Ethiopia in particular.

From a practical perspective, measuring maternal mortality is difficult everywhere in the world and there is no universally agreed upon single method for obtaining perfect data [42]. However, the standard method (referred to as the gold standard) used by the developed countries is the regular registration of population events (births, marriages, population movements, and deaths) known as vital registration. In developing countries, vital registrations are rare and incomplete. The reason for a lack of registry-based data on births and birth outcomes is that the large proportion of population in these countries live in rural villages where health service and household information is difficult to access [138].

As a result, sample based household surveys that ask family members and relatives about deaths that took place several years ago were widely implemented. However, these small-scale surveys were not able to permit international and national estimates to help compare regions and countries. As such, another source of information, the statistical modelling of proxy data for national and international estimation, is widely practiced [5, 7]. The modelled data are important in providing an overview of the problem at the national level, though often with controversial results [57]. Moreover, they mask the local variations in mortality, and limit the efforts to establish sustainable data sources at local levels.

Ethiopia adopted the Health Extension Programme (HEP) as the Primary Health Care (PHC) strategy by training and deploying HWEs in every village (kebele) starting in 2003, which increased access to basic preventive and promotive health services. Consequently, Ethiopia registered remarkable health outcomes, such as an increased uptake of methods of fertility control and a reduction in child mortality that achieved the MDG4 target before the 2015 schedule [132]. Nevertheless, using that opportunity as a source of sustainable registry-based data to monitor births and birth outcomes has not been explored. Fortunately, Ethiopia is preparing towards the universal registration of vital events with the approval of a new national legislation in 2012 [139], and the findings in this thesis may be used as a learning step for implementation. The thesis reports the prospective community-based birth and birth outcome registration as a feasible tool to measure maternal mortality from a large rural community study using the Ethiopian HEP as an opportunity (Paper I). Given the universal presence of HEWs in all parts of Ethiopia, as well as sustainable and timely nature of data obtained through a prospective registration of births and birth outcomes, it can be applied throughout the country and in other developing countries with a similar community health system.

Yet due to the inherent problem in the complexity of measuring maternal mortality because of its under-reporting problem, the use of mixed methods is recommended to reach sound estimates [39]. Accordingly, with the aim of supplementing and comparing results from the birth registry with alternative methods, we used two additional surveys: A large household survey to measure maternal and neonatal mortality (Paper II) and the sisterhood method,

which is considered as simple and cheap for resource-limited settings. Several Asian and African countries applied the sisterhood method to estimate maternal mortality indicators [140, 141]. Still, it had a limited use in Ethiopia, and we did not know how a result from the sisterhood study compared to findings through other community-based methods (birth registry and household survey). To that effect, the thesis also applied the sisterhood method (Paper III) by including the simplified indirect sisterhood questions into a large household survey, as recommended by the developers of the method. Observations into inequalities (socio-economic and service-access variations) associated with mortality outcomes provide important information to help plan targeted interventions. However, such information is scarce in the study area and in the country at large. Two papers in this thesis (Papers I and II) attempt to look at selected factors associated with the maternal and neonatal mortality.

Most maternal deaths are preventable, and there are effective solutions to cut the problem. Nevertheless, we do not know the status (population coverage, quality, and utilization) of the UN-emphasized emergency obstetric care (EmOC) in the study area. Measuring maternal mortality without assessing the status of obstetric services does not give a complete image of maternal health conditions. To achieve that effect, the WHO prepared a universal guideline to help measure the status of EmOC and recommended the minimum standards for the service. Using the UN tool, we assessed the status (coverage, quality, and utilization) of EmOC in a population of nearly two million people (Paper IV). In addition, the studies in the thesis provide estimates of neonatal mortality (Paper II), and describe that neonatal survival was associated with maternal outcomes. Furthermore, we report socio-economic inequalities associated with mortality. As such, information in the thesis has important significance in helping understand the current level of mortality, to planning an improvement of the obstetric service, and to monitor future progress. Additionally, achievability of a high-coverage birth registry is an important lesson for future efforts in obtaining real-time, country-owned, locally available data.

3 Objectives

3.1 General objective

The overall aim of the thesis is to measure and compare maternal mortality using four different methods, and assess the coverage and quality of obstetric services in south Ethiopia in 2010.

3.2 Specific objectives

- I. To measure maternal mortality through establishing a community-based birth registry in all rural villages in three districts (Paper I);
- II. To measure the maternal and neonatal mortality and socio-economic inequalities in mortality outcomes using a household survey (Paper II);
- III. To estimate maternal mortality indicators using the sisterhood method (Paper III);
- IV. To assess the status (coverage, quality, and utilization) of emergency obstetric services and maternal mortality through a review of health facilities (Paper IV)

4 Methods

4.1 Study area and setting

The Federal Democratic Republic of Ethiopia has nine ethnic-based regional states and two city administrations. Regions are subdivided into zones (provinces), zones into woredas (districts) and woredas into kebeles (villages). A kebele is the lowest administrative unit in Ethiopia, with an average population of 5,000 people (equivalent to 1,000 households), whereas a woreda is a group of about 20-70 kebeles. Papers in this thesis used studies done in two zones of the Southern Nations Nationalities and Peoples' Regional State (SNNPRS) in Ethiopia (Gamo Gofa and Segen Area People's zones); Figure 3 shows a map of the area:



Figure 3: The map of the study area in Southern Nations Nationalities and Peoples Regional State (SNNPRS) in Ethiopia.

Gamo Gofa is one of the remote areas in Ethiopia with Arba Minch, the central town, located 505 km south of Addis Ababa. The Segen Area Peoples' zone is also a similar adjacent zone with Segen, the centre, being 575 km from Addis Ababa. In 2010, the Gamo Gofa zone had a population of 1,740,828 people living in two town administrations and 15 woredas, while the Segen Area Peoples' zone had 636,794 people in five woredas [142]. The birth registry study (Paper I) was conducted in three woredas, two in Gamo Gofa (Bonke and Arba Minch Zuria) and a third (Derashe) in the Segen Area Peoples' zone. Two studies (Paper II and III) were conducted in the Bonke woreda in Gamo Gofa. One study (Paper IV) was conducted in all three hospitals and 63 health centres in Gamo Gofa.

Bonke has a health centre in Geresse, the central town, and three new health centres in Gezeso, Shalakaye, and Dembile. However, no health institution provided comprehensive emergency obstetric care, and there were no doctors when we collected the data. The nearest comprehensive EmOC service was at the Arba Minch Hospital, which is 70-120 km depending on which village you are driving from in Bonke. However, most of the Bonke population live in inaccessible mountainous villages.

The Arba Minch Zuria woreda has two distinctly different populations: Most of the population live in mountainous highlands with poor roads and limited health service access from the health centres in Maze-Doysa and Zigiti. By contrast, the lowland population live closer to an asphalt road and closer to a relatively better-equipped health centres in Lante and Shele, as well as Arba Minch Hospital.

Derashe is 60 km from Arba Minch. The central town of Gidole has a district hospital with a maternity waiting area, where mothers with high-risk pregnancy can wait until delivery [143]. In addition, Derashe has four health centres in Gidole, Gato, Holte, and Busa.

The Health Extension Programme and the agents

In 2003, Ethiopia started the community-based health extension programme by training the health extension workers (HEWs). The first batch of the HEWs were deployed in 2004, and over 38,000 HEWs are currently working in the country (30,000 rural and 8,000 urban) [144].

The work of HEWs focuses on health promotion and disease prevention through regular home visits in their catchment area. In addition, they give a prioritized follow-up to households with pregnant women, newborn babies, and sick people. HEWs also provide antenatal examinations and delivery services both at home and health posts. Five to 10 laywomen from sub-kebeles, known as volunteer health promoters (VHP), assist the HEWs. VHPs receive a few days general training from the Woreda Health Departments, and work to provide timely information and organize schedules for HEWs [145].

4.2 Study designs and data collections

Table 2 below presents the summary of the design, the participants, and the period of the studies. For Paper I, we prospectively registered birth and birth outcomes involving over 200 HEWs in 75 kebeles in three woredas, covering a total of 421,639 residents. Each HEW is responsible for about 500 households. Accordingly, a HEW is expected to register six-seven births per week. Starting in January 2010, we kept a printed registry book for each HEW. They registered information in two copies, transferring the first copy to the Research and Training Centre at Arba Minch Hospital, with the second remaining in the kebeles with the book. HEWs registered most of the births on the date of birth except for a delayed registration of births at hospitals and in places other than the villages of residence. HEWs made follow-up household visits after delivery on the 28th day to record the neonatal outcome (surviving or died), and on the 42nd to 45th day to learn about maternal survival. The conventional last day of observation is day 42, but we allowed three more days to give room for HEWs when they were busy. However, most maternal deaths were reviewed and recorded on the day they occurred.

The study in Paper II used a cross-sectional household survey in 15 randomly selected of 30 rural kebeles in Bonke. In February 2011, data collectors (who all completed the 12th grade) visited all households, asking if the household had births and pregnancy outcomes in the previous five years (between January 2006 and December 2010). They completed interviews in 6,572 households that had births and pregnancy outcomes out of 11,920 households visited. We purposely selected data collectors from their respective kebeles of residence because by living and participating in social events, they remember most of the births and birth outcomes that have occurred in their kebeles. We aimed to minimize an under-reporting

of deaths, especially those of neonatals because of recall-bias and the cultural values attached to the death of a newborn baby in the area. In the ethnic “Gamo” culture, the birth of a dead foetus and the early death of a newborn are not publicized, and are not publicly mourned. Only close relatives and family members are informed, while other people are told about the incident that “something went wrong”, as expressed in local terms. This can make it difficult for an outsider to distinguish between a neonatal death and a stillbirth. The Principal Investigator (PI) and five college graduates supervised the interviewers.

In Paper III, we conducted a cross-sectional interview among 8,870 respondents, of which 8,503 (96%) provided complete answers. To collect the data, we used the standard questions of the indirect sisterhood study [146] to ask both adult men and women during household visits. A retrospective cohort analysis of risk exposure among respondents' sisters was done using adjustment factors developed by demographic survival methods. The information about risk exposure and the number of pregnancy-related sister deaths was used to determine the lifetime risk of a woman's death. By using the lifetime risk and total fertility rate, we calculated the corresponding MMR.

For the fourth study (Paper IV), we conducted a one-year (July 2009 to June 2010) retrospective record review in all three hospitals and 63 health centres in the Gamo Gofa zone. We used a questionnaire developed by the WHO to monitor the coverage and quality of emergency obstetric care in health facilities [107], and 15 graduating class health officer students (one in each woreda) collected the data after two-days of training. The data collectors reviewed birth registry logbooks, admission and discharge books, charts, and monthly reports to the government. In addition, they interviewed professional and coordinators responsible for obstetric services on the availability of important service packages, drugs, and procedures performed in the previous three and 12 months. Data collectors visually observed the drug and equipment stores, and recorded the availability of items such as blood and drugs. We calculated the catchment population of the respective facilities based on the population information used by the Zonal Health Department and woreda Health Offices.

Table 2: Summary of study designs and participants

Paper	Title	Study design	Participants	Data collection
I	Maternal mortality measured through community -based birth registry	Prospective birth registry	10,987 births among 421, 639 residents in 75 kebeles in 3 woredas of 2 zones	January to December 2010
II	Maternal and neonatal mortality measured through household survey	Cross-sectional study	11,762 births between January 2006 and December 2010 in 6,572 households in randomly selected 15 kebeles	February 2011
III	Maternal mortality indicators estimated through the indirect sisterhood method	Cross-sectional study	8,503 respondents reported 22,473 sisters; resulting in 8,068 sister-units exposed to risk	February 2011
IV	Assessment of the coverage and quality of obstetric services	Retrospective record review	All 63 health centres and 3 hospitals in Gamo Gofa were assessed for obstetric services provided between July 2009 to June 2010	November to December 2010

4.3 Data analysis and statistics

We used descriptive statistics to present data as proportions (education among mothers, fathers, proportion of received antenatal care, delivered in health facilities...), ratios (MMR, NMR), and means with standard deviations (ages, number of pregnancies, distances from roads, health facilities). We also did a logistic regression analysis to determine the effect of selected independent (predictor) variables on the binary dependent (outcome variables). To test goodness of the model fit to the data, we used Hosmer-Lemeshow statistic. The regression model had good fit to the data if Hosmer-Lemeshow had a significance value > 0.05 . We reported results in terms of OR with confidence intervals (95% CI). A predictor variable with the effect size (value), for example, OR, and a CI that did not cross the null value of 1, was considered to have a statistically significant association with the outcome variable (Paper II).

We performed a principal component analysis (PCA) based on 10 household-asset variables to construct a wealth index for each of the 6,572 households studied (Paper II). For each asset variable, we calculated a mean, standard deviation, communality, and its factor score on a component that the variable was associated with. In the model, we included asset variables with the highest mean score (>0.20), as recommended by Vyas and colleagues [147]. We used the wealth index based on the first component, which explained 20.6 % of the variations explained by the variables, and the Eigen value was 2.06. We also used a chi-square (χ^2) test to assess the relationship between the maternal mortality outcome and selected variables (Paper I). The result is reported by a χ^2 value with a degree of freedom (df), and a P-value. A significant relationship of a variable with maternal mortality was set at a P-value of 0.05 or smaller.

In Paper III, we used a lifetime risk analysis to determine the risk of a maternal death in the study area. We used an inflation factor to determine the final number of surviving adult-sisters for the younger respondents (15-24 years of age). This was done by multiplying the number of respondents in the young age groups by the average number of sisters among the older respondents (25-49 years of age) [146]. The inflation factor was used with the assumption that the younger respondents had sisters who had yet to reach reproductive age. This provided the expected proportion of sisters that would have finished their reproductive age for respondents in each age category. Thus, 90% of the sisters of respondents from 45-49 years of age are expected to have passed through their reproductive life, but only 10.7% of the sisters of 15-19 year-old respondents. The purpose of the adjustment was to determine the number of sister units exposed to the risk of maternal death, which serves as a denominator for lifetime risk calculation [148].

To assess the correlation of midwife- to-population ratio against the proportion of institutional deliveries in woredas, we used Pearson's product moment correlation test and the result was reported by the correlation coefficient (r) and the P-value (Paper IV). We entered, checked and analysed most of the data using the Statistical Package for Social Sciences (SPSS-16) [149] (Papers I, II, and IV). We also used Open Epi — Open Source Epidemiologic Statistic for Public Health (openepi.com) for chi-square tests and two-by-two

table analysis (Paper I). Excel spread sheets and manual calculators were also used in Paper III (Table 3 below summarizes the main statistical methods used):

Table 3: The main statistical analysis used in the papers of the thesis

Statistical methods	Papers
Logistic regression analysis	Paper II
Principal component analysis (PCA)	Paper II
Lifetime risk of mortality analysis	Paper III
Pearson product-moment correlation	Paper IV
Descriptive analysis	Papers I, II, III, and IV

4.4 Ethical considerations

The Ethical Review Committee for Health Research in the Southern Nations Nationalities and Peoples' Regional State (SNNPRS) Health Bureau in Ethiopia, and the Regional Committee for Health Research Ethics of North Norway (REK Nord), approved the studies included in this thesis. In addition, the research review committee of Gondar University in Ethiopia approved the fourth study (Paper IV). We also obtained permission from the Gamo Gofa Zonal Health Department in writing to the Woreda Health Offices where they provided good cooperation (ethical approvals are attached in the appendix).

In Paper I, the HEWs, as part of their routine work, are expected to visit all households in their catchment area, with a priority to households with pregnant mothers, newborns, and sick persons. Hence, they are expected to record vital events such as births and deaths. We further systematized and standardized the HEWs' routine work by printing a birth registry book, supervising their registration, and giving feedbacks and refresher training. For the household and sisterhood surveys in Paper II and III, we obtained informed verbal consent from the heads of households or other adult respondents. Personal identifiers were removed from the data, and all the data are stored in a secured computer at the Research and Training Centre in the Arba Minch Hospital in south Ethiopia. We have not included minors in our studies.

5 Results

5.1 Maternal mortality measured through community-based birth registry (Paper I)

We aimed to establish and assess the feasibility of birth registration in three districts, with nearly half a million people and use the registry as a tool to measure maternal mortality.

We registered 10,987 births, 81% of the expected 13,492 births (annual CBR of 32 per 1,000 population) among 421,639 people in 2010. Out of the registered births, 90% (9,863) delivered at home, 4% (430) at health posts, 2.5% (282) at health centres, and 3.5% (412) in hospitals. We recorded 10,833 live births and 53 maternal deaths, (an MMR of 489 per 100,000 LBs). Among the maternal deaths, 83% (44/53) occurred at home. Five mothers (9.4%) died during pregnancy, 21 (39.6%) during labour, and 27 (51 %) during the post partum period. Most of the dead mothers [19 (35.8%)] had bleeding with two of them related to abortion, 12 (22.6%) to fever, 9 (17%) to convulsion, and 7 (13.2%) with a history of obstructed or prolonged labour.

The MMR increased if male partners were illiterate (609 vs. 346, $p=0.051$), the villages had no road access (946 vs. 410, $p=0.039$), and mothers complained of illness during pregnancy (1763 vs. 306, $p<0.0001$). A validation study of house-to-house survey in 15 of the registry villages after eight months of registration showed that births in 71.6% (1,718) of the surveyed 2,401 households were registered with similar a MMR between registered and unregistered (474 vs. 439). The findings of the validation study therefore helped to improve registration coverage based on feedback discussions.

5.2 Maternal and neonatal mortality measured through household survey (Paper II)

The aim of this study was to measure maternal and neonatal mortality and socio-economic inequalities in these outcomes through a household survey of pregnancy and birth outcomes in the five previous years before the survey.

We found 11,762 births that occurred in 6,572 households within five years before the survey (average crude birth rate of 3.2% per year), including 11,536 live and 226 stillbirths. There were 308 neonatal deaths with a neonatal mortality ratio (NMR) of 27 per 1,000 LBs (95% CI: 24-30). We also identified 49 maternal deaths, yielding an MMR of 425 per 100,000 LBs (95% CI: 318 - 556).

Neonatal mortality was more likely to occur in the poorest households, with an adjusted odds ratio (AOR) = 2.84 (95% CI: 1.92-4.22); households headed by illiterates, AOR = 1.40 (95% CI: 1.06-1.86); far away from a driveable road (≥ 6 km), AOR = 2.82 (95% CI: 1.85-4.29); and households that had three or more births in five years, AOR = 3.35 (95% CI: 2.56-4.39). MMR was high in households in the poorest wealth quartile compared to the richest (850 vs. 250) per 100,000 LBs, OR = 3.35 (95% CI: 1.33-9.42). Households that had a maternal mortality were 11 times more likely to have stillbirths, OR = 11.6 (95% CI: 6.00-22.7), and seven times more likely to have neonatal deaths, OR = 7.2 (95% CI: 3.6-14.3). The average institutional delivery rate was only 3.7 % in the period between 2006 and 2010.

5.3 Maternal mortality estimated through the sisterhood method (Paper III)

The objective of the study was to estimate maternal mortality indicators (life time risk and maternal mortality ratio, as well as the proportion of maternal death out of the deaths of adult females [PMDF]) through using the simple and cheap indirect sisterhood.

We analysed 8,503 of 8,870 (96%) respondents who provided complete responses. Of the responding siblings, 5,262 (62%) were men (brothers) and 3,241 (38%) were women (sisters). The mean age of the respondents was 26.4 (SD, 8.7) years, ranging from 15–49. The 8,503 respondents reported 22,473 sisters (an average of 2.6 sisters per respondent) who survived to reproductive age and 2,552 died from all causes. Of the 2,552 sisters who had died, 819 (32%) occurred during pregnancy and childbirth. This retrospective cohort analysis provided 8,068 sister units exposed to the risk of maternal death, which served as the denominator for calculating the lifetime risk (LTR) of maternal deaths. The lifetime risk of

death from maternal causes was 0.102 (95% CI, 0.096-0.108) or 1 in 10. Using a total fertility rate (TFR) of 6.4 for south Ethiopia during the reference period for the estimate, we converted the LTR into an MMR of 1667 (95% CI, 1564–1769) per 100,000 live births. Because of the indirect nature of the sisterhood method, the time for this estimate goes back to 1998 (about 12 years before the data collection). A separate analysis of data from male and female respondents provided similar estimates of maternal mortality.

5.4 Obstetric services and maternal mortality assessed through health facility data (Paper IV)

In this study, we aimed to assess the coverage, quality, utilization status of EmOC and institutional maternal mortality using a standard tool prepared by the UN for EmOC assessment.

There were 4,231 pregnancy- and birth-related admissions over a period of one year (between July 2009 and June 2010) in all 66 health facilities (63 health centres and three hospitals) in Gamo Gofa. This provided a skilled birth attendance rate of 6.6% out of a total of 64,413 births expected during the year (CBR of 32 per 1,000 population). We recorded 79 (1.9%) maternal deaths out of 4,231 mothers admitted to the institutions. The approach through health facility data provided an MMR of 120 per 100,000 LBs (out of 64,413 expected births). This shows that approximately 25% of expected maternal deaths occur at health institutions if the MMR of 489 from the birth registry (Paper I) is considered a reference.

However, the variation in the proportion of maternal admissions and maternal mortality between institutions and districts was large. Districts with a higher proportion of midwives per capita, and where hospitals and health centres were capable of doing emergency caesarean sections, had higher institutional delivery rates. We counted 521 caesarean sections (0.8% of the 64,413 expected deliveries, and 12.3% among 4,231 admitted to institutions). Of the 66 health facilities, three health institutions (a hospital in Chench, and two health centres at Kamba and Mirab Abaya) met basic emergency obstetric care standards, and two hospitals (Arba Minch and Sawla) satisfied the comprehensive emergency obstetric care quality during the time of the study. These institutions served 1,740,885 people in Gamo Gofa in 2010.

Women were most often admitted to the health institutions because of postpartum haemorrhage (42%), obstructed labour (15%), and puerperal sepsis (15%). Remote districts far from the capital of the zone had a lower proportion of institutional deliveries (<2% of expected births compared to an overall average of 6.6%). Moreover, some remotely located institutions had very high maternal deaths (>4% of facility deliveries, which was much higher than the average of 1.9%, and the WHO minimum expectation of < 1% maternal deaths among facility deliveries to achieve the MDG5 goal).

Table 4: Summary of maternal mortality measurements described in the papers

Paper	targets	At risk	Maternal deaths	MMR per 100,000 LB	Maternal deaths at home	SBA ^x	Reference year
I (birth registry)	421,639 people	10,833 LBs ^y	53	489	44 (83%)	6.3%	2010
I (validation study)	2,401 households	1,698 LBs	8	474	-----	-----	2010
II (household survey)	6,572 households	11,536 LBs	49	425	43 (87%)	3.7%	2006-2010
III (sisterhood survey)	8,503 siblings	8,068 sister units exposed to risk	819	1667 (LTR of 1 in 10) ^z	-----	-----	1998
IV (facility study)	66 health facilities	64,413 births out of 1,740,885 people	79	120 (from births in the area)	237* (75%)	6.6%	2010
		4,231 Maternal admissions	79	1867 (among admitted)			2010

Note: SBA^x = skilled birth attendance (institutional delivery), LBs^y = live births

LTR^z = lifetime risk of pregnancy related deaths, * estimated number of maternal deaths

Additional results (not included in the papers)

A further stratified analysis on the household survey data (Paper II) showed that both education and wealth were independently associated with neonatal mortality. Nevertheless, a stratification of the data revealed that education modified the effect of wealth on neonatal mortality. In other words, when the association between wealth and neonatal mortality was analysed separately, for educational level, wealth was associated with neonatal mortality in only in households headed by illiterate adults, and there was no such association in households where the heads had education. This means that in the illiterate households, wealth may have had a positive effect in preventing neonatal deaths, but in the educated households whether wealthy or poor may have had no effect (Table 5). However, education had not modified the effect of distance from driveable road on neonatal mortality (data not presented).

Table 5 (additional results): The modifying effect of education on the association between wealth and neonatal mortality from household survey data, Bonke, Gamo Gofa, 2010

Strata (Education)	Wealth category	Neonatal mortality (in the household)		OR	95% CI
		Yes	No		
Over all (N= 6,453)	Richest 25%	31	1,322	Ref	Ref
	Rich 25%	124	1,685	3.14	2.12, 4.74
	Poor 25%	46	1,662	1.18	0.74, 1.89
	Poorest 25%	57	1,526	1.59	1.02, 2.48
Illiterate (n= 3,766)	Richest 25%	19	907	Ref	Ref
	Rich 25%	99	1,254	3.77	2.29, 6.20
	Poor 25%	28	805	1.66	0.92, 2.99
	Poorest 25%	32	622	2.46	1.38, 4.37
Educated (n= 2,687)	Richest 25%	12	415	Ref	Ref
	Rich 25%	25	431	2.00	0.99, 4.05
	Poor 25%	18	857	0.73	0.34, 1.52
	Poorest 25%	25	904	0.96	0.47, 1.92

Note: The household data had 6,572 cases (households) of which 6,453 had complete assets used in the wealth index construction

6 Discussion

6.1 Discussion of the methodology (design and validity)

6.1.1 Study design and sampling

Studies included in this thesis used different observational study designs. The main study design was a prospective birth registry (cohort) to determine maternal mortality (Paper I). Other designs were comprised of a cross-sectional household survey that used descriptive and analytical approaches (Paper II), a survey of a retrospective event of pregnancy-related deaths of sisters reported by surviving adult siblings (sisterhood method) (Paper III), and a retrospective record review in health facilities to help assess the status of emergency obstetric services and outcomes (Paper IV).

In general, epidemiological studies have two broader designs (experimental trials and observational studies). Experimental studies (trials) involve a random allocation of study participants (clusters in community trials and individuals in clinical trials) into intervention (exposed) and control (unexposed) groups before looking for outcomes. By contrast, observational studies observe the outcomes in naturally exposed and unexposed groups (cohort studies), examine the presence or absence of exposure in study participants who already have the outcome (cases) and do not have outcomes (controls) or look into both exposure and outcome at the same time (cross-sectional studies) [150].

For a particular study, the choice of the design depends on its suitability to answer a particular research question, the cost it demands, the length of time needed for the study, and whether a particular design can be applied ethically and logistically [151]. Accordingly, when the fundamental objective of a study is to assess the outcome of an intervention, randomized controlled trials (RCTs) are considered as the gold standards to determine causal relationships between exposure and outcome [152]. This is because randomization minimizes the problem of confounding by randomly distributing potential or known confounders into intervention and control arms.

Conversely, observational studies are perceived to be prone to the problem of confounding and bias. As such, evidence obtained through observational studies is considered weak compared to information from randomized trials. Even so, there are conditions in which randomization is unnecessary or inappropriate [153]. For example, in Paper II we aimed to describe the effect of household variables such as wealth, distance from a road, and educational status on maternal and neonatal mortality outcomes where randomizing households across these variables is not practical.

Observational studies can provide useful information about incidence (cohort studies), prevalence (cross-sectional surveys), risk factors (case-control), and health care needs of the people. Consequently, information from properly conducted observational studies can be useful for planning public health interventions, priority setting, and resource distribution [154]. In addition, findings from observational studies can help as initial steps to formulate intervention studies.

The cohort design is a natural equivalent of experimental studies because exposure happens naturally, unlike experimental studies where the investigator assigns the exposure. A cohort study follows exposed and unexposed groups until they develop an outcome of interest or the study time is completed and observation is stopped (censored), in addition to a loss-to-follow up of some participants [155]. Two directions can be used to observe cohorts from the time of a study (retrospective — where information recorded before the outcome occurs is reviewed and prospective — in which exposed and unexposed groups followed towards the future). A cohort study has two purposes: describing the incidence of outcomes (descriptive) and analysing associations between risk factors and outcomes (analytical) [156].

We used a cohort study design to prospectively follow women who terminate their pregnancy (by birth or abortion) until maternal death occurred or the follow up ended six weeks after the termination of pregnancy (Paper I). Due to the difficult nature of following what happens at each household in a short interval of time for the HEWs, the study was not concerned with time-to-event, but instead was concerned with the outcome of maternal death or survival within a six-week period. The predictor variables such as distance from health

facility, availability and quality of road facility between households and health institutions, maternal age, education of parents, and similar others were measured at baseline.

Active registration of births and birth outcomes is a standard procedure used by developed countries to measure pregnancy or birth outcomes. The birth registration can help the health system to conduct continued epidemiological studies on health services provided during pregnancy, childbirth, and neonatal period with the aim of improving the quality. Moreover, it can provide good data to study maternal and neonatal deaths, stillbirths, birth defects, and related adverse perinatal outcomes, as well as the causes of these outcomes [157].

The disadvantages of the cohort studies are that they take a longer time to do (especially prospective), are prone to a loss-to-follow up, and are expensive [155]. In the prospective birth registry study (Paper I), mothers were observed in their usual place of residence, while information on births that took place anywhere (at home, health institutions, or at the parents' home) was possible to record through their home with little chance for a loss-to-follow up. As a result, we have not lost registered births until the observation of maternal survival. Furthermore, the fact that this study was integrated into an existing health extension system and has not required additional salary for data collectors means it was not an expensive exercise. However, it required the low cost of a few days of training for HEWs, supervisors, and local health authorities gathered in their respective woreda centres. It also required a small cost related to the printing of registry books and supervisions.

The thesis also used a cross-sectional study design (Paper II) of a household survey. The challenge related to analytical results from cross-sectional studies is the limitation to determine whether the exposure or the outcome occurred first (temporality) [158]. Yet, with exposures that have known to be in place for predictably long time such as sex, race, and blood group, it is easier to infer the causality of an association when it exists. For example, in Paper II, having three or more births in five years was associated with neonatal mortality. However, it was difficult to know whether the death of the first or second children led to further births or whether the frequent births caused deaths due to poor care because of a competition for scarce resources. Similarly, the same study has showed that household wealth was linked with maternal and neonatal mortality. Nevertheless, we cannot clearly claim

whether the deaths required expenses for treatment before deaths occurred and caused poor wealth or whether a prior poverty existed in households, which created little resources for treatment and resulting deaths.

Still, household exposure variables, such as the educational status of the heads and distance from driveable road were likely to have been there before deaths occurred. This is because there were no observable adult education programmes and new road constructions in the study area in the same reference period of the study. As such, these variables were more likely to have existed before maternal and neonatal deaths and lack of temporality may not be a concern. Conversely, in Paper IV, the rate of facility delivery was higher in districts with a higher ratio of midwife-to-population. Nonetheless, it is difficult to characterize whether the presence of midwives increased facility deliveries or districts with higher number of facility delivery received more midwives.

Even so, the difficulty of ensuring temporality alone cannot rule out the importance of these associations. Some mechanisms to improve the worthiness of the findings are comparing the results for consistency with other findings and measuring the outcomes through different methods [156]. Consequently, though describing associated risk factors was mainly exercised in the household survey (Paper II), the results from the birth registry (Paper I) also showed that factors such as education and road access were associated with maternal mortality, highlighting consistency of associations.

Sampling issues

The size of the sample and selection methods is important to achieve enough power for a given study to reach reliable findings (precision). Studies included in this thesis have considered sample size, and in all the studies large number of participants were included. In the birth registry (Paper I) we registered around 11,000 births, in 75 kebeles in three districts with the exception of a few that had administrative problems (transferred to new districts), as well as in kebeles where HEWs were sick or in maternity leave. In the birth registry our aim was to find a perceived MMR of 531 (95% CI: 413, 669) and to determine group differences in maternal mortality based on socio-economic and access-related variables. However, the result after the study showed that the MMR was 489 (95% CI: 366, 628), which is within the

95% CI of what was perceived, and the MMR in villages without a driveable-road compared to villages with such a road was twice as high. We also used sufficient sample size in the household survey (Paper II) to find out about 11,000 births and their outcomes.

However, in both papers (Papers I and II), the unavoidable problem related to rarity (in absolute numbers) of maternal deaths caused wider confidence intervals. Practically speaking, the wider confidence interval around the estimates of MMR is a well-understood challenge, and precise estimates would be much expensive. Paper III used over 8,500 siblings interviewed in 15 randomly selected of 30 rural kebeles within Bonke. This amount of study size was well over the recommended 5,000 siblings for the indirect sisterhood study in a setting with a similar magnitude of maternal mortality and fertility [159]. In Paper IV, all of the 66 health facilities that were expected to provide basic and comprehensive emergency obstetric care (health centres and hospitals) were studied because the WHO suggests assessing all such institutions when the number of facilities are fewer than 100 [107].

Concerning the technique of sample selection, probability sampling (simple random, stratified, cluster, and systematic), is the gold standard. For this reason, making inferences about the population from observations made in samples assumes this standard technique has been applied [160]. However, health science studies also use non-random designs such as convenience sampling. Papers in this thesis used random techniques (Papers II and III) and included all eligible participants in purposely-selected areas (Papers I and IV).

6.1.2 Internal validity

Epidemiologic studies are measurement exercises that aim to obtain valid results (accurate and precise) with minimized error [150]. Precision (reliability) can be achieved by using a large sample size to minimize chance error. However, increased sample size cannot solve the problem of accuracy. Accuracy needs a careful design and analysis of the study to help minimize bias and confounding. Unfortunately, epidemiologic studies often appear to have random errors (chance) that affect precision, as well as systematic errors (bias and confounding) that influence accuracy. Systematic errors arise from three important sources:

selection bias (biased sampling), information bias (biased measurements), and confounding (false inferences on associations).

Random error (chance)

Random error is the extent to which sampling variability (chance) explains the observed association in the data. The role of chance error can be assessed using statistical techniques (significance tests and confidence intervals) and this type of error can be reduced by increasing the sample size [161]. Papers in this thesis addressed the role of chance by performing statistical tests appropriate for the measured effect sizes. Effect sizes such as Odds-ratio were reported together with a 95% CI, and chi-square tests were reported with the P-values as necessary. Hence, in Paper II, maternal mortality was statistically associated with few variables, which unlike neonatal mortality that showed a statistical association with more variables when assessed using the P-value of a cut-off point of ≤ 0.05 . The reason for this may be that the maternal mortality had a lower chance of yielding a statistically significant association, thereby causing chance error to be the likely explanation.

Selection bias

Selection bias is a systematic error due to a problem in the study design, where participants are differentially enrolled into the study. In other words, when a fewer or larger number of participants with a potential outcome than the normal average in the community are selected, the result is artificially biased towards lower or higher estimates [162]. Selection bias has a clear potential for estimating maternal mortality through the facility study (Paper IV) because often it is only a few selected severe cases visit health facilities for delivery or for treatment of complications. This is particularly a prevalent problem in settings where the awareness of users and the quality of health service providers are poor. As such, the MMR would be too high among those who visited health facilities because already complicated cases visit these facilities, and many die.

The MMR could also be too low when facility deaths are directly translated to the catchment population because many deaths occur at home. In the birth registry study (Paper I), we registered 81% of births estimated for 2010 in the study communities and reported the MMR outcomes. However, the measurement concern is whether the outcome (maternal mortality) is

differentially lower or higher in the remaining unregistered 19% of the expected births. The validation study showed that HEWs were more likely to register births to mothers who attended antenatal services and deliveries in households physically closer to the HEW stations (health posts), which may highlight the introduction of a selection bias. The same validation study also showed that the MMR between registered and unregistered births was similar: RR, 1.06 (95% CI: 0.28, 3.98). The similarity in maternal mortality and a high coverage in the registration of estimated births may imply a minimized influence of selection bias in affecting the overall value of the MMR.

In addition, the maternal mortality estimate obtained from birth registry (Paper I) was consistent with a finding from another community-based measurement through household survey (Paper II). In conclusion, even if selection bias may have been difficult to completely avoid in the birth registry and the validation studies, it may have been less likely to be differential in terms of the outcome (maternal mortality).

Another important source of selection bias is refusal (self-selection bias), in which participants who are perceived to have less or more likely to have the outcome of interest, fail to participate in a study. For example, if many households refused to participate in the maternal mortality study and the MMR was different between those who responded and refused, this could lead to an artificially lower or higher estimate of MMR. However, since the studies in this thesis (Papers II, III and IV) had more than a 95% response rate, selection bias due to refusal may not have been a problem. In the birth registry study (Paper I), given the difficulty of registering births in rural communities who often live in scattered households, the 81% registration coverage we achieved is high.

In Paper III (the sisterhood paper), more male siblings were interviewed than females about the deaths of their sisters. This may have been because women often travel to rural open markets, collect firewood, fetch water, while men stay in the garden cultivating the farms, which makes men more available for interviews. Additionally, the difference could also be due to a self-selection of women who shy away from interviews, as women usually stay the secluded parts of the home, while men respond to questions from outsiders who visit their homes. However, we found that maternal mortality indicators obtained through male and

female respondents were similar, which was also confirmed in a recent study by the original founders of the sisterhood method [163]. Therefore, the sisterhood estimate of MMR in our study (Paper III) may not have been greatly affected by selection bias.

Information (measurement bias)

Information bias is a systematic error in epidemiologic studies, in which differential measurements of exposures or outcomes are made between groups. Information bias has different sources: 1) Observer bias — related to a bias introduced by interviewers in surveys, readers of measuring gauges, assessors of diagnosis, and readers of laboratory and x-ray results. 2) Subject bias — is a respondent bias caused by a recall bias, a socially desirable response, or intentionally biasing of information by respondents. 3) Instrument bias — is related to the problem of materials used for measuring the exposure or outcome (the change of a reader machine at different settings), and confusing (non-standardized) guidelines for the classification of cases and deaths.

Recall bias is a concern in the household survey and sisterhood studies (Papers II& III) because these studies required memorizing past events of maternal deaths in the families. Observer bias also has a potential because people who respond to interviews about maternal deaths may not be able to properly classify the cause of a woman's death as maternal or not, or may not recognize early pregnancy when a woman has died.

We attempted to minimize information bias by selecting interviewers who had lived and knew about most of the vital events in their respective villages for a long time (Paper II). Moreover, pregnancy and maternal death are memorable events that cannot be easily forgotten within five years. We also believe that there was a minimal chance for information bias related to misclassifications deaths during early pregnancy because the study was done in a socially connected rural community. In these communities, unlike with urban dwellers, information about important events such as pregnancy is closely shared with family members and communities.

Even so, for the sisterhood study (Paper III), it is difficult to know how much information bias has played a role in the unexpectedly high estimate, though due to the inbuilt nature of

the method, the reference time for the estimate was more than a decade before the study. In the birth registry study (Paper I), data collectors were not aware how the predictor variables (road distance and type, literacy of father and mother, sickness during pregnancy, antenatal follow-up) would be used. As a result, the HEWs had little reason for a biased classification of maternal mortality outcome based on these variables.

In summary, however, I admit that the maternal mortality estimation is often affected by under-estimation due to misclassifications and recall biases [164], and that studies in this thesis might not have completely avoided these problems.

Confounding and effect modification

Confounding is an important concern in epidemiologic studies and is defined as a confusion or mixing of the effect of one exposure variable with the effect of another exposure variable on the outcome [150]. For this to happen, a confounding variable should be associated with both the exposure (predictor) and the outcome variables. Nonetheless, a confounder is not an intermediate variable in the pathway between exposure and outcome. The household survey (Paper II) showed that exposure variables such as the education of the head of household, the household distance from a driveable road, three or more births in five years, and the wealth status of households were associated with neonatal mortality outcomes.

However, the heads of households closer to driveable roads or in wealthy households may have been more educated than those living in poor or distant households. Consequently, independent of the distance from a driveable road, or the wealth of the household, educated heads of household are more likely to seek medical care for their sick neonates and reduce mortality. In other words, education may have been the true cause of the difference in mortality, and others (non-spaced birth, wealth, road distance) may have been potential confounders.

Several design and analysis techniques have been developed for epidemiological studies to control for confounding. During the design, randomization, specification of inclusion criteria, and matching may be applied. At the time of analysis, we may use stratifications and

adjustments (regression models) to control for the measured confounder variables in a study [150, 151, 165]. In the household study (Paper II), we used the logistic regression to adjust for the potential confounders mentioned above, and we also did a stratified analysis to assess whether education had an effect on the modification of the association between wealth and neonatal mortality. The analysis showed that education modified the effect of wealth on neonatal mortality, in which wealth was only associated with neonatal mortality among illiterates, and the neonatal mortality was similar between the wealthy and poor households headed by educated adults (Table 5, under additional results). Conversely, as all studies included in the thesis were observational studies, except for using some specific inclusion criteria, we did not use randomization in the design as a solution for confounding problem.

6.1.3 External validity (generalization)

External validity refers to whether or not a research finding can be generalized to a population in different settings [166]. The birth registry study (Paper I) was conducted using the existing community health workers, in which household visit is their routine activity, with priority given to households with pregnancies and births. The same study involved people from different cultural backgrounds and three ethnic groups in south Ethiopia (Gamo, Zeisse, and Derashe). Moreover, health extension workers who performed the birth registration and identified maternal deaths are distributed in the same proportion to the population and have the same training background, all are females and all have similar working conditions in the country. This may highlight that HEWs can conduct a birth registration of high coverage and optimum quality, and can classify pregnancy and birth outcomes in any rural community in Ethiopia.

Furthermore, the area we conducted the studies in were similar in demographics, health services, road access, and economic structure with most rural communities in Ethiopia. These facts may indicate that the findings of maternal and neonatal mortalities, along with the associated access and socio-economic factors may be generalized to many parts of rural Ethiopia. Nevertheless, because of specific local differences in health service quality, utilization, and cultural contexts, the rate of skilled birth attendance and the MMR may vary in a few places. However, the findings in three studies in this thesis which showed over 80% of maternal deaths occurring at home may be true for many rural communities in Ethiopia. In

fact, this generalization may also apply to developing countries at similar stages of health service access and socio-economic development, as a study from Mozambique also found similar results (86% of maternal deaths found through community-based study were not registered in the existing passive civil registration) [167].

6.2 Discussion of main findings

6.2.1 Overview of the work and findings

To the best of our knowledge, we assessed maternal mortality for the first time by using different methods that combined community and facility data in south Ethiopia. More importantly, we describe the possibility of birth registration and a registry-based measurement of maternal mortality in rural communities using the existing primary health care workers (HEWs). Although we admit that measuring maternal mortality in rural communities in developing countries is difficult, our findings suggest that it may be possible in places where functional system of community health service exists. As a result, we challenge the idea about whether to stop measuring maternal mortality in resource-limited countries and depend on process indicators [45]. Reducing maternal mortality depends on sustainable information from a measured magnitude of mortality, understanding socio-economic factors associated with the problem, as well as information on the coverage, quality, and utilization of obstetric services.

Alternative information for tackling maternal mortality can be obtained from process indicators such as financial commitments and skilled birth attendance (SBA) to help facilitate planning, implementation, and monitoring services. By contrary, evidence show that the level of process indicators may not necessarily match maternal mortality rate. For example, Ethiopia had one of the lowest skilled birth attendance rates in the world (< 10 until 2010) but the MMR was lower than some countries that had over 50% facility deliveries.

Thus, it is important to describe the measured changes in terms of the ultimate goal of reducing maternal and neonatal mortality. The MDG5 aims to see the measured reduction in maternal mortality as the main goal (goal 5A). The same goal also emphasizes monitoring of

the level of skilled birth attendance as a key indicator of progress. In developing countries, as is also true in Ethiopia, there is limited routine data from vital registration, which is considered the gold standard in measuring maternal mortality. The major reason for a lack of routine vital data is shortage of information systems accessible to the largest proportion of people living in remote rural areas in resource-poor settings (e.g. 85% in Ethiopia) [168]. Fortunately, Ethiopia has partly solved this problem through the health extension programme that placed two trained and salaried women in every village of the country. This innovative approach has met the goal of achieving MDG4 by reducing the mortality of children under-five years of age [132]. However, this programme has not been tested for its effect on the much needed registry-based data.

In this thesis, these health extension workers were able to register more than 80% of expected births (Paper I) in a country where only 7% of births were registered in 2013 [169], and with almost non-existent registry in rural areas. By so doing, we describe that the registration of births and birth outcomes in rural communities in developing countries where functional community health workers exist is feasible. This feasibility of birth registration served as an important tool to measure maternal mortality. The community birth registration (Paper I) and other community and facility studies in the thesis (Paper II and IV) also demonstrated that for every one maternal death that occurred at a health facility, four others died at home without any notice by the health system. Furthermore, we believe that the primary health-care workers (HEWs) were able to note the true proportion and types of skilled care received by mothers during pregnancy and at birth, and the distribution of major causes and time of maternal deaths through the prospective data.

The thesis also validated the birth registry data, and supplemented the findings with other community and health facility studies. As such, measuring maternal and neonatal mortality using a large household survey (Paper II) showed that the MMR is close to the estimate obtained through the birth registration. One major weakness of the paper-based birth registry is its limited capacity to link the outcomes with socio-economic factors because of recording of mainly pregnancy- and birth-related variables without any details about socio-economic conditions of households. Consequently, the household survey has complemented the weakness of birth registry by informing about socio-economic factors associated with maternal and neonatal mortality. Moreover, these two community-based approaches (Papers I

and II) and the assessment of health facilities (Paper IV) have shown consistent results that most maternal deaths occurred at home. Additionally, because of its complexity, measuring the level of maternal mortality itself requires a mixed methods approach (vital registrations, confidential inquiries, and other data sources), even in developed countries.

Another simple and cheap method of estimating maternal mortality in high fertility and mortality settings is the sisterhood method (Paper III), which helped to provide an overview of the problem in the area a decade before 2010. Approaches through community-based methods (Paper I and II) and the health facility study (Paper IV) have also shown that many existing health institutions do not provide the level of delivery care expected. Moreover, the quality of emergency obstetric care institutions was far below the UN recommended minimum to attain MDG5 goal (Paper IV).

6.2.2 Maternal and neonatal mortality

The knowledge of the magnitude and differentials of maternal and neonatal mortality is critical for the policy and programme response. Reporting the level of maternal mortality at this period is especially important because the result would indicate how the area is progressing towards the MDG5 target of reducing the MMR by 75% in 2015 from the 1990 level [7]. The MMR in Ethiopia was estimated to be 968 (95% CI: 600-1507) in 1990. This level needs to be reduced to 242 per 100,000 live births in 2015 for Ethiopia to achieve the MDG5 goal. Community-based studies in this thesis have shown measured value of an MMR between 425 in the household survey (Paper II) and 489 in the birth registry (Paper I), which are nearly 500 maternal deaths per 100,000 live births. The sisterhood study (Paper III) has also showed a higher rate of maternal mortality (an MMR of 1667 per 100,000 LBs) that refers to a time of a decade ago (Paper III).

These values indicate that there was a high MMR in 2010, when there was five years remaining for the final target in 2015. However, the findings also highlight that maternal mortality in rural Ethiopia might have been decreasing over time compared to what we estimated through the sisterhood method and other global estimates for the MMR in Ethiopia in the 1990s. The sisterhood method (Paper III) resulted in unexpectedly high estimate with a

lifetime risk of maternal mortality of 1 in 10, which translated to a very high MMR of 1,667, close to the natural MMR expected to occur without any modern intervention. However, because of the in-built characteristics of the method, the estimate points to the year 1998 which is when the MMR for Ethiopia was similarly high from other reports [170]. In fact, the district of Bonke where the sisterhood study was conducted had few safe motherhood interventions that could have prevented maternal deaths before 1998. Consequently, maternal mortality might have been very high in the area before 1998, and is currently showing a decline. Nevertheless, since there was no previous empirical data from the area, it is difficult to describe the trends in decline.

The maternal mortality rate was not previously reported from community-based birth registration in Ethiopia, although there have been few community-based household and sisterhood surveys conducted in other rural districts in Ethiopia. The MMR per 100,000 LBs was 440 in Butajira in 1996, 570 in Illubabor in 1995, 402 in Jimma in 1990, and 566 in Addis Ababa in 1983 [17, 171-173]. Unfortunately, many of these studies were conducted a decade before our studies. However, the community-based studies mentioned above reported an MMR similar to what we measured in this thesis. However, the time difference between our studies and previous studies is long. For this reason, the similarity of these estimates with our findings may highlight that the previous studies in other parts of Ethiopia might have been under-estimates. Alternative explanation could be that the MMR in the area we did our studies in had been higher than in those other districts.

An alternative source of community-based data is the DHS, which reported an MMR of 671 in 2005 [168] and 676 in 2010 [174], thereby indicating no change. However, the DHS uses very few households as being representative to the entire country and this, compounded with the rarity in absolute numbers of maternal deaths, might have resulted in unrealistically higher estimates with wide confidence intervals. Modelled national estimates are also available from the UN and the Institute of Health Metrics and Evaluation (IHME). However, the UN-estimate for the MMR in Ethiopia is much lower (350 per 100,000 LBs in 2010) [5] compared to our findings of MMR of 489 and 425 (Paper I & II). The IHME estimate of MMR in Ethiopia was 590 for 2008 [7], which is relatively higher than our findings, possibly because it was two years earlier than our studies.

We also measured an NMR of 27 per 1,000 LBs in Bonke (Paper II), which was lower than the DHS national estimate of 37 per 1,000 LBs in 2010 [174] and the UN Inter-agency group estimation of 31 in 2011 [175] in Ethiopia. Yet, there was no previous local estimate from the area, which makes it difficult to conclude whether the rate we found was under-reported or represents reality. In fact, the child mortality rate has substantially declined in Ethiopia from 204 in 1990 to 68 in 2012 [135], and there may have been reductions in neonatal mortality in the same period. If we consider international estimates that attribute 30-40% of under-five mortality to neonatal deaths, the NMR we found (27) was 40% of the national under-five mortality rate (68) during the same period, highlighting a consistency in our results with other reports. Even so, concrete evidence for the rate of neonatal mortality requires further studies.

In summary, our community-based MMR estimates were consistent with each other, as well as agreeing with information from health facilities that showed high proportion of maternal deaths outside of health facilities. Moreover, we believe that the MMR estimate (489) obtained through the prospective birth registry represents the best estimate, as we have also validated this finding. Furthermore, the MMR measured through the birth registry was in between the controversially high DHS (676) and low UN (350) estimates for the same period (2010) in Ethiopia. Therefore, the community-based measurement methods, particularly the findings from the birth registry (Paper I), may have represented the reality on the ground.

6.2.3 Inequalities in mortality outcomes

Even within a narrow area such as districts and provinces, maternal and neonatal mortalities can vary depending on access to health service and socio-economic conditions. While obstetric causes such as bleeding or infection are responsible for the mortality of an individual woman, at the population level, these causes can have a differential effect for a group of women with certain common backgrounds (illiterate, poor, far from road, and with poor access to health services) compared to others without these exposures. In our studies (Papers I and II), we report inequalities in maternal and neonatal mortality based on household wealth, educational status, distance to and quality of driveable roads, and frequent births.

The MMR was higher in the poorest households, among households in distant villages, and where the head of households were illiterate (Paper II). The birth registry study (Paper I) has also shown that the educational status of the heads of household and the type of road to the villages was associated with the MMR. The importance of the educational level of the father of babies as a factor for maternal mortality has also been reported before, and may be related to the importance of the male partner's knowledge for seeking health services, and affording the related costs. Similarly, the distance from road and the poor condition of roads may decide the availability and speed of transport when families want to receive medical care.

The implication of these findings, from the health service point of view, is that health professionals should give a priority to pregnant women with poor socio-economic backgrounds and in difficult to access villages, if a programme is to reduce maternal mortality without waiting for changes in education and wealth in these households. A similar explanation may also be true for the neonatal mortality, which was associated with household wealth, education of the head of household, road distance from the household, and the frequency of births within five years in households (Paper II).

6.2.4 Skilled birth attendance and emergency obstetric care

In Ethiopia, an aggressive expansion of health centres took place in the past few years with the aim of making a health centre available within a 10 km distance of households. As such, we found that the median distance of households was 10 km from health centres, and 57% of households were within 10 km of a health centre in 2010 (Paper I). Nonetheless, the quality standards and the public utilization of existing health facilities was very low.

The community and facility studies included in the thesis have shown that the overall rate of delivery in skilled health facilities (health centres and hospitals) was less than 10% until 2010. The rate was 3.7% in between 2006 and 2010 in rural villages (Paper II), 6% in 2010 in rural villages (Paper I), and 6.6% in 2010 through the facility study that includes cases from urban areas (Paper IV). Our result is consistent with the findings of a nation-wide assessment of the status of emergency obstetric care in the country in 2008 [176]. The aforementioned

national assessment reported that 7% of deliveries in Ethiopia took place in institutions of any type and 3% in facilities that provided all the signal functions of emergency obstetric care.

In fact, the rate of skilled birth attendance in Ethiopia has stagnated at a very low level for decades. Furthermore, the institutional delivery rate was widely varied between urban and rural areas within Ethiopia (84% in Addis Ababa and 7.2% in the Afar region in 2010) [174]. According to national DHS studies, skilled birth attendance was 5.7% in 2005 [168] and 10% in 2010 [174]. Encouragingly, an improvement to 15% was reported in 2014 [121], but in the same DHS report in 2014, the rate was still 10% in rural areas and 12% in the southern region where we conducted the studies. Overall, this rate is far lower than the 45.5% average for Africa and 35.3% for least developed countries in 2008 according to a WHO update [177].

Review of the evidence suggest that emergency obstetric care should be a critical component of an effort to reduce maternal mortality [178]. Consequently, the WHO has developed assessment tools and minimum standards for monitoring the status of EmOC services [179]. This WHO tool was tested and proven effective in reflecting the level of EmOC in the field [180]. In the facility study (Paper IV) we used the UN standard and the assessment instrument to describe the physical coverage, quality, and utilization of EmOC services because measuring maternal mortality without assessing the status of obstetric services cannot adequately inform policy makers and programme planners. We found that the number of health centres and their physical proximity to the population was promising. However, many of these institutions did not meet the minimum standards expected to provide emergency obstetric services [179]. As a result, fewer mothers use the facilities for delivery and the institutional MMR was high, thus highlighting a formidable challenge to rapidly reducing maternal and neonatal mortality.

6.2.5 Why a sign of reduction in maternal mortality in Ethiopia with a low skilled delivery rate?

Ethiopia has achieved the MDG 4 target for reducing the mortality of children under the age of five by two-thirds through general preventive and health promotion measures by implementing community-based primary health care [132]. However, reducing the neonatal

component of child mortality and the maternal mortality needs better clinical care, and in the future further reductions will depend on improving clinical excellence. Because of statistical challenges related to wide confidence intervals surrounding MMR due to a relative rarity in the numbers of maternal deaths, it is often difficult to comment on changes in the MMR. In addition, a lack of real-time and continuous data makes it hard to regularly update information.

Model-based estimates [5, 7] show that there has been a decline in maternal mortality in Ethiopia in the face of exceptionally low levels of skilled birth attendance and access to emergency obstetric care. Recently, the Federal Ministry of Health of Ethiopia and the United Nations Population Fund (UNFPA-Ethiopia) have released a joint statement which suggests Ethiopia is making good progress in reducing maternal mortality to achieve its MDG 5 goal [181]. However, the statement was not backed by concrete data for the claim.

By contrast, Yifru Berhan and Asres Berhan, in their recent review argue that there has been no significant change in maternal mortality over the last 30 years, citing the overlaps in 95% CIs and inconsistencies in several estimates issued since 1980 [182]. However, because of the nature of a relative rarity in absolute numbers of maternal mortality, which often fails to satisfy the power of statistical analysis, entirely depending on the 95% CI may be difficult to witness a progress in MMR reduction. To obtain a reliable 95% CI with adequate statistical power may need a large number of maternal deaths, which is much costly. Hence, it may be wise to assess the central level of estimate of MMR at a given time for a given area.

Our findings (Paper I and II) also consistently measured an MMR below 500 per 100,000 LBs compared to the MMR of over 1,000 in Ethiopia in 1990s, although the paradox of a maternal mortality reduction without marked improvements in clinical obstetric care remains unexplained. Ethiopia's rapid expansion of the physical coverage of health centres since 2005 has had little impact on increasing the utilization of facility intrapartum care, which is the key strategy for reducing maternal mortality. In addition, the HEWs were expected to be involved in delivery services, but they had little clinical skills. Consequently, the government is now upgrading them with one year of additional training on the maternal and child health

curriculum. Hence, the effect of the upgrading of HEWs may help reduce the MMR in the future by improving the skilled birth rate, but cannot explain the current declines in MMR.

However, an unexplained reduction of maternal mortality in places with a low utilization of professional care at birth is not a new phenomenon only seen in Ethiopia. It has been seen in other countries and is the subject of debate [183]. For example, skilled birth attendance was 10% in Ethiopia and 50% in Tanzania in 2010, though both countries had a similar MMR (420 in Ethiopia and 410 in Tanzania) [184]. On the other hand, Somalia had three times higher skilled birth attendance (33%) compared to Ethiopia; even so, this is a contradiction given the MMR of 850 in Somalia [184]. As such, some experts do not agree on a high emphasis on clinical services to reduce maternal mortality, arguing in favour of some “context-specific interventions” such as women’s support groups, vitamin-A distributions, and related community interventions. The reason cited for this is that achieving a high coverage of skilled birth attendance in remote communities is unrealistic and cannot be achieved in the foreseeable future [185].

The Ministry of Health of Ethiopia attributes recent health gains to the decentralized community-based HEP. However, what specific and measureable interventions HEWs conduct to reduce maternal mortality is a question that remains to be answered. Our studies have demonstrated that HEWs conducted a low proportion of births that took place in their villages, 13.4% in 2010 (Paper I) and 4% on average between 2006 and 2010 (Paper II). Rather, the following four preventive interventions might have contributed to the beginning of a decline in maternal mortality in Ethiopia.

First, fertility has markedly declined in rural Ethiopia in the past decade, from an annual crude birth rate (CBR) of 43 births per 1,000 population in 2000 [186] to 28 in 2014 [121] in which HEWs may have played important role by providing birth control medications. Similarly, the total fertility rate (TFR, the average number of births a woman would give throughout her reproductive life span) has decreased to 4.1 in 2014 from 5.9 in 2000. This fertility decline was simultaneous, with an increased uptake of contraceptive technologies [121]. Second, general improvements in living conditions, nutrition, and hygiene that have

implications for deaths related to anaemia and infections may have played some role, as Ethiopia has shown economic growth in recent years.

Third, the decline of infectious diseases such as malaria [187] and HIV [188] might have also contributed to the beginning of a decline in maternal mortality in Ethiopia. Fourth, Ethiopia passed a law in May 2005 that liberalized abortion, and the Ethiopian Ministry of Health issued a technical and procedural guideline in 2006 [189]. The new law gives women more authority to request a safe abortion if the pregnancy was due to rape or incest (from a closely-related person or family), or when the mother or the foetus has severe medical problem. Moreover, girls under the age of 18 can obtain an abortion without any conditional requirements if they make a claim.

A five-year follow-up study in a hospital setting in Addis Ababa on abortion-related admissions before and after the 2005 legislation has highlighted a decreased trend of abortion admissions and abortion related maternal mortality [190]. A national study also estimated the incidence of abortion in Ethiopia at 23 per 1,000 women of reproductive age in 2008, which is a lower rate compared to the WHO estimate of 39 per 1,000 reproductive women in East Africa [191].

In our facility-based study (Paper IV), abortion-related admissions in 2010 were only 291 cases among 1.8 million people served by the surveyed facilities, which may also indicate a lower rate of admission, though this could be somewhat biased because of a low rate of abortion service utilization. Similarly, in the northern Ethiopia in Tigray, a pilot study reported decreased admission of abortion complications after the introduction of the new abortion law [192]. However, more concrete evidence is needed to suggest whether a reduction in abortion is contributing to maternal mortality decline in Ethiopia.

7 Conclusion and recommendations

7.1 Conclusion

Community-based measurement methods (birth registry and household survey) provided consistent maternal mortality estimates, in addition to describing inequalities in the mortality outcomes across selected variables. Moreover, the birth registry provided a more valid MMR compared to the alternative measurement methods. The finding of the feasibility of prospective birth registration and its usefulness as a tool to measure maternal mortality can be considered an important learning step towards implementation of the recently approved law of universal vital registration in Ethiopia. Through using different methods of assessment, the studies in the thesis characterize the magnitude, main causes, time, and associated factors related to maternal and neonatal mortality. The thesis also describes the coverage, quality, and utilization status of obstetric service. The findings should therefore serve as a baseline for the future monitoring of progress in maternal and neonatal mortality and obstetric services in the study area, which can be replicated in other rural settings in Ethiopia, as well as elsewhere in developing countries with a functional community health system.

7.2 Recommendations

For further research

1. Long-term prospective studies of birth registration may be important to oversee whether such follow-ups have any effect on reducing maternal mortality.
2. Replication of the birth registry study in other areas with a different cultural and health service status may help to strengthen the evidence for its wider application.
3. Such an effort may take further a step towards establishing a system of starting the registry during pregnancy to improve the quality of the data.
4. Future birth outcome studies through the use of a community birth registry should consider the concerns of the diagnostic qualities of cause-of-death ascertainment. A mechanism of linking HEWs to medical specialists could be an option.
5. Future integration of birth registration with the WHO's "maternal death surveillance and response" (MDSR) strategies may help improve the overall results.

6. Complementing the quantitative finding with qualitative analysis on the effects of maternal mortality on the surviving babies and families may help to provide full images of the consequences of maternal mortality.
7. Intermittent use of household and sisterhood methods may be useful to help compare the findings and to learn about the strengths and weaknesses of measurement methods.
8. A repeated assessment of the quality and utilization of obstetric services using the standard document produced by the UN may help to oversee changes in obstetric services.

For programme implementation

1. Programme planners and implementers may need to base their work on the information produced, and support the generation of new data such as birth registration in their respective localities.
2. The fact that maternal and neonatal mortality is differentially high in extremely poor households, households with lower education for the head, and with frequent births highlights the importance of a focused follow-up of pregnancies in such households.
3. Strengthening the quality of the emergency obstetric service facilities is crucial to both increase the very low utilization rate, and to reduce high maternal mortality rates in health facilities. Special attention needs to be given to the critical problem of lack of blood for transfusions and a shortage of parenteral drugs.
4. The initiative of upgrading the HEWs to midwifery should be backed with supplies because the current shortage of supplies could hamper their practice. Such initiatives should also be backed by clear strategies and guidelines to link HEWs with referral facilities.

Policy recommendations

1. Policy makers may consider the presence of HEWs as opportunity and prioritise the universal registration of births and birth outcomes. The information can provide important data that can be useful to the health sector and others such as education, legal services, and equity analysis.
2. The policy attention given to expanding health centres for physical access should be backed by a similar commitment to help improve the quality of these facilities.

8 References

1. Horton R: Maternal mortality: surprise, hope, and urgent action. *The Lancet* 2010, 375(9726):1581-1582.
2. Kassebaum NJ, Bertozzi-Villa A, Coggeshall MS, Shackelford KA, Steiner C, Heuton KR, Gonzalez-Medina D, Barber R, Huynh C, Dicker D *et al*: Global, regional, and national levels and causes of maternal mortality during 1990 to 2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet* 2014.
3. Ronsmans C, Graham WJ: Maternal mortality: who, when, where, and why. *The Lancet*, 368(9542):1189-1200.
4. Mahler H: The Save Motherhood Initiative: A Call to Action. *The Lancet* 1987, 329(8534):668.
5. UNFPA: UN Inter-agency Group for Maternal Mortality Estimation. Trends in maternal mortality 1990 to 2010: WHO, UNICEF, UNFPA, and the World Bank Estimates. Geneva: World Health Organization, 2012. available at: https://www.unfpa.org/webdav/site/global/shared/documents/publications/2012/Trends_in_maternal_mortality_A4-1.pdf (accessed 5 May, 2014). 2012.
6. Donnay F: Maternal survival in developing countries: what has been done, what can be achieved in the next decade. *International Journal of Gynecology & Obstetrics* 2000, 70(1):89-97.
7. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, Makela SM, Lopez AD, Lozano R, Murray CJL: Maternal mortality for 181 countries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5. *The Lancet* 2008, 375(9726):1609-1623.
8. Kinney MV, Kerber KJ, Black RE, Cohen B, Nkrumah F, Coovadia H, Nampala PM, Lawn JE, on behalf of the Science in Action: Saving the lives of Africa's mothers and children working group: Sub-Saharan Africa's Mothers, Newborns, and Children: Where and Why Do They Die? *PLoS Med* 2010, 7(6):e1000294.
9. Bicego G, Boerma JT, Ronsmans C: The effect of AIDS on maternal mortality in Malawi and Zimbabwe. *AIDS* 2002, 16(7):1078-1081.
10. Fawcus SR, van Coeverden de Groot HA, Isaacs S: A 50-year audit of maternal mortality in the Peninsula Maternal and Neonatal Service, Cape Town (1953–2002). *BJOG: An International Journal of Obstetrics & Gynaecology* 2005, 112(9):1257-1263.

11. Paul BK: Maternal mortality in Africa: 1980–87. *Social Science & Medicine* 1993, 37(6):745-752.
12. Rush D: Nutrition and maternal mortality in the developing world. *The American Journal of Clinical Nutrition* 2000, 72(1):212s-240s.
13. Karlsen S, Say L, Souza J-P, Hogue C, Calles D, Gulmezoglu AM, Raine R: The relationship between maternal education and mortality among women giving birth in health care institutions: Analysis of the cross sectional WHO Global Survey on Maternal and Perinatal Health. *BMC Public Health* 2011, 11(1):606.
14. Freedman LP, Waldman RJ, de Pinho H, Wirth ME, Chowdhury AMR, Rosenfield A: Transforming health systems to improve the lives of women and children. *The Lancet*, 365(9463):997-1000.
15. Royston E, AbouZahr C: Measuring maternal mortality. *BJOG: An International Journal of Obstetrics & Gynaecology* 1992, 99(7):540-543.
16. Hill K: Measuring maternal mortality. *The Lancet* 2006, 368(9553):2121.
17. Berhane Y, Andersson T, Wall S, Byass P, Högberg U: Aims, options and outcomes in measuring maternal mortality in developing societies. *Acta Obstetrica et Gynecologica Scandinavica* 2000, 79(11):968-972.
18. Hill K, El Arifeen S, Koenig M, Al-Sabir A, Jamil K, Raggars H: How should we measure maternal mortality in the developing world? A comparison of household deaths and sibling history approaches. *Bulletin of the World Health Organization* 2006, 84:173-180.
19. Say L, Souza JP, Pattinson RC: Maternal near miss – towards a standard tool for monitoring quality of maternal health care. *Best Practice & Research Clinical Obstetrics & Gynaecology* 2009, 23(3):287-296.
20. WHO: Beyond the numbers: reviewing maternal deaths and complications to make pregnancy safer. Available at: http://www.who.int/maternal_child_adolescent/documents/9241591838/en/ (accessed 20 June, 2013). . *World Health Organization* 2004.
21. WHO: Maternal mortality: Fact sheet N^o 348, WHO-media centre. available at: <http://www.who.int/mediacentre/factsheets/fs348/en/> (accessed 15 May 2014). 2014.
22. WHO-PMNCH: The Partner for Maternal, Newborn and Child Health (PMNCH) fact sheet: Maternal mortality. available at: http://www.who.int/pmnch/media/press_materials/fs/en/ (accessed 14 May 2014). 2011.

23. Khan KS, Wojdyla D, Say L, Gülmezoglu AM, Van Look PFA: WHO analysis of causes of maternal death: a systematic review. *The Lancet* 2006, 367(9516):1066-1074.
24. Say L, Chou D: Better understanding of maternal deaths—the new WHO cause classification system. *BJOG: An International Journal of Obstetrics & Gynaecology* 2011, 118:15-17.
25. ANYA SE: Seasonal variation in the risk and causes of maternal death in The Gambia: Malaria appears to be an important factor. *The American Journal of Tropical Medicine and Hygiene* 2004, 70(5):510-513.
26. Romagosa C, Ordi J, Saute F, Quintó L, Machungo F, Ismail MR, Carrilho C, Osman N, Alonso PL, Menendez C: Seasonal variations in maternal mortality in Maputo, Mozambique: the role of malaria. *Tropical Medicine & International Health* 2007, 12(1):62-67.
27. Brabin BJ, Hakimi M, Pelletier D: An Analysis of Anemia and Pregnancy-Related Maternal Mortality. *The Journal of Nutrition* 2001, 131(2):604S-615S.
28. Fauveau V, Blanchet T: Deaths from injuries and induced abortion among rural Bangladeshi women. *Social Science & Medicine* 1989, 29(9):1121-1127.
29. Ganatra B, Coyaji K, Rao V: Too far, too little, too late: a community-based case-control study of maternal mortality in rural west Maharashtra, India. *Bulletin of the World Health Organization* 1998, 76(6):591.
30. Ronsmans C, Khat M: Adolescence and risk of violent death during pregnancy in Matlab, Bangladesh. *The Lancet* 1999, 354(9188):1448.
31. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller A-B, Daniels J, Gülmezoglu AM, Temmerman M, Alkema L: Global causes of maternal death: a WHO systematic analysis. *The Lancet Global Health* 2014.
32. AbouZahr C, Wardlaw T: Maternal mortality at the end of a decade: signs of progress? *Bulletin of the World Health Organization* 2001, 79:561-573.
33. Høj L, da Silva D, Hedegaard K, Sandström A, Aaby P: Maternal mortality: only 42 days? *BJOG: An International Journal of Obstetrics & Gynaecology* 2003, 110(11):995-1000.
34. Pradhan EK, West Jr KP, Katz J, Christian P, Khattry SK, LeClerq SC, Dali SM, Shrestha SR: Risk of death following pregnancy in rural Nepal. *Bulletin of the World Health Organization* 2002, 80:887-891.

35. Li XF, Fortney JA, Kotelchuck M, Glover LH: The postpartum period: the key to maternal mortality. *International Journal of Gynecology & Obstetrics* 1996, 54(1):1-10.
36. WHO: International Statistical Classification of Diseases and Health Related Problems. tenth revision (ICD-10).Geneva. online version available at:<http://apps.who.int/classifications/icd10/browse/2010/en>. (accessed 15 May 2014). *World Health Organization* 1992.
37. WHO: Maternal mortality: helping women off the road to death *WHO Chronicle* 1986, 40(5):175-183. available at: http://whqlibdoc.who.int/chronicle/1986/WHO_Chronicle_1986_40%285%29_175-183_eng.pdf (accessed 1910 May 2014)
38. Graham WJ, Foster LB, Davidson L, Hauke E, Campbell OMR: Measuring progress in reducing maternal mortality. *Best Practice & Research Clinical Obstetrics & Gynaecology* 2008, 22(3):425-445.
39. Graham W, Ahmed S, Stanton C, Abou-Zahr C, Campbell O: Measuring maternal mortality: An overview of opportunities and options for developing countries. *BMC Medicine* 2008, 6(1):12.
40. WHO: Reduction of maternal mortality: A joint WHO/UNFPA/UNICEF/World Bank statement. Available at: <http://www.who.int/reproductivehealth/publications/monitoring/9789241561952/en/> (accessed 20 June 2014). *WHO Sexual and Reproductive Health publications* 1999.
41. Högberg U: The decline in maternal mortality in Sweden: the role of community midwifery. *American Journal of Public Health* 2004, 94(8):1312.
42. WHO: The world health report 2005: Make every mother and child count, World Health Organization (2005). available at: http://www.who.int/whr/2005/whr2005_en.pdf?ua=1 (accessed 9 May 1024).
43. Stanton, Cynthia, Noureddine Abderrahim, and Kenneth Hill (1997) DRSMaternal Mortality Indicators: AnAssessmentofData Quality and Implications for Data Use. DHS Analytical Reports No.4. Calverton, Maryland: Macro International Inc. available at: http://pdf.usaid.gov/pdf_docs/PNACB889.pdf (accessed June 20,2014).
44. Hill K: Making deaths count. *Bulletin of the World Health Organization* 2006, 84:162-162.

45. Pitt C, Greco G, Powell-Jackson T, Mills A: Countdown to 2015: assessment of official development assistance to maternal, newborn, and child health, 2003–08. *The Lancet*, 376(9751):1485-1496.
46. Countdown Working Group on Health Policy and Health Systems. Assessment of the health system and policy environment as a critical complement to tracking intervention coverage for maternal, newborn, and child health. *The Lancet*, 371(9620):1284-1293.
47. Graham WJ: Now or never: the case for measuring maternal mortality. *The Lancet* 2002, 359(9307):701-704.
48. Hoyert D: The autopsy, medicine, and mortality statistics National Center for Health Statistics Vital Health Stat, 3 (33) (2001)
http://www.cdc.gov/nchs/data/series/sr_03/sr03_032.pdf. *Centers for Disease Control* 2001.
49. Deneux-Tharaux C, Berg C, Bouvier-Colle M-H, Gissler M, Harper M, Nannini A, Alexander S, Wildman K, Breart G, Buekens P: Underreporting of Pregnancy-Related Mortality in the United States and Europe. *Obstetrics & Gynecology* 2005, 106(4):684-692 610.1097/1001.AOG.0000174580.0000124281.e0000174586.
50. Arthure H: Confidential inquiries into maternal deaths. *British medical journal* 1975, 1(5953):322.
51. Saucedo M, Deneux-Tharaux C, Bouvier-Colle M: Confidential enquiries into maternal deaths. *BJOG: An International Journal of Obstetrics & Gynaecology* 2010, 117(7):894-895.
52. Gibb D: Confidential enquiry into maternal death. *International Journal of Obstetrics & Gynaecology* 1990, 97(2):97-99.
53. Mathers CD, Ma Fat D, Inoue M, Rao C, Lopez AD: 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* 2005, 83:171-177c.
54. AbouZahr C: Safe Motherhood: a brief history of the global movement 1947–2002. *British Medical Bulletin* 2003, 67(1):13-25.
55. WHO: Health and the Millennium Development Goals: available at:http://www.who.int/hdp/publications/mdg_en.pdf?ua=1 (accessed 15 May 2014). *World Health Organization* (2005).

56. Cross S, Bell JS, Graham WJ: What you count is what you target: the implications of maternal death classification for tracking progress towards reducing maternal mortality in developing countries. *Bulletin of the World Health Organization* 2010, 88:147-153.
57. Graham WJ, Adjei S: A Call for Responsible Estimation of Global Health. *PLoS Med* 2010, 7(11):e1001003.
58. Hill K, Stanton C, Gupta N: Measuring maternal mortality from a census: guidelines for potential users (2001). <http://www.cpc.unc.edu/measure/publications/pdf/ms-01-04.pdf#search=%22stanton%20hill%20census%20maternal%20mortality%22> (accessed May 15, 2014)
59. Stanton C, Hobcraft J, Hill K, Kodjogbé N, Mapeta WT, Munene F, Naghavi M, Rabeza V, Sisouphanthong B, Campbell O: Every death counts: measurement of maternal mortality via a census. *Bulletin of the World Health Organization* 2001, 79:657-664.
60. Byass P: The Imperfect World of Global Health Estimates. *PLoS Med* 2010, 7(11):e1001006.
61. de Brouwere V, Van Lerberghe W: Safe motherhood strategies: a review of the evidence. *Studies in Health Services Organisation and Policy*, 17, 2001. iTG Press Antwerp, Nationalestraat 155, B-2000 Antwerp, Belgium.
62. Hogberg U, Innala E, Sandstrom A: Maternal mortality in Sweden, 1980-88. *Obstet Gynecol* 1994, 84: 2404.
63. Dawson I: The confidential enquiry into maternal deaths: its role and importance for pathologists. *Journal of clinical pathology* 1988, 41(8):820-825.
64. Van Lerberghe W, De Brouwere V: Of blind alleys and things that have worked: history's lessons on reducing maternal mortality. *Studies in Health Services Organisation and Policy* 2001, 17:7-35.
65. Horder J: General practice in 2000. Alma Ata declaration. *British medical journal (Clinical research ed)* 1983, 286(6360):191.
66. Werner D, Saunders D, Schweiger M: Questioning the solution: the politics of primary health care and child survival. *BMJ-British Medical Journal-International Edition* 1997, 315(7107):555.
67. WHO: Prevention of Maternal Mortality: Report of the WHO Interregional Meeting, November 1985 *World Health Organization*.

68. Starrs AM: Safe motherhood initiative: 20 years and counting. *The Lancet*, 368(9542):1130-1132.
69. Rosenfield A, Maine D: Maternal Mortality —A Neglected Tragedy: Where is the M in MCH? *The Lancet* 1985, 326(8446):83-85.
70. De Brouwere V, Tonglet R, Van Lerberghe W: Strategies for reducing maternal mortality in developing countries: what can we learn from the history of the industrialized West? *Tropical Medicine & International Health* 1998, 3(10):771-782.
71. Greenwood AM, Bradley A, Byass P, Greenwood B, Snow R, Bennett S, Hatib-N'Jie A: Evaluation of a primary health care programme in The Gambia. I. The impact of trained traditional birth attendants on the outcome of pregnancy. *The Journal of tropical medicine and hygiene* 1990, 93(1):58-66.
72. Hall M, Chng PK, Macgillivray I: Is Routine Antenatal Care worthwhile? *The Lancet* 1980, 316(8185):78-80.
73. McDonagh M: Is antenatal care effective in reducing maternal morbidity and mortality? *Health Policy and Planning* 1996, 11(1):1-15.
74. WHO: Making pregnancy safer: the critical role of the skilled attendant. A joint statement by WHO, ICM, and FIGO. *WHO, International Confederation of Midwives, and International Federation of Gynaecologists and Obstetricians, Geneva: 2004.*
75. Graham WJ, Bell JS, Bullough CH: Can skilled attendance at delivery reduce maternal mortality in developing countries. In: *Safe motherhood strategies: a review of the evidence (available at: <http://www.jsieuropeorg/safem/collect/safem/pdf/s2934e/s2934e.pdf> (accessed 30 June, 2014)* 2001, 17:97-130.
76. Freedman LP, Graham WJ, Brazier E, Smith JM, Ensor T, Fauveau V, Themmen E, Currie S, Agarwal K: Practical lessons from global safe motherhood initiatives: time for a new focus on implementation. *The Lancet*, 370(9595):1383-1391.
77. Haines A, Cassels A: Can the millennium development goals be attained? *BMJ: British medical journal* 2004, 329(7462):394.
78. Borghi J, Ensor T, Somanathan A, Lissner C, Mills A: Mobilising financial resources for maternal health. *The Lancet*, 368(9545):1457-1465.
79. Powell-Jackson T, Borghi J, Mueller DH, Patouillard E, Mills A: Countdown to 2015: tracking donor assistance to maternal, newborn, and child health. *The Lancet*, 368(9541):1077-1087.

80. Johns B, Sigurbjörnsdóttir K, Fogstad H, Zupan J, Mathai M, Tan-Torres Edejer T: Estimated global resources needed to attain universal coverage of maternal and newborn health services. *Bulletin of the World Health Organization* 2007, 85(4):256-263.
81. Shiffman J: Generating Political Priority for Maternal Mortality Reduction in 5 Developing Countries. *American Journal of Public Health* 2007, 97(5):796-803.
82. Maine D, Rosenfield A: The Safe Motherhood Initiative: why has it stalled? *American Journal of Public Health* 1999, 89(4):480-482.
83. Weil O, Fernandez H: Is safe motherhood an orphan initiative? *The Lancet* 1999, 354(9182):940-943.
84. AbouZahr C: Cautious champions: International agency efforts to get safe motherhood onto the agenda. *Stud Health Serv Organ Pol* 2001, 17:384-411.
85. Lozano R, Wang H, Foreman KJ, Rajaratnam JK, Naghavi M, Marcus JR, Dwyer-Lindgren L, Lofgren KT, Phillips D, Atkinson C *et al*: Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. *The Lancet*, 378(9797):1139-1165.
86. Shiffman J, Smith S: Generation of political priority for global health initiatives: a framework and case study of maternal mortality. *The Lancet*, 370(9595):1370-1379.
87. Shen C, Williamson JB: Maternal mortality, women's status, and economic dependency in less developed countries: a cross-national analysis. *Social Science & Medicine* 1999, 49(2):197-214.
88. Garg B: Safe Motherhood: Social, Economic, and Medical Determinants of Maternal Mortality: available at:http://www.the-networktufh.us.be/sites/default/files/attachments/basic_pages/WHLP%20Safe%20Motherhood.pdf (accessed 30 May 2014). *TUFH Women and Health Taskforce* September 2006, Second edition
89. McCarthy J, Maine D: A framework for analyzing the determinants of maternal mortality. *Studies in family planning* 1992:23-33.
90. Graham WJ, Fitzmaurice AE, Bell JS, Cairns JA: The familial technique for linking maternal death with poverty. *The Lancet* 2004, 363(9402):23-27.
91. Loudon I: Maternal mortality in the past and its relevance to developing countries today. *The American Journal of Clinical Nutrition* 2000, 72(1):241s-246s.
92. Topping A: Maternal mortality and public opinion. *Public Health* 1935, 49(0):342-349.

93. Kunst AE, Houweling T: A global picture of poor-rich differences in the utilisation of delivery care. *Stud Health Serv Organ Policy* 2001, 17:297-315.
94. Gill K, Pande R, Malhotra A: Women deliver for development. *The Lancet*, 370(9595):1347-1357.
95. Bhutta ZA, Ali S, Cousens S, Ali TM, Haider BA, Rizvi A, Okong P, Bhutta SZ, Black RE: Interventions to address maternal, newborn, and child survival: what difference can integrated primary health care strategies make? *The Lancet*, 372(9642):972-989.
96. Campbell OMR, Graham WJ: Strategies for reducing maternal mortality: getting on with what works. *The Lancet* 2006, 368(9543):1284-1299.
97. Buekens P: Over-medicalisation of maternal care in developing countries. *Stud Health Serv Organ Policy* 2001, 17:195-206.
98. Liljestrand J, Pathmanathan I: Reducing Maternal Mortality: Can We Derive Policy Guidance from Developing Country Experiences? Critical Elements in Reducing Maternal Mortality. *Journal of Public Health Policy* 2004, 25(3/4):299-314.
99. Chowdhury ME, Ahmed A, Kalim N, Koblinsky M: Causes of maternal mortality decline in Matlab, Bangladesh. *Journal of health, population, and nutrition* 2009, 27(2):108.
100. W Van Lerberghe, V De Brouwere. Of blind alleys and things that have worked: history's lessons on reducing maternal mortality. *Studies Health Serv Organ Policy* 2001, 17:7-33.
101. Seneviratne HR, Rajapaksa LC: Safe motherhood in Sri Lanka: a 100-year march. *International Journal of Gynecology & Obstetrics* 2000, 70(1):113-124.
102. Campbell O, Gipson R, Issa AH, Matta N, El Deeb B, El Mohandes A, Alwen A, Mansour E: National maternal mortality ratio in Egypt halved between 1992-93 and 2000. *Bulletin of the World Health Organization* 2005, 83(6):462-471.
103. Shiffman J, Stanton C, Salazar AP: The emergence of political priority for safe motherhood in Honduras. *Health Policy and Planning* 2004, 19(6):380-390.
104. Lucas AO: Introductory remarks: History of the Prevention of Maternal Mortality Network. *International Journal of Gynecology & Obstetrics* 1997, 59, Supplement 2(0):S11-S13.
105. Rosenfield A, Min CJ, Freedman LP: Making Motherhood Safe in Developing Countries. *New England Journal of Medicine* 2007, 356(14):1395-1397.

106. Koblinsky M, Matthews Z, Hussein J, Mavalankar D, Mridha MK, Anwar I, Achadi E, Adjei S, Padmanabhan P, van Lerberghe W: Going to scale with professional skilled care. *The Lancet* 2006, 368(9544):1377-1386.
107. WHO: Monitoring emergency obstetric care: a hand book. WHO, UNICEF, UNFPA, and AMDD. available at: http://www.unfpa.org/webdav/site/global/shared/documents/publications/2009/obstetric_monitoring.pdf (accessed 13 Nov. 2013). 2009.
108. Derman RJ, Kodkany BS, Goudar SS, Geller SE, Naik VA, Bellad MB, Patted SS, Patel A, Edlavitch SA, Hartwell T *et al*: Oral misoprostol in preventing postpartum haemorrhage in resource-poor communities: a randomised controlled trial. *The Lancet*, 368(9543):1248-1253.
109. Mobeen N, Durocher J, Zuberi NF, Jahan N, Blum J, Wasim S, Walraven G, Hatcher J: Administration of misoprostol by trained traditional birth attendants to prevent postpartum haemorrhage in homebirths in Pakistan: a randomised placebo-controlled trial. *BJOG: An International Journal of Obstetrics & Gynaecology* 2011, 118(3):353-361.
110. Winikoff B, Dabash R, Durocher J, Darwish E, Ngoc NTN, León W, Raghavan S, Medhat I, Chi HTK, Barrera G *et al*: Treatment of post-partum haemorrhage with sublingual misoprostol versus oxytocin in women not exposed to oxytocin during labour: a double-blind, randomised, non-inferiority trial. *The Lancet*, 375(9710):210-216.
111. Starrs A, Winikoff B: Misoprostol for postpartum hemorrhage: Moving from evidence to practice. *International Journal of Gynecology & Obstetrics* 2012, 116(1):1-3.
112. ten Hoop-Bender P, Liljestrand J, MacDonagh S: Human resources and access to maternal health care. *International Journal of Gynecology & Obstetrics* 2006, 94(3):226-233.
113. Anand S, Bärnighausen T: Human resources and health outcomes: cross-country econometric study. *The Lancet*, 364(9445):1603-1609.
114. Kabakian-Khasholian T, Campbell O, Shediak-Rizkallah M, Ghorayeb F: Women's experiences of maternity care: satisfaction or passivity? *Social Science & Medicine* 2000, 51(1):103-113.
115. Shiferaw S, Spigt M, Godefrooij M, Melkamu Y, Tekie M: Why do women prefer home births in Ethiopia? *BMC Pregnancy and Childbirth* 2013, 13(1):5.

116. Thaddeus S, Maine D: Too far to walk: Maternal mortality in context. *Social Science & Medicine* 1994, 38(8):1091-1110.
117. Kowalewski M, Mujinja P, Jahn A: Can Mothers Afford Maternal Health Care Costs? User Costs of Maternity Services in Rural Tanzania. *African Journal of Reproductive Health / La Revue Africaine de la Santé Reproductive* 2002, 6(1):65-73.
118. Borghi J, Hanson K, Acquah CA, Ekanmian G, Filippi V, Ronsmans C, Brugha R, Browne E, Alihonou E: Costs of near-miss obstetric complications for women and their families in Benin and Ghana. *Health Policy and Planning* 2003, 18(4):383-390.
119. Nahar S, Costello A: The Hidden Cost of 'Free' Maternity Care in Dhaka, Bangladesh. *Health Policy and Planning* 1998, 13(4):417-422.
120. Afsana K: The Tremendous Cost of Seeking Hospital Obstetric Care in Bangladesh. *Reproductive Health Matters* 2004, 12(24):171-180.
121. CSA-Ethiopia: Ethiopia Mini Demographic and Health Survey 2014. *Central Statistical Agency, Addis Ababa, Ethiopia July 2014 (available at: http://www.unicef.org/ethiopia/Mini_DHS_2014_Final_Report.pdf (accessed 15 August 2014))* 2014.
122. Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, Bassani DG, Jha P, Campbell H, Walker CF, Cibulskis R *et al*: Global, regional, and national causes of child mortality in 2008: a systematic analysis. *The Lancet*, 375(9730):1969-1987.
123. Lawn JE, Cousens S, Zupan J: 4 million neonatal deaths: When? Where? Why? *The Lancet*, 365(9462):891-900.
124. Souza JP, Gülmezoglu AM, Vogel J, Carroli G, Lumbiganon P, Qureshi Z, Costa MJ, Fawole B, Mugerwa Y, Nafiou I *et al*: Moving beyond essential interventions for reduction of maternal mortality (the WHO Multicountry Survey on Maternal and Newborn Health): a cross-sectional study. *The Lancet* 2013, 381(9879):1747-1755.
125. CSA-Ethiopia: Central Statistical Agency of Ethiopia: Population projection of Ethiopia for all Regions at wereda level from 2014 - 2017. Available at: http://www.csa.gov.et/images/general/news/pop_pro_wer_2014-2017 (accessed 09 July 2014). 2014.
126. CIA-USA: The World Fact Book: Africa- Ethiopia, Economy: Ethiopia. available at: <https://www.cia.gov/library/publications/the-world-factbook/geos/et.html> (accessed 09 July 2014).

127. UNDP: Human Development Report 2014. Sustaining Human Progress: Reducing Vulnerabilities and Building Resilience. available at: <http://hdr.undp.org/sites/default/files/hdr14-report-en-1.pdf> (accessed 25 July 2014). *United Nations Development Programme* 2014.
128. OPHI-MPI: Oxford Poverty and Human Development Initiative (OPHI): Global multi-dimensional poverty index (MPI) Interactive Data Bank (2014) available <http://www.dataforall.org/dashboard/ophi/index.php> (accessed 09 July 2014).
129. Kloos H: Primary Health Care in Ethiopia: from Haile Sellassie to Meles Zenawi. *Northeast African Studies* 1998 (new series), 5 (1):83-113.
130. TGE: Transitional Government of Ethiopia. Health Policy of transitional government of Ethiopia, Addis Ababa, TGE. 1993.
131. Teklehaimanot H, Teklehaimanot A: Human resource development for a community-based health extension program: a case study from Ethiopia. *Human Resources for Health* 2013, 11(1):39.
132. UNICEF: In Ethiopia, a far-reaching health worker programme has helped reduce child mortality across the country. available at: http://www.unicef.org/infobycountry/ethiopia_70372.html [accessed 03 October 2013]. 2013.
133. FMOH-Ethiopia: H.E Dr. Keseteberhan Admasu (Minister of Health) Speech in the Two Years Anniversary of: "A Promised Renewed: Celebrating Progress and Mapping the Road Ahead", Washington, D.C. available at: <http://www.moh.gov.et/home/> (accessed 16 July 2014). 2014.
134. WHO: Trends in maternal mortality:1990 to 2010. WHO, UNICEF, UNFPA and The World Bank estimates. Available at : http://whqlibdoc.who.int/publications/2012/9789241503631_eng.pdf [accessed 10 September 2012]
135. Girma M, Yaya Y, Gebrehanna E, Berhane Y, Lindtjorn B: Lifesaving emergency obstetric services are inadequate in south-west Ethiopia: a formidable challenge to reducing maternal mortality in Ethiopia. *BMC Health Services Research* 2013, 13(1):459.
136. FMOH-Ethiopia: Federal Democratic Republic of Ethiopia, Ministry of Health: Health Sector Development Program IV 2010/11 – 2014/15 Final Draft, October 2010.

137. FMOH-Ethiopia: Federal Democratic Republic of Ethiopia Ministry of Health Policy and Practice Information for Action. *Ministry of Health Quarterly Bulletin* April 2014, Vol. 6 No. 1.
138. Graham WJ, Campbell OMR: Maternal health and the measurement trap. *Social Science & Medicine* 1992, 35(8):967-977.
139. FDR-Ethiopia: Registration of Vital events and National Identity Card Proclamation (proclamation no.760/2012). . *Ethiopian Federal Democratic Republic Federal Negarit Gazeta* 2012.
140. Shahidullah M: The Sisterhood Method of Estimating Maternal Mortality: The Matlab Experience. *Studies in family planning* 1995, 26(2):101-106.
141. Font F, González MA, Nathan R, Lwilla F, Kimario J, Tanner M, Alonso P: Maternal mortality in a rural district of southeastern Tanzania: an application of the sisterhood method. *International Journal of Epidemiology* 2000, 29(1):107-112.
142. CSA-Ethiopia: Statistical Tables for the 2007 Population and Housing Census of Ethiopia: SNNPR1 available at www.csa.gov.et (accessed February 24, 2012). In.: CSA-Ethiopia; September 2010.
143. Gaym A, Pearson L, Soe KW: Maternity waiting homes in Ethiopia--three decades experience. *Ethiopian Medical Journal* 2012, 50(3):209-219.
144. Argaw H: The Health Extension Program (HEP) of Ethiopia: Summary of Concepts, Progress, Achievements and Challenges. Addis Ababa, Ethiopia. 2007
145. FMOH-Ethiopia: Federal Ministry of Health of Ethiopia: Guidelines for Health Extension Programme; Addis Ababa, 2007.
146. Graham W, Brass W, Snow RW: Estimating Maternal Mortality: The Sisterhood Method. *Studies in Family Planning* 1989, 20(3):125-135.
147. Vyas S, Kumaranayake L: Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning* 2006, 21(6):459-468.
148. Hanley JA, Hagen CA, Shiferaw T: Confidence Intervals and Sample-size Calculations for the Sisterhood Method of Estimating Maternal Mortality. *Studies in Family Planning* 1996, 27(4):220-227.
149. IBM: SPSS software: Predictive analytics software and solutions. available at: <http://www-01.ibm.com/software/analytics/spss/> (accessed 20 November 2013).
150. Rothman KJ: *Epidemiology: An Introduction*: Oxford University press, 198 Madison Avenue, New York, New York 10016; 2002.

151. Hennekens CH, Buring JE, Mayrent SL, Doll R: Epidemiology in medicine. Ed. Sherry L. Mayrent. Reprinted by Lippincott Williams & Wilkins. 530 Walnut St. Philadelphia, PA 19106 USA; 1987.
152. Harbour R, Miller J: A new system for grading recommendations in evidence based guidelines. *BMJ* 2001.
153. Black N: Why we need observational studies to evaluate the effectiveness of health care. *BMJ* 1996, 312(7040):1215-1218.
154. Grimes DA, Schulz KF: Descriptive studies: what they can and cannot do. *The Lancet* 2002, 359(9301):145-149.
155. Grimes DA, Schulz KF: Cohort studies: marching towards outcomes. *The Lancet* 2002, 359(9303):341-345.
156. Cummings SR, Newman TB, Hulley SB: Designing and Observational study: Cohort studies. In: *Designing Clinical Research: An Epidemiologic Approach* by Stephen B Hulley MD, Steven R Cummings MD, Warren S Browner MD and Deborah Grady. Volume 2nd edn.: Lippincott Williams & Wilkins; 2001.
157. Irgens LM: The Medical Birth Registry of Norway. Epidemiological research and surveillance throughout 30 years. *Acta Obstetricia et Gynecologica Scandinavica* 2000, 79(6):435-439.
158. Rothman K, Greenland S: Causation and causal inference in epidemiology. *Am J Publ Health* 2005, 95:S144 - 150.
159. Hanley JA, Hagen CA, Shiferaw T: Confidence intervals and sample-size calculations for the sisterhood method of estimating maternal mortality. *Studies in family planning* 1996:220-227.
160. Hulley SB, Newman TB, Cummings SR: Choosing the study subjects: Specification, Sampling and recruitment. In: *Designing Clinical Research: An Epidemiologic Approach* by Stephen B Hulley MD, Steven R Cummings MD, Warren S Browner MD and Deborah Grady. Volume 2nd edn.: Lippincott Williams & Wilkins; 2001.
161. Browner WS, Newman TB, Cummings SR, Hulley SB: Estimating Sample Size and Power: The Nitty-gritty. In: *Designing Clinical Research: An Epidemiologic Approach* by Stephen B Hulley MD, Steven R Cummings MD, Warren S Browner MD and Deborah Grady Volume 2nd edn.: Lippincott Williams & Wilkins; 2001.
162. Boyko EJ: Observational research — opportunities and limitations. *Journal of Diabetes and its Complications* 2013, 27(6):642-648.

163. Merdad L, Hill K, Graham W: Improving the Measurement of Maternal Mortality: The Sisterhood Method Revisited. *PLoS ONE* 2013, 8(4):e59834.
164. Kao S, Chen L-M, Shi L, Weinrich MC: Underreporting and misclassification of maternal mortality in Taiwan. *Acta Obstetricia et Gynecologica Scandinavica* 1997, 76(7):629-636.
165. Newman TB, Browner WS, Hulley SB: Enhancing Causal Inference in Observational studies. In: *Designing Clinical Research: An Epidemiologic Approach* by Stephen B Hulley MD, Steven R Cummings MD, Warren S Browner MD and Deborah Grady. Volume 2nd edn.: Lippincott Williams & Wilkins; 2001.
166. Bobby JC, Phillips LW, Tybout AM: The Concept of External Validity. *Journal of Consumer Research* 1982, 9(3):240-244.
167. Songane FF, Bergström S: Quality of registration of maternal deaths in Mozambique: a community-based study in rural and urban areas. *Social Science & Medicine* 2002, 54(1):23-31.
168. CSA-Ethiopia: Ethiopian Demographic and Health Survey 2005. Addis Ababa, Ethiopia and Calverton, MD, USA, Ethiopian Central Statistical Agency and ORC Macro, 2006. ([http://dhsprogram.com/pubs/pdf/FR179/FR179\[23June2011\].pdf](http://dhsprogram.com/pubs/pdf/FR179/FR179[23June2011].pdf)). accessed 11 August 2014. 2006.
169. UNICEF: United Nations Children's Fund, Every Child's Birth Right: Inequities and trends in birth registration, UNICEF, New York, 2013. Available at: http://www.unicef.org/mena/MENA-Birth_Registration_report_low_res.pdf (accessed 10 January 2014). . 2013.
170. Hill K, AbouZahr C, Wardlaw T: Estimates of maternal mortality for 1995. *Bulletin of the World Health Organization* 2001, 79:182-193.
171. Shiferaw T, Tessema F: Maternal mortality in rural communities of Illubabor, southwestern Ethiopia: as estimated by the "sisterhood method". *Ethiopian medical journal* 1993, 31(4):239-249.
172. Kwast BE, Rochat RW, Kidane-Mariam W: Maternal mortality in Addis Ababa, Ethiopia. *Studies in family planning* 1986:288-301.
173. Mersha A, Jira C, Demessie S: Community based study on maternal mortality in Jimma town, south western Ethiopia. *Indian journal of public health* 1995, 40(2):30-34.

174. CSA-Ethiopia, ICF-International: Ethiopia Demographic and Health Survey 2011 *Central Statistical Agency of Ethiopia and ICF International Addis Ababa, Ethiopia and Calverton, Maryland, USA available at: <http://www.measuredhs.com/publications/publication-fr255-dhs-final-reports.cfm> (accessed 25 June 2013) 2012.*
175. WHO: Levels & Trends in Child Mortality Report 2012. Estimated Developed by the UN Inter-agency Group for Child Mortality Estimation. In. New York, USA. available at: http://www.who.int/maternal_child_adolescent/documents/levels_trends_child_mortality_2012.pdf (accessed 20 June 2013); 2012.
176. Admasu K, Haile-Mariam A, Bailey P: Indicators for availability, utilization, and quality of emergency obstetric care in Ethiopia, 2008. *International Journal of Gynecology & Obstetrics* 2011, 115(1):101-105.
177. WHO: Proportion of births attended by a skilled health worker 2008 updates. *Department of Reproductive Health and Research* 2008, WHO/RHR/08.22(available at: http://apps.who.int/iris/bitstream/10665/69950/1/WHO_RHR_08.22_eng.pdf?ua=1 (accessed 11 August 2014)).
178. Paxton A, Maine D, Freedman L, Fry D, Lobis S: The evidence for emergency obstetric care. *International Journal of Gynecology & Obstetrics* 2005, 88(2):181-193.
179. WHO, UNICEF, UNFPA, AMDD: Monitoring Emergency Obstetric Care, a handbook. *WHO publications, 2009 Geneva, Switzerland: World Health Organization; 2009* available at: http://whqlibdoc.who.int/publications/2009/9789241547734_eng.pdf (Accessed 10 August 2014).
180. Paxton A, Bailey P, Lobis S: The United Nations Process Indicators for emergency obstetric care: Reflections based on a decade of experience. *International Journal of Gynecology & Obstetrics* 2006, 95(2):192-208.
181. UNFPA-Ethiopia: Joint Press conference discloses Ethiopia on track to achieve MDG5 (available at http://countryoffice.unfpa.org/ethiopia/2014/05/12/9693/joint_press_conference_discloses_ethiopia_on_track_to_achieve_mdg5/ (accessed 17 September 2014). *UFPA and FMOH of Ethiopia Joint statement* 2014.

182. Berhan Y, Berhan A: Review of Maternal Mortality in Ethiopia: A Story of the Past 30 Years. *Ethiopian Journal of Health Sciences* 2014, 24(0 Suppl):3-14.
183. Christian P, Sommer A, West Jr KP: Reducing maternal mortality where rates are greatest. *The Lancet*, 368(9553):2122-2123.
184. WHO: Maternal, newborn and child health score cards (by country). *World Health Organization Document Centre (Maternal, newborn, child and adolescent health)* 2014, available at: http://www.who.int/maternal_child_adolescent/documents/countries/indicators/en/ (accessed 15 August, 2014).
185. Costello A, Azad K, Barnett S: An alternative strategy to reduce maternal mortality. *The Lancet*, 368(9546):1477-1479.
186. CSA-Ethiopia: Ethiopia Demographic and Health Survey 2000. Central Statistical Agency of Ethiopia and ORC Macro, Calverton, Maryland, USA, 2001 (available at: <http://dhsprogram.com/publications/publication-FR118-DHS-Final-Reports.cfm> (accessed 20 August 2014). 2000.
187. Otten M, Aregawi M, Were W, Karema C, Medin A, Bekele W, Jima D, Gausi K, Komatsu R, Korenromp E: Initial evidence of reduction of malaria cases and deaths in Rwanda and Ethiopia due to rapid scale-up of malaria prevention and treatment. *Malaria Journal* 2009, 8(1):14.
188. Wolday D, Meles H, Hailu E, Messele T, Mengistu Y, Fekadu M, Parekh BS, Wuhib T: Temporal trends in the incidence of HIV infection in antenatal clinic attendees in Addis Ababa, Ethiopia, 1995–2003. *Journal of Internal Medicine* 2007, 261(2):132-137.
189. MOH-Ethiopia: Technical and Procedural Guidelines for Safe Abortion Services in Ethiopia. . *Federal Democratic Republic of Ethiopia, Ministry of Health, Addis Ababa*, June 2006.
190. Gebrehiwot Y, Liabsuetrakul T: Trends of abortion complications in a transition of abortion law revisions in Ethiopia. *Journal of Public Health* 2009, 31(1):81-87.
191. Singh S, Fetters T, Gebreselassie H, Abdella A, Gebrehiwot Y, Kumbi S, Audam S: The Estimated Incidence of Induced Abortion In Ethiopia, 2008. *International Perspectives on Sexual and Reproductive Health* 2010, 36(1):16–25.
192. Prata N, Gessessew A, Campbell M, Potts M: “A new hope for women”: medical abortion in a low-resource setting in Ethiopia. *Journal of Family Planning and Reproductive Health Care* 2011, 37(4):196-197.

Papers I-IV and Appendices

RESEARCH ARTICLE

Maternal Mortality in Rural South Ethiopia: Outcomes of Community-Based Birth Registration by Health Extension Workers

Yaliso Yaya^{1,2*}, Tadesse Data³, Bernt Lindtjörn¹

1 Centre for International Health, University of Bergen, Bergen, Norway, **2** Arba Minch College of Health Sciences, Arba Minch, Ethiopia, **3** Gamo Gofa Zone Health Department, Arba Minch, Ethiopia

* yalisoyaya@gmail.com



Abstract

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Introduction

Rural communities in low-income countries lack vital registrations to track birth outcomes. We aimed to examine the feasibility of community-based birth registration and measure maternal mortality ratio (MMR) in rural south Ethiopia.

Methods

In 2010, health extension workers (HEWs) registered births and maternal deaths among 421,639 people in three districts (Derashe, Bonke, and Arba Minch Zuria). One nurse-supervisor per district provided administrative and technical support to HEWs. The primary outcomes were the feasibility of registration of a high proportion of births and measuring MMR. The secondary outcome was the proportion of skilled birth attendance. We validated the completeness of the registry and the MMR by conducting a house-to-house survey in 15 randomly selected villages in Bonke.

Results

We registered 10,987 births (81.4% of expected 13,492 births) with annual crude birth rate of 32 per 1,000 population. The validation study showed that, of 2,401 births occurred in the surveyed households within eight months of the initiation of the registry, 71.6% (1,718) were registered with similar MMRs (474 vs. 439) between the registered and unregistered births. Overall, we recorded 53 maternal deaths; MMR was 489 per 100,000 live births and 83% (44 of 53 maternal deaths) occurred at home. Ninety percent (9,863 births) were at home, 4% (430) at health posts, 2.5% (282) at health centres, and 3.5% (412) in hospitals. MMR increased if: the male partners were illiterate (609 vs. 346; $p=0.051$) and the villages had no road access (946 vs. 410; $p=0.039$). The validation helped to increase the registration coverage by 10% through feedback discussions.

Competing Interests: The authors have declared that no competing interests exist.

Conclusion

It is possible to obtain a high-coverage birth registration and measure MMR in rural communities where a functional system of community health workers exists. The MMR was high in rural south Ethiopia and most births and maternal deaths occurred at home.

Introduction

The global maternal mortality ratios (MMRs) were halved between 1990 and 2010. However, of all maternal deaths in the world, 99% occur in low-income countries; 36 of the 40 countries with the highest MMR are in sub-Saharan Africa [1]. The MMR is the conventional key indicator to help monitor progress towards the MDG5 target of reducing maternal mortality by 75% in 2015 from the level in 1990 [2]. Unfortunately, measuring maternal mortality is difficult in low-income countries because of limited registration of births and deaths [3]. In 2013, UNICEF reported that 44% of births in sub-Saharan Africa, and only 7% in Ethiopia, were registered [4]. The continued failure of vital registration in low-income countries was noted as “*the single most critical development failure over the past 30 years*” [5].

Following the safe motherhood initiative (SMI) in 1987 and MDG declaration in 2000, several alternative approaches, such as survey methods [6–8] and statistical modelling of proxy data for national and international use [1,9], have been devised to estimate maternal mortality indices in low-income countries. While these methods provide important information for global and national planning, the evidence obtained using these techniques are often inconsistent and sometimes contradictory [10]. Progress towards the planned MDG goal and equity in health outcomes as well as post-MDG efforts require concrete data from population-based registries [11].

The study in context

We conducted this study at a time when Ethiopia acknowledged the importance of and made practical movements towards improving maternal health and formulating a law for compulsory vital registration. As such, the five year (2010–2015) National Health Sector Strategic Plan emphasizes the intention to improve maternal and newborn health [12]. In addition, the government of Ethiopia was amidst discussions to pass a law for compulsory vital registration, which was approved in 2012 [13]. To implement the new registration law, the Central Statistical Agency (CSA) suggested the use of health extension workers (HEWs) as registrars of vital events in rural Ethiopia [14]. On the other hand, the World Health Organization (WHO) issued the maternal death review (MDR) and maternal death surveillance and response (MDSR) guidelines as part of international efforts to reduce maternal mortality [15,16]. When we conducted the current study, however, there was a limited such committees or systems for reviewing maternal deaths in rural Ethiopia. As a result, we did not know whether the continuous registration of births and surveillance of maternal deaths could result in intended outcomes of complete birth registration and maternal mortality measurement in rural areas of Ethiopia.

In 2003, Ethiopia adopted a community-based health extension programme (HEP) [17], and currently over 38,000 HEWs are working in all rural villages. However, the opportunity for using these community health workers to obtain useful data for public health policy and action has not been explored. Consequently, the objective of this study was to assess whether HEWs can effectively register births and actively identify maternal deaths in the rural villages to

measure the magnitude and associated factors for maternal mortality through a community-based birth registration system.

Methods

Ethics statement

The Ethical Review Committee for the Health Research of Southern Nations Nationalities and Peoples' Regional State (SNNPRS) Health Bureau in Ethiopia, and the Regional Committee for Health Research Ethics of North Norway (REK Nord) in Norway approved the study. Birth and birth-outcome registration is part of the routine work of the HEWs in Ethiopia, which is acknowledged by the government. We systematized the registry by preparing a standardized format and providing technical support. Personal identifiers were removed from the stored data used for research. We obtained informed verbal consent from respondents for the validation study of house-to-house survey and the responses were recorded on the questionnaire as "accepted" or "declined" to participate. Written consent was not considered because a large number of the respondents were illiterate and the Ethics Committee approved the verbal consent procedure.

Study area

The Ethiopian government has autonomous regional states within the Federal Republic. In turn, regional states are subdivided into zones (provinces), Woredas (districts), and Kebeles (villages). A zone is a cluster of 10–15 districts, and a district is a group of 20–50 villages. A Kebele is the lowest administrative structure and is comprised of 1,000–1,500 households. This study was conducted in three districts (Arba Minch Zuria, Bonke, and Derashe) in two zones (Gamo Gofa and Segen Area Peoples') in the Southern Nations, Nationalities, and Peoples' Region (SNNPR, Fig. 1). The Gamo Gofa Zone (population = 1,740,828 people in 2010) [18], the centre of which is at Arba Minch, is 505 km from Addis Ababa to the southwest and the Segen Area Peoples' Zone (636,794 residents in 2010) [18] is 575 km from Addis Ababa.

Bonke, with a population of 166,913 people in 2010, had no hospital providing comprehensive emergency obstetric care at the time of the study. The nearest such service was at Arba Minch Hospital, which is 50–150 km from the villages of Bonke. Arba Minch Zuria, with a population of 179,785 people, has a hospital, although the largest proportion of the population lives in the highlands far from the hospital and driveable roads. Derashe, with a population of 141,589 has a district hospital in the main town of Gidole, as well as well-functioning maternity waiting homes, traditional thatched huts built in the hospital compound, where mothers with high-risk pregnancies are referred and observed until delivery [19].

Sampling and study participants

Fig. 2 presents the study profile. In 2008, the MMR in Ethiopia was 590 per 100,000 live births (LBs) [9]. Assuming this would be comparable for the study area, we expected there could be a 10% decline in two years resulting in an MMR of 531 (95% CI: 413, 669) per 100,000 LBs in 2010. Thus, we expected 70 maternal deaths in a year (95% CI: 55, 88) out of estimated 13,492 births (13,223 LBs) in a population of 421,639 people. LBs were approximated 98% of all births in the area [20]. To estimate the expected number of births, we used an annual crude birth rate (CBR) of 32 per 1,000 population based on the following two sources of birth rate information: a finding from a household survey in 2010 in one of the study districts (Bonke) [20], and the same estimate by The World Bank of CBR in Ethiopia for 2010 [21]. To identify group



Fig 1. The map of the study area within southern Ethiopia.

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differences in the MMR, we assumed the number of maternal deaths amongst births determined above would provide sufficient data.

We purposely selected three districts with the number of residents expected to produce the above estimated births and maternal outcomes. The districts were assumed to represent the area in terms of health services, demographics, and road access. In these districts, we included all kebeles (villages), except those where the HEWs were sick or on maternity leave at the time of starting the registration. We used OpenEpi software (Open Source Epidemiologic Statistics for Public Health version 3.01, www.openepi.com) to calculate the sample size.

The HEP and the HEWs

The HEP is a community-based healthcare system with two female HEWs serving a rural village of 1,000–1,500 households. Most of the HEWs have completed a 10th grade education and received one year of general health training. Their work focuses on family health (child vaccinations, family planning, antenatal care, and assisting normal deliveries) and health promotion. HEWs are expected to routinely visit each household in their catchment once a month, prioritizing households with pregnancies, newborns, and sick persons. HEWs are part of the permanent health workforce and receive a monthly salary of 40–50 USD from the government based on their years of service. In addition, 5–10 lay-women known as volunteer health promoters (VHPs), assist the work of HEWs by informing of households with a recent delivery, sick people, and deaths in the sub-villages.

Data collection procedures (the birth registry)

We conducted one week training at each woreda centre for HEWs, supervisors, and the district health authorities before the registry started. Supervisors were experienced nurses (one per district), who helped the HEWs in reviewing and classifying deaths, monitoring the quality of data, and transferring the registered information from HEWs to the central data clerk. During

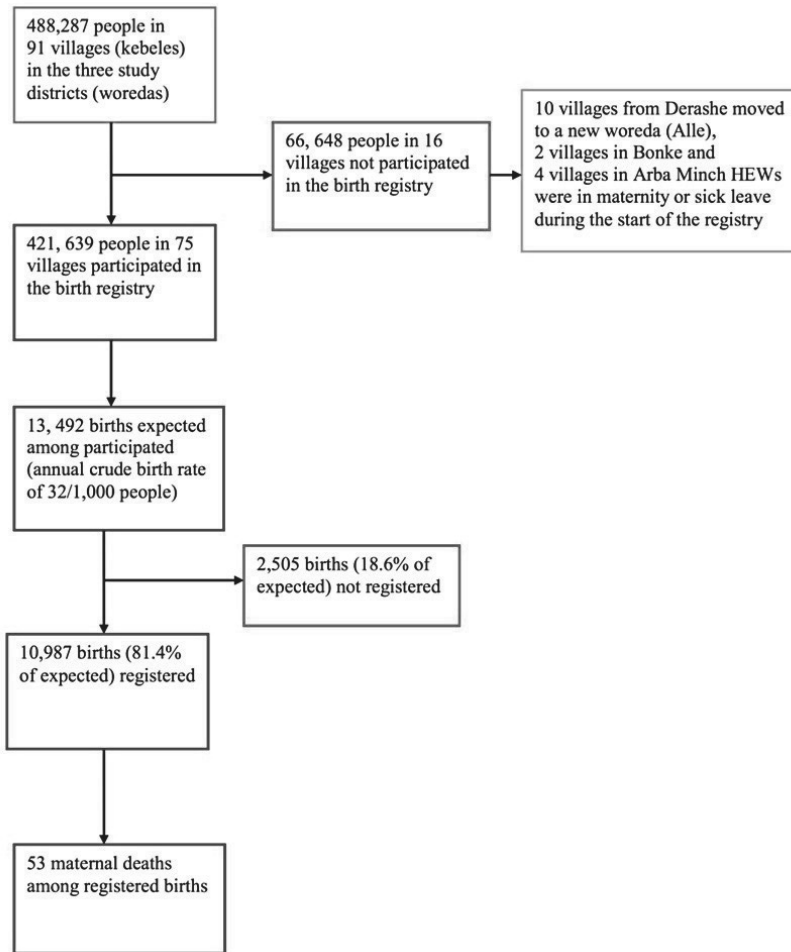


Fig 2. The profile of the birth registry.

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the training, we clarified the WHO ICD-10 definition and classification of maternal deaths [22]. Accordingly, if a woman died during ante- or intra-partum periods, or within six weeks after termination of a pregnancy and her pregnancy status was known, her death was considered a maternal death if the death was not because of an accident or incident such as suicide. We also used extractions from the WHO maternal death review (MDR) manual published in 2004 to determine the cause of deaths [15]. As such, diagnosing the cause of death was based on symptomatic approaches such as convulsions attributed to hypertensive disorders, fevers to infections, and excessive bleeding due to haemorrhage.

The specific registration and maternal death ascertainment procedure is presented as follows. HEWs visited homes within hours or days after the pregnancy ended depending on the distance and the speed of notification from the sub-village VHPs or families. At the household, HEWs assessed and registered birth and births conditions. The HEWs continued the follow-up until a maternal death was occurred or six-week post-partum. This collection of information was similar to births that occurred at home and in health facilities because all births were available for recording at homes. In addition, in households in which a woman of reproductive age died without giving birth, HEWs critically reviewed the conditions at the time of death to determine the pregnancy status of the deceased and determine the probable cause of death. Husbands or fathers of the baby (FOBs) were primary sources of information for maternal deaths; however, in the cases where obtaining information from the husbands or FOBs was not possible, adult members of the family helped in providing information.

HEWs registered the data in printed birth registry books (Fig. 3). The book contained important socio-demographic variables, such as the distance of the village from the nearest health centre and the nearest hospital recognized by the respective district health offices, as well as the type (quality) of road to the village as a general heading information. The actual body of the book rows contained personal background information, such as education of the mother and father and age of the mother. In addition, the woman's parity, the place of birth, the attendant of birth, the condition of the newborn at birth (alive or stillbirth), the gender of the foetus, and maternal deaths (including the place, cause, and time) were among the variables. Registration was made in duplicate and the first copy was detached and sent to the Research and Training Centre at Arba Minch Hospital, while the second copy remained with the book in the village. Most births were registered within 24 hours of delivery, unless there was a special reason for a delay (births in distant health institutions, where the household was far from the HEW station or HEWs were not informed in a timely manner). Similarly, most maternal deaths were identified immediately. Nevertheless, HEWs made a final follow-up home visit six weeks after birth or abortion when death information was not obtained prior to the stated deadline.

Outcomes

The primary outcomes were the coverage of birth registration (percentage registered out of the estimated) and the MMR. The secondary outcome was the proportion of skilled birth attendance, facility deliveries supervised by skilled professionals.

Data quality control (the validation study)

To check the validity of the registration eight months after the start of the registration, we conducted a house-to-house survey in 15 of the 30 rural villages in the Bonke. Data collectors who had completed the 12th grade visited every household and searched for a birth or pregnancy outcome since the start of the birth registry. For births already registered in the birth registry, they checked the content (date of birth, date of death, and baby's gender). The unregistered were recorded and the data were transferred to the registry book. Based on the findings of the validation study, we discussed the feedback with the HEWs and supervisors to improve the coverage of the registration.

Data analysis

We entered, checked, and analyzed the registry and validation data using the statistical package for social sciences (SPSS-16) describing the results in tables showing proportions and means. To show the variation in maternal mortality, we used a chi-square test. For the validation study, we produced a descriptive table showing the proportion of births registered and

Table 1. Socio-demographic data on parents, services, and infrastructures in the birth registry districts of south Ethiopia in 2010.

Background variable	Value
Age of mother (years): mean (SD)	28.1 (4.5)
Education of fathers N = 10,987*	
Illiterate: no. (%)	6,001 (54.6)
Literate: no. (%)	4,986 (45.4)
Education of mothers N = 10,987*	
Illiterate: no. (%)	8,454 (77.0)
Literate: no. (%)	2,533 (23.0)
Health Centre distance (km): median** (IQR)	10 (5–18)
Hospital distance (km): median (IQR)	40 (24–67)
Pregnancy (gravity): mean (SD)	3.7 (2.2)
Antenatal visits: mean (SD) N = 10,987	
No antenatal: no. (%)	1,655 (15.1)
1–2 visits: no. (%)	3,767 (34.3)
3 or more: no. (%)	5,565 (50.7)
Place of Delivery (%): N = 10,987	
Home: no. (%)	9,863 (90)
Health post: no. (%)	430 (4.0)
Health Centre: no. (%)	282 (2.5)
Hospital: no. (%)	412 (3.5)
Road access (%): N = 10,987	
All-weather: no. (%)	4,214 (38.4)
Dry weather: no. (%)	5,446 (49.6)
No car road: no. (%)	1,327 (12.0)

Note:

* Education: illiterate are those cannot read/write and had no formal education, literate include those who can read/write and completed higher education,

** 57% of households with births were within 10 km of health centres (10 km is the government target for access)

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unregistered out of the births found during the validation survey. We made a cross-tabulation for crude analysis to determine the risk of maternal deaths among registered births compared to unregistered and the effect of antenatal follow-up and distance from HEW station on the likelihood of births being registered.

Results

Socio-demographic characteristics of registered births

Table 1 presents the background information about the parents and the maternal services received during pregnancy and delivery. We registered 10,987 births (5,612 [(51.1%) boys and 5,375 (48.9%) girls). The average age of the mothers was 28.1 (SD = 4.5) years, and the median number of pregnancies was 3 (IQR = 2–5). The illiteracy rate was 77% (8,454/10,987) among mothers, and 54.6% among the husbands and FOBs (6,001/10,987). The median distance to health centres was 10 km (IQR = 5–18), and 57% (6,236/10,987) of the births had a health centre within 10 km. The median distance to hospitals was 40 km (IQR = 24–67).

Table 2. District distribution of births, birth outcomes, and services during pregnancy and delivery in south Ethiopia in 2010.

	Districts			
	Derashe	Bonke	Arba Minch	Overall
All births	3,134	3,571	4,282	10,987
Live births	3,099	3,529	4,205	10,833
Maternal deaths (number)	14	18	21	53
Antenatal visits: Mean (SD)*	2.5 (1.6)	2.1 (1.4)	2.5 (1.3)	2.4 (1.4)
No antenatal: no (%)	546 (17.4)	669 (18.7)	440 (10.3)	1,655 (15.1)
1–2 visits: no (%)	826 (26.4)	1,418 (39.7)	1,523 (35.6)	3,767 (34.3)
3 and more: no (%)	1,762 (56.2)	1,484 (41.6)	2,319 (54.1)	5,565 (50.6)
Place of delivery no (%) N = 10,987				
Home	2843 (90.7)	3,183 (89.1)	3,837 (89.6)	9,863 (90)
Health post	40 (1.3)	290 (8.2)	100 (2.4)	430 (4.0)
Health Centre	25 (0.8)	81 (2.2)	176 (4.1)	282 (2.5)
Hospital	226 (7.2)	17 (0.5)	169 (3.9)	412 (3.5)
Delivery attendant no (%)				
Family member or relative	234 (7.5)	1,823 (51.1)	1,937 (45.3)	3994 (36.4)
Traditional birth attendant	2,434 (77.7)	1,027 (28.8)	1,364 (31.8)	4825 (44.0)
Health Extension Worker	215 (6.8)	623 (17.4)	636 (14.9)	1,474 (13.4)
Health professionals (skilled)	251 (8.0)	98 (2.7)	345 (8.0)	694 (6.3)

Note:

* SD, standard deviation

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Completeness of birth registration

The 10,987 registered births were 81.4% of the 13,492 expected births based on the annual CBR for the year. Because the CBR was estimate-based, we made sensitivity analysis of the expected births by increasing the annual CBR by two to 34 and again by decreasing by two to 30 per 1000 population. If the CBR was 34, the number of expected births was 14, 336 of the 421, 639 residents in the registry villages. This decreased the registration coverage from 81.4% to 77%, and if the CBR was 30, the registration coverage rose to 87% from our best estimate of 81.4% because the expected number of births was 12,649.

Maternal mortality outcomes

We registered 53 maternal deaths (Table 2), yielding an MMR of 489 per 100,000 live births. The MMR of 489 per 100,000 live births was within the 95% confidence interval of the expected MMR of 531 (95% CI: 413–669). Table 3 compares the MMR estimates between the birth registry (489), the validation study (474), the previous household survey finding from the area (425), and the national estimates by IMHE (590), UN (350), and DHS (676) per 100,000 live births. In the birth registry study, five mothers (9.4%) died during pregnancy, 21 (39.6%) died during labour and 27 (51%) died within six weeks post-partum. Of the maternal deaths, 35.8% (19/53) were due to bleeding, 22.6% (12 /53) due to infection, 17% (9/53) because of hypertensive disorders, 13.2% (7/53) because of obstructed labour, and 11% (6/53) registered as “others”. Additional inquiries indicated that three of the six cases categorized as ‘other causes’ and two cases in the haemorrhage category were probable complications of abortion. Of all 53 maternal deaths identified, 83% (44) occurred at home and 17% (9) were in health institutions.

Table 3. Variations in maternal mortality across variables, south Ethiopia, 2010.

Variable	Maternal deaths	Live births	MMR*(95% CI)	p-value (2-tail)
District				
Bonke	18	3,529	510 (312, 789)	
Arba Minch	21	4,205	500 (318, 750)	
Derashe	14	3,099	452 (257, 740)	
Maternal age				
≤ 20	4	709	564 (180, 1,355)	
21–35	45	9,475	475 (351, 630)	
≥ 36	4	649	616 (196, 1,480)	
Parity (no. of births)				
≤3	32	5,760	556 (386, 774)	
≥4	21	5,073	414 (263, 621)	
Mother's education**				
Illiterate	40	8,331	480 (347, 647)	
Literate	13	2,502	520 (290, 865)	
Father's education**				
Illiterate	36	5,913	609 (433, 833)	0.051
Literate	17	4,920	346 (208, 541)	
Antenatal visits				
No ANC	11	1,628	676 (356, 1,172)	
1–2 visits	17	3,711	458 (276, 717)	
3 or more	25	5,494	455 (301, 661)	
Place of birth				
Home	44	9,757	451 (332, 599)	
Institution	9	1,066	844 (412, 1,544)	
Distance to health centre				
≤10	35	6,151	569 (403, 782)	
≥11	18	4,649	387 (237, 600)	
Distance to hospital				
≤25	14	3,196	438 (250, 716)	
≥26	39	7,604	513 (370, 693)	
Road to the village[§]				
All weather drive	17	4,150	410 (247, 642)	
Dry weather drive	24	5,377	446 (293, 653)	
No driveable road	12	1,269	946 (513, 1,602)	0.039
Sickness in pregnancy				
Yes	24	1,361	1,763(1,159, 2,572)	0.000
No	29	9,472	306 (209, 433)	
Total	53	10,833	489 (366, 628)	

Note:
 *maternal mortality ratio per 100,000 live births. Cells with P-value > 0.05 (with no statistical significance) are left empty. MMR in the parenthesis are 95% CIs.

**Education: illiterate are those who cannot read/write and had no formal education, literate include those who can read/write and more educated up to higher education.

[§] Compared only all-weather road against no driveable road

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Place of birth and assistance during labour

Table 2 also shows the place of delivery and who assisted the births. Of the registered births, 85% of the mothers (9332/10987) received antenatal care. However, 90% of the mothers (9863/10987) delivered at home, 4% (430) at health stations (two-room buildings staffed by HEWs), 2.5% (282) at health centres (staffed by nurses and midwives), and 3.5% (412) in hospitals. One-third of the births were (36.4% [3,994/10,987]) were assisted by family members and relatives, 44% (4,825) by traditional birth attendants (TBAs), 13.4% (1,474) by HEWs, and 6.3% (694) by skilled professionals (physicians, health officers, midwives, and nurses). Regarding road access, 61.6% of the births (6,773/10,987) took place in villages without driveable-road or access to driveable road during the dry season only.

Variations in maternal mortality

The MMR was similar in the three districts, and there was no difference between educated and illiterate mothers (Table 3). However, the MMR was higher in the villages where there was no driveable road access compared to villages where there was at least a dry-weather road (946 vs. 446) and an all-weather road [946 vs. 410; χ^2 (df): 6.11 (2), $p = 0.039$]. Maternal mortality was six times higher among mothers who had illness of any kind during pregnancy, compared to those who had not complained of any illness [1,763 vs. 306; χ^2 (df): 48.6 (1), $p < 0.0001$], and increased when the male partners were illiterate, compared to those who were literate [609 vs. 346; χ^2 (df): 3.8 (1), $p = 0.051$].

Results from the validation study

Table 4 shows findings from a house-to-house validity study compared to the birth registry. Of the 2,401 births identified during house-to-house checks, 1,718 (71.6%) were registered and 683 (28.4%) were not registered. Births to women who attended antenatal clinics (ANCs) were more likely to be registered compared to mothers who did not have any ANC visits (74.6% [1413/1895] vs. 60.3% [305/506]; RR = 1.24 [95% CI: 1.15–1.33]). Births that had occurred within 5 km from a HEW station were also more likely to be registered compared to births that occurred > 6 km from a HEW station (75.2% [1072/1425] vs. 66.2% [646/976]); RR = 1.14

Table 4. Results from house-to-house validation study to check completeness of birth registry in south Ethiopia during 2010.

Variables	registered number (%)	unregistered number (%)	checked (100%)	RR** (95% CI)
All births	1,718 (71.6)	683 (28.4)	2,401	
Live births	1,698 (71.5)	675 (28.5)	2,373	
Maternal death	8	3	11	
MMR*	474	439	464	1.06 (0.28, 3.98) [§]
Antenatal care visit				
Yes	1,413 (74.6)	482 (25.4)	1,895	1.24 (1.15, 1.33)
No	305 (60.3)	201 (39.7)	506	Ref
Distance to HEW [§] station				
≤ 5 km	1,072 (75.2)	353 (24.8)	1,425	1.14 (1.08, 1.20)
≥ 6 km	646 (66.2)	330 (33.8)	976	Ref

Note:

* MMR, maternal mortality ratio per 100,000 live births,

** RR, relative risk,

§ relative risk of MMR among registered births compared to unregistered. HEW[§], health extension worker

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Table 5. Estimates of the maternal mortality ratio per 100,000 live births in the study area compared with national estimates in Ethiopia during the years around 2010.

MMR ^β	Year	Source	Estimated for	Remarks
489	2010	Birth registry	Study area	This paper
474	2010	Validation of birth registry	study area	This paper
425	2010	Household survey	Study area	Yaya et al [20]
350	2010	UN modelled estimate	National level	WHO and co [1]
676	2010	DHS*	National level	CSA-Ethiopia** [6]
590	2008	IHME modelled estimate***	National level	Hogan et al [9]

Note: MMR,

^β maternal mortality ratio per 100,000 live births, DHS,

* Demographic and Health Survey, CSA,

** Central Statistical Agency IHME,

*** Institute of Health Metrics and Evaluation, Washington University, USA.

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[95% CI = 1.08–1.20]). The MMR was similar among registered and unregistered (474 vs. 439) per 100,000 LBs, (RR = 1.06 [95% CI: 0.28–3.98]).

Comparing maternal mortality in the study area with national estimates

To provide a better understanding of the MMR in the study area obtained by using different methods of measurement with the national estimates for Ethiopia, we provide a summary table (Table 5).

Discussion

In 75 rural kebeles, we registered 81% of expected births in nearly half a million residents. The MMR was 489 per 100,000 LBs. In addition, four of every five maternal deaths occurred at home without the attention of health facilities in the area. A validation study also showed a high initial coverage of birth registration out of births identified through checks by household visits, and there was a similar MMR between registered and unregistered births. These findings suggest that it is possible to register a high percentage of births expected in rural communities using community health workers. In addition, the community-based birth registry appears to be a useful tool to identify and measure maternal mortality. Majority (90%) of the registered births took place at home while > 90% of maternal deaths occurred during intra- and post-partum periods. Haemorrhage and infections were the leading causes of maternal deaths. The MMR was higher in remote areas without roads, amongst couples in which the male partners were illiterate, and among mothers who experienced illnesses during pregnancy.

We are not aware of other studies that have tested the feasibility of registration of births and pregnancy outcomes such as maternal deaths in rural Ethiopia. The 2013 UNICEF report showed that only 7% of births are registered in Ethiopia, which is the third lowest in the world ahead of Liberia (4%) and Somalia (3%) [4].

Unfortunately, because of resource constraints we were not able to conduct a baseline survey of fertility for 2010 in the study area. Consequently, we assessed the completeness of the birth registry using the coverage of the registry out of expected (estimated) births in the area, depending on a finding from a previous survey (CBR = 32 per 1,000 population between 2006 and 2010) [20]. Expecting the number of births through the annual CBR estimation may under- or over-estimate the true number of births, and the coverage may vary from the 81.4%

we report. Additionally, we conducted a validation study for births occurring in 8 months, and this presents a problem in measuring the annual CBR. As such, the validation study only serves the purpose of determining what proportion of actually observed births at households were registered and whether or not there was a difference in an outcome of interest (MMR) between registered and unregistered births. The validation study cannot help to estimate annual CBR that needs 12 months of data on births.

Given the continuous decline in fertility in rural areas, as indicated by a decrease in CBR per 1,000 population (43 in 2000 to 28 in 2014) according to the DHS showed by findings from DHS [23], the CBR in 2010 may have been < 32 per 1,000 people or we are uncertain whether or not the CBR was even higher. We did a sensitivity analysis by using annual CBRs of 34 and 30 to compare the registration coverage against the CBR of 32 used in the analysis. The analysis provided registration coverage between 77% and 87%. The true CBR in the area may be between 30 and 32 per 1,000 population, which implies that the actual coverage of birth registration may have been > 81%. Therefore, we argue that the registration coverage for the study was high for a beginning community-based birth registry in rural settings.

Nevertheless, the uncertainty on the number of expected births does not affect our MMR because we calculated MMR from registered births rather than expected births. The concern, however, is whether there was a difference in MMR between registered and unregistered births. We attempted to address this partly by doing a validation study, which resulted in a similar MMR between the two groups. Theoretically, both the continuous birth registration and the validation survey may give an under- or over-estimate of the MMR. In practice, the problem related to measuring maternal mortality is under-reporting rather than over-reporting. As such, reported maternal deaths under estimate up to 30% of the actual MMR worldwide [16].

Important factors related to under-reporting of maternal mortality among registered pregnancy outcomes are problems of identifying early pregnancy maternal deaths before the pregnancy is clearly recognized and deaths due to abortion because of secrecy and stigma [24]. Thus, we made a rigorous effort to review every adult woman's death to determine whether it was pregnancy-related, mainly by using the advantage of a close relationship between HEWs and the people in their villages. Nevertheless, we recognize that it is difficult to avoid under-reporting and we cannot estimate how many early pregnancy, and abortion-related deaths went unnoticed. Future studies may consider beginning the registration of pregnancies (instead of pregnancy outcomes used in this study) to better capture maternal deaths during pregnancy. Another important concern of under-reporting is the limited knowledge of the proportion of maternal deaths among unregistered pregnancy outcomes. Our validity check showed no difference in the MMR between registered and unregistered births. Nevertheless, because the validation study took place in 15 of 75 villages during the 8th of a 12-month registration, there may have been limitations to representing a complete picture of similarity.

While these limitations are acknowledged, we have reported an MMR estimate closer to reality and the MMR herein may be one important step in measuring maternal mortality through a community-based birth registry in rural Ethiopia. Furthermore, the current finding of the proportion of maternal deaths at facilities and homes is also consistent with our previous report [20,25]. In addition, our findings showed that 83% of maternal deaths occurred at home without access to a health institution, which is similar with the results of a study from Mozambique that tracked maternal mortality through active community-based approaches, and showed that health institutions did not identify 86% of maternal deaths that occurred in their area [26]. The percentage of maternal deaths at home was less than the proportion of births in the same place (83% vs. 90%). The reason could be that some severe cases selectively visited health facilities and died in the facilities. The severity-based selective facility utilization argument is also supported by the findings of a higher MMR among facility births compared to

births at home (844 vs. 451) in the current study. These results have two implications. First, the finding of four of five maternal deaths occurring at home means health facilities had no means to avoid these deaths and were not able to identify and record when the deaths occurred. Second, the higher MMR among facility deliveries implies that the health institutions had low ability to save mothers who had sought help.

In the study area, we have limited documentation to describe progress in terms of maternal mortality in previous years. A household survey in one of the districts to measure maternal mortality between 2006 and 2010 provided an MMR of 425 per 100,000 LBs [20], which is similar to the current finding. In addition, we published maternal mortality indices (MMR and lifetime risk) from the area using the indirect sisterhood method [27]. Nonetheless, because of the indirect nature, the estimate refers to a time of more than a decade ago and indirect sisterhood estimates provide the order of magnitude with limited value to oversee trends.

The MMR we report (489 per 100,000 LBs in 2010) is higher than the level of reduction required to attain the MDG5 target (from 968 in 1990 to 242 in 2015 in Ethiopia) [9]. The MMR was also higher than the joint estimate provided by WHO, UNFPA, UNICEF, and The World Bank (350) for 2010 in Ethiopia [1], but lower than the DHS reported national estimate (676) for a similar period [28]. However, our finding was similar to most results from previous community-based studies in Ethiopia. The MMR per 100,000 LBs was 402 in Jimma (1990) using a cross-sectional survey [29], 440 in Butajira (1996) using a surveillance approach [30], 570 in Illubabor (1991) using the indirect sisterhood method [31], and 566 in Addis Ababa (1983) using a household survey [32].

Nevertheless, given decades of time between the aforementioned studies and the current study, the MMR may have been different in this study area compared to those provinces. An alternative explanation could be that the survey and periodic surveillance techniques used in the aforementioned studies resulted in under-estimations of MMR at that time. This could also be explained by the fact that Ethiopia had a high MMR estimate nationally during the time when these studies were conducted [33]. As such, the prospective method we used and the presence of the HEWs within the villages that increases the awareness of important events might have helped our study provide a better estimation of the current MMR.

We showed that there was no difference in the MMR between districts with better health institutions (Arba Minch and Derashe) and a district with less poor health facilities (Bonke). This may be explained by the low utilization rate of existing health institutions for deliveries in all the districts. Hence, this emphasizes the importance of improving people's behaviours with respect to utilizing institutional delivery by skilled professionals in addition to distributing and strengthening health facilities. The findings of a high MMR in the remotest villages without driveable roads highlight the inequalities in health outcomes experienced by these women. Maternal mortality was also higher where husbands and FOBs were illiterate. This may explain the importance of male partners as decision makers for receiving care (health), as well as their general contribution as providers to improved living conditions (wealth). This finding is in agreement with the suggestions of the Oxford Multi-dimensional Poverty Index (MPI) Study, which described the importance of an educated person in a household for a positive health outcome [34]. In addition to the aimed outcomes, the study also showed the existence of substantial missed opportunities in maternal care by the health system. Fortunately, 85% of pregnant women visited health workers for antenatal check-ups at least once, whereas only 10% returned for delivery at the health facilities for supervised delivery.

The weaknesses of the current study follow. First, although we made a rigorous effort to identify early maternal deaths, an important limitation of the study was our inability to explain the amount of unnoticed early pregnancy-related maternal deaths. Specifically, we might have missed some of the abortion-related deaths because of the stigma and secrecy associated with

abortion. Second, although we achieved a high coverage of > 80% registration, not all expected births were registered, thus leaving concerns about whether or not the MMR is higher or at least different among unregistered births. Our finding was a significant increase from the 7% national birth registration in Ethiopia [4], and almost non-existent in rural areas. Third, despite similar MMRs between registered and non-registered births, our validation study showed that HEWs were more likely to register births that occurred near their station and those who attended antenatal care, highlighting potential selection bias. Fourth, the death ascertainment method through the HEWs was less valid compared to the standard techniques of death confirmation by physicians or using autopsy [35].

Nevertheless, we believe that the diagnostic technique we used is better than asking a family member about a death that occurred years ago in survey studies. Furthermore, the standard methods of ascertaining maternal death are less likely to reach rural communities in low-income countries. Hence, it may be important to use and improve available opportunities, such as community health workers (HEWs in Ethiopia) to prospectively identify, review, and record maternal deaths, even when it means less accurate diagnosis of the cause of death in resource-limited settings.

Finally, because of the short period of observation, we cannot show in this paper whether community-based registration contributes for the reduction of MMR. Future studies may try to address these concerns. In addition, although it is difficult to suggest similar achievements in all areas, the study can be repeated in any part of Ethiopia because all villages have the same HEWs working under similar conditions. The same can also be applied in low-income countries that have an organized community health workforce.

Conclusion

It is possible to register most births in rural Ethiopia through the HEWs and use the registry as a tool to measure maternal mortality. The MMR was high in the study area compared to the reductions needed to attain MDG5 and most births and maternal deaths occur at home without the attention of the health service.

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Author Contributions

Conceived and designed the experiments: YY TD BL. Performed the experiments: YY TD BL. Analyzed the data: YY TD BL. Wrote the paper: YY TD BL.

References

1. WHO, UNICEF, UNFPA, World-Bank Trends in maternal mortality:1990 to 2010. WHO, UNICEF, UNFPA and The World Bank estimates. Available: http://whqlibdoc.who.int/publications/2012/9789241503631_eng.pdf. Accessed 10 September 2012.

2. Bhutta ZA, Chopra M, Axelson H, Berman P, Boerma T, et al. (2010) Countdown to 2015 decade report (2000–10): taking stock of maternal, newborn, and child survival. *Lancet* 375: 2032–2044. doi: [10.1016/S0140-6736\(10\)60678-2](https://doi.org/10.1016/S0140-6736(10)60678-2) PMID: [20569843](https://pubmed.ncbi.nlm.nih.gov/20569843/)
3. Graham W, Ahmed S, Stanton C, Abou-Zahr C, Campbell O (2008) Measuring maternal mortality: An overview of opportunities and options for developing countries. *BMC Medicine* 6: 12. doi: [10.1186/1741-7015-6-12](https://doi.org/10.1186/1741-7015-6-12) PMID: [18503716](https://pubmed.ncbi.nlm.nih.gov/18503716/)
4. UNICEF United Nations Children's Fund, Every Child's Birth Right: Inequities and trends in birth registration, UNICEF, New York, 2013. Available: http://www.unicef.org/mena/MENA-Birth_Registration_report_low_res.pdf (accessed 10 January 2014).
5. AbouZahr C, Cleland J, Coullare F, Macfarlane SB, Notzon FC, et al. (2007) The way forward. *Lancet* 370: 1791–1799. PMID: [18029003](https://pubmed.ncbi.nlm.nih.gov/18029003/)
6. CSA-Ethiopia, ICF-International Ethiopia Demographic and Health Survey 2011 Central Statistical Agency of Ethiopia and ICF International Addis Ababa, Ethiopia and Calverton, Maryland, USA 2012. Available: <http://www.measuredhs.com/publications/publication-fr255-dhs-final-reportscfm> (accessed 25 June 2013).
7. Campbell O, Gipson R, Issa AH, Matta N, El Deeb B, et al. (2005) National maternal mortality ratio in Egypt halved between 1992–93 and 2000. *Bulletin of the World Health Organization* 83: 462–471. PMID: [15976898](https://pubmed.ncbi.nlm.nih.gov/15976898/)
8. Graham W, Brass W, Snow RW (1989) Estimating Maternal Mortality: The Sisterhood Method. *Studies in Family Planning* 20: 125–135. PMID: [2734809](https://pubmed.ncbi.nlm.nih.gov/2734809/)
9. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, et al. (2010) Maternal mortality for 181 countries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5. *The Lancet* 375: 1609–1623.
10. Graham WJ, Adjei S (2010) A Call for Responsible Estimation of Global Health. *PLoS Medicine* 7: e1001003. doi: [10.1371/journal.pmed.1001003](https://doi.org/10.1371/journal.pmed.1001003) PMID: [21151346](https://pubmed.ncbi.nlm.nih.gov/21151346/)
11. Jamison DT, Summers LH, Alleyne G, Arrow KJ, Berkley S, et al. (2013) Global health 2035: a world converging within a generation. *The Lancet* 382: 1898–1955.
12. FMOH-Ethiopia (2010) Health Sector Development Program IV 2010/11–2014/15 Final Draft, October 2010. Federal Democratic Republic of Ethiopia, Ministry of Health.
13. FDR-Ethiopia (2012) Registration of Vital events and National Identity Card Proclamation (proclamation no.760/2012). Ethiopian Federal Democratic Republic Federal Negarit Gazeta.
14. Samia ZG (2011) Source of Vital Statistics in Ethiopia: United Nations Expert Group Meeting on International Standard for Civil Registration and Vital Statistics System, New York, 27–30 June 2011. Available: <https://unstats.un.org/unsd/demographic/meetings/egm/CRVS2011/EGM%20PowerPoints/Session%201-04%20Ethiopia.ppt> (accessed 25 July 2014).
15. WHO (2004) Beyond the numbers: reviewing maternal deaths and complications to make pregnancy safer. Available: http://www.who.int/maternal_child_adolescent/documents/9241591838/en/ (accessed 20 June, 2013). World Health Organization.
16. WHO (2013) Maternal death surveillance and response: technical guidance. Information for action to prevent maternal death. Available: http://www.who.int/maternal_child_adolescent/documents/maternal_death_surveillance/en/ accessed 15 August 2014. World Health Organization and partner organizations.
17. Koblinsky M, Tain F, Gaym A, Karim A, Carnell M, et al. (2010) Responding to the maternal health care challenge: The Ethiopian Health Extension Program. *Ethiopian Journal of Health Development* 24.
18. CSA-Ethiopia (2010) Statistical Tables for the 2007 Population and Housing Census of Ethiopia/CENSUS 2007 TABLES/SNNPR1. Available: www.csa.gov.et (accessed February 24, 2013). Central Statistical Agency of Ethiopia.
19. Gaym A, Pearson L, Soe KW (2012) Maternity waiting homes in Ethiopia—three decades experience. *Ethiopian Medical Journal* 50: 209–219. PMID: [23409404](https://pubmed.ncbi.nlm.nih.gov/23409404/)
20. Yaya Y, Eide KT, Norheim OF, Lindtjorn B (2014) Maternal and Neonatal Mortality in South-West Ethiopia: Estimates and Socio-Economic Inequality. *PLoS ONE* 9: e96294. doi: [10.1371/journal.pone.0096294](https://doi.org/10.1371/journal.pone.0096294) PMID: [24787694](https://pubmed.ncbi.nlm.nih.gov/24787694/)
21. World-Bank Crude Birth Rate in Ethiopia (2010) World Bank report 2012. Available: <http://www.tradingeconomics.com/ethiopia/birth-rate-crude-per-1-000-people-wb-data.html>. Accessed 10 August 2013.
22. WHO International Statistical Classification of Diseases and Related Health Problems 10th Revision, ICD-10: 2010 Version. Available: <http://apps.who.int/classifications/icd10/browse/2010/en>. Accessed 09 December 2011.

23. CSA-Ethiopia (2014) Ethiopia Mini Demographic and Health Survey 2014. Central Statistical Agency, Addis Ababa, Ethiopia July 2014. Available: http://www.unicef.org/ethiopia/Ethiopia_Mini_Demographic_and_Health_Survey_2014pdf. Accessed 15 August 2014.
24. Major B, Gramzow RH (1999) Abortion as stigma: Cognitive and emotional implications of concealment. *Journal of Personality and Social Psychology* 77: 735–745. PMID: [10531670](#)
25. Girma M, Yaya Y, Gebrehanna E, Berhane Y, Lindtjorn B (2013) Lifesaving emergency obstetric services are inadequate in south-west Ethiopia: a formidable challenge to reducing maternal mortality in Ethiopia. *BMC Health Services Research* 13: 459. doi: [10.1186/1472-6963-13-459](#) PMID: [24180672](#)
26. Songane FF, Bergström S (2002) Quality of registration of maternal deaths in Mozambique: a community-based study in rural and urban areas. *Soc Sci Med* 54: 23–31. PMID: [11820679](#)
27. Yaya Y, Lindtjorn B (2012) High maternal mortality in rural south-west Ethiopia: estimate by using the sisterhood method. *BMC Pregnancy Childbirth* 12: 136. doi: [10.1186/1471-2393-12-136](#) PMID: [23176124](#)
28. CSA-Ethiopia, ICF-International (2012) Ethiopia Demographic and Health Survey 2011 Central Statistical Agency of Ethiopia and ICF International Addis Ababa, Ethiopia and Calverton, Maryland, USA. Available: <http://www.measuredhs.com/publications/publication-fr255-dhs-final-reportscfm> Accessed 25 June 2013.
29. Mersha A, Jira C, Demessie S (1996) Community based study on maternal mortality in Jimma town, south western Ethiopia. *Indian J Public Health* 40: 30–34. PMID: [9090901](#)
30. Berhane Y, Andersson T, Wall S, Byass P, Högberg U (2000) Aims, options and outcomes in measuring maternal mortality in developing societies. *Acta Obstet Gynecol Scand* 79: 968–972. PMID: [11081662](#)
31. Shiferaw T, Tessema F (1993) Maternal mortality in rural communities of Illubabor, southwestern Ethiopia: as estimated by the "sisterhood method". *Ethiop Med J* 31: 239. PMID: [8287858](#)
32. Kwast BE, Rochat RW, Kidane-Mariam W (1986) Maternal mortality in Addis Ababa, Ethiopia. *Stud Fam Plann* 17: 288–301. PMID: [3798492](#)
33. WHO, UNICEF, UNFPA, World-Bank (2012) Trends in maternal mortality:1990 to 2010. WHO, UNICEF, UNFPA and The World Bank estimates. Available: http://whqlibdoc.who.int/publications/2012/9789241503631_eng.pdf. Accessed 10 September 2012.
34. Alkire S, Santos ME (2011) Acute Multidimensional Poverty: A New Index for Developing Countries. Proceedings of German Development Economics Conference (Berlin). Available: <http://www.econstor.eu/handle/10419/48297>. Accessed 25 May 2013.
35. Menéndez C, Romagosa C, Ismail MR, Carrilho C, Saute F, et al. (2008) An autopsy study of maternal mortality in Mozambique: the contribution of infectious diseases. *PLoS Med* 5: e44. doi: [10.1371/journal.pmed.0050044](#) PMID: [18288887](#)



Maternal and Neonatal Mortality in South-West Ethiopia: Estimates and Socio-Economic Inequality

Yaliso Yaya^{1,3*}, Kristiane Tislevoll Eide², Ole Frithjof Norheim^{1,2}, Bernt Lindtjørn¹

1 Centre for International Health, Faculty of Medicine and Dentistry, University of Bergen, Bergen, Norway, **2** Department of Global Public Health and Primary Care, Faculty of Medicine and Dentistry, University of Bergen, Bergen, Norway, **3** Arba Minch College of Health Sciences, Arba Minch, Ethiopia

Abstract

Introduction: Ethiopia has achieved the fourth Millennium Development Goal by reducing under 5 mortality. Nevertheless, there are challenges in reducing maternal and neonatal mortality. The aim of this study was to estimate maternal and neonatal mortality and the socio-economic inequalities of these mortalities in rural south-west Ethiopia.

Methods: We visited and enumerated all households but collected data from those that reported pregnancy and birth outcomes in the last five years in 15 of the 30 rural kebeles in Bonke woreda, Gamo Gofa, south-west Ethiopia. The primary outcomes were maternal and neonatal mortality and a secondary outcome was the rate of institutional delivery.

Results: We found 11,762 births in 6572 households; 11,536 live and 226 stillbirths. There were 49 maternal deaths; yielding a maternal mortality ratio of 425 per 100,000 live births (95% CI:318–556). The poorest households had greater MMR compared to richest (550 vs 239 per 100,000 live births). However, the socio-economic factors examined did not have statistically significant association with maternal mortality. There were 308 neonatal deaths; resulting in a neonatal mortality ratio of 27 per 1000 live births (95% CI: 24–30). Neonatal mortality was greater in households in the poorest quartile compared to the richest; adjusted OR (AOR): 2.62 (95% CI: 1.65–4.15), headed by illiterates compared to better educated; AOR: 3.54 (95% CI: 1.11–11.30), far from road (≥ 6 km) compared to within 5 km; AOR: 2.40 (95% CI: 1.56–3.69), that had three or more births in five years compared to two or less; AOR: 3.22 (95% CI: 2.45–4.22). Households with maternal mortality had an increased risk of stillbirths; OR: 11.6 (95% CI: 6.00–22.7), and neonatal deaths; OR: 7.2 (95% CI: 3.6–14.3). Institutional delivery was only 3.7%.

Conclusion: High mortality with socio-economic inequality and low institutional delivery highlight the importance of strengthening obstetric interventions in rural south-west Ethiopia.

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* E-mail: yalisoyaya@gmail.com

Introduction

In 2010, there were 287,000 maternal deaths in the world from causes of pregnancy related complications, which is 50% down from the 1990 baseline [1]. Every year, four million newborns die during the neonatal period (28 days after birth) [2], while 3.2 million pregnancies end with stillbirths [3]. Among these deaths, 99% of the neonatal deaths and stillbirths as well as 98% of maternal deaths, occur in low- and middle-income countries. Moreover, 40% of global, and 29% of African child mortality is caused by neonatal deaths [4]. The Millennium Development Goals (MDG-4 and 5) aim to reduce child mortality by two-thirds, and maternal mortality by three-quarters, between 1990 and 2015. High maternal and neonatal deaths and stillbirths often occur because of inadequate care during pregnancy and childbirth. Accordingly, these deaths are considered sensitive indicators of the quality of a healthcare system in an area [5]. High neonatal deaths and stillbirths are often related to maternal health; complications

during pregnancy, childbirth, and the post-natal period increase the risk of death for both the baby and the mother [6].

Ethiopia has achieved MDG-4 by reducing two-thirds of under 5 mortality per 1000 live births from 204 in 1990 to 68 in 2012 [7]. Ethiopia's achievement has been attributed to the country's community-based health promotion and disease prevention programme through a health extension package [8]. However in terms of neonatal mortality, maternal mortality, and stillbirth reduction, challenges still remain. Ethiopia is among 10 countries that contributed to two-thirds of global neonatal deaths in 2005 [2] and stillbirths in 2009 [9]. UN agencies (WHO and UNFPA) and World Bank data also indicate a decline in the maternal mortality ratio (MMR) per 100,000 live births in Ethiopia from 950 in 1990 to 350 in 2011 [1]. Nevertheless, there are often controversies over these estimates. For example, the 2011 national Demographic and Health Survey (DHS) reported an MMR of 676 per 100,000 live births, which is close to two-folds higher compared to the UN estimate [10]. According to the 2007 National Census, over 84% of the estimated 90 million people in Ethiopia live in rural areas

with limited access to quality health care [11]. In 2008, a nationwide study showed that 7% of all deliveries took place at health institutions while only 3% in facilities that could provide comprehensive essential obstetric care [12].

In places such as rural Ethiopia, where there is no birth and death registration and the majority of births and deaths take place outside of health institutions, measuring maternal and neonatal mortality is difficult [13]. In some places, methods such as demographic surveillance systems help to find and measure maternal and neonatal mortalities [14]. Unfortunately, this alternative method does not exist in the Gamo Gofa province of Ethiopia. Maternal mortality can also be estimated through low-cost innovative options of the sisterhood method, which asks adult siblings about their sisters' death related to pregnancy or childbirth during reproductive age [15]. Nevertheless, results from the sisterhood method refer to many years before the survey and may not show the current magnitude of the problem [16]. Findings from well-planned household surveys that use large samples in high fertility and high mortality areas can be useful in providing real-time data to motivate actions [17]. The aim of this study was to estimate maternal and neonatal mortality, the stillbirth rate, the institutional delivery rate, and household risk factors associated with these mortality outcomes in rural south-west Ethiopia.

Methods and Materials

Ethics statement

The Ethical Review Committee for the Health Research of Southern Nations Nationalities and Peoples' Regional State (SNNPRS) Health Bureau in Ethiopia, and the Regional Committee for Health Research Ethics of North Norway (REK Nord) approved the study. We obtained informed verbal consent from all respondents and the response was recorded on the questionnaire as "accepted" or "declined" to participate. Almost all approached households were willing to be interviewed, and written consent was not considered because a large number of the respondents were illiterates. The study involved only interview and the ethics committee approved the verbal consent procedure. Additionally, minors were not included in this study.

Definitions

Verbal autopsy for maternal deaths. A method for finding out the medical causes of death and ascertaining the factors that may have contributed to the death in women who died outside of a medical facility. It consists of interviewing people (family members, neighbours, traditional birth attendants) who had knowledge about the events leading to the death [18].

Neonatal mortality. A death within 28 days of an alive born baby.

Maternal mortality. A death of a woman while pregnant, in labour, or within 42 days of the 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 (ICD-10) [19].

Stillbirth. A birth of a dead fetus after 28 weeks of gestation. We did not use the baby-weight criteria of classifying stillbirths, as it was not possible to measure weight in the rural area.

Household. A person or a group of people living in a room or rooms and sharing common things together. In cases of polygamy (more than one wife for a man, we considered each wife as a separate household as they culturally have separate houses.

Maternal mortality ratio (MMR). Is the number of maternal deaths in a population during a given time period per 100,000 live births during the same period.

Neonatal mortality ratio (NMR). Is the number of newborn deaths (within 0–28 days) in a population per 1,000 live births in the same population.

Stillbirth rate. Is the number of births of dead fetuses after 28 weeks of gestation per 1,000 births.

Study area

We conducted this study in Bonke, one of the 15 woredas in the Gamo Gofa zone in south-west Ethiopia. In 2010, the woreda had a population of 173,240 people [11]. A kebele is the lowest administrative structure with 5,000 to 7,000 residents in the Ethiopian government system. Bonke has 31 kebeles and one of these, the administrative centre, has a town status with a population of 6,347 people in 2007. Table 1 shows the profile of the 15 kebeles included in this study. Bonke is 618 km from Addis Ababa, and 68 km from Arba Minch (zonal capital) where the nearest hospital is situated. Nevertheless, over half of the remote areas of Bonke are more than 100 km (20 hours walking distance) away from the hospital in Arba Minch. An estimated three-fourths of the population also live in villages far from the motorable road (≥ 6 km). The only road to the woreda is the road from Arba Minch to Kamba, which crosses parts of Bonke. Overflowing rivers during the rainy season often interrupt the road. So, often people have to carry critical patients or use transport animals such as horses and mules to go to the hospital.

Health care is provided by a health centre in the town (Geresse) as well as three other rural health centres. There are no medical doctors working in the woreda; a few health officers (people with a bachelor's degree in medical training), nurses, and midwives staff the health centres. In Bonke, there is no access to lifesaving comprehensive essential obstetric care that can provide caesarean sections, blood transfusions, and effective care to sick and low birth-weight newborns. This study was part of an implementation project to reduce maternal mortality in Gamo Gofa. The project trains health officers in emergency obstetric services, community health workers in identifying and referring high-risk mothers, in addition to equipping health centres and hospitals with essential instruments.

Study design and period

The study was a cross-sectional household survey with a five-year recall of events prior to the data collection. We collected the data in February 2011 from all households that had births and pregnancy outcomes between January 2006 and December 2010. We purposely selected January 2006 as the starting reference period for the recall because it was the immediate period after the 2005 National Election, an event well known to all respondents.

Sampling

We based our sample size calculation on the assumptions of a crude national birth rate of 35 per 1,000 population, and a neonatal mortality ratio of 35 per 1,000 live births [20]. We aimed to detect a minimum of 350 neonatal deaths to make empirical estimates and assess the household risk factors associated with neonatal deaths. To find 350 neonatal deaths we needed to find at least 10,000 live births in five years (an average of 2,000 per year) within the population. With a fertility rate of 35 births per 1,000 people, 2,000 live births per year could be obtained from an estimated population of 57,143. Assuming a constant birth rate over the five years, we projected the population of 57,143 in 2006 to be 67,244 in 2010 (half the rural population in Bonke).

Table 1. Background information comparing study population with national census data.

	Bonke 2010 (current study)	Census 2007 [16] (adjusted to 2010)
Number of households in 15 Kebeles	11 920	12 681
Population of the 15 Kebeles	72 712 [§]	78 181
Average persons per household	6.14	6.17
Crude birth rate (per 100 population)	3.22	3.60 [†]
Percent of under-5 year population	15	16 [‡]
Percent of illiterate adults (≥15 years)	58.5 ^Δ	64.5 [⊖]

[§] = obtained by multiplying average persons per household in studied households (6.1) with the total households counted during the study (11 920).

[†] = DHS 2011 for rural Ethiopia (no separate data for Bonke) [10].

[‡] = rural Bonke.

^Δ = Heads of interview households, Bonke, 2010.

[⊖] = Adult men (≥15 years of age) Gamo Gofa zone (rural).

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We used OpenEpi, open source calculator (www.openepi.com), and calculated the minimum sample needed based on information that three-fourths of the study households resided far from the motorable road (≥6 km), thereby expecting a neonatal mortality prevalence twice that among households far from the road. We used a statistical power of 80%, a 95% confidence interval, and an assumption that 4% of households far from motorable road could experience neonatal mortality to calculate the number of households needed for the study. This provided 5,187 households with expected births in the five years before the survey. On average, we expected two births per household over five years yielding 10,374 births. The neonatal mortality rate from the estimated number of households was also assumed to provide enough power to detect other risk factors (wealth, education, non-spaced births).

We also assumed that a number of maternal deaths among the estimated 10,374 births would give an optimum MMR estimate, and a similar assumption was applied for stillbirths. Taking into account a potential 10% of non-responders, we decided to study 50% of the rural population in the Bonke woreda and we randomly selected 15 of the 30 rural kebeles in Bonke. Data collectors visited all of the households in the selected 15 kebeles asking about any pregnancy and birth outcomes (abortion, alive and stillbirths, neonatal and maternal deaths) in the households over the previous five years. Enumerators noted the number of households in each kebele, collecting data from the households that had pregnancy and birth outcomes during the stated time period. As projected from the Ethiopian 2007 census [11], the selected kebeles had a population of 78,181 people in 2010.

Variables and questions

The primary outcome variables were maternal and neonatal mortality and stillbirth rates while a secondary outcome variable was rate of skilled delivery service utilization. We also used the following household predictor variables: household wealth (assets index), educational level of heads of households, the number of births in a household over five years, and household distance to a motorable road.

Survey questions included: where each delivery took place (home, health post, health centre, and hospital) and who attended the birth (family member, community health extension worker, skilled health professional-doctor, midwife). We also asked about the place where the maternal death occurred (at home or within a health facility) as well as what had happened to the fetus (stillbirth, neonatal death, or alive at the time of data collection).

Respondents were asked about whether the newborn was alive or dead at the end of the 4th week after delivery. If the response was “dead”, then we asked about the timing of death (in weeks) in relation to the birth. However, we did not investigate the causes of deaths for neonatal deaths and stillbirths, assuming it would be difficult for rural respondents to answer it properly. In the households that had deaths of women -in reproductive age (15–49 years), we used questions modified from the WHO manual for verbal autopsy for maternal death to investigate the causes of deaths [18].

The questions included: whether the mother was pregnant, in the process of giving birth, or in postnatal period after birth, what main medical condition or symptom was associated with her death, what assistance she received, and from whom she received help. A nurse decided on pre-coded choices of the major causes of maternal deaths (bleeding, prolonged labour, fever and convulsions, including the option of “others”) based on quick algorithmic analysis of information provided by the respondents. Sensitive questions related to abortion deaths were placed at the end of the interview to minimize the intentional hiding of information. We collected information on the estimated walking distance (in hours) from each house to the nearest health centre, the nearest motorable road, and the nearest hospital. Based on the local experience of one hour of walking time per 5 km for an average person, we converted the walking distance into kilometers.

Data collection

We recruited 15 natives from the respective study villages who had completed the 12th grade for data collection. The purpose of selecting data collectors from their respective kebele of data collection was to reduce the potential recall bias by the respondents. Data collectors are aware of many vital events in the villages they collected data by living and participating in social events such as birth celebrations, mourning rituals, and burials at the time of the deaths. Five diploma graduates who had a thorough knowledge of the culture and language of the area supervised the data collection.

The data collectors were trained for two days on pre-testing field interviews, translating the questions from “Amharic” (the official Ethiopian state language) to “Gamo” (the language of the ethnic “Gamo” community) and how to introduce the simplified verbal autopsy questions. Depending whoever was present at home during the visit, the respondent was the father or mother for a recently deceased newborn. In cases of death of a married woman, we interviewed a husband while in the absence of a

husband, an adult relative or an adult child of the deceased was interviewed. For those who were unmarried, we asked parents or siblings. If the respondents were not present at home during the first visit, the data collectors re-visited the next day in the early morning. Less than 1% of households were missed after two visits.

The wealth-index creation

For the wealth index, we selected 10 variables of household assets with the highest standard deviation (>0.20), as recommended by Seema Vyas and colleagues [21]. The types of asset variables and their standard deviations are presented in Table S1 in File S1. We transformed the categorical variables into dichotomous (0–1) indicators: 0 for indicators of poor wealth and 1 for indicators of good wealth. We examined the dichotomous variables by using the principal component analysis (PCA) to produce a factor score for each household with households being assigned a rank according to the factor score. Because of the low number of maternal deaths in the socio-economic classes for calculation, we divided households into four equal categories (quartiles), rather than the widely used five classes. Each category was comprised of 25% of the households studied. Table S2 in File S1 shows the mean score, standard deviations, communalities, and correlations of the variables to the first (main) component. The total variance explained by the first component was 20.58%, with an eigenvalue of 2.06.

Data analysis

We used two units of analysis (household and birth). By using births as the unit of analysis, we presented descriptive tabulations of outcomes in the form of rates and ratios. By using the household as a unit of analysis, and applying logistic regression, we present household risk factors associated with the mortality outcomes (Tables 2, 3, and 4). We used SPSS 16 (Statistical Package for Social Sciences) for the data entry and analysis [22]. Data are freely available from the corresponding author on request.

Results

Demographic description

Table 1 describes households and population of the study area. Data collectors enumerated all households (11,920) in the selected 15 kebeles but collected data from 6,572 households that had pregnancy and birth outcomes in the last five years before the data collection. In the 6,572 households that had pregnancy and birth outcomes, there were 40,357 persons, an average of 6.1 persons per household.

Of the 6,572 household heads, 3,842 (58.5%) were not able to read and write (illiterate), 2,446 (37.2%) had an elementary education (grade 1–8), and 279 (4.2%) had completed 9th grade or more. Regarding the occupations of the head of the households, 6,289 (95.7%) engaged in farming, 204 (3.1%) in farming mixed with small trade, while 79 (1.2%) were salary employed (\$ 25–50 per month) (Table 2).

Description of births

Table 2 presents the backgrounds of households with pregnancy and birth outcomes and description of births. We found 11,762 births in 6,572 households over 5 years (3.2% annual crude birth rate), of which 11,536 were live births. Of the 11,762 total births, 10,861 (92.3%) took place at home, 470 (4%) at health posts, 338 (2.9%) at health centres and 93 (0.8%) at hospitals. A health post is a two-room building which is the lowest ranked health facility and staffed by two community agents known as health extension workers whom received one year of general health training.

Health centres are medium level institutions with health officers and nurses, and some have midwives. The overall institutional delivery rate (health centre and hospital combined) was 3.7% (431/11762).

Health centre births

Births that occurred within a 10 km distance of health centres, were five-times more likely to use health centres for delivery, 4.75% (274/5766), compared to households ≥ 11 km away, 1.07% (64/5996); OR: 4.62 (95% CI: 3.51–6.09) (Table 2). A 10 km distance is the Ethiopian government plan to achieve health centre physical access to the population.

Description of deaths

There were 49 maternal deaths, resulting in a maternal mortality ratio (MMR) of 425 (95% CI: 318–556) per 100,000 live births. Among the 49 maternal deaths, 6 (12%) occurred during pregnancy, 18 (37%) during labour, and 25 (51%) after birth within six weeks (Figure 1). The primary causes of death were: fever 14 (29%), bleeding 13 (27%), prolonged labour 8 (16%), convulsion 8 (16%), and others 6 (12%) (Table 3). Other causes included two abortions and one anemia while three deaths were not classified. Regarding the places of maternal death, most [88% (43/49)] of the maternal deaths occurred during home deliveries, and health facilities were able to identify only 12% (6/49) of the maternal deaths found in this study (Table 3).

We found 308 neonatal deaths, which yields a neonatal mortality ratio (NMR) of 27 (95% CI: 24–30) per 1,000 live births. Out of the 308 neonatal deaths reported, 143 (46.4%) died in the first week, 72 (23.4%) in the second week, 63 (20.5%) in the third week and 30 (9.7%) in the fourth week (Figure 2). There were 226 stillbirths out of 11,762 total births yielding a stillbirth rate (SBR) of 19 (95% CI: 17–22) per 1,000 births.

Household risk for mortality outcomes

Maternal mortality. Table 4 shows the MMR differences across different risk factors. The MMR was increased in households in the poorest quartile compared to the richest (550 vs 239 per 100,000 live births); OR: 2.29 (95% CI: 0.91–6.44). However, socio-economic factors examined (wealth, distance from road, education, and non-spaced births) did not have statistically significant association with maternal mortality because of the relative rarity of maternal deaths in terms of absolute numbers.

Neonatal mortality. Table 5 describes the household risk factors associated with neonatal mortality. Neonatal mortality was greater among the poorest quartile households compared to the richest; adjusted OR (AOR): 2.62 (95% CI: 1.65–4.15). However, the highest risk was in the wealthy class; AOR: 3.57 (95% CI: 2.37–5.38). The poorest were in the second highest at risk groups. The likelihood of neonatal mortality was also increased among households with illiterate heads compared to where the heads had a higher education (9th grade or more); AOR: 3.54 (95% CI: 1.11–11.30), in households far from a motorable road (≥ 6 km) compared to those within 5 km of a road; AOR: 2.40 (95% CI: 1.56–3.69), and greater among households that had three or more births in five years compared to those that had two or less births; AOR: 3.22 (95% CI: 2.45–4.22).

Stillbirths. Table 6 shows the factors associated with stillbirth which were greater in households in the poorest quartile compared to the richest; AOR: 3.13 (95% CI: 1.66–5.87). However, similar to neonatal mortality, the highest risk of stillbirth was in the households in the rich category compared to the richest; AOR: 6.40 (95% CI: 3.69–11.11). Stillbirth was greater among households far from motorable road (≥ 6 km) compared to those

Table 2. Socio-demographic backgrounds of household-survey participants, Bonke, Gamo Gofa, south-west Ethiopia, 2011.

Variables	Category	number	%
Visited households	With pregnancy and birth outcomes ^A	6572	55
	Without pregnancy and birth outcomes	5348	45
	Total (visited HHs)	11920	100
Births	Live births	11536	98
	Still births	226	2
	Total (all births)	11762	100
Households with events	Stillbirths	192	3
	Neonatal deaths	265	4
	Maternal deaths	49	0.7
	Without events	6066	92.3
Education of heads of households	Total (HHs)	6572	100
	Illiterate (cannot read/write)	3842	58.5
	Primary (1–8th)	2446	37.2
	Higher (9th +)	279	4.2
	Missing	5	0.1
Occupation of heads of households	Total (HHs)	6572	100
	Subsistence farming	6289	95.7
	Farming and small trade	204	3.1
	Salary employed	79	1.2
Distances of HHs from motorable road	Total (HHs)	6572	100
	≤5 km	1624	24.7
	≥6 km	4948	75.3
Health centre distance	Total (HHs)	6572	100
	≤10 km ^B	3258	49.6
	≥11 km	3314	50.4
Place of delivery	Total (HHs)	6572	100
	Home (assisted by family or relative)	10861	92.3
	Health post (attended by HEWs) ^C	470	4.0
	Skilled institutions (HC and Hospital)	431	3.7
Health centre delivery vs HC distance	Total (births)	11762	100
	HC deliveries among ≤10 km from HC	274/5766	4.75
Total HC births out of all births	HC deliveries among ≥11 km from HC	64/5996	1.07
	Total HC births out of all births	338/11762	2.87

Note: ^AHouseholds that had the outcomes over five years before the survey (focus of this study), ^B10 km distance is Ethiopian government plan for physical access to health centres, HC = Health Centre, HHs = households, HEWs = ^CHealth Extension Workers (non-skilled birth attendants).
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at a distance of 5 km to the road; AOR: 3.40 (95% CI: 1.91–6.06), and greater in households that had three or more births in five years compared to two or fewer births; adjusted OR: 4.55 (95% CI: 3.35–6.16).

Clustering of mortality in similar households

Table 7 presents the concentration of maternal and newborn mortality in certain households. Of the 49 households that had maternal deaths, nearly half (46.9%) also experienced either a stillbirth or neonatal death; 12 (24.5%) had stillbirths, and 11 (22.4%) had neonatal deaths. The likelihood of neonatal death in households that had maternal deaths was seven times higher compared to households that had no maternal mortality; OR: 7.2 (95% CI: 3.6–14.3). The similar likelihood of having a stillbirth in households that had maternal mortality was 11 times greater

compared to households without maternal death; OR: 11.6 (95% CI: 6.0–22.7).

Discussion

In this household study we found a maternal mortality ratio of 425 per 100,000 live births, a neonatal mortality ratio of 27 per 1,000 live births, and a stillbirth rate of 19 per 1,000 births. The risk of neonatal mortality was associated with the wealth status of the households, literacy status of the head, non-spaced births, and the distance from motorable road of households. The risk of stillbirth was also associated with the wealth, distance of the household from motorable road, and non-spaced births. The maternal mortality was also high among the poorest households compared to the richest and households that had maternal mortality also experienced a clustering of neonatal mortality or

Table 3. Causes and places of maternal deaths, Bonke, Gamo Gofa, south-west Ethiopia, 2006–2010.

Variables		number	%
Causes of death	Fever	14	29
	Bleeding	13	27
	Prolonged labour	8	16
	Convulsion	8	16
	Others*	6	12
	Total (deaths)	49	100
Places of death	Home (community)	43	88
	Health institution	6	12
	Total (deaths)	49	100

Note: *other causes include: two abortions, two anaemia, and two cause not reported.
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stillbirths. Moreover, the institutional delivery rate was unacceptably low.

To the best of our knowledge, this study is the first to describe three mortality estimates and associated household-risk factors using a large sample with high response rate in Gamo Gofa. In fact, there is a limited amount of evidence of maternal and neonatal mortality and stillbirths using community-based data from southern Ethiopia [14]. We used data collectors who had experience and were sensitive to the cultural taboos of the respective villages where they collected the data. Being the residents in their villages, they participated in all social events, including involvements in vital events such as celebrating births, caring for the sick, and funerals for the dead. The experience and deep knowledge of the area enabled them with the skill to handle sensitive questions and recall many of the deaths that occurred in their villages. We also used an experienced nurse as a field technical supervisor to help in classifying deaths by using the verbal autopsy method.

Because of lack of previous reports from the area, we compare our findings with community-based studies from other provinces

and the national level estimates for Ethiopia. As a result, we do not know whether our findings were under-reported or represent the reality of the area. The maternal mortality ratio of 425 per 100,000 live births was similar to the findings of community-based studies decades ago in other parts of Ethiopia: the MMR per 100,000 live births was 402 in Jimma in 1990 [23], and 440 in Butajira in 1996 [24]. However, our estimate is higher than the UN and World Bank's estimate for Ethiopia of 350 per 100,000 live births in 2010 [1]. If we adjust our maternal mortality estimate upward by a factor of 1.6, it yields an MMR of 680 per 100,000 live births. The 2011 DHS reported MMR of 676 per 100,000 live births for Ethiopia [25] which is similar to our upwardly adjusted estimate. The suggestion as well as the factor of adjustment were conducted according to the recommendation by Santon and colleagues for the correction of the potential under-reporting of demographic studies [26]. The under-reporting of maternal deaths is a well-recognized global problem [27–29], and our study may not have escaped the challenge. However, given a general downward trend of Ethiopia's MMR estimate by the UN inter-

Table 4. Maternal mortality across socio-economic factors, south-west Ethiopia, 2006–2010.

Variable	Category	Maternal deaths	Live births	MMR ^A	OR (95% CI)
Wealth ^B	Richest 25%	6	2506	239	Ref
	Rich 25%	11	3146	350	1.46 (0.54, 4.28)
	Poor 25%	14	2953	474	1.98 (0.77, 5.59)
	poorest 25%	15	2725	550	2.29 (0.91, 6.44)
	Higher (9th +)	0 ^D	468	---	Ref
Education ^C	Primary (1–8th)	18	4492	401	2.85 (0.42, 77.9)
	Illiterate	31	6568	472	3.35 (0.52, 89.9)
	Distance to road	≤5 km	9	2754	327
	≥6 km	40	8782	455	1.40 (0.67, 2.88)
No. of births (in 5 yr)	≤2	39	8620	452	Ref
	≥3	10	2916	343	0.76 (0.38, 1.52)
Place of deaths	Home (comm.)	43	11160	385	Ref
	Health institution	6	376	1596	4.14 (1.75, 9.79)

Note: ^Amaternal mortality ratio per 100,000 live births.

^B119 households, including 3 with maternal deaths, have missing value on the wealth index due to incomplete asset variables.

^CEducation of head of household. ^Dzero was replaced by 0.5 during analysis to make calculation defined.

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Time of maternal deaths in Bonke, Southwest Ethiopia

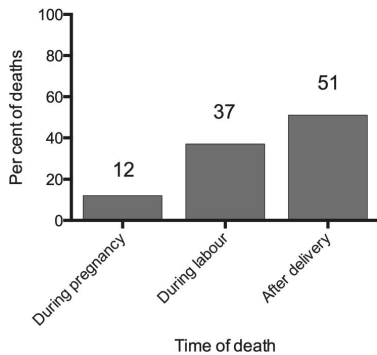


Figure 1. Time of maternal deaths, Bonke woreda, south-west Ethiopia, 2010.
doi:10.1371/journal.pone.0096294.g001

Time of neonatal deaths in Bonke, Southwest Ethiopia

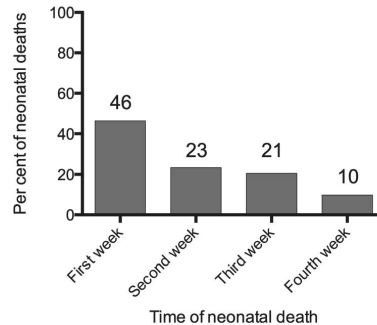


Figure 2. Time in weeks of neonatal deaths, Bonke woreda, south-west Ethiopia, 2010.
doi:10.1371/journal.pone.0096294.g002

agency [1], and Hogan et al [30], our direct (unadjusted) estimate of an MMR of 425 per 100,000 may be close to reality.

Our neonatal mortality estimate of 27 per 1,000 live births is lower than the DHS national estimate of 37 [31], and the UN Inter-agency estimate of 31 for Ethiopia in 2011 [20]. However, since mathematically modeled UN estimations often have inconsistencies with survey findings, and we have limited locally available estimates, we cannot judge whether our finding is due to under-reporting. Regarding stillbirths, Cousens et al estimated Ethiopia's stillbirth rate as 26 per 1,000 births in 2009 [9], which is still higher than our finding of 19 per 1,000 births. In the ethnic "Gamo" culture, a birth of a dead fetus and the early death of a newborn are not publicized and not publicly mourned. Only close relatives and family members are informed and other people are told the incident as "something went wrong" in local terms. This can make it difficult for an outsider to distinguish between a neonatal death and a stillbirth. Accordingly, though we tried to minimize under-reporting by carefully choosing the data collectors, some of the neonatal deaths and stillbirths may have been missed in this study. Global estimates suggest that 75% of neonatal deaths take place in the first week of life [4]. In our finding, first-week deaths were approximately half of the neonatal deaths (46.4%) which may also suggest an under-reporting of early neonatal deaths and stillbirths.

The present study showed that indicators of the socio-economic status (SES) of households (wealth, education of head of household, the distance of households from a motorable road), and a factor related to reproductive health (non-spaced births) were associated with stillbirths and neonatal mortality outcomes. We examined the effect of household wealth (poor-rich differences) on mortality outcomes and found a significant variation. The poorest households were more likely to have mortality outcomes compared to the richest. Nevertheless, when compared to the richest quartile, the greatest risk of both neonatal mortality and stillbirth was to the rich households, not to the poorest.

Households in the poorest category were the second most at-risk group for the mortality outcomes. This finding needs further investigation with a focus on how the true wealth status can be determined at the particular stage of socio-economic development in the rural Ethiopia [21]. Our opinion is that the asset variables selected to indicate wealth status may not have correctly reflected the actual wealth status of all households. For example, farming

land, cattle, and crops may not be owned by young people who returned to rural residence after certain years of education in urban areas. In addition, educated residents such as government employees who usually do not have these rural assets may have been wrongly classified as poor. Our finding of the association of education with neonatal mortality could also support the idea that the educated, but classified as poor and poorest in terms of rural wealth, may have been relatively better-off compared to those in the rich category because of the knowledge advantage.

On the other hand, households in the richest wealth category had the lowest risk of mortality possibly because of their economic access to health services and expected better living conditions. In general, the findings that the richest households had advantages while households in the three other categories experience greater risk could be due to the situation of wealth where few households have greater possession of assets and the other majority is homogeneously poor. The finding agrees with a previous analysis of Ethiopian rural asset data that classified the majority (up to 60%) of households as having low SES, thereby suggesting a homogeneity of most households in asset ownership [21].

Economists measure economic status indicators through information from income or expenditure, which is difficult to gather in low-income countries, and asset-based wealth is an alternative proxy in less developed areas [32]. Practically speaking, the wealth index is equally valid to income or expenditure data for health surveys in Africa [33], and the effect of household wealth on health outcome is well known [34–36]. Less clear, however, is how wealth causes mortality difference in areas where the overall access to health services and service utilization is very low to all people such as those in our study area. For instance, in our results, there is the poorest-richest difference in maternal mortality and stillbirths. Even so, very few households (including the richest) utilize health institutions for delivery service. This indicates that household wealth contributes to maternal mortality in mechanisms other than those that create economic access to health service. These mechanisms may include, e.g., improved, clean housing and better nutrition [37]. Unfortunately, this is beyond the aim and limitations of our study.

Regarding the association of wealth with neonatal mortality, the poorest-richest difference may be due to economic access to antibiotics and other drugs from rural private vendors, where a wealthy family often has a better access in addition to better

Table 5. Factors associated with neonatal mortality, south-west Ethiopia, 2006–2010.

Predictors	Category	Neonatal deaths in the household ^A (n = 6572 HHs)		Crude		Adjusted ^E	
		Yes	No	OR	95% CI	OR	95% CI
Wealth ^B	Richest 25%	31	1322	Ref		Ref	
	Rich 25%	124	1685	3.14	2.12, 4.74	3.57	2.37, 5.38
	Poor 25%	46	1662	1.18	0.74, 1.89	1.92	1.19, 3.10
Education ^C	Poorest 25%	57	1526	1.59	1.02, 2.48	2.62	1.65, 4.15
	Higher (9th +)	3	276	Ref		Ref	
Primary (1–8th)		79	2367	3.07	1.08, 12.37	2.86	0.89, 9.18
	Illiterate ^D	182	3660	4.57	1.64, 18.24	3.54	1.11, 11.30
Distance to road	≤5 km	28	1596	Ref		Ref	
	≥6 km	237	4711	2.87	1.93, 4.26	2.40	1.56, 3.69
No. of births ^F	≤2	170	5388	Ref		Ref	
	≥3	95	919	3.28	2.53, 4.25	3.22	2.45, 4.22

^AHH = households (because there were more than one events in some households, the number of households having neonatal deaths are different from the number of neonatal deaths; 308 neonatal deaths in 265 households).
^B119 households, including 7 with neonatal deaths, have missing value on the wealth index due to incomplete asset variables.
^CEducation of head of household. ^DIlliterate = cannot read and write. ^EAdjusted to the other variables in the table. ^FNumber of births in five years.
 Note: Hosmer-Lemeshow Test of Model fit: χ^2 (df) = 9.14 (7); p = 0.24. A p-value greater than 0.05 shows that the model well fit the data.
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Table 6. Factors associated with stillbirths, south-west Ethiopia 2006–2010.

Predictors	Stillbirths in household? (n = 6572 HH ^a)		Crude		Adjusted ^e	
	Yes	No	OR	95% CI	OR	95% CI
Wealth ^b						
Richest 25%	16	1337	Ref		Ref	
Rich 25%	106	1703	5.20	3.12, 9.11	6.40	3.69, 11.11
Poor 25%	35	1673	1.75	0.97, 3.25	3.28	1.76, 6.11
Poorest 25%	32	1551	1.72	0.95, 3.23	3.13	1.66, 5.87
Education ^c						
Higher (9th+)	5	274	Ref		Ref	
Primary (1–8)	52	2394	1.19	0.50, 3.40	1.03	0.40, 2.65
Illiterate ^d	134	3708	1.98	0.87, 5.52	1.25	0.50, 3.16
Distance to road						
≤5 km	14	1610	Ref		Ref	
≥6 km	178	4770	4.29	2.48, 7.42	3.40	1.91, 6.06
No. of births ^f						
≤2	107	5451	Ref		Ref	
≥3	85	929	4.66	3.48, 6.25	4.55	3.35, 6.16

^aHH = households (because there were more than one such events in some households, the number of households having stillbirths are different from the number of stillbirths; 226 stillbirths in 192 households).

^b119 households, including 3 with stillbirths, have missing value on the wealth index due to incomplete asset variables.

^cEducation of head of household ^dilliterate = cannot read and write ^eadjusted to the other variables in the table ^f number of births in five years.

Note: Hosmer Lemeshow Test of Model fit: χ^2 (df) = 7.98 (7); p = 0.33. A p-value greater than 0.05 shows that the model well fit the data.

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Table 7. Clustering of maternal and neonatal mortality and stillbirth in households, south-west Ethiopia 2006–2010.

		Maternal death in the household? ^x		OR (95% CI)
		Yes (n = 49)	No (n = 6523)	
Stillbirths in household?	yes	12 (24.5%)	180 (2.8%)	11.6 (6.0, 22.7)
	No	37 (75.5%)	6343 (97.2%)	Ref
Neonatal deaths in household?	yes	11(22.5%)	254 (3.9%)	7.2 (3.6, 14.3)
	No	38 (77.5%)	6269 (96.1%)	Ref

Note: ^xMaternal mortality in a household was considered an exposure variable for stillbirth and neonatal death outcomes.
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nutrition and improved housing since access to antibiotics plays an important role in newborn survival [38]. In addition, the association of neonatal mortality with the education of the heads of a households and the distance to a motorable road further suggests the importance of these variables as tools to access health interventions. The education of parents has a positive correlation with better health of children through better knowledge of solutions and critical decisions during crisis, in addition to the opportunity education creates for job and economic access [39–42]. However, in the rural area where this study took place, few people had achieved better jobs despite higher levels of education. The knowledge advantage may have played a role related to access and utilization of treatments in households with educated heads.

Our study also demonstrated an association of household distance from a motorable road with neonatal death. Travel distance is clearly an important factor once the decision is made to seek medical care during critical conditions and distance to a motorable road has dual effects: 1) as a disincentive to seek health care, and 2) as a barrier to reach the relevant facility [43]. As such, people in households closer to a motorable road are more likely to seek health care and save lives. We also found an increased likelihood of neonatal mortality and stillbirths among households where there was a maternal death. This is in agreement with a finding in a WHO multi-country maternal and newborn health survey, which showed a seven fold greater early neonatal mortality, in which mothers had died or developed nearmiss (dangerous illness) compared to mothers without these events [44]. The clustering of maternal and neonatal mortality, as well as stillbirths in certain households, illustrates how impoverished households are trapped in many adverse outcomes.

The findings of a low utilization of facilities for skilled delivery, compounded with high mortality rates, call for educating mothers and other family members the importance of seeking skilled delivery service (institutional deliveries). Furthermore, improving the quality of the existing poorly equipped health institutions in the area [45] might help to increase the willingness and trust of families to utilize these institutions. The Ethiopian health extension workers have the opportunity to educate women and family, as they have close contact during the antenatal care and the routine household visits. In summary, our findings highlighted that households living in the villages far from road access, poor SES, and having illiterate household heads and non-spaced births, had greater risks of mortality. Therefore, a targeted follow-up of pregnancies in these households could help to achieve reduced mortality outcomes. Interventions such as family planning education and the availability of FP technology choices to support women in poor households may help prevent deaths caused due to the risk of non-spaced births.

In order to obtain ongoing data to help monitor progress, the community-based registration of pregnancy and birth outcomes

(abortions, stillbirths, livebirths, neonatal and maternal deaths) may be the ideal option. In addition to providing sustainable data for evaluation of effectiveness of policy and programmes, ongoing registration can provide evidence for rights-based advocacy for improvement of health services, and many other benefits outside of the health sector [46]. For prospective registration to occur, Ethiopia must utilize the privilege of the available two health extension workers (HEWs) responsible for each kebele (average 500 households per HEW). Registration-based information may have benefits of reduced risk of recall bias and the cost of surveys by using the already available community health workers for active data collection.

In the following, we address some of the limitations of the study. First, recall bias and under-reporting are widely recognized problems in studies that ask respondents about past events. The intensity of the bias depends on the time interval between the event and the sensitivity of the event to memory [3]. We tried to reduce recall bias in two ways: 1) by selecting data collectors from the respective villages of the data collection that the data collectors helped the respondents to recall the events through their in depth knowledge of social events that happened in their villages, and 2) by choosing a memorable and short time reference period for the event to be recalled. However, there might have been some deaths that were missed due to recall bias in the current data. Second, as it is well-known in survey studies, we cannot show the temporality (time sequence) of the occurrence of exposures and outcomes [47]. For example, having more than three births in the last five years in households was associated with both neonatal mortality and stillbirth. Nevertheless, we cannot assure whether neonatal mortality and stillbirths led to more births or whether more births led to a greater risk.

Third, we used reported information from family members on mortality outcomes and mid-level expert decisions of the cause-of-death classifications using a simplified verbal autopsy technique, which also has the potential for misclassification (misdiagnosis). The existence of misclassification in using the verbal autopsy was reported from a well-designed prospective study of maternal deaths in Guinea-Bissau in Africa as 30% of maternal deaths were left unclassified [48]. The confirmatory diagnostic method used to ascertain the cause of maternal death is an autopsy test which has been used in a hospital setting in Mozambique in Africa [49]. However, such a modern technology cannot be applied in a rural community such as Bonke. Fourth, we were not able to show yearly changes in mortality. We aimed to describe at least aggregated measures by using a single reference period in a community where the date of the event is not easy to identify. From a practical point, it is difficult and inappropriate to expect a specific time-related response from a largely illiterate rural society where there is no vital registration system.

Conclusions

Mortality rates are still lagging behind the MDG targets for Ethiopia. There also exist socio-economic inequalities in maternal and neonatal mortalities, as well as stillbirths in the area. The socio-economic inequality in mortality and the low utilization of existing institutions for delivery care highlight the importance of quality emergency obstetric care service. The services need to target the poorest households where mortalities cluster and disproportionately high. It is important to address barriers to accessing institutional delivery services in a way that is acceptable for rural women.

Supporting Information

File S1 Supporting information file (two tables informing variables included in Principal Component Analysis (PCA)). Table S1. Variables included in Principal Component

References

1. WHO, UNICEF, UNFPA, World-Bank Trends in maternal mortality:1990 to 2010. WHO, UNICEF, UNFPA and The World Bank estimates. Available: http://vdhqlibdoc.who.int/publications/2012/9789241503631_eng.pdf. Accessed 10 September 2012.
2. Lawn JE, Cousens S, Zupan J (2005) 4 million neonatal deaths: When? Where? Why? *The Lancet* 365: 891–900.
3. Lawn J, Yakoub M, Haws R, Soomro T, Darmstadt G, et al. (2009) 3.2 million stillbirths: epidemiology and overview of the evidence review. *BMC Pregnancy and Childbirth* 9: S2.
4. Black RE, Cousens S, Johnson HL, Lawn JE, Rudan I, et al. (2010) Global, regional, and national causes of child mortality in 2008: a systematic analysis. *The Lancet* 375: 1969–1987.
5. Lawn JE, Blencowe H, Pattinson R, Cousens S, Kumar R, et al. (2011) Stillbirths: Where? When? Why? How to make the data count? *The Lancet* 377: 1448–1463.
6. Ngoc NTN, Meriardi M, Abdel-Alem H, Carroli G, Purwar M, et al. (2006) Causes of stillbirths and early neonatal deaths: data from 7993 pregnancies in six developing countries. *Bulletin of the World Health Organization* 84: 699–705.
7. UNICEF (2013) Committing to Child Survival: A Promise Renewed – Progress Report 2013. Available: http://www.unicef.org/publications/files/APR_Progress_Report_2013_9_Sept_2013.pdf. Accessed 03 October 2013.
8. UNICEF (2013) In Ethiopia, a far-reaching health worker programme has helped reduce child mortality across the country. Available: http://www.unicef.org/infobycountry/ethiopia_70372.html. Accessed 03 October 2013.
9. Cousens S, Blencowe H, Stanton C, Chou D, Ahmed S, et al. (2011) National, regional, and worldwide estimates of stillbirth rates in 2009 with trends since 1995: a systematic analysis. *The Lancet* 377: 1319–1330.
10. CSA-Ethiopia, ICF-International (2012) Ethiopia Demographic and Health Survey 2011 final report. Central Statistical Agency of Ethiopia and ICF-International Addis Ababa, Ethiopia and Calverton, Maryland, USA. Available: <http://www.measure DHS.com/publications/publication-fr255-dhs-final-reportsfm>. Accessed 25 June 2013.
11. CSA-Ethiopia (2010) Statistical Tables for the 2007 Population and Housing Census of Ethiopia/CENSUS 2007 TABLES/SNNPR1. Available: www.csa.gov.et. Accessed February 24, 2012. Central Statistical Agency of Ethiopia.
12. Admasu K, Haile-Mariam A, Bailey P (2011) Indicators for availability, utilization, and quality of emergency obstetric care in Ethiopia, 2008. *International Journal of Gynecology & Obstetrics* 115: 101–105.
13. Graham WJ, Ahmed S, Stanton C, Abou-Zahr CL, Campbell OMR (2008) Measuring maternal mortality: an overview of opportunities and options for developing countries. *BMC medicine* 6: 12.
14. Docherty M, Smith R (1999) The case for structuring the discussion of scientific papers. *British Medical Journal* 318: 1224–1225.
15. Graham W, Brass W, Snow RW (1989) Estimating maternal mortality: the sisterhood method. *Studies in family planning* 20: 125–135.
16. Yaya Y, Lindtjorn B (2012) High maternal mortality in rural south-west Ethiopia: estimate by using the sisterhood method. *BMC Pregnancy and Childbirth* 12: 136.
17. Kwast BE, Rochat RW, Kidane-Mariam W (1986) Maternal mortality in Addis Ababa, Ethiopia. *Studies in family planning*: 288–301.
18. WHO (2004) Beyond the numbers: reviewing maternal deaths and complications to make pregnancy safer. *World Health Organization* 2004. Available: http://www.who.int/maternal_child_adolescent/documents/9241591838/en/. Accessed 20 June, 2013.
19. Ronmans C, Graham WJ (2006) Maternal mortality: who, when, where, and why. *The Lancet* 368: 1189–1200.
20. WHO (2012) Levels & Trends in Child Mortality Report 2012. Estimated Developed by the UN Inter-agency Group for Child Mortality Estimation. New

York, USA. Available: http://www.who.int/maternal_child_adolescent/documents/levels_trends_child_mortality_2012.pdf. Accessed 20 June 2013.

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Author Contributions

Conceived and designed the experiments: YY OFN BL. Performed the experiments: YY OFN BL. Analyzed the data: YY KTE OFN BL. Wrote the paper: YY KTE OFN BL. Reviewed and approved the final version of the manuscript: YY KTE OFN BL.

21. Vyas S, Kumaranayake L (2006) Constructing socio-economic status indices: how to use principal components analysis. *Health Policy and Planning* 21: 459–468.
22. IBM SPSS software for data entry and analysis. SPSS version-16. Available: <http://www-01.ibm.com/software/analytics/spss/>.
23. Mersha A, Jira C, Demessie S (1996) Community based study on material mortality in Jimma town, south western Ethiopia. *Indian J Public Health* 40: 30–34.
24. Berhane Y, Andersson T, Wall S, Byass P, Högberg U (2000) Aims, options and outcomes in measuring maternal mortality in developing societies. *Acta Obstetrica et Gynecologica Scandinavica* 79: 968–972.
25. WHO International Statistical Classification of Diseases and Related Health Problems 10th Revision, ICD-10: 2010 Version. available at : <http://apps.who.int/classifications/icd10/browse/2010/en> (accessed 09 December 2011).
26. Stanton C, Hoberaft J, Hill K, Kodjogbé N, Mapeta W, et al. (2001) Every death counts: measurement of maternal mortality via a census. *Bulletin of the World Health Organization* 79: 657–664.
27. Kao S, Chen LM, Shi L, Weirich MC (1997) Underreporting and misclassification of maternal mortality in Taiwan. *Acta Obstetrica et Gynecologica Scandinavica* 76: 629–636.
28. Karimian-Teherani D, Haidinger G, Waldhoer T, Beck A, Vutuc C (2002) Under-reporting of direct and indirect obstetrical deaths in Austria, 1980–98. *Acta Obstetrica et Gynecologica Scandinavica* 81: 323–327.
29. Deneux-Tharoux C, Berg C, Bouvier-Colle M-H, Gissler M, Harper M, et al. (2005) Underreporting of pregnancy-related mortality in the United States and Europe. *Obstetrics & Gynecology* 106: 684–692.
30. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, et al. (2010) Maternal mortality for 181 countries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5. *The Lancet* 375: 1609–1623.
31. CSA-Ethiopia, ICF-International (2012) Ethiopian Demographic and Health Survey 2011 final report. Available: <http://www.measure DHS.com/publications/publication-fr255-dhs-final-reports.cfm>. Accessed 25 June 2013. Central Statistical Agency of Ethiopia and ICF-International Addis Ababa, Ethiopia and Calverton, Maryland, USA.
32. Montgomery MR, Gragnoli M, Burke KA, Paredes E (2000) Measuring living standards with proxy variables. *Demography* 37: 155–174.
33. Morris SS, Carletto C, Hoddinot J, Christiansen LJM (2000) Validity of rapid estimates of household wealth and income for health surveys in rural Africa. *Journal of Epidemiology and Community Health* 54: 381–387.
34. Pollack CE, Chideya S, Cubbin C, Williams B, Dekker M, et al. (2007) Should Health Studies Measure Wealth? A Systematic Review. *American Journal of Preventive Medicine* 33: 250–264.
35. Duncan GJ, Daly MC, McDonough P, Williams DR (2002) Optimal Indicators of Socioeconomic Status for Health Research. *American Journal of Public Health* 92: 1151–1157.
36. Menchik PL (1993) Economic Status as a Determinant of Mortality Among Black and White Older Men: Does Poverty Kill? *Population Studies* 47: 427–436.
37. Christian P (2002) Maternal nutrition, health, and survival. *Nutrition reviews* 60: S59–S63.
38. Dawodu AH, Effiong CE (1985) Neonatal Mortality: Effects of Selective Pediatric Interventions. *Pediatrics* 75: 51–57.
39. Alkire S, Santos ME Acute Multidimensional Poverty: A New Index for Developing Countries. Proceedings of German Development Economics Conference, 2011 (Berlin). Available: <http://www.econstor.eu/handle/10419/48297>. Accessed 25 May 2013.

40. Cleland JG, van Ginneken JK (1988) Maternal education and child survival in developing countries: The search for pathways of influence. *Social science & medicine* 27: 1357–1368.
41. Asefa M, Drevett R, Tessema F (2006) A birth cohort study in South-West Ethiopia to identify factors associated with infant mortality that are amenable for intervention. *Ethiopian Journal of Health Development* 14: 161–168.
42. Cutler DM, Lleras-Muney A (2006) Education and health: evaluating theories and evidence the National Bureau of Economic Research. NBER Working Paper No.12352.
43. Gabrysch S, Campbell OMR (2009) Still too far to walk: Literature review of the determinants of delivery service use. *BMC Pregnancy and Childbirth* 9: 34.
44. Souza JP, Gülmezoglu AM, Vogel J, Carroli G, Lumbiganon P, et al. (2013) Moving beyond essential interventions for reduction of maternal mortality (the WHO Multicountry Survey on Maternal and Newborn Health): a cross-sectional study. *The Lancet* 381: 1747–1755.
45. Girma M, Yaya Y, Gebrehanna E, Berhane Y, Lindtjorn B (2013) Lifesaving emergency obstetric services are inadequate in south-west Ethiopia: a formidable challenge to reducing maternal mortality in Ethiopia. *BMC health services research* 13: 459.
46. Okonjo-Iweala N, Osafo-Kwaako P (2007) Improving health statistics in Africa. *The Lancet* 370: 1527–1528.
47. Grimes DA, Schulz KF (2002) Bias and causal associations in observational research. *The Lancet* 359: 248–252.
48. Hoj L, Stensballe J, Aaby P (1999) Maternal mortality in Guinea-Bissau: the use of verbal autopsy in a multi-ethnic population. *International Journal of Epidemiology* 28: 70–76.
49. Menéndez C, Romagosa C, Ismail MR, Carrilho C, Saute F, et al. (2008) An autopsy study of maternal mortality in Mozambique: the contribution of infectious diseases. *PLoS Medicine* 5: e44.

RESEARCH ARTICLE

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High maternal mortality in rural south-west Ethiopia: estimate by using the sisterhood method

Yaliso Yaya^{1,2*} and Bernt Lindtjorn¹

Abstract

Background: Estimation of maternal mortality is difficult in developing countries without complete vital registration. The indirect sisterhood method represents an alternative in places where there is high fertility and mortality rates. The objective of the current study was to estimate maternal mortality indices using the sisterhood method in a rural district in south-west Ethiopia.

Method: We interviewed 8,870 adults, 15–49 years age, in 15 randomly selected rural villages of Bonke in Gamo Gofa. By constructing a retrospective cohort of women of reproductive age, we obtained sister units of risk exposure to maternal mortality, and calculated the lifetime risk of maternal mortality. Based on the total fertility for the rural Ethiopian population, the maternal mortality ratio was approximated.

Results: We analyzed 8503 of 8870 (96%) respondents (5262 [62%] men and 3241 ([38%] women). The 8503 respondents reported 22,473 sisters (average = 2.6 sisters for each respondent) who survived to reproductive age. Of the 2552 (11.4%) sisters who had died, 819 (32%) occurred during pregnancy and childbirth. This provided a lifetime risk of 10.2% from pregnancy and childbirth with a corresponding maternal mortality ratio of 1667 (95% CI: 1564–1769) per 100,000 live births. The time period for this estimate was in 1998. Separate analysis for male and female respondents provided similar estimates.

Conclusion: The impoverished rural area of Gamo Gofa had very high maternal mortality in 1998. This highlights the need for strengthening emergency obstetric care for the Bonke population and similar rural populations in Ethiopia.

Keywords: High maternal mortality, Maternal mortality, Sisterhood method, Bonke, Gamo Gofa, Southwest Ethiopia, Ethiopia, Sub-Saharan Africa

Background

Maternal mortality is defined as the death of a woman during pregnancy or within 42 days after termination of pregnancy from any cause related to or aggravated by the pregnancy or management of the pregnancy [1]. Maternal mortality is particularly high in developing countries [2], where 98% of the yearly 500,000 maternal deaths occur [3,4]. Of the 20 countries with the highest maternal mortalities in the world, 17 are in Africa. The Millennium Development Goals aim to reduce maternal deaths by 75% by 2015 from the 1990 baseline (MDG-5)

[5]. The indicator chosen to measure the progress is the maternal mortality ratio (MMR; number of maternal deaths per 100,000 live births). Unfortunately, the progress in many sub-Saharan African countries has been slow or non-existent [6].

Ethiopia is one of the six countries where > 50% of the total maternal deaths worldwide occur; the other countries are the Democratic Republic of Congo, Nigeria, India, Pakistan, and Afghanistan [6]. Since 1990, Ethiopia has reduced child mortality [7]. There are also reports of reductions in MMR, but not statistically significant. The MMR for Ethiopia was 1061 (665–1639) in 1980, 968 (600–1507) in 1990, 937 (554–1537) in 2000, and 590 (358–932) in 2008 [6]; however, these estimates have

* Correspondence: yalisoaya@gmail.com

¹Centre for International Health, University of Bergen, Bergen, Norway

²Arba Minch College of Health Science, Arba Minch, Ethiopia

wide and overlapping confidence intervals that highlight the difficulty in detecting real changes. It was as recent as 2008 that the upper uncertainty limit of the MMR decreased to < 1000 . Also, there are discrepancies between estimates from different sources and methods. For example, the MMR was 590 (358–932) for 2008 according to the Institute for Health Metrics and Evaluation by Hogan et al. [6], while the UN agencies and The World Bank estimated the MMR to be 470 (270–790) [8]. Estimates of the MMR from community-based studies also vary; specifically, for 1982/83 the MMR was 566 in Addis Ababa [9], 570 (420–720) for Illubabor in western Ethiopia in 1991 [10], and between 440 (314–598) and 665 (558–785) by surveillance and sisterhood method respectively for Butajira in south central Ethiopia in 1996 [11]. These surveys showed lower estimates than the mathematically-modelled estimates for the country.

African countries, unlike developed nations, lack reliable vital registrations to provide good MMR estimates. Developed countries use birth registries and link such registries to causes of death registries, which are the gold standard by which maternal mortality is estimated. An alternative source of information includes health service data, which depends on reports of health institutions; however, the health service reports in developing countries are often biased, as only few people use these services. Also, information gathered through health services is incomplete. It is thus difficult to estimate the accurate MMRs based on institutional data [12]. Therefore, developing countries with limited health service coverage attempt to include maternal mortality-related questions in household surveys, such as the Demographic and Health Survey (DHS). Although these surveys have contributed important information for monitoring interventions, the surveys are expensive and do not provide the regional and local estimates which are needed to improve health services.

For countries with high maternal mortality and fertility rates, Graham and colleagues [13] developed an indirect sisterhood method for calculating maternal mortality indices. This method is widely used in Africa and Asia to provide community-based maternal mortality estimates [13–15]. Unfortunately, there are no such reports from south Ethiopia. Our study aimed to determine the lifetime risk of death of women from pregnancy-related causes and to calculate the MMR in a rural area in Gamo Gofa.

Methods

The setting

We conducted this study in 15 of 30 randomly selected rural kebeles (lowest administrative units) in the Bonke woreda (district) of the Gamo Gofa zone in south-west Ethiopia. Bonke is one of 15 woredas in the Gamo Gofa

zone and had a population of 173,240 in 2010 [16]. The woreda consists of 31 kebeles; 1 of these kebeles is a town. Geresse, the administrative centre of Bonke, is 618 km from Addis Ababa and 68 km from the zonal town, Arba Minch. However, greater than two-thirds of the people in Bonke live in highlands, which are far from roads. The only road to the woreda is the road from Arba Minch to Kamba. The road is often interrupted because of overflowing rivers during the rainy season and most of the population lives in remote villages far from the road.

The district is divided into the cold and mountainous highlands, and hot lowlands with malaria endemic to the lowland area. Healthcare is provided by a health centre at the town, and three other rural health centres. There are no medical doctors working in the district, and the health institutions are staffed by a few health officers and nurses. In the woreda, there is no access to comprehensive emergency obstetric care providing caesarean deliveries and blood transfusions. There are villages that are as far as a 14-h walk (approximately 72 km) from a road and a 20-h walk (100 km) from the nearest comprehensive emergency obstetric care at Arba Minch Hospital.

We conducted this study as part of an intervention project to reduce maternal mortality in Gamo Gofa. The work also included studies on the estimation of maternal mortality through a community-based birth registry, a retrospective 5-year recall period household survey, and a health facilities obstetric care quality study.

The sisterhood method

In the sisterhood method, adult men and women report the proportion of their adult sisters (born to the same mother) dying during pregnancy, childbirth, or within 6 weeks following pregnancy [17]. The main objective of this method is to create a retrospective cohort of women at risk of pregnancy-related death, and to estimate the lifetime risk (LTR; the chance of a woman dying from pregnancy-related causes during her entire reproductive period). Then, the LTR is translated into the more conventional MMR.

The MMR estimate obtained through the indirect sisterhood method using respondents 15–49 years of age refers to events approximately 10–12 years before the collection of data. The time of estimation for the MMR extends up to 35 years from the time of data collection, when the respondents are older (if included, > 50 years of age). Therefore, the information obtained from such surveys is used as a quick reference of past mortality rather than of recent events. This method is not recommended for overseeing the trend over the long period of maternal mortality or for geographic comparisons [18].

To translate the lifetime risk into the MMR, the method recommends that the total fertility rate (TFR; the average number of children that would be born to a woman over her lifetime) should be ≥ 5 . In 2000, the TFR for the rural Ethiopian population was 6.4 [19]. Because this rural area has a high illiteracy rate, and is a densely-populated, subsistent-farming community, we assumed the population to have similar fertility with other rural areas in Ethiopia. Therefore we used a TFR of 6.4 in the current study.

The data collection

We recruited data collectors who had completed the 12th grade, lived in the area, and were familiar with the local language and culture. Five diploma graduates who also had a thorough knowledge of the culture and language of the area supervised the data collectors. Each enumerator was trained for 2 days. The training included pre-test field interviews, translation of the questions, and understanding the different interpretations of the questions by the respondents.

We asked men and women 15 – 49 years of age the following standard questions using the sisterhood method [17]:

1. How many sisters (born to the same mother) have you had who survived to reproductive age (15 years of age)?
2. How many sisters who reached reproductive age (15 years of age) are alive now?
3. How many sisters died?
4. How many sisters died during pregnancy, childbirth, or 6 weeks after delivery or termination of pregnancy

In addition, we collected data on the age, gender, and education of each respondent. Fifteen years of age was considered the common age at which women are expected to undergo menarche. Therefore, we used 15 years as the proxy age for reaching reproductive age with additional probing of a reproductive age phrase itself. Data collectors were carefully trained not to include the responding woman in the reported number of sisters born to her mother.

The questions were translated to Amharic (Ethiopian official state language), and the enumerators administered Amharic using the local Gamotho language. The enumerators visited each household in the selected communities that had at least one pregnancy during the 5 years prior to the study. The enumerators asked the four questions (*vide supra*) to the husband and wife, and to the children, if any, who were 15–49 years of age.

Other extended adult family members in the household were also interviewed. If an adult person was not

present during the first visit, the data collectors re-visited the household the following morning.

Sample size and sampling technique

The sample size recommended by Graham and colleagues was 3000–6000 adult respondents [17]. A more precise recommendation of the sample size estimation, which considers the margin of error, confidence level, power of the estimate, and the required number of maternal deaths of sisters, suggests a more detailed sample size determination [20]. The formula which calculates the number of maternal deaths required for reporting by respondents was determined as follows: $r \geq [Z\alpha/2]^2 * [100\div\% ME]^2$, where r is the number of sister deaths due to maternal causes that were required, $Z\alpha/2$ is the standard normal deviate at a two-sided confidence level of $100[1-\alpha]$, and the % ME is the percentage margin of error tolerated by the investigators.

We used a tolerable margin of error of 10%, and an α value of 5% (two-sided 95% CI). From the formula we calculated $[1.96]^2 * [100/10]^2 = 384$ sister deaths due to pregnancy, childbirth, or 6 weeks after the pregnancy terminated. Hanely and colleagues [20] have suggested that with 80% statistical power for a community with a MMR > 750 per 100,000 live births, a report of ≥ 384 maternal deaths is expected from interviewing 8000 adult siblings. In 2000, the MMR estimate was 937 for Ethiopia [6]. To account for non-responses and missed information, we decided to interview 9000 respondents.

We grouped the 30 kebeles of Bonke Woreda into three climatic zones (hot, temperate, and cold). To ensure fair representation of all three climatic conditions, we selected one-half of the kebeles in each climatic zone using a lottery method. Thus, we selected 8 of 16 Dega (cold weather), 4 of 8 Woinadega (moderate temperature), and 3 of 6 Kolla (hot temperature) kebeles. Then, the 9000 respondents were distributed to the study kebeles proportionate to the population size.

Data analysis

SPSS 16 (SPSS, Inc., Chicago, IL, USA) was used for data entry and analysis [21]. We used an inflation adjustment to determine the final number of surviving adult sisters for the younger respondents (15–24 years of age). This was done by multiplying the number of respondents in the young age groups by the average number of sisters among the older respondents (25–49 years of age), which was 2.65 in this data. For example, $2.65 * 2443 = 6471$ adjusted sisters for the 15–19 year old respondents [17]. This factor was used with the assumption that the younger respondents had sisters who had yet to reach reproductive age.

Using standard adjustment factors [17], we adjusted for the expected proportion of sisters that would have

finished their reproductive age for respondents in each age category. Thus, 90% of the sisters of respondents 45–49 years of age are expected to have passed through their reproductive life, but only 10.7% of the sisters of 15–19 year old respondents. The adjustment was implemented so as to determine the number of sister units exposed to maternal death.

This retrospective cohort analysis provided 8,068 sister units exposed to the risk of maternal death that served as the denominator for calculating the lifetime risk of maternal death.

The lifetime risk (Q) of maternal death was calculated by $Q=r/\beta$, where r is the number of maternal deaths and β is the sister units exposed to the risk of maternal death. We calculated the MMR as $MMR = 1 - (P)^{1/TFR}$, where P is the probability of surviving, which equals (1-Q), and TFR is the total fertility rate [20].

Ethics approval

This study was approved by the Ethical Review Committee for Health Research of the Southern Nations Nationalities and the Peoples' Regional State (SNNPRS) Health Bureau in Ethiopia, and the Regional Committee for Medical and Health Research Ethics of North Norway (REK Nord). We obtained informed oral consent from all of the respondents.

Results

We interviewed 8870 people of the 9000 sample (98.5% response rate), and included 96% (8503/ 8870) of respondents in the analysis. The missing information from the excluded 4% (367 people) of the respondents was mainly because of misclassification of age (outside the 15–49 year age range) and missing information regarding the gender of the respondents. There were no maternal deaths reported by those excluded from the analysis.

Of the 8503 respondents in the analysis, 5262 (62%) were men and 3241 (38%) were women. The mean age of the respondents was 26.4 (SD = 8.7) years (range, 15–49 years). The most frequently reported age of the respondents was 30 years, followed by 20 and 18 years (Figure 1).

The 8503 respondents reported 22,473 sisters born to the same mother who survived to the reproductive age. The average number of adult sisters per respondent was 2.6. Of the 22,473 sisters who survived to reproductive age, 2,552 (11.35%) had died. Among the sisters who had died, 32% (819/2552) were pregnancy-related deaths.

The lifetime risk of death from maternal causes was 0.102 (95% CI, 0.096-0.108) or 10.2% (Table 1). Using a TFR of 6.4 for south Ethiopia, we calculated a MMR of

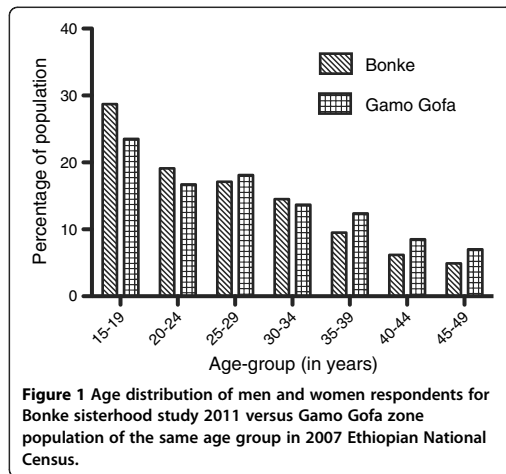


Figure 1 Age distribution of men and women respondents for Bonke sisterhood study 2011 versus Gamo Gofa zone population of the same age group in 2007 Ethiopian National Census.

1667 (95% CI, 1564–1769) per 100,000 live births for 1998.

Table 2 also shows estimates obtained from male and female sibling respondents separately. The lifetime risk estimate based on male respondents was 0.095 (95% CI, 0.086-0.105) with a corresponding MMR of 1547 (95% CI, 1395-1718) per 100,000 live births (LB). A similar estimate based on information from female respondents provided a slightly higher lifetime risk of 0.121 (95% CI, 0.104-0.127) and MMR of 1995 (95% CI, 1701–2099) per 100,000 LB.

Discussion

We calculated a lifetime risk of maternal mortality of 10.2%, which corresponded to a MMR of 1667 per 100,000 LB in 1998. There have been no prior community-based maternal mortality estimations from Gamo Gofa, and our study presents the highest estimate for community-based studies using the sisterhood method in Ethiopia.

In Butajira, which is in south central Ethiopia, the MMR was estimated to be 665 per 100,000 LB in 1996 using the sisterhood method [11]. The Butajira study might have been methodologically more robust than the current study as it was linked to demographic surveillance and probably had a more precise age estimation. However, Butajira also had better access to health services, and this could also explain the differences in MMR compared with Bonke. Shiferaw et al. [10] reported a MMR of 570 per 100,000 LB from Illubabor in western Ethiopia in 1991; however, both studies reported MMR rates below the international estimates for Ethiopia at that time.

Table 1 Maternal mortality estimate using the sisterhood method for the reference period 1998 in rural Bonke, Gamo Gofa, south-west Ethiopia, 2011

Age of respondents	No. of respondents	sisters survived age ≥ 15 yrs	Dead from all causes	Maternal deaths (r)	adjustment factor (f)	Sisters units exposed to risk (β)	Lifetime risk (Q)
	k	e	C	r	f	$\beta = ef$	$Q=r/ \beta$
15-19	2443	6471*	428	240	0.107	693	0.346
20-24	1625	4306*	370	152	0.206	887	0.172
25-29	1450	3889	375	152	0.343	1334	0.114
30-34	1235	3135	358	103	0.503	1576	0.065
35-39	812	2201	331	89	0.664	1461	0.061
40-44	523	1397	255	52	0.802	1120	0.046
45-49	415	1074	225	31	0.900	997	0.031
Total	8503	22473	2342	819		8068	0.102

*inflated number of sisters obtained by multiplying the average number of sisters survived for respondents aged 25-49 (which is 2.65 in this data) by the number of respondents in the younger age groups (age 15-19 and 20-24). Originally reported sisters by the young group were: 5425 for aged 15-19 and 4230 for 20-24 years old respondents.

Hill and colleagues [3] estimated the MMR for Ethiopia in 1995 to be 1814 per 100,000 LB, which was similar to our finding. Our estimate was close to the natural MMR expected without access to contemporary obstetric care. We believe the impoverished and rural Bonke area had a high MMR in recent decades when the population had no access to basic and comprehensive emergency obstetric care because the population resided in isolated villages with limited transportation. A recent national survey in 2008 showed that 7% of all deliveries take place with health care facilities, and only 3% of facilities provide comprehensive emergency obstetric care [22]. Taking in to account the year of the estimate (1998) and the typical rural location of Bonke, our estimate may have reflected the reality the Bonke women experienced. Also, between 1996 and 2000 there were severe malaria epidemics in southern Ethiopia, and the Bonke lowlands was no exception, which might have caused additional maternal deaths. High MMRs have been associated with high HIV prevalence rates elsewhere [23]. In Ethiopia, however, the effect of the HIV epidemic might not have

been important as the HIV prevalence was < 1% in rural areas [24].

An alternative explanation for the high MMR in the current study may be that the sisterhood method provides a biased estimate through selection or information errors and data adjustments. With respect to selection bias, we could have obtained information from many siblings on a death that involved a single woman. Such multiple counting is considered the basis for over-estimation. Potential information biases include misreporting of age or recall errors on the timing of maternal deaths, or even non-recognition of early pregnancy-related deaths.

To ensure correct age determination, we asked several probing questions, such as the number of children the respondents had, the year of marriage, and past events (local calendar) to determine the respondent's age. Because Ethiopia has no system of birth registry, determination of age data is uncertain, which could lead to errors, such as digit preference, as observed in our data. Some respondents may also claim to be younger than their real age, as suggested in Figure 1.

With respect to multiple counting as a potential basis for overestimation, Graham et al. [17] argued that because the sisterhood method is based on a proportional relationship, multiple counting in the denominator is offset by counting sister deaths in the numerator, thus there is no biased result. Trusell et al. [25] emphasized multiple counting of siblings who fall in the sample as essential for the success of the sisterhood method. Therefore, because we did not restrict the siblings during data collection and analysis, we cannot rule out multiple counting, but we believe this is not a major source of bias influencing our estimates.

People often forget past dates of events when responding to research questions. We asked the respondents to recall and report the time and cause of maternal deaths

Table 2 Maternal mortality indicators estimated separately for male and female respondents using the sisterhood method for year 1998 in rural Bonke, Gamo Gofa, South-west Ethiopia, 2011

	Male	Female	total
Number of respondents	5262 (62%)	3241(38%)	8503
Sisters survived 15 years+	11235	8838	22473
Sisters died of all causes	1483	859	2342
Pregnancy related deaths	482	337	819
Sister units of risk exposure	5094	2785	8068
Lifetime risk of maternal death	0.095	0.121	0.102
MMR*	1,547	1,995	1,667

* per 100,000 live births.

of their adult sisters. Two potential forms of error are of concern. First, the respondent could forget the exact time of the death. This could incorrectly increase the MMR if the respondents reported that the sisters died 6 weeks after pregnancy termination. Second, underreporting could occur if the cause of death was misclassified without recognizing early-pregnancy- and abortion-related deaths. However, in rural areas there are strong social ties, and events such as pregnancy are announced early, suggesting a reduced risk of missed early pregnancy-related maternal deaths. We attempted to probe respondents, especially those reporting maternal deaths, to ensure the death was within 6 weeks after the pregnancy was terminated. The information provided is most likely accurate because the 6-week period is the time that most mothers remain at home. The Gachino tradition of women staying at home after delivery is strictly followed by the rural Bonke population.

The 95% CI of our MMR estimate was narrower compared to some other reports using similar methods. The interval was calculated from the 95% CI of the lifetime risk, which in turn depends on the number of maternal deaths counted in the study. In the current study we expected a minimum number of maternal deaths of 384 for 8 000 respondents; however, there was actually 8503 respondents and 819 reported maternal deaths. The large number of maternal deaths that resulted in the narrow 95% CI of the lifetime risk may have caused a narrow interval in the MMR.

We also showed separate estimates based on information from male and female respondents (Table 2). In the current study there were more male respondents than women respondents, which may have occurred for the following reasons: women usually travel to rural open market places that are often far from home in Bonke; and in rural Ethiopia women usually sit in a hidden part of their home ('Guada' in Amharic) as men chat in the living room, thus women may not be available for interview as they shy away from interviewers. Nevertheless, the estimates were similar with a slight increase for female respondents, which could be because of the close relationship sisters have with each other regarding the sharing of information, such as pregnancy. Most previous studies have only enrolled female respondents, despite the recommendation by Graham and colleagues [17] in their original introduction of the sisterhood method to include men in subsequent studies. Male respondents can more easily be accessed for interviews in rural places where they gather for social meetings than women who mostly stay at home or travel to market places. Thus, in future studies interviewing men alone may be an efficient way to reduce the house-to-house visits in search of women respondents among the often scattered households in rural areas.

Although the estimate obtained by the sisterhood method cannot be used to make geographic comparisons and time trend changes, it is useful in providing the magnitude of the situation in a given area. There have been several policy interventions implemented by the Ethiopian government during the past decade. We consider it encouraging that the public health authorities are using Emergency Obstetric Care Guidelines for improving health care in resource-poor settings, and are working to strengthen the referral system. The Ethiopian Government is also setting up primary hospitals for every 100,000 population, and thus improving access to health care. Other important interventions include a malaria prevention campaign through the distribution of bed nets for households, the introduction of two health extension works to all rural villages, training and posting of midwives and health offices, and rapid expansion of health centres. Therefore, the findings of this study may help establish a baseline to assess the current situation and the effects of the interventions using other methods, such as household surveys.

Conclusion

Our findings suggest that people living in remote and underprivileged Bonke have high MMRs. This highlights the importance to strengthen lifesaving comprehensive emergency obstetric care in this area, and in similar rural areas in Ethiopia. Because of uncertainties in our estimates, we also advise using alternative sources of information, such as birth registries and short recall-period household interviews to improve the accuracy of the MMR estimate.

Competing interests

We declare we have no competing interests. YY receives a PhD stipend from The Norwegian state loan for higher education, and BL receives a salary from the University of Bergen in Norway.

Authors' contributions

YY designed the study, organized the data collection, analyzed the data, and wrote the first draft of the manuscript. BL participated in the design of the study, supervised the entire process, and reviewed and modified the drafts of the manuscript. Both authors revised and approved the final draft of the manuscript.

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References

1. WHO: *International statistical classification of diseases and related health problems, tenth revision instruction manual*. Geneva: World Health Organization; 2004.

2. Ronsmans C, Graham WJ: **Maternal mortality: who, when, where, and why.** *Lancet* 2006, **368**(9542):1189–1200.
3. Hill K, Abouzahr C, Wardlaw T: **Estimates of maternal mortality for 1995.** *Bull World Health Organ* 2001, **79**:182–193.
4. Hill K, Thomas K, Abouzahr C, Walker N, Say L, Inoue M, Suzuki E: **Estimates of maternal mortality worldwide between 1990 and 2005: an assessment of available data.** *Lancet* 2007, **370**(9595):1311–1319.
5. WHO: *Health and the Millennium Development Goals.* Geneva: World Health Organization; 2005.
6. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, Makela SM, Lopez AD, Lozano R, Murray CJL: **Maternal mortality for 181 countries, 1980–2008: a systematic analysis of progress towards Millennium Development Goal 5.** *Lancet* 2010, **375**(9726):1609–1623.
7. Bhutta ZA, Chopra M, Axelson H, Berman P, Boerma T, Bryce J, Bustreo F, Cavagnero E, Cometto G, Daelmans B, et al: **Countdown to 2015 decade report (2000–10): taking stock of maternal, newborn, and child survival.** *Lancet* 2010, **375**(9730):2032–2044.
8. Ngoc NTN, Merialdi M, Abdel-Aleem H, Carroli G, Purwar M, Zavaleta N, Campodonico L, Ali MM, Hofmeyr GJ, Mathai M: **Causes of stillbirths and early neonatal deaths: data from 7993 pregnancies in six developing countries.** *Bull World Health Organ* 2006, **84**(9):699–705.
9. Kwast BE, Rochat RW, Kidane-Mariam W: **Maternal Mortality in Addis Ababa, Ethiopia.** *Stud Fam Plann* 1986, **17**(6):288–301.
10. Shiferaw T, Tessema F: **Maternal mortality in rural communities of Illubabor, southwestern Ethiopia: as estimated by the sisterhood method.** *Ethiop Med J* 1993, **31**(4):239–249.
11. Berhane Y, Andersson T, Wall S, Byass P, Hogberg U: **Aims, options and outcomes in measuring maternal mortality in developing societies.** *Acta Obstet Gynecol Scand* 2000, **79**(11):968–972.
12. Graham W, Ahmed S, Stanton C, Abouzahr C, Campbell O: **Measuring maternal mortality: an overview of opportunities and options for developing countries.** *BMC Med* 2008, **6**(1):12.
13. David P, Kwar S, Graham W: **Estimating maternal mortality in djibouti: an application of the sisterhood method.** *Int J Epidemiol* 1991, **20**(2):551–557.
14. Font F, González MA, Nathan R, Lwilla F, Kimario J, Tanner M, Alonso PL: **Maternal mortality in a rural district of southeastern Tanzania: an application of the sisterhood method.** *Int J Epidemiol* 2000, **29**(1):107–112.
15. Bhat PNM: **Maternal mortality in India: an update.** *Stud Fam Plann* 2002, **33**(3):227–236.
16. Central Statistical Authority of Ethiopia: *Statistical Tables for the 2007 Population and Housing Census of Ethiopia: SNNPR vol.1, September 2010; 2012.* www.csa.gov.et (accessed February 24, 2012).
17. Graham W, Brass W, Snow RW: **Estimating maternal mortality: the sisterhood method.** *Stud Fam Plann* 1989, **20**(3):125–135.
18. Olsen ØE, Ndeki S, Norheim OF: **Human resources for emergency obstetric care in northern Tanzania: distribution of quantity or quality?** *Hum Resour Heal* 2005, **3**(1):5.
19. Central Statistical Authority AA: *Demographic and Health Survey Report 2000.* Ethiopia and ORC Macro, Calverton, Maryland, USA: Ethiopia: DHS, 2000, Final Report (English); 2001.
20. Hanley JA, Hagen CA, Shiferaw T: **Confidence Intervals and Sample-size Calculations for the Sisterhood Method of Estimating Maternal Mortality.** *Stud Fam Plann* 1996, **27**(4):220–227.
21. Olsen ØE, Ndeki S, Norheim OF: **Availability, distribution and use of emergency obstetric care in northern Tanzania.** *Health Policy Plan* 2005, **20**(3):167–175.
22. Admasu K, Haile-Mariam A, Bailey P: **Indicators for availability, utilization, and quality of emergency obstetric care in Ethiopia, 2008.** *Int J Gynecol Obstet* 2011, **115**(1):101–105.
23. Bicego G, Boerma JT, Ronsmans C: **The effect of AIDS on maternal mortality in Malawi and Zimbabwe.** *AIDS* 2002, **16**(7):1078–1081.
24. WHO, UNICEF, UNFPA, The World Bank: *Trends in maternal mortality: 1990 to 2010.* WHO, UNICEF, UNFPA and The World Bank estimates. Geneva: World Health Organization; 2012.
25. Trussell J, Rodriguez G: **A note on the sisterhood estimator of maternal mortality.** *Stud Fam Plann* 1990, **21**(6):344–346.

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RESEARCH ARTICLE

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Lifesaving emergency obstetric services are inadequate in south-west Ethiopia: a formidable challenge to reducing maternal mortality in Ethiopia

Meseret Girma¹, Yaliso Yaya^{2,4*}, Ewenat Gebrehanna³, Yemane Berhane³ and Bernt Lindtjorn²

Abstract

Background: Most maternal deaths take place during labour and within a few weeks after delivery. The availability and utilization of emergency obstetric care facilities is a key factor in reducing maternal mortality; however, there is limited evidence about how these institutions perform and how many people use emergency obstetric care facilities in rural Ethiopia. We aimed to assess the availability, quality, and utilization of emergency obstetric care services in the Gamo Gofa Zone of south-west Ethiopia.

Methods: We conducted a retrospective review of three hospitals and 63 health centres in Gamo Gofa. Using a retrospective review, we recorded obstetric services, documents, cards, and registration books of mothers treated and served in the Gamo Gofa Zone health facilities between July 2009 and June 2010.

Results: There were three basic and two comprehensive emergency obstetric care qualifying facilities for the 1,740,885 people living in Gamo Gofa. The proportion of births attended by skilled attendants in the health facilities was 6.6% of expected births, though the variation was large. Districts with a higher proportion of midwives per capita, hospitals and health centres capable of doing emergency caesarean sections had higher institutional delivery rates. There were 521 caesarean sections (0.8% of 64,413 expected deliveries and 12.3% of 4,231 facility deliveries). We recorded 79 (1.9%) maternal deaths out of 4,231 deliveries and pregnancy-related admissions at institutions, most often because of post-partum haemorrhage (42%), obstructed labour (15%) and puerperal sepsis (15%). Remote districts far from the capital of the Zone had a lower proportion of institutional deliveries (<2% of expected births compared to an overall average of 6.6%). Moreover, some remotely located institutions had very high maternal deaths (>4% of deliveries, much higher than the average 1.9%).

Conclusion: Based on a population of 1.7 million people, there should be 14 basic and four comprehensive emergency obstetric care (EmOC) facilities in the Zone. Our study found that only three basic and two comprehensive EmOC service qualifying facilities serve this large population which is below the UN's minimum recommendation. The utilization of the existing facilities for delivery was also low, which is clearly inadequate to reduce maternal deaths to the MDG target.

* Correspondence: yalisoyaya@gmail.com

²Centre for International Health, University of Bergen, Bergen, Norway

⁴Arba Minch College of Health Sciences, Arba Minch, Ethiopia

Full list of author information is available at the end of the article



Background

The fifth Millennium Development Goal (MDG 5) is to reduce maternal mortality by 75% between 1990 and 2015. Although there are good tools available to help reduce maternal deaths [1], the limited availability and poor quality of services cause nearly 300,000 maternal deaths in the world every year, with approximately 85% of the 287,000 global maternal deaths taking place in both Sub-Saharan Africa (56%) and southern Asia (29%) [2]. In 2008, more than half of all maternal deaths in the world occurred in six countries: Afghanistan, Democratic Republic of the Congo, Ethiopia, India, Nigeria and Pakistan [3], with most of these preventable and unacceptable deaths occurring around delivery or a few days after [4]. Bleeding during pregnancy and birth, obstructed and prolonged labour and pregnancy-related hypertension represent the leading causes of deaths among women of reproductive age in resource-poor countries [5].

The maternal mortality ratio (MMR) for Ethiopia was 1,061 (665–1,639) in 1980, 968 (600–1,507) in 1990, 937 (554–1,537) in 2000 and 590 (358–932) in 2008 [3]. Nevertheless, the results of the 2011 Demographic and Health Survey (DHS) revealed that there has been little progress in reducing maternal mortality [6]. The DHS estimate of the MMR for 2011 was 676 (541–810) per 100,000 live births. A study has also showed that in sub-Saharan African countries, the progress towards achieving MDG5 has been slow because of a poor quality of care, low access, inadequate skilled personnel and financial barriers to care [3].

The WHO recommends the use of process indicators on emergency obstetric care (EmOC) facilities to assist in monitoring the progress in maternal mortality reduction efforts, which are considered necessary for planning, implementing and monitoring initiatives to improve maternal health [7]. Unfortunately, there is limited evidence regarding how these institutions are distributed, how well the existing facilities perform and how many people use them in Gamo Gofa, Ethiopia. The investment in maternal health programmes can be evaluated by measuring input indicators (midwifery training), process (the number of midwives posted) and outcomes (the uptake of skilled delivery care). However, the assessment of impacts such as the reduction in mortality in a community can show the effects of long-term interventions.

The availability and use of emergency obstetric care services is important for reducing maternal morbidity and mortality. Based on the capacity to provide lifesaving emergency obstetric procedures, a health institution can be classified as basic or comprehensive emergency obstetric care facility [8]. Basic EmOC institutions are expected to provide the following six services (signal

functions): administration of parenteral antibiotics, parenteral oxytocic drugs, parenteral anticonvulsants for pre-eclampsia, manual removal of retained placentas, removal of retained products of conception and assisted vaginal delivery (vacuum extractions or forceps deliveries) [8]. Institutions providing comprehensive EmOC should also be capable of performing caesarean sections, blood transfusions and services provided by the basic EmOC institutions.

The findings of an assessment regarding the availability, quality and distribution of EmOC services is important for health professionals and policymakers involved in maternal health services. With high maternal mortality rates and a mostly rural population, it is important to evaluate emergency obstetric care provided at public health institutions in Ethiopia.

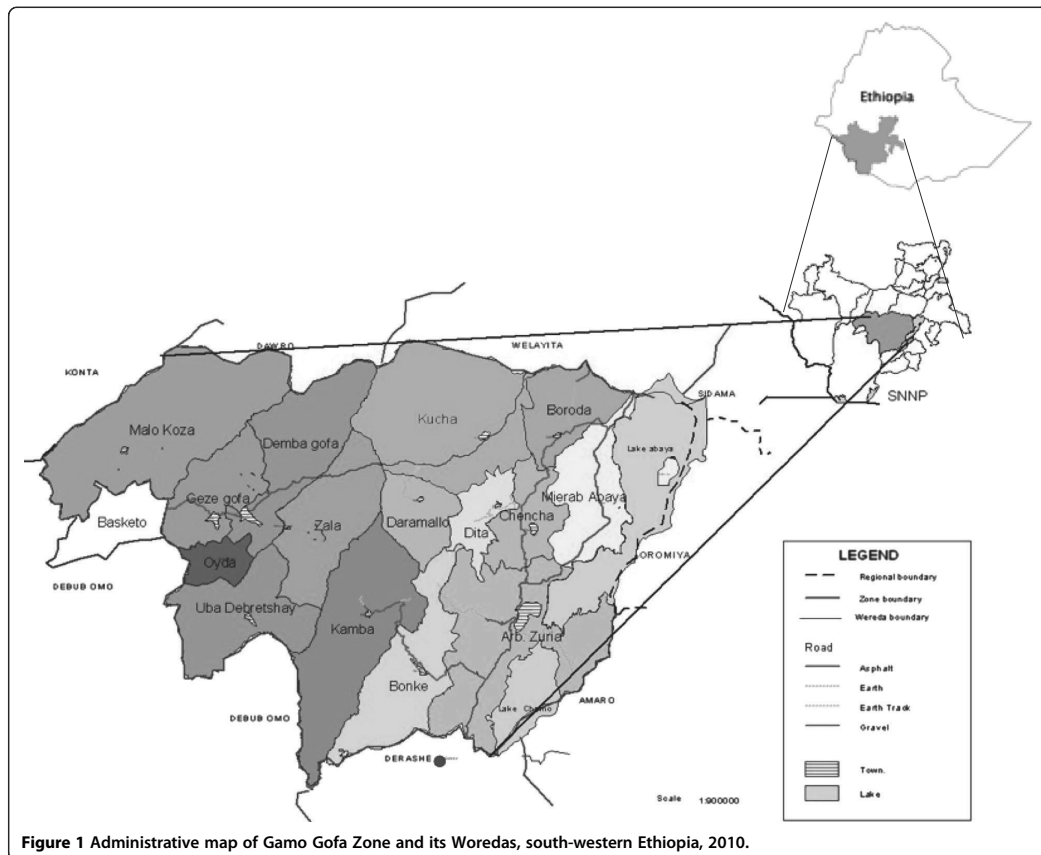
A recent study has shown there are too few health institutions providing EmOC to meet the UN standards of at least five (four basic and one comprehensive) EmOC institutions per 500,000 population in Ethiopia [9]. Only 7% of deliveries took place in institutions, including only 3% in institutions that routinely provided all signal functions. Six percent of women with obstetric complications were treated in health institutions, whereas only one-half of these women were treated in fully functional comprehensive EmOC facilities [9]. The study concluded that far too few public institutions in Ethiopia meet the indicators set by the UN standards.

Ethiopia therefore faces many challenges, not only because of a limited number of adequately functioning obstetric facilities, but also because of its large population and mountainous topography, with large parts of the populations living in remote areas. We conducted this study to assess the availability (coverage), quality (functionality) and utilization of emergency obstetric care facilities in Gamo Gofa in south-west Ethiopia.

Methods

Setting

The study was conducted in the Gamo Gofa Zone in south-west Ethiopia (see map in Figure 1). Nearly 1.7 million people live in the area, with 90% living in rural communities. The Zone has 15 woredas (districts) and two town administrations, each being directly administratively responsible to the Zone. However, people in the surrounding districts of the towns, as well as the towns themselves, use the health facilities/services/ in these towns. The Zone represents three climatic zones (cold, temperate and hot), where most of the people live in highlands 2,000 metres above sea level and practice subsistence farming. There are few all-weather roads in the area, although most of the population lives in the highlands without access to roads. Health care is provided by three hospitals, 63 health centres and by rural health



extension workers in 483 kebeles, which are Ethiopia's lowest administrative units, with an average coverage of 1,000 households (population of 5,000). Hospitals are expected to provide comprehensive emergency obstetric care, while the health centres are expected to provide basic emergency obstetric care. Due to limited access to hospitals, senior staff (health officers) are given minimal training, and provide services such as caesarean sections in some health centres. Four (6%) of the health institutions in the area are accessible by asphalt roads, 21 facilities (32%) are accessed by all-weather gravel roads, 30 health centres (46%) are only accessible by car during the dry season and 11 institutions (17%) could not be accessed by a vehicle at the time of the survey.

We conducted this study as part of a public health intervention project aimed at reducing maternal mortality in Gamo Gofa. A few years prior to the study, the intervention programme ("Reducing Maternal Mortality in south-west Ethiopia") had started training non-physician clinicians (NPCs) to provide EmOC, including

caesarean sections. The programme aims to support public health services to help reduce maternal and neonatal deaths [10], and is primarily a support to government institutions with training, supervision and providing the institutions with basic equipment. Thus, while the population in 2007 had only one hospital capable of doing comprehensive EmOC for approximately 1.7 million people, the services such as caesarean section delivery had improved to three hospitals and two health centres (one institution per 350,000 people) by 2010. The project also includes studies on estimating maternal and neonatal mortality through community-based birth registries, estimations of maternal mortality through the sisterhood method, large-sample household survey to estimate maternal and neonatal deaths and a health facilities obstetric care quality study (the current study).

Data collection and instruments

We collected data using questionnaires and procedures developed according to UN guidelines [8], and assessed

the performance of health institutions using the same guidelines. We recruited eight health officers (people with bachelor's degrees in clinical and community medicine) to collect the data, and the health officers were trained for two days before visiting the institutions. If deemed necessary, key health personnel at each institution were interviewed for the clarification of any recorded data.

Between September and November 2010, we visited 66 health institutions, the three hospitals in Arba Minch, Chenchu and Sawla and 63 health centres throughout the Zone. When visiting the institutions, we retrospectively reviewed one year of available obstetric services, records, documents, cards and registration books related to delivery services. As a result, we collected information from records and registers such as admission registers, delivery registers, delivery log books, referral registers and death registers. We also registered the number of staff available for obstetric care at each of the health institutions we reviewed. As recommended by the WHO guidelines for areas with fewer than 100 facilities, we included all hospitals and health centres in Gamo Gofa in the current study [8].

Data analysis

We used SPSS (version 16; SPSS, Inc., Chicago, IL, USA) for data entry and statistical analysis, and we performed a descriptive analysis to present rates and ratios. We calculated the expected number of deliveries for each woreda using the Central Statistical Authority (CSA) estimates for birth rates (3.7%) and woreda population size [11].

Operational definition

An EmOC facility refers to whether or not an institution is fully functioning as a basic or comprehensive facility [8]. Functioning is defined by nine signal functions, as follows: administering parenteral antibiotics, administering parenteral oxytocic drugs, administering parenteral sedatives, manual removal of the placenta, removal of retained products of conception, vacuum-assisted vaginal deliveries or forceps deliveries, performing caesarean sections, performing newborn resuscitation and the availability of a blood transfusion service. An institution that had not performed any or only some of the signal functions during the past three months was defined as a non-functioning EmOC. The reasons for not performing signal functions may vary, and include a lack of equipment or medications or a lack of available skilled personnel.

Ethical issues

The data for this study was collected as a part of Meseret Girma's master thesis at the University of

Gondar, so ethical clearance was therefore obtained from the University of Gondar. After obtaining the clearance, we received written permission to carry out the study from the Gamo Gofa Zone Health Department and each of the woreda health authorities. Before starting to record information about the health institutions, we informed the leaders of each of the health institutions about the study. Lastly, we received a written consent from the head of each facility to allow us to conduct the study at the institution. The Regional Committee for Medical and Health Research Ethics of North Norway (REK Nord) also approved this study.

Results

Availability of EmOC

We visited and reviewed all of the 66 health institutions (hospitals and health centres) in Gamo Gofa. Of these, only the two hospitals in Arba Minch and Sawla (3% of institutions) provided all signal functions, and were thus designated as providing comprehensive EmOC. Three health centres (4.5%) provided basic EmOC, but did not have a blood bank, while 61 (92%) facilities lacked some or all signal functions and 40 (60.6%) institutions lacked > 5 of the signal functions. Only 36 (54.5%) institutions provided parenteral antibiotics when needed, 61 of 66 (92%) performed assisted vaginal deliveries, 47 (71%) performed the manual removal of placentas, 23 (35%) used parenteral oxytocin and 14 (21%) used anticonvulsants during eclampsia when indicated in the last three months (Figure 2).

Delivery, complications, and deaths

A total of 4,231 deliveries and related admissions took place at the health institutions over the course of 1 year. Furthermore, there was an annual average of 522 deliveries at each hospital, 213 deliveries at two health centres capable of providing emergency obstetric care, including caesarean sections, and an average of 32 deliveries at each of the remaining 61 health centres. Five health centres did not have any recorded deliveries and 24 health centres had one delivery per month during the year surveyed. A total of 521 deliveries were done by caesarean section (0.8% of 64,413 expected births and 12.3% of 4,231 facility births), and over the one year, we recorded 10 neonatal deaths and 178 stillbirths.

We reviewed 1,031 of 4,231 (24.3%) births and pregnancy-related admissions at the health facilities as complicated cases. The complications were further categorized as complications associated with abortions (28.2%), obstructed labour (18%), prolonged labour (16.9%), post-partum haemorrhage (7.3%), antepartum haemorrhage (6.3%), pre-eclampsia or eclampsia (4%) and unclassified (7.5%). We recorded 79 maternal deaths, with the primary causes of deaths being haemorrhage

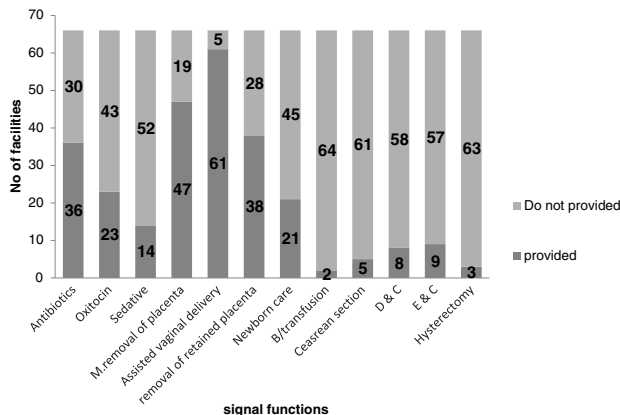


Figure 2 Signal functions provided at all health centres and hospitals in Gamo Gofa Zone between July 2009 and June 2010.

(42%), obstructed labour (15%), puerperal sepsis (15%), prolonged labour (8%) and complications from abortions (8%, Table 1). Table 2 shows that the proportion of institutional deaths varied between districts. Very high mortality rates (61% and 28%) were recorded in two rural and remote woredas; these woredas also had very low institutional delivery rates, and few midwives worked at the institutions (Table 2).

Proportions of births in all facilities and caesarean sections

Over the course of one year, we recorded 4,231 births at the health institutions. Consequently, 6.6% of the expected 64,413 deliveries occurred at institutions in Gamo Gofa. Table 2 shows the variations in institutional deliveries between the different administrative districts,

Table 1 Major causes of pregnancy and birth complications and maternal deaths in hospitals and health centres in Gamo Gofa, south-west Ethiopia, July 2009 to June 2010

Causes	Complications		Deaths	
	No.	%	No.	%
Ante partum haemorrhage	65	6.3	1	1
Post-partum haemorrhage	75	7.3	33	42
Prolonged labour	174	16.9	6	8
Obstructed labour	186	18.0	12	15
Puerperal sepsis	57	5.5	10	13
Complication of abortion	291	28.2	6	8
Pre-eclampsia	41	4.0	4	5
Ruptured uterus	65	6.3	5	6
Others	77	7.5	2	3
Total	1,031	100	79	100

with the woredas with the largest towns (Arba Minch and Sawla), having the highest proportion of institutional deliveries. When analysing the proportion of institutional deliveries per institutional catchment area, we determined that the proportion varied from zero to an average of >20% in the two woredas with towns having hospitals. The institutional delivery rate was approximately 3% in areas with health centres not fulfilling the criteria of basic EmOC, while in contrast, areas such as Kamba, with health centres capable of providing EmOC and performing caesarean sections, had a higher rate of institutional deliveries. We used a Pearson product-moment correlation analysis to determine the correlation of the rate of institutional deliveries in the districts to the proportion of midwives in the catchment population of the district and the number of physicians in the districts (where possible). Woredas with a higher ratio of midwives per population ($r = 0.71$; $p < 0.01$), and where doctors worked ($r = 0.66$; $p < 0.01$), were associated with a higher proportion of institutional deliveries.

Discussion

Based on the total population of 1,740,885, there should have been 14 basic and four comprehensive EmOC facilities in the Zone. There was a sufficient number of health facilities in the Zone, if functional, that could serve as a basic EmOC, and the current study showed that only three basic and two comprehensive EmOC facilities served the population, which is clearly inadequate and below the UN’s minimum recommendations [8]. The proportion of institutional deliveries varied greatly, and five of the health centres did not offer delivery services to the catchment population, whereas 24 health centres provided one or fewer deliveries per month for at least one year. Hence, the population in the area has

Table 2 Expected births, institutional deliveries and health human resource distributions for 66 health institutions, 2010, Gamo Gofa, south-west Ethiopia

Woreda	Population	No. of institutions	Expected no. of births [§]	Institutional deliveries		Midwives		Nurses and health officers [†]		Doctors [‡]	Maternal deaths
				No.	%	No.	Per 100,000 population	No.	Per 100,000 population		
Melokoza	131,009	5	4,847	102	2.1	2	1.5	20	15.3	0	0
Denba Goffa**	114,309	5	4,230	417	9.9	11	9.6	8	7	1	17
Kucha	162,513	6	6,013	108	1.8	2	1.2	13	8	0	5
Boreda	74,008	4	2,738	30	1.1	5	6.8	22	29.7	0	1
Merab Abaya	81,819	4	3,027	287	9.5	4	4.9	22	26.9	0	5
Arba Minch Zuria*	264,927	7	9,802	1,809	18.5	17	6.4	54	20.4	5	3
Chencha	122,193	5	4,521	409	9	8	6.5	45	36.8	2	6
Dita	91,433	4	3,383	163	4.8	3	3.3	16	17.5	0	7
Daramalo	88,232	2	3,265	54	1.7	3	3.4	3	3.4	0	0
Zala	80,931	5	2,995	58	1.9	3	3.7	36	44.5	0	2
Ubadebretsehay	75,377	3	2,789	37	1.3	2	2.7	15	19.9	0	0
Kemba	169,756	7	6,281	411	6.5	4	2.4	13	7.7	0	3
Bonke	173,240	5	6,410	276	4.3	4	2.3	11	6.3	0	3
Geze Goffa	74,951	3	2,773	56	2	3	4	2	2.7	0	21
Oyida	36,187	1	1,339	14	1	2	5.5	1	2.8	0	6
Gamo Gofa Zone	1,740,885	66	64,413	4,231	6.6	73	4.2	281	16.1	8	79

*Includes Arba Minch Town; **Includes Sawla Town; †Available for obstetric care means those who participated in obstetric care.

§Expected number of births = 3.7% (national annual crude birth rate) of the woreda catchment population.

unequal access to obstetric care. Areas with hospitals and health centres providing comprehensive EmOC had higher rates of institutional deliveries. The number of midwives per population was also an important determining factor for institutional delivery rates.

Another important finding was that 28% of women had abortion complications. Ethiopian law allows an abortion when the pregnancy is due to rape (without the woman being asked to provide evidence of rape), when there is a medical threat to the mother and when the foetus has serious irreversible malformations [12]. The current findings suggest that the women are either unaware of such services, or may have limited access to and use of contraceptive services.

Our study represents the first mapping of delivery services in a rural Ethiopian district, and the strength of the study was that it included all health institutions in the Gamo Gofa Zone. Although we attempted to record the relevant work being done at the institutions, our data may be incomplete, as facility records of delivery complications and deaths are often incomplete.

Approximately one-fourth of facilities did not provide at least three or four of the signal functions, while 60% did not provide > 5 of the signal functions. This could be because of an inadequate number of trained staff and a lack of the necessary supplies such as medications, blood transfusion bags and resuscitation equipment. Another

possible explanation could be the idea that basic emergency obstetric care is rather new, and that these services have not yet been given sufficient priority within the health system. A study conducted in Tanzania has also revealed that there were fewer basic EmOC facilities compared to comprehensive EmOC facilities, which is in contrast to UN standards [13]. A study conducted in a low-income country has shown that many women reported dissatisfaction with unprofessional and careless behaviour at health facilities, and preferred the care of traditional birth attendants or relatives [14].

Our study demonstrated that only 6.6% of expected deliveries occurred at health institutions, while a caesarean section was performed for only 0.8% of the expected births. The overall rate of facility deliveries was even lower without the relatively higher contribution of births in the five better EmOC facilities. The UN minimum is that 10% of expected deliveries should take place in EmOC facilities to help reduce maternal mortality in an area [8]. Additionally, the rates of institutional deliveries varied from one area to the other, thus suggesting unequal use and access to obstetric care. Using the UN guidelines as a reference, both the number of institutional deliveries and caesarean sections were far below what is regarded as adequate in order to reduce maternal deaths [8]. These results agree with earlier research conducted in Ethiopia, as well as in other countries

[9,14]. The possible reasons for these findings could be because people live far away from adequately functioning institutions or because of social and cultural restrictions for women to use health institutions during deliveries [15]. Our data suggest that most of the institutions do not provide essential delivery services, and a lack of availability of services near the patients' homes probably explains the low caesarean section rates.

Seventy-nine maternal deaths occurred at the institutions during the one year surveyed, and the case fatality rate among women with obstetric complications was higher than the minimum standard set by the UN [8]. The causes of deaths are similar to studies elsewhere [16], and if the maternal mortality ratio is 590 per 100,000 live births [3], only one in five of expected maternal deaths are recorded at health institutions.

Approximately one-fourth of all deliveries were complicated. This high proportion of complicated deliveries shows that the population seeks care when complications arise during home deliveries. It is therefore recommended that all women with complicated deliveries should be treated in obstetric emergency care facilities; however, with an expected complication rate of 10%, far too few women with complications received adequate care. A qualitative study with informants of 42 maternal deaths in the Gambia highlighted the challenges mothers face to reach lifesaving health facilities. The major barriers described were as follows: an under-estimation of the severity of the complications, a bad experience with the health-care system, a lack of transportation and prolonged transportation [17]. Moreover, large parts of the population in our study area live in remote mountainous areas, far away from the health institutions. The high proportion of obstetric complications and high maternal death rates in some institutions suggest that health centres do not refer such cases to places where the proper management of complicated births are available. It may also show that there is a lack of trained personnel who can provide correct interventions.

We have noted that remote rural districts without institutions doing comprehensive or basic EmOC have lower institutional deliveries, which is consistent with previous a study in a low-income country [13]. The distance to health services exerts a dual influence on use, as a disincentive to seeking care first and as an obstacle to reaching care after a decision has been made to seek care [14]. Although we showed an inadequate coverage of delivery services, these results can be used as baseline data for planning, improving and implementing delivery services in rural Ethiopia. Studies have shown that the UN guidelines to assess the process indicators have been proven to be generally effective in identifying the level of emergency obstetric care [18]. We suggest that similar studies should be conducted at all zones in the country,

and that such information should be used to improve the coverage and quality of health services.

Conclusion

Our study showed that the availability, use and quality of basic and comprehensive EmOC facilities fell below the accepted standard. This poses a formidable challenge to achieving the MDG related to maternal health. Many women visiting health facilities with complications after abortions need closer attention. Nonetheless, we find it encouraging that current efforts by the public health authorities to use emergency obstetric care guidelines for improving health care in resource-poor settings, and the works to help strengthen the referral system. It is also encouraging to learn a new effort by the Ethiopian government to set up primary hospitals for every 100,000 of the population, thereby improving access to health care.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MG conceived the study, coordinated data collection, analysed and interpreted the data, and prepared the draft manuscript. YY conceived the study, helped to organize the data collection, analysed and interpreted the data, and prepared the draft manuscript. EG and YB supervised MG's master thesis, and took part in the data collection, data analysis, and writing of the paper. BL conceived the study, advised on the data collection, interpreted the data, and helped to write the manuscript. All the authors have read and approved the submitted version of the manuscript.

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Author details

¹Department of Public Health, College of Medicine and Health Sciences, Arba Minch University, Arba Minch, Ethiopia. ²Centre for International Health, University of Bergen, Bergen, Norway. ³Department of Reproductive Health and Nutrition, Addis Continental Institute of Public Health, Addis Ababa, Ethiopia. ⁴Arba Minch College of Health Sciences, Arba Minch, Ethiopia.

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References

1. Campbell OMR, Graham WJ: **Strategies for reducing maternal mortality: getting on with what works.** *Lancet* 2006, **368**(9543):1284-1299.
2. WHO, UNICEF, UNFPA, The World Bank: *Trends in maternal mortality:1990 to 2010.* WHO, UNICEF, UNFPA, and The World Bank estimates. Geneva, Switzerland: World Health Organization. available at: http://whqlibdoc.who.int/publications/2012/9789241503631_eng.pdf [accessed 10 September 2012].
3. Hogan MC, Foreman KJ, Naghavi M, Ahn SY, Wang M, Makela SM, Lopez AD, Lozano R, Murray CJL: **Maternal mortality for 181 countries, 1980-2008: a systematic analysis of progress towards Millennium Development Goal 5.** *Lancet* 2010, **375**(9726):1609-1623.
4. Ronsmans C, Graham WJ: **Maternal mortality: who, when, where, and why.** *Lancet* 2006, **368**(9542):1189-1200.
5. Khan KS, Wojdyla D, Say L, Gülmezoglu AM, van Look PFA: **WHO analysis of causes of maternal death: a systematic.** *Lancet* 2006, **367**:1066-1074.
6. CSA-Ethiopia, ICF-International: *Ethiopia Demographic and Health Survey 2011.* Maryland, USA: Central Statistical Agency of Ethiopia and ICF International Addis Ababa, Ethiopia and Calverton; 2012.

7. Wardlaw TMD: **Process indicators for maternal mortality programmes.** In *Reproductive Health Matters*. Blackwell: Safe Motherhood Initiatives: Critical Issues Oxford; 1999:24–30.
8. WHO, UNICEF, UNFPA, AMDD: *Monitoring Emergency Obstetric Care, a handbook. WHO publications, 2009.* Geneva, Switzerland: World Health Organization; 2009. available at: http://whqlibdoc.who.int/publications/2009/9789241547734_eng.pdf (Accessed 10 March 2012).
9. Admasu K, Haile-Mariam A, Bailey P: **Indicators for availability, utilization, and quality of emergency obstetric care in Ethiopia, 2008.** *Int J Gynaecol Obstet* 2011, **115**(1):101–105.
10. Project, RMM: *Project document for Reduction of maternal mortality (RMM) in south-west Ethiopia.* <http://www.lindtjorn.no/page1/page11/page11.html> (accessed December 30, 2011).
11. Federal Democratic Republic Ethiopia, Population Census Commission: *Summary and Statistical Report of the 2007 Population and Housing Census.* Addis Ababa: UNFPA; 2008.
12. FDR-Ethiopia: *Technical and Procedural Guidelines for Safe Abortion Services in Ethiopia.* Addis Ababa: Ministry of Health; 2006.
13. Olsen ØE, Ndeki S, Norheim OF: **Availability, distribution and use of emergency obstetric care in northern Tanzania.** *Health Policy Plan* 2005, **20**(3):167–175.
14. Gabrysch S, Campbell OM: **Still too far to walk: literature review of the determinants of delivery service use.** *BMC Preg Childbirth* 2009, **9**:34.
15. Berhane Y, Gossaye Y, Emmelin M, Hogberg U: **Women's health in a rural setting in societal transition in Ethiopia.** *Soc Sci Med* 2001, **53**(11):1525–1539.
16. Gaym A: **Maternal mortality studies in Ethiopia—magnitude, causes and trends.** *Ethiop Med J* 2009, **47**(2):95–108.
17. Cham M, Sundby J, Vangen S: **Maternal mortality in the rural Gambia, a qualitative study on access to emergency obstetric care.** *Reprod Health* 2005, **2**(3):1–8.
18. Paxton A, Bailey P, Lobis S: **The United Nations Process Indicators for emergency obstetric care: reflections based on a decade of experience.** *Int J Gynecol Obstet* 2006, **95**(2):192–208.

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Appendices I: Questionnaires

Validation of the birth registry study questionnaire (Paper I part 2)

N.B: To data collector: please collect the birth registry book from the health extension worker before you start home visits and cross-check with answers you receive at household with the registration book. At the end register the unregistered births before you leave the household.

Informed oral consent

I am (name) ----- working at -----institution.

The following study is about measuring maternal and neonatal mortality in this area. Specifically this study is about whether birth registration in this kebele is going well or not. I appreciate study. The result of the study may help to improve services. We will keep the confidentiality of all information you give us. Your names and any identifier will not be used publicly. We will only use the aggregate data. It will take approximately half an hour discussion. Participation is voluntary but I hope you will be willing to participate as your idea may have important benefits.

Do you have any question? Can I start interviewing?

1) Yes, I can participate

2) No I will not want to participate

If the person approached does not want to participate, give thanks and proceed to the next household

Kebele.....

Sub-kebele (village) _____

Date-----

Name of the head of HH _____ sex.....age.....education.....

Name of the mother -----

The following are the questions to be tick (the format to be filled) in box in front of the answer (Coding) by asking the head of the household where there is birth since last 12 months.

S. no	Questions	Choice	Coding	Skip
101	Distance of the household from health post (km) hint 1 hr walk of normal person= 5 km	Write number in km-----		
102	Is the head of household model farmer in that locality?	1. Yes 2. No	<input type="checkbox"/> <input type="checkbox"/>	
103	Do you know that there is a birth registration in your kebele?	1. Yes 2. No(I do not know)	<input type="checkbox"/> <input type="checkbox"/>	
104	If yes for Q103 from whom you heard?	1. HEW(health extension worker) 2. CHP(community health promoters) 3. Kebele leaders	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
105	Do you think registration of all births is important?	1.Yes 2. No 3.I do not know	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
106	Have you followed antenatal care service during your pregnancy?	1. Yes 2. No	<input type="checkbox"/> <input type="checkbox"/>	
107	How many pregnancies have you had(gravidity)	Write the number.....		
108	The level of this birth in all your births is.....	(first ,second or-----)		
109	Do you think this birth registered in the birth registry?	1.Yes 2.Not registered 3. do not know	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	

110	What is the age of the newborn today (in days)	Write the number of days.....		
111	If your newborn registered, how was it registered	1) Myself visiting the HEW 2) HEW visited our home and registered it. 3) CHP(volunteer health promoters) visited and registered 4) Other (specify)_____	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
112	If not registered, why do you think?	1. Since we do not know 2. Since we do not want 3. Nobody asked us	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
113	If your current newborn was not registered, do you have intention for future registration?	1 Yes 2.No, I do not want	<input type="checkbox"/> <input type="checkbox"/>	
114	Who attended the delivery?	1.Parent 2.TBA 3.HEW 4.Health works	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
115	Place of birth	1.Home 2.Health post 3.Health center 4. Hospital 5. Family home	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	

116	Is the mother alive now?	1. Yes 2. No	<input type="checkbox"/> <input type="checkbox"/>	
117	If died for Q116 when?	1. During pregnancy 2. During child birth 3. After birth until 42 days 4. After 42 days of birth	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
118	If the mother died cause of the death (use simplified verbal autopsy questions)	1. Fever 2. Bleeding(retained placenta) 3. Convulsion 4. obstructed/prolonged labour 5. other (specify)-----	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
119	Is the neonate (infant) alive?	1. Yes 2. No	<input type="checkbox"/> <input type="checkbox"/>	
120	If not for Q 119 (dead), when?	1. During birth 2. After birth until 28 days 3. After 28 days of birth	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	
121	For data collector: Was the birth registered in birth registry?	1. Yes 2. No	<input type="checkbox"/> <input type="checkbox"/>	
122	If registered, the date of registration	Date registered.....		
123	If registered, write registration number	Serial number on the book.....		

Thank you so much for responding

Questionnaire for household survey (Paper II)

House code-----

Date -----

Time -----

Informed Oral consent

I am (name) ----- working at -----institution.

The following study is about measuring maternal and neonatal mortality in this area. I appreciate your participation. The result of the study may help to improve services. We will keep the confidentiality of all information you give us. Your names and any identifier will not be used publicly. We will only use the aggregate data. The interview will take approximately 45 minutes. Participation is voluntary but I hope you will be willing to participate as your idea may have important benefits.

Do you have any question? Can I start interviewing?

1) Yes, I can participate

2) No I will not want to participate

If the person approached does not want to participate, give thanks and proceed to the next household

General backgrounds

1. Name of Kebele-----
2. Name of Sub-Kebele (Mender) -----
3. Distance of the house from all-weather driveable road -----km
4. Distance of the house from the nearest health center -----km
5. Distance of the house from the nearest hospital -----km
6. Is there an all-weather driveable road reaching this household? 1- Yes 2-No

Household information

7. Name of head of HH (respondent) -----
8. Age----- (years)
9. Sex-----
10. Educational level----- (completed grade)
11. Occupation (main job) ----- 1. Farming 2. Mixed (farming +trading), 3. Trading 4. Employed
12. Number of people living in the house since last 1 year: total _____ Male _____ Female _____ under 5 year _____

13. Had there been any birth in this house in the last 5 years (January 2006 to December 2010) HINT: Election 2005

1- Yes 2- No

1. 13. If "yes" to question "9" _____ 1) yes 2) no births

14. If yes to Q.13, how many to total births? _____

15. How many live births _____

16. How many still births _____

17. How many of these children born alive are still living -----

19. What was the main problem that caused the death of the mother? Ask several respondents about the conditions preceding the death (husband, sister, any relevant adult), and use the verbal autopsy extraction paper

1- Bleeding (hemorrhage) 2- Fever (sepsis) 3- Convulsion (hypertension) 4- prolonged/obstructed labour 5- Others
(Specify other cause of death)_____

20. Could the cause be related to abortion? (be skillful on this issue, approach systematically as it is sensitive)

Proceed to the asset (wealth) questionnaire in the following pages

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP																								
21	What is the main source of drinking water for members of your household?	PIPED (TAP) PIPED INTO DWELLING11 →23 PIPED INTO COMPOUND12 →23 PIPED OUTSIDE COMPOUND13 OPEN WELL/SPRING OPEN WELL22 OPEN SPRING23 COVERED WELL/SPRING COVERED WELL31 COVERED SPRING32 SURFACE WATER RIVER42 POND/LAKE/DAM43 RAINWATER51 →23 OTHER96 (SPECIFY)																									
22	How long does it take you to go there, get water, and come back?	MINUTES <input type="text"/> <input type="text"/> <input type="text"/> ONE DAY OR LONGER995 ON PREMISES996																									
23	What kind of toilet facility do most members of your household use?	FLUSH TOILET11 PIT TOILET/LATRINE TRADITIONAL PIT TOILET21 VENTILATED IMPROVED PIT LATRINE (VIP)22 NO FACILITY/BUSH/FIELD31 →25 OTHER96 (SPECIFY)																									
24	Do you share this facility with other households?	YES1 NO2																									
25	Does your household have:	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th style="text-align: center;">YES</th> <th style="text-align: center;">NO</th> </tr> </thead> <tbody> <tr> <td>Electricity?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>A radio?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>A television?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>A telephone?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>An electric mitad?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>A kerosene lamp / pressure lamp?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>A bed/ table?</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> </tbody> </table>		YES	NO	Electricity?	1	2	A radio?	1	2	A television?	1	2	A telephone?	1	2	An electric mitad?	1	2	A kerosene lamp / pressure lamp?	1	2	A bed/ table?	1	2	
	YES	NO																									
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	YES	NO																									
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Have sheep/goats?	1	2																									
Grow cash crops?	1	2																									

NO.	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP															
26	What type of fuel does your household mainly use for cooking?	ELECTRICITY01 LPG/NATURAL GAS02 BIOGAS03 KEROSENE04 CHARCOAL05 FIREWOOD, STRAW06 DUNG07 OTHER96 (SPECIFY)																
27	MAIN MATERIAL OF THE FLOOR. RECORD OBSERVATION.	EARTH/SAND11 DUNG12 WOOD PLANKS21 REED/BAMBOO22 PARQUET OR POLISHED WOOD31 VINYL SHEETS/TILES32 CEMENT33 CEMENT TILES/BRICK34 CARPET35 OTHER96 (SPECIFY)																
27A	MAIN MATERIAL OF THE ROOF RECORD OBSERVATION.	CORRUGATED IRON01 CEMENT/CONCRETE02 WOOD AND MUD03 THATCH04 REED/BAMBOO05 PLASTIC SHEET06 MOBILE ROOFS OF NOMADS07 OTHER96 (SPECIFY)																
27B	How many rooms in your house are used for sleeping?	ROOMS <input type="text"/> <input type="text"/>																
28	Does any member of your household own: A bicycle? A motorcycle or motor scooter? A car or truck? A horse or mule for human transport only?	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th></th> <th style="text-align: center;">YES</th> <th style="text-align: center;">NO</th> </tr> </thead> <tbody> <tr> <td>BICYCLE</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>MOTORCYCLE/SCOOTER</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>CAR/TRUCK</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> <tr> <td>HORSE/MULE</td> <td style="text-align: center;">1</td> <td style="text-align: center;">2</td> </tr> </tbody> </table>		YES	NO	BICYCLE	1	2	MOTORCYCLE/SCOOTER	1	2	CAR/TRUCK	1	2	HORSE/MULE	1	2	
	YES	NO																
BICYCLE	1	2																
MOTORCYCLE/SCOOTER	1	2																
CAR/TRUCK	1	2																
HORSE/MULE	1	2																

Verbal autopsy extraction for cause of maternal death assessment (Papers I & II)

REF	Questions and filters	Coding categories
Q 01	<i>How many children had (NAME) given birth to when she died?</i>	1. Live births _____ 2. Don't know
Q02	<i>Did (NAME) die during pregnancy or childbirth or within 6 weeks of giving birth?</i>	1. Yes 2. No 3. Do not know
Q03	<i>Did (NAME) have her periods coming regularly?</i>	1. Yes 2. No 3. Do not know
Q04	<i>Did (NAME) have bleeding from the vagina?</i>	1. Yes 2. No 3. Do not know
Q05	<i>How many months was she pregnant when she died?</i>	_____ months
Q06	<i>Did she suffer from any complaints during her last pregnancy?</i>	1. Yes (specify) 2. No 3. Do not know
Q07	<i>Did she attend antenatal clinics during her last pregnancy?</i>	1. Yes (____ times) 2. No 3. Do not know
Q08	<i>Did (NAME) have high blood pressure during pregnancy?</i>	1. Yes 2. No 3. Do not know
Q09	<i>Was there bleeding during pregnancy?</i>	1. Yes 2. No 3. Do not know
Q10	<i>Did (NAME) have oedema of the limbs during pregnancy?</i>	1. Yes 2. No 3. Do not know
Q11	<i>At what stage of the pregnancy did (NAME) die?</i>	1. During pregnancy 2. During labour 3. In 6 weeks after birth/abortion
Q12	<i>Was there excessive bleeding during delivery?</i>	1. Yes 2. No 3. Do not know
Q13	<i>Was she complaining of severe Headaches during delivery?</i>	1. Yes 2. No 3. Do not know
Q14	<i>Did the placenta come out within half an hour of the birth of the child?</i>	1. Yes 2. No 3. Do not know
Q15	<i>Did (NAME) have convulsions during delivery?</i>	1. Yes 2. No 3. Do not know
Q16	<i>Was there high fever starting after delivery?</i>	1. Yes 2. No 3. Do not know

Q 17:

Please discuss deeply with the respondent and describe conditions preceding the death of the mother in the following free space

Indirect sisterhood questions for (Paper III)

The informed oral consent in the household survey questionnaire (Paper II) is also used for this interview as both studies administered together.

Serial No. of respondents	Age	sex	How many sisters have you ever had who were born to your mother and who reached the age of 15 years?	How many of these sisters who reached the age of 15 are still alive?	How many of these sisters who reached the age of 15 have died?	How many of these dead sisters died while pregnant, during child birth, or in 6 weeks after pregnancy ended?
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Questionnaire for Paper IV

A Format for Data Collection for a survey on Assessment of Availability and Utilization of Emergency obstetric care service in Gamo Goffa Zone 2010.

Part one: Facility review

1. Name of facilities _____ Woreda _____

1.1 Facilities type 1. hospital 2. health center 3. Others (specify) _____

1.2 Distance from 1. Woreda center _____ Km

2. Zone center _____ Km

3. from the nearest hospital _____ Km

4. from the nearest all-weather road _____ KM

1.3 Driveable road access to the facility is: 1. Asphalt 2. All-weather gravel road

3. Dry weather gravel road 4. No road access

1.4 Facility status _____ 1. Basic EMOc 2. Comp EMOc

1.5 Functional status of the Basic EOC facility is 1) fully functional 2) partially functional

3) not functional

2. Were the following signal functions (services) performed at least once during the last 3 months & 12 months?

No	Items	Last3 month (1 April 2010 to 30 June 2010)	Last12 month (1 July 2009 to 30 June 2010)	(If "yes"), are medicines/equipments available today	If not performed in past 3 months, why?
2.1	Parental antibiotics	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.2	Parental oxytocin	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.3	Parental sedatives	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.4	Manual removal of placenta	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.5	Removal of retained product	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.6	Assisted vaginal delivery	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.7	Perform newborn resuscitation(e.g. with bag and mask)	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.8	Blood transfusion	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.9	Caesarean section	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
2.10	Others(currtage	D & C	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
		E& C	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	
	Hysterectomy....		<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No	<input type="checkbox"/> 1.Yes <input type="checkbox"/> 2.No

Note: Please choose 1 or more reasons for "If not performed in past 3 months,(if "NO" why?"

1. Training issues 2. Supplies, equipment, drugs issue 3. Management issue 4. Policy issues

5. No indication

3. For each health facility (fill the following information)

No	Types of services	1 July 2009_ 30 June 2010
3.1	Catchment population (use data officially used by the facility)	
3.2	Expected number of delivery from catchment population (With CBR of 32 per 1000 population)	
3.3	<u>No</u> of births and pregnancy related admissions	
3.4	<u>No</u> of vaginal deliveries	
3.5	Caesarean sections performed	
3.6	<u>No</u> of total maternal deaths	
3.7	<u>No</u> of still births	
3.8	No of neonatal deaths	
3.9	No of referral	

4. Number of clinical staffs working in obstetrics in the facility

No	Staffs	During the last 3 month (1 April 2009 to 30 June 2010)	1 July 2009- 30 June 2010	Is there 24hrs services? (Yes/No)
4.1	Doctors(specialist)			
4.2	Doctors (generalists)			
4.3	Health officers (HO)			
4.4	Nurses	Bsc		
		Diploma		
4.5	Midwives	Bsc		
		Diploma		
4.6	Anesthetics nurses			
	Total			

7. What sources of data were used to complete this form?

- a. maternal ward register
- b. delivery book
- c. general admission register
- d. operating theatre register
- e. others (specify)_____

8. In your opinion (from talking to staff, the record system etc), what proportion of the complications treated in this facility is recorded on this form?

- a. none
- b. some(less than half)
- c. most (more than half)
- d. all

9. In your informed opinion (from talking to staff, looking at the record system, etc.), what

Proportion of the maternal deaths that occurred in the facility is recorded on this form?

- a. none
- b. some
- c. most
- d. all

Thank you very much for your corporation!

10. Date of review _____

11. Reviewed by (Data collector):

Name _____ Sign. _____

N.B to the data collector: Please receive a stamped letter of confirmation from the head of the facility that describes you have reviewed in the particular facility

Appendices II: Ethical approvals



የደቡብ ብሄሮች ብሔረሰቦችና ሕዝቦች ክልላዊ
 መንግሥት ጤና ቢሮ
 South Nations Nationalities and People's Regional
 State Health Bureau

ቁጥር W P 42 / 6677
 Ref. No
 ቀን 12/5/2008
 Date



**Southern nations nationalities and peoples regional State Health Bureau
 Health Research Ethical Clearance form (Office use)**

Name of the Researcher/s Yaliso Yaya

Address - Gamo Gofa ,Arbaminch , Health science colledge

Topic of Proposal - Measuring maternal and neonatal mortality in South West Ethiopia

Dear Sir/Madam

The regional health Bureau Health Research Ethics Review committee has reviewed the
 aforementioned project proposal with especial emphases on the following points

1 . Are all ethical principles considered?

- 1.1 Respect for persons yes No
- 1.2 Beneficence yes No
- 1.3 Justice yes No

2. Are the objectives of the study ethically achievable ? Yes No

3. Are the proposed research methods ethically sound? Yes No

4. Comments of the Ethical committee. Attach questioneries, the documents should have
 Acronyms, operational definitions, the objective should be SMART.

Based on the above mentioned ethical assessment the regional Ethical clearance committee
 has

- A. Approved the proposal for implementation
- B. Conditionally approved
- C. Not approved





የደቡብ ብሄሮች ብሔረሰቦችና ሕዝቦች ክልላዊ
 መንግሥት ጤና ቢሮ
 South Nations Nationalities and People's Regional
 State Health Bureau



ቁጥር _____
 Ref. No _____
 ቀን _____
 Date _____

Chair of regional Ethical Committee

Name Meka Melekia

Date 12.5.2003

Signature Meka Melekia-shamma
 የጤና ፖሊሲና ቴክኖሎጂ ጥናት
 ኮሌግ ሥነ ምግባርና ጤና ቢሮ



Southern Nations Nationalities and Peoples Regional State Health Bureau Health Research

Ethics Review committee Members

Review committee Members

1. Sr.Fekerte Abera _____
2. Ato Wassie Shiferaw _____
3. Ato lopiso Erosie _____
4. Ato Shimeles Esatu _____
5. Ato Samson Tadiwos _____
6. Sr Mohabaw Shamel _____

Signature

(Handwritten signatures for each member listed above)

Let us fight HIV/AIDS together!



በደቡብ ብሔር ብሔረሰቦችና ሕዝቦች ክልል መንግሥት ጤና ቢሮ

S/N/N/P/R/ HEALTH BUREAU

የጋሞ ጎፋ ዞን ጤና መምሪያ

GAMO GOFFA ZONE HEALTH DEPARTMENT



#ጥር ፶፯፡፴፳፱/፯፻፸፮/፯፻፳፱
Ref No
ቀን 13-5-2018
Date

ለቦንኬ ወ/ጤ/ጥ/ጽ/ቤት

ለአ/ም/ዙሪያ ወ/ጤ/ጥ/ጽ/ቤት

ለደምባ ጎፋ ወ/ጤ/ጥ/ጽ/ቤት

በያሉበት፣

አቶ ያሊሶ ያዩ፣ አቶ ታደሰ ዳታና ወ/ሪት መሠረት ግርማ በmeasuring maternal and neonatal mortality in south west Ethiopia በሚል ርዕስ ላይ PHD እና የማስተር ዲግሪያቸውን ትምህርት የምርምር ሥራ የሚያደርጉ ስልሆኑ ለባለሙያዎቹ መልካም ትብብራችሁ እንዳይለያቸው እናሳስባለን።

ግልባጭ፣

→ ለአቶ ያሊሶ ያዩ

ለአቶ ታደሰ ዳታ

ለወ/ሪት መሠረት ግርማ

አ/ምንጭ፣



“ ኤድስን በጋራ እንከላክል”

Konchie Tullamo
KONCHIE TULLAMO
Head. Health Department

☎ (046) 881-00-27
(046) 881-05-27
(046) 881-04-18

☎ Fax (046) 881-14-18
☒ 26 ARBA MINCH ETHIOPIA

Region: REK nord	Saksbehandler:	Telefon:	Vår dato: 31.01.2012	Vår referanse: 2011/2495/REK nord
			Deres dato: 13.12.2011	Deres referanse:

Vår referanse må oppgis ved alle henvendelser

Yaliso Yaya Balla
Overlege Danielseens Hus
Universitetet i Bergen

2011/2495 Measuring Maternal and neonatal mortality in southwest Ethiopia

We refer to form for application for approval of research for this project.

Regional Committees for Medical and Health Research Ethics, Northern Norway (REC north) processed the application in the meeting January 12 th 2012.

Institution responsible for the research: University of Bergen, by Prof. Rune Nilsen
Chief Investigator: MPhil Yaliso Yaya Balla (PhD candidate)

Chief Investigator's research project description

Introduction: The maternal mortality rate remains high in many countries. Half of maternal deaths in the world occurred in six countries of which one is Ethiopia. There is need and demand for reliable empirical evidence to monitor effects of interventions. Objective: The overall aim of the study is to estimate maternal and neonatal mortality by using different approaches that links the data from community birth registry with health institution registries and demographic surveys in south Ethiopia. Materials and methods: 1. We shall use data from population based birth and birth outcome registry by the health extension workers (HEWs). 2. Institutional birth registry: we shall assess past one year birth and its outcome data in 68 health institutions in Gamo Goffa. We shall also assess the the quality of obstetric care. 3. Using the sisterhood and household death survey method we shall collect data from Bonke district (population 173,015) to estimate maternal deaths in the past years.

Remarks from the Committee:

It is presupposed that approval is given by Ethiopian REC. The project is considered Justifiable and can be conducted as requested. The Committee also presuppose that other necessary approval from Ethiopian authority is given.

Decision:

The project is approved.

It is presupposed that the project is approved by other relevant authorities before it is implemented. The project must be presented before the committee again, if complications or changes to the conditions the committee had based its decision on, arise during implementation. The committee has to be notified if the project is not implemented.

The approval is valid until December 20 th 2013. Data collected through the project can be stored until December 20 th 2018. The project manager is obliged according to the Health Research Act §12 to inform the committee when the project is completed.

Data collected through the project must be treated without names or other recognizable information.

Information and the list linking names and ID-numbers must be stored at separate locations.

The decision of the Committee can be appealed by a part or others with judicial appeal interest in the case cf. Public administration Act §28. The time-limit of the appeal is three weeks from the time when the party has been notified of the decision, cf. Public administration Act § 29. The court of appeal is the national committee for research ethics, but an appeal should be addressed to the Regional Committee for Research Ethics, Northern Norway.

Letters from REK are approved transmitted electronic without signature.

Sincerely

May Britt Rossvoll
Sekretariat leader

Monika Rydland Gaare
Executive officer

Copy: Rune Nilsen: post@cih.uib.no