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Estimation of maternal and neonatal mortality at the subnational level in Liberia

Heidi Moseson^{a,*}, Moses Massaquoi^b, Luke Bawo^c, Linda Birch^{c,d}, Bernice Dahn^c, Yah Zolia^c, Maria Barreix^b, and Caitlin Gerdtz^e

^aDepartment of Epidemiology and Biostatistics, University of California San Francisco, San Francisco, CA, USA

^bClinton Health Access Initiative, Monrovia, Liberia

^cMinistry of Health and Social Welfare, Monrovia, Liberia

^dBomi County Health Team/Ministry of Health and Social Welfare, Tubmanburg, Liberia

^eBixby Center for Global Reproductive Health, University of California San Francisco, San Francisco, CA, USA

Abstract

Objective—To establish representative local-area baseline estimates of maternal and neonatal mortality using a novel adjusted sisterhood method.

Methods—The status of maternal and neonatal health in Bomi County, Liberia, was investigated in June 2013 using a population-based survey (n=1985). The standard direct sisterhood method was modified to account for place and time of maternal death to enable calculation of subnational estimates.

Results—The modified method of measuring maternal mortality successfully enabled the calculation of area-specific estimates. Of 71 reported deaths of sisters, 18 (25.4%) were due to pregnancy-related causes and had occurred in the past 3 years in Bomi County. The estimated maternal mortality ratio was 890 maternal deaths for every 100 000 live births (95% CI, 497–1301]. The neonatal mortality rate was estimated to be 47 deaths for every 1000 live births (95% CI, 42–52). In total, 322 (16.9%) of 1900 women with accurate age data reported having had a stillbirth.

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*Corresponding author: Heidi Moseson, Department of Epidemiology and Biostatistics, University of California San Francisco, 185 Berry Street, Lobby 5, Suite 5700, San Francisco, CA 94158, USA. Tel.: +1 503 550 8076; fax: +1 415 514 8150. heidi.moseson@ucsf.edu.

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Conflict of interest

The authors have no conflicts of interest.

Conclusion—The modified direct sisterhood method may be useful to other countries seeking a more regionally nuanced understanding of areas in which neonatal and maternal mortality levels still need to be reduced to meet Millennium Development Goals.

Keywords

Liberia; Low-income countries; Maternal deaths; Maternal mortality ratio; Measurement; Millennium Development Goals; Neonatal deaths; Stillbirth

1. Introduction

As the deadline for the 2015 Millennium Development Goals (MDGs) approaches, a concerted global effort is underway to reduce high levels of neonatal and maternal mortality (MDGs 4 and 5). Despite much forward momentum with regard to reforming and revitalizing health services, Liberia continues to face high levels of maternal and neonatal mortality [1]. Maternal and neonatal mortality in Liberia continue to rank among the 10 highest in the world [2–6]. As in many low-income settings, the majority of these deaths are due to preventable or treatable conditions.

The Liberian government, along with governments in many other low-income countries, is working to implement locally tailored initiatives to reduce maternal mortality based on the unique needs at the subnational level [1]. However, to date, there are no representative, area-specific data in Liberia that can be used to inform the implementation of these efforts. Although the challenges of measuring maternal deaths in low-income settings and in small geographical areas have been well established [7, 8], obtaining data on the magnitude of the health problem and its causes at the subnational level is crucial for effective policy and program development [9, 10].

The aims of the present study were to pilot-test a method for measuring levels of maternal and neonatal mortality at the county-level using an adjusted direct sisterhood approach to record the location of the maternal death, and to determine the feasibility of extending this county-specific method to the rest of Liberia and in other low-income countries with high maternal and neonatal mortality.

2. Materials and methods

The status of maternal and infant health in Bomi County, Liberia, was investigated between May 20 and June 10, 2013. A population-based survey was used that included questions about deaths, knowledge of and access to family planning services, incidence of abortion, and basic demographic information. Approximately half the enumeration areas were to be sampled. A random sample of 126 (46%) of 273 enumeration areas in Bomi County (Figure 1) was selected with probability proportional to size [11] using a program in the R statistical package (<http://www.R-project.org/>). Within each sampled enumeration area, survey teams randomly selected every fourth household using global positioning system (GPS)-enabled maps.

In these enumeration areas, a household was eligible if at least one woman of reproductive age (15–49 years) lived there or if a child had been born there in the past 3 years. Within each eligible household, one woman aged 15–49 years was randomly selected for interview based on which woman had most recently celebrated her birthday [12]. Verbal informed consent was obtained from both the household head and the female respondent. The study protocol was approved by the Institutional Review Board of the National Ethical Committee of the Liberian Ministry of Health and Social Welfare.

The planned sample size was 2400 households and was calculated on the basis of the total fertility rate [5], the most recent estimate of the maternal mortality ratio [2], an inflation factor to accommodate a margin of error [13], and subsequent adjustment for the proportion of the female population represented by women in Bomi County. The survey was designed using the Open Data Kit software platform (<http://opendatakit.org>) and installed on 12 tablet computers. The survey was conducted by 12 enumerators (six male and six female) who were divided into six teams of two.

In accordance with the 10th revision of the International Classification of Diseases, a pregnancy-related death was defined as “the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the cause of death” [14]. The main indicators of maternal mortality measured were: the maternal mortality ratio (MMR), defined as the number of maternal deaths for every 100 000 live births [15]; the maternal mortality rate, defined as the number of maternal deaths over a period in women of reproductive age; the lifetime risk of maternal death, defined as the probability of a woman dying of maternal causes over her reproductive life span; and the proportion of maternal deaths among deaths of females of reproductive age, which measures the contribution of maternal deaths to overall female deaths of reproductive age [9]. MMR was calculated as the maternal mortality rate divided by the general fertility rate [4]. Lifetime risk of maternal death was calculated as $1 - (1 - \text{maternal mortality ratio}/100\,000)^{\text{total fertility rate}}$ [16].

A modified direct sisterhood method was used to measure maternal mortality. The direct sisterhood method involves asking each respondent questions about all siblings that have the same mother: (1) How many children did your mother give birth to? (2) How many of these births did your mother have before you were born? (3) What was the name given to your (oldest, next oldest, etc) brother or sister? (4) Is (NAME) male or female? (5) Is (NAME) still alive? (6) How old is (NAME)? (7) In what year did (NAME) die? (8) How old was (NAME) when she died? Questions 5–8 were only asked if the reported sibling was female. For any sisters aged 15–49 years who were reported to have died, three follow-up questions were asked: (1) was (NAME) pregnant when she died? (2) Did (NAME) die during childbirth? (3) Did (NAME) die within 2 months after the end of pregnancy or childbirth? In the present study, the survey was modified with the addition of a fourth question about any sisters aged 15–49 years reported to have died: in what county did (NAME) live in when she died? This additional question enabled data about deaths that occurred only in the geographical area of interest to be captured. Respondents were also asked to report deaths occurring only in the past 3 years to determine more recent and relevant estimates. The information reported by respondents about their sisters was used to calculate each of the four indicators for Bomi County. The R statistical package was used to calculate the 95%

confidence intervals (CIs) for the MMR using bootstrapping, a resampling-based method for estimating the variability of a sample estimate, with 10 000 replications.

Neonatal mortality was measured via the neonatal mortality rate (NMR), defined as the number of neonatal deaths in a period divided by the number of live births, multiplied by 1000 [5]. Neonatal deaths are defined as any death of a neonate in the first 28 days of life [5]. Stillbirth, defined by WHO as "a baby born with no signs of life at or after 28 weeks' gestation" [17], was assessed as a binary outcome: ever having had a stillbirth versus never. To ascertain these outcomes, survey respondents were asked to provide a history of all their births, with follow-up questions for any reported child deaths. For each outcome, multivariate logistic regression was used to identify demographic predictors of neonatal death and stillbirth, resulting in adjusted odds ratios (ORs) and 95% CIs. Demographic characteristics assessed included maternal age, parity, household income, religion, education, marital status, contraceptive use, and food security. Stillbirths and neonatal deaths were mapped using GPS data, and spatial patterns were subsequently analyzed using Quantum Geographic Information System Software version 1.8.0 (<http://qgis.osgeo.org>). Data management and analyses were completed using R and Stata version 12 (College Station, TX, USA). $P < 0.05$ was considered statistically significant.

3. Results

Consent was obtained from 2263 (96.0%) of 2357 household heads (Figure 2). An eligible female respondent resided at 2052 (90.7%) of the consenting households; 1985 (96.7%) of these women consented to participate in the female-specific questions. The mean age of the 1985 female respondents in the sample was 32 ± 0.4 years and average parity was 4.2 ± 0.1 births (Table 1). In total, 715 (36.0%) respondents had attended primary school. 1489 (75.0%) women were married or living with a partner. More than 30% were currently using contraceptives, and almost 60% reported not having had enough food to eat in the past 4 weeks (Table 1). Women who had ever had a neonatal death or a stillbirth were, on average, 3–5 years older than the sample as a whole, and were less likely to have had formal schooling ($P < 0.01$).

Among the 4042 sisters listed by the survey respondents, 71 maternal deaths had occurred over the past 3 years (Table 2). Fifty-three of these deaths were excluded from the study because they occurred outside Bomi County. The data for the 18 maternal deaths recorded in Bomi County were used to calculate an estimated MMR for Bomi County of 890 maternal deaths for every 100 000 live births (95% CI, 497–1301) (Table 2). The age-adjusted maternal mortality rate was 1.6, indicating an estimated 1.6 maternal deaths for every 1000 women of reproductive age (15–49 years) in Bomi County, adjusted for age. The risk of maternal death was 5.3% over a woman's reproductive lifespan (Table 2).

Respondents reported 6930 live births in the past 3 years, of which 324 (4.7%) ended in neonatal death. Among these 324 neonatal deaths, 107 (33.0%) occurred in Bomi County. From these data, an NMR was calculated of 47 neonatal deaths for every 1000 live births (95% CI, 42–52). In an adjusted multivariate logistic regression analysis, primary education and household poverty were significantly associated with neonatal mortality ($P < 0.05$), and

contraceptive use was borderline significant ($P=0.06$) (Table 4). Women who had attended primary school had less than half the adjusted odds of experiencing neonatal death compared with women that had not received any formal education (OR 0.4; 95% CI, 0.3–0.7; $P<0.01$). However, relative poverty increased the odds of experiencing a neonatal death (OR 1.7; 95% CI, 1.1–2.6; $P<0.05$). Women who were using contraceptives had 30% lower odds of having a neonatal death compared with women who were not using contraceptives; however, this was not statistically significant (OR 0.7; 95% CI, 0.4–1.0; $P=0.06$). Parity was excluded from the final model owing to high correlation with maternal age [18], confirmed by a likelihood ratio test ($P=0.4$).

Out of 1900 female respondents with accurate age data, 322 (16.9%) reported ever having had a stillbirth (Table 3). In a multivariate logistic regression model, maternal age, parity, and household poverty were associated with increased odds of stillbirth ($P=0.05$) (Table 4). For every 5-year increase in maternal age, the odds of having had a stillbirth were 3% higher than that for younger women (OR 1.03; 95% CI, 1.02–1.05; $P<0.01$). Similarly, with each additional birth, the odds of having had a stillbirth increased by 5% (OR 1.05; 95% CI, 1.0–1.1; $P=0.05$). Women living in the poorest households had 30% higher odds of ever having had a stillbirth (OR 1.3; 95% CI, 1.1–1.8; $P=0.03$).

GPS data revealed that 1904 (95.9%) surveys were conducted within the correct enumeration area. No spatial patterns were detected with regard to the location of infant deaths (Figure 3).

4. Discussion

In the present study, the pilot test of an adjusted method for measuring maternal mortality in small areas, coupled with measurement of neonatal mortality and stillbirth, resulted in representative estimates of maternal and neonatal mortality and of stillbirth at the subnational level. Owing to the relative rarity of maternal deaths, the 95% CI for the estimate of maternal mortality produced via this method was large, and the true MMR value could plausibly lie anywhere within this range. With the addition of data from surrounding counties, the precision of these estimates could be improved [7], thereby increasing their utility for monitoring progress toward reducing maternal mortality. A modified direct-sisterhood method was used to estimate maternal mortality, which has previously been shown to be a valid and cost-effective method of estimating maternal mortality in high-fertility populations [8, 19], even though the estimates are less precise than are those calculated using indirect and census-based methods [3].

The estimated MMR in Bomi County for 2010–2013 (890 maternal deaths for every 100 000 live births) is consistent with previous studies that estimated the Liberian national MMR as ranging from 740 to 994 for every 100 000 live births [2, 3]. This high level of maternal mortality in Bomi—a predominantly rural county—may largely be attributable to the absence of skilled birth attendants at many births as a result of shortages in the healthcare workforce, and because over 40% of Liberians live more than 5 km from the nearest health facility [1]. Recall bias may have caused some respondents to incorrectly report the occurrence, timing, and/or location of maternal deaths, which could have biased the data;

however, the direction of bias cannot be determined because recall bias could have operated in either direction.

The International Classification of Disease definition of a pregnancy related death [14] includes deaths that are not necessarily causally linked to the pregnancy itself but that occur while the woman is pregnant. This overestimation is balanced by the omission of maternal deaths owing to sensitive issues such as abortion, and those that occur early in pregnancy before the pregnancy is known [7–9]. Thus, pregnancy related deaths in the present study were referred to as maternal deaths for consistency with the literature.

The NMR calculated for Bomi (47 neonatal deaths for every 1000 live births; 95% CI, 42–52) in the present study was higher than the NMR reported for Liberia (26 neonatal deaths per 1000 live births) in the 2013 Demographic and Health Survey (DHS) [6]. However, no CIs have been provided yet for the DHS estimate, so it is possible that the estimates overlap. The NMR reported in the present study was consistent with NMRs reported for the surrounding countries in West Africa: for example, Sierra Leone has an NMR of 49 neonatal deaths per 1000 live births [5]. Given that the DHS estimate is a national estimate, the lower NMR estimated in the present study may reflect the lower neonatal death rate in urban areas compared with that in rural areas. Alternatively, it could be that some deaths reported as neonatal deaths in the present survey occurred after 28 days of life and were misclassified owing to inaccurate subject recall.

The rate of stillbirths in Liberia has previously been modeled but not directly estimated [1, 20], although the overall number of stillbirths has been estimated by the DHS [6]. Owing to low-quality vital statistics and gaps in facility level reporting, estimates of the stillbirth rate for many countries have been generated by national covariates, including the national NMR, rate of low birth weight, gross national income, type of data source, definition of stillbirth, and region [20]. Using models, the stillbirth rate in Liberia has been estimated to be 27 stillbirths for every 1000 live births [4]. Although the estimate generated from the survey conducted in the present study was limited to a lifetime measure of ever having had a stillbirth, it is nevertheless a useful baseline measure derived from data. In total, 346 (17.4%) of 1985 women in the sample population had experienced a stillbirth. The major causes of stillbirth are generally thought to be childbirth complications, maternal infection in pregnancy, maternal disorders, fetal growth restriction, and congenital abnormalities [20]—risk factors that are shared across maternal and neonatal deaths [10]. In the multivariate analyses of neonatal death and stillbirth, most of the associations observed were in the expected direction.

The key limitation of the present study was sample size. To estimate maternal mortality with sufficiently narrow margins of error at the subnational level would require a household census. Given the pressing priorities facing the Liberian Ministry of Health and other health ministries in similarly resource-limited countries, such an intensive survey may not be the most efficient use of scarce financial and staff resources. In view of the budget available, the most efficient sampling method was selected—the direct sisterhood method. If the method were to be implemented full-scale, countrywide empirical best linear unbiased prediction methods could be used to obtain more precise county level MMRs [7].

Despite these limitations, the implementation of a modified version of the direct sisterhood method enabled the location of maternal deaths to be tagged, and area-specific estimates to be subsequently calculated. Furthermore, the use of durable new technology in the form of the tablets with surveys coded on free, open-source software improved the accuracy of the sampling method and streamlined data collection and uploading, protecting surveys from being lost in the often rough conditions of the field.

Through the use of a novel adjusted sisterhood method and accuracy enhancing technology, the pilot survey conducted in the present study provides data on key maternal and infant health indicators that are representative at the subnational level in Liberia. Measurement of the current level of maternal and neonatal mortality is crucial as a starting point for more detailed analysis of the causes and circumstances surrounding maternal and neonatal deaths, which, ultimately, should enable the number of these deaths to be reduced [14]. The methods piloted in the present study provide an efficient means of measuring the incidence, prevalence, and geographical spread of maternal and infant deaths at a local level—information that is crucial to prevention efforts.

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Figure 1.

Satellite map delineating the boundary of a selected enumeration area (blue line). Taken as a screenshot from a tablet used by the enumerators during the survey. Copyright 2013 Google —Imagery. Copyright 2013 Cnes/Spot Image, DigitalGlobe, Map data copyright 2013 Google.

Figure 2.
Recruitment of the study population.

Figure 3.
Location of neonatal deaths and stillbirths in Bomi County.

Table 1Demographic characteristics of survey sample.^a

Characteristic	Overall (n=1985)	Women with at least one neonatal death ever (n=307) ^b	Women who had ever had a stillbirth (n=346) ^b
Age, y	32 ± 0.4	35 ± 0.7	37 ± 0.7
Parity	4.2 ± 0.1	4.6 ± 0.2	4.9 ± 0.2
Household income, US\$	38 ± 4.0	36 ± 8.0	42 ± 6.0
Walking time to nearest clinic, min	103 ± 10	114 ± 31	135 ± 30
Religion			
Muslim	794 (40.0)	151 (49.2)	159 (46.0)
Christian	1171 (59.0)	153 (49.8)	183 (52.9)
Other	20 (1.0)	3 (1.0)	4 (1.1)
Education			
None	992 (50.0)	200 (65.1)	190 (55.0)
Some primary	417 (21.0)	55 (17.9)	55 (15.9)
Completed primary	298 (15.0)	31 (10.1)	35 (10.1)
Traditional education	99 (5.0)	6 (2.0)	45 (13.0)
Some or all high school	159 (8.0)	15 (4.9)	17 (4.9)
College or university	20 (1.0)	0	4 (1.1)
Marital status			
Single	337 (17.0)	27 (8.8)	25 (7.2)
Living with partner	655 (33.0)	83 (27.0)	113 (32.7)
Married	834 (42.0)	163 (53.1)	163 (47.1)
Divorced or separated	60 (3.0)	16 (5.2)	14 (4.0)
Widowed	99 (5.0)	18 (5.9)	31 (9.0)
Current contraceptive use	631 (31.8)	78 (25.4)	105 (30.3)
Injection use	330 (16.6)	44 (14.3)	55 (15.9)
Pill use	173 (8.7)	21 (6.8)	31 (9.0)
Condom use	72 (3.6)	7 (2.3)	10 (2.9)
Implant	23 (1.2)	6 (2.0)	5 (1.4)
IUD	14 (0.7)	0	1 (0.3)
Rhythm	8 (0.4)	0	2 (0.6)
Female condom	4 (0.2)	0	0
Withdrawal	3 (0.2)	0	0
Not specified	4 (0.2)	0	1 (0.3)
Food security in past 4 weeks			
No food to eat in the house because of lack of resources	1172 (59.0)	175 (57.0)	225 (65.0)
Went 24 hours without eating because of lack of food	576 (29.0)	110 (35.8)	135 (39.0)

Abbreviation: IUD, intrauterine device.

^aValues are given as mean ± SD, or number (percentage).^b131 women reported both a stillbirth and a neonatal death.

^c Noninstitutionalized and nonstandardized education of a child in the tasks of daily living, cultural practices, and values of the particular setting in which they live.

Table 2

Maternal mortality results for past three years (2010–2013).^a

Age of sisters, y	No. of sisters	No. of deaths among sisters in past 3 years	No. of sisters who died of maternal causes in Bonni County in past 3 years	Age-adjusted MMRate ^b for past 3 years	Lifetime risk of maternal death	% sisters who died in past 3 years who died of maternal causes in Bonni County	MMRatio ^c for past 3 years
15–19	566	10	2	1.7	0.102	20.0	868
20–24	703	9	5	2.4	0.067	55.6	925
25–29	756	8	5	2.2	0.054	62.5	1124
30–34	565	10	1	0.6	0.048	10.0	364
35–39	604	8	2	1.1	0.023	25.0	764
40–44	386	4	1	0.9	0.018	25.0	686
45–49	349	5	2	1.9	0.058	40.0	1761
Unknown	113	17	0	–	–	0	–
Total	4042	71	18	1.6	0.053	25.4	890 ^d

Abbreviations: MMRate, maternal mortality rate; MMRatio, maternal mortality ratio.

^a Values are given as number (percentage) unless otherwise indicated.

^b Number of maternal deaths per year in every 1000 women.

^c Number of maternal deaths expected for every 100 000 live births.

^d 95% confidence interval, 479–1301.

Table 3

Neonatal mortality results for past three years (2010–2013).

Age of respondent, y	No. of respondents	No. of births in past 3 years	No. of neonatal deaths, ever	No. of neonatal deaths in past 3 years in Bomi County	% births ending in neonatal death in past 3 years	Neonatal mortality rate ^a	No. that ever had a stillbirth	% respondents who had ever had a stillbirth
15–19	219	155	5	2	1.3	32	5	2.3
20–24	339	704	49	24	3.4	70	30	8.8
25–29	397	1332	64	23	1.7	48	71	17.9
30–34	301	1275	61	21	1.6	48	58	19.3
35–39	306	1554	57	18	1.2	37	67	21.9
40–44	179	994	39	8	0.8	39	47	26.3
45–49	159	916	49	11	1.2	53	44	27.7
Total	1900 ^b	6930	324	107	1.5	47 ^c	322	16.9

^a Number of neonatal deaths (deaths in the first month of life) for every 1000 live births.

^b 1900 (95.7%) of 1985 respondents had accurate age data recorded.

^c 95% confidence interval, 42–52.

Table 4Odds of neonatal death and stillbirth in past three years.^a

Independent variable	Neonatal death		Stillbirth	
	Adjusted odds ratio (95% confidence interval)	P value	Adjusted odds ratio (95% confidence interval)	P value
Maternal age ^b	1.0 (0.9–1.1)	0.31	1.03 (1.02–1.05)	<0.01
Maternal parity ^{b,c}	–	–	1.05 (1.0–1.1)	0.05
Household poverty ^b	1.7 (1.1–2.6)	0.03	1.3 (1.1–1.8)	0.03
Marital status (unmarried)	0.5 (0.2–1.2)	0.12	0.6 (0.3–1.1)	0.09
Muslim	1.1 (0.7–1.8)	0.73	1.4 (0.3–6.8)	0.60
Primary school, some or all	0.4 (0.3–0.7)	<0.01	0.8 (0.6–1.2)	0.30
Secondary school, some or all	0.7 (0.2–3.1)	0.61	0.4 (0.1–1.3)	0.12
College or university	0.8 (0.1–6.4)	0.81	1.2 (0.3–4.9)	0.80
Food insecurity	1.2 (0.8–1.9)	0.46	1.1 (0.8–1.4)	0.70
Current contraceptive use	0.7 (0.4–1.0)	0.06	1.2 (0.9–1.7)	0.20

^aResults from multivariate logistic regression model for the odds of neonatal death and stillbirth in past 3 years. The reference group includes married, Christian, uneducated, food-secure women who were not using contraception.

^bMaternal age, parity, and poverty are measured at multiple levels, with the odds ratio in reference to the average change in relative odds of neonatal death or stillbirth between two adjacent categories.

^cExcluded from final model for neonatal death because of high correlation with maternal age [18].