



Does place and attendance at birth improve early neonatal mortality? Secondary analysis of nine Demographic and Health Surveys

S Bellizzi,^a HL Sobel,^a M Mathai,^b M Temmerman^c

^a World Health Organization, Western Pacific Regional Office, Manila, Philippines ^b Centre for Maternal and Newborn Health, Liverpool School of Tropical Medicine, Liverpool, UK ^c Department of Obstetrics and Gynaecology, Ghent University, Ghent, Belgium

Correspondence: H Sobel, World Health Organization, Western Pacific Regional Office, PO Box 2932 (United Nations Avenue), 1000 Manila, Philippines. Email sobelh@who.int

Accepted 31 August 2016. Published Online 15 November 2016.

Objectives To determine the relation between place and skilled birth attendance at birth and early neonatal mortality.

Design Retrospective analysis using data from Demographic and Health Surveys on obstetric complications.

Setting Nine low and middle income countries between 2006 and 2013.

Population 71 758 women aged 15–49 years.

Methods A secondary analysis was carried out to investigate the occurrence and effect of obstetric complications on early neonatal mortality and association with place and attendance at birth.

Obstetric complications studied were prolonged labour, puerperal infection and eclampsia.

Main outcome measures Association between early neonatal mortality and place and attendance at birth, unadjusted and adjusted for presence of severe obstetric complications.

Results Thirty-five percent of all births were at home: 70% of these were without skilled attendants. Obstetric complications

were reported in 17 079 women: 82% of these women gave birth in health facilities. Overall, no association was observed between place of birth or attendance at birth and early neonatal mortality. When adjusted for obstetric complications, the odds of early neonatal deaths for births at home without a skilled attendant were 1.3 (95% CI 1.1–1.5) compared with 1.2 (95% CI 1.0–1.5) with a skilled attendant and births in health facilities.

Conclusions When adjusted for obstetric complications, births in health facilities were associated with reduced early neonatal mortality. However, reporting and referral bias account for at least part of the association.

Keywords Demographic Health Survey, early neonatal mortality, health facility.

Tweetable abstract Births in health facilities are linked with fewer early newborn deaths when adjusted for obstetric complications.

Linked article This article is commented on by MW Weber. To view this mini commentary visit <http://dx.doi.org/10.1111/1471-0528.14489>.

Please cite this paper as: Bellizzi S, Sobel HL, Mathai M, Temmerman M. Does place and attendance at birth improve early neonatal mortality? Secondary analysis of nine Demographic and Health Surveys. BJOG 2016; DOI: 10.1111/1471-0528.14422.

Introduction

Child mortality has decreased worldwide in the past few decades,^{1–9} with accelerated declines in more than 100 countries in the final phase of the Millennium Development Goals era.³ These are due to a series of interconnected improvements in areas such as maternal education,¹⁰ per capita income,¹¹ immunisation, sanitation, 'better nutrition',¹² and wider coverage of a short list of proven health technologies.^{13,14}

Of the estimated 130 million infants born each year worldwide,¹⁵ 2.8 million die in the first 28 days of life, with three-quarters of deaths occurring in the first week of life.³

In 2013, neonatal deaths accounted for 41.6% of under-five deaths compared with 37.4% in 1990,¹⁶ and the share of neonatal deaths is projected to increase to 52% of under-five deaths in 2030.¹⁷

Neonatal deaths result from complications of preterm birth, asphyxia or trauma during birth, infections, severe malformations or other specific perinatal causes.¹⁸ Obstetric complications are a major cause of stillbirths and early neonatal deaths,¹⁹ responsible for up to 58% of such outcomes.²⁰ Therefore, prevention and treatment of pregnancy complications are critical to reduce neonatal deaths.²¹

In developing countries, many births occur at home for reasons related to poverty, illiteracy and control on

decision-making authority, contributing to poor neonatal and maternal health status.^{22,23} In countries where uptake of skilled care at birth is low, women may only seek care when problems arise. If skilled care is sought when labour is prolonged, it is highly likely that hypoxia and infection have already set in, leading to poor perinatal outcomes even if skilled care is provided.²⁴

The cornerstone of safe motherhood programmes is skilled care for all births. Essential competencies that a skilled birth attendant (SBA) should have include those required for the management of women during normal pregnancy, childbirth, and the immediate postnatal period, as well as identification, management and/or referral when complications arise.²⁵ However, neither type of attendance nor place of birth have been found to be strongly associated with lower neonatal mortality.^{26,27} The presence of an SBA in a health facility does not guarantee good quality care.²⁸ Although sub-optimal quality of care is well known, late referral of women with complications may also mask the benefit of facility births.^{26,27}

Using Demographic and Health Surveys (DHS), which had reported complications during birth, we examined the association between reported complications at birth, type of attendance and place of birth with early neonatal mortality. We further adjusted for reported complications at birth, to study the beneficial effects of facility births and births attended by SBAs on early neonatal mortality.

Methods

We conducted a secondary analysis of national DHS data from nine countries on the association between place and attendance at birth, and maternal complications during delivery with reported early neonatal mortality. These data were from Bangladesh (2007), Colombia (2010), Honduras (2011), Indonesia (2012), Mali (2006), Niger (2006), Peru (2011), Philippines (2013), and Sao Tome and Principe (2008/2009).

DHS are nationally representative random household sample surveys measuring indicators of population including maternal and child health.²⁹ The target population in most DHS surveys is all or ever-married women of reproductive age (15–49 years). Data are collected via face-to-face interviews by same sex-trained personnel and in each survey, questionnaires are translated into major local languages. The core content of every round DHS is standard across countries to maximise the comparability of information, and includes a complete birth and death history for the children of each eligible woman. Countries may also select additional questions related to pregnancy complications from the survey questionnaire on antenatal, childbirth and postnatal care.

Our analysis included only the most recent survey in these countries presenting data on reported life-threatening obstetric complications during birth of the last infant, thus limiting our analysis to one birth per woman.

The markers of life-threatening complications included high fever, convulsions, vaginal bleeding and/or prolonged labour. We pooled national data sets into one cross-sectional data set containing 71 758 live births.

Data on obstetric complication and place of birth were calculated for all live births ($n = 71\,758$). Data on newborns with missing information on place and attendance at birth ($n = 324$) and maternal complications ($n = 698$) were excluded from the analysis of early neonatal mortality and obstetric complications, thus leaving 71 060 individuals in the analysis (99.0%). There were 819 early neonatal deaths in the data set.

Three complications during and immediately following pregnancy and childbirth were the first exposure variables in our analysis and were defined as follows: prolonged labour when regular uterine contractions reportedly lasted >12 hours; high fever when associated with foul smelling discharge (proxy for puerperal infection and possibly associated with poor neonatal outcome if secondary to intra-partum chorio-amnionitis or prolonged labour); convulsion not caused by fever (proxy for eclampsia).

Although severe antepartum haemorrhage usually results in stillbirths,³⁰ we excluded 'excessive bleeding' from our analysis, as most of the severe haemorrhages reported are likely to be postpartum haemorrhages, which are less likely to impact on newborn outcomes.

We derived three new variables: 'one complication', 'two complications' and 'three complications', to include all women who experienced one, two and three obstetrical complications in the same birth, respectively.

Births at home with and without an SBA were based on the reported place and type of assistance at last birth. DHS defines facility birth as 'birth at any place other than at home, at someone else's home, or en route to a facility'; in this category we grouped all private and public health facilities regardless of size. Births at home with an SBA included respondents who answered that they gave birth at home with a doctor, nurse, nurse midwife, or auxiliary nurse midwife.

The pooled analysis was performed after merging all the nine DHS country files. STATA 13.1 SE (StataCorp LP, USA) was used for statistical analysis.³¹ Considering the stratified sampling nature of DHS, we used a random effect model to control for unobserved factors at primary sampling unit; we also included country random effect in the pooled analysis.³²

We tabulated incidence of each obstetric complication by country together with data on place of birth. We also described the distribution of maternal complications by socio-economic variables, birth order, birth spacing and

place of delivery. Maternal age, maternal education, residence and household wealth quintiles, preceding birth interval (less than 18 months, 18–23 months, 24–35 months and more than 35 months), sex of infant and birth order (first born; latter born) affect perinatal outcomes.^{33,34} We considered all these variables as potential confounders and adjusted for them place of birth in further analysis.

A similar analysis was conducted to evaluate the risk of early deaths when women reported one, two or all three complications in the same birth.

For each country and for the pooled analysis, odds ratios (OR) were determined for early neonatal mortality and place and attendance at birth (using multiple logistic regression analysis) with and without adjustments for reported obstetric complications. *P*-values <0.05 were considered significant.

The odds ratio between early neonatal mortality and place of birth was obtained using three distinct analyses: (1) home births without SBA versus home births with SBAs, (2) home births without SBAs versus births in health facilities, and (3) home births with SBAs versus births in health facilities. Heterogeneity among countries in the pooled association between early neonatal mortality and place of delivery was tested. We performed a subgroup analysis of countries with high institutional births choosing 80% cutoff coverage threshold from previous findings.²⁷

Results

Of the 71 758 births in the nine countries with available data in their Demographic and Health Surveys, 64.4% (46 230) occurred in a health facility, 10% (7424) at home with SBA and the remaining 24.8% (17 780) at home without an SBA (missing values <1%). SBA coverage ranged from 18.9% (Bangladesh) to 91.0% (Colombia).

Almost 19% (13 423) reported prolonged labour, 7.0% (5032) high fever and 3.1% (2210) convulsions. Reports of prolonged labour ranged from 7.3% (Bangladesh) to 30.4% (Indonesia), high fever from 1.7% (Philippines) to 21.6% (Honduras), and convulsions from 1.1% (Peru) to 11.8% (Honduras; Table 1). Missing data for attendance, place of birth and complications were <1% (Table 1).

Of the 21 506 first order births, 6516 (30.3%) had obstetric complications; only 21.1% latter order births reported complications (Table 2). Of the 17 069 births with reported complications and information on place of birth, 1379 (8.1%) were at home without an SBA, 1712 (10.0%) at home with an SBA and the remainder in health facilities.

A clear significant linear trend appeared in the association between maternal age and complications, with fewer complicated births for older mothers. Fewer obstetric complications were reported by women who had had no education, lived in rural areas, were from the poorest wealth quintile and gave birth at home without an SBA (Table 2).

All obstetric complications were associated with higher early neonatal mortality in the pooled analysis when adjusted for these factors and for place of birth.

In the individual country analyses, there was a significant association between prolonged labour and early neonatal death in Bangladesh, Honduras, Mali and Niger. Data from all countries other than Honduras and Sao Tome and Principe showed significant association between infection with early neonatal mortality. Data from Honduras, Indonesia, Mali, Niger and Peru showed an association between convulsions and early neonatal mortality. Sao Tome and Principe had no data on early neonatal death due to convulsions (Table 3).

Odds ratios (95% CI) for early neonatal mortality among infants born to women with obstetric complications increased from 1.2 (1.1–1.4) with one complication to 1.9 (1.5–2.5) for two and 3.9 (2.1–5.8) for three complications (Table S1).

After adjusting for obstetric complications, maternal age, maternal education, household wealth, rural/urban residence, sex, birth spacing and birth order, early newborn mortality among home births with an SBA was not statistically different (OR 1.1, 95% CI 0.5–1.8) from home births without an SBA in any country and in the pooled analysis. However, with similar adjustments, early neonatal deaths in the pooled analysis were significantly more among births at home without an SBA than among births in health facilities (OR 1.3, 95% CI 1.1–1.5) (Table 4). Moderate heterogeneity ($I^2 = 35.3\%$) was found. Similarly, a trend to increased early neonatal mortality was noted among births at home with an SBA (OR 1.2, 95% CI 1.0–1.5) when compared with births in health facilities.

In sub-group analyses of pooled data from countries with more than 80% institutional births (Colombia, Honduras and Peru), the odds of early newborn mortality among home births without an SBA increased to 2.4 (95% CI 1.3–4.5) while the odds of early newborn mortality among home births with SBA increased to 1.8 (95% CI 1.1–2.6).

Discussion

Main findings

In many low- and middle-income countries, women may seek care in health facilities only when complications arise and the chain of adverse events leading to newborn deaths has already been initiated. Not adjusting for obstetric complications among women giving birth in facilities could therefore lead to incorrect conclusions on the effects of facility birth on newborn mortality. This secondary analysis of DHS data from nine countries showed that when adjusted for reported maternal complications during birth, births in a health facility were associated with reduced early

Table 1. Number of newborns by place of birth and reported obstetric complications around birth in nine low- and middle-income countries between 2005 and 2013

Country, survey years	No. of live births	Early neonatal deaths	Place and attendance at birth, n (%)			Complications, n (%)		
			Home without SBA	Home with SBA	Health facility	Prolonged labour	Infection	Convulsions
Bangladesh 2007	4846	72	3713 (76.7)	202 (4.2)	916 (18.9)	352 (7.3)	133 (2.7)	101 (2.1)
Colombia 2010	14 429	104	1147 (8.0)	113 (0.8)	13 138 (91.0)	3145 (21.8)	683 (4.7)	200 (1.4)
Honduras 2011	8635	86	280 (3.3)	1365 (15.8)	964 (80.6)	937 (10.8)	1863 (21.6)	1018 (11.8)
Indonesia 2012	15 068	156	2798 (18.7)	3681 (24.4)	8521 (56.5)	4587 (30.4)	1004 (6.7)	228 (1.5)
Mali 2006	8554	205	4123 (48.3)	367 (4.3)	4027 (47.1)	1330 (15.5)	648 (7.6)	238 (2.8)
Niger 2006	5603	77	3163 (56.4)	858 (15.3)	1539 (27.5)	640 (11.4)	293 (5.2)	118 (2.1)
Peru 2011	7951	60	930 (11.7)	238 (3.0)	6724 (84.6)	1039 (13.1)	263 (3.3)	89 (1.1)
Philippines 2013	5253	47	1378 (26.2)	548 (10.4)	3297 (62.8)	1192 (22.7)	88 (1.7)	178 (3.4)
Sao Tome and Principe 2008/2009	1419	12	248 (17.5)	52 (3.7)	1104 (77.8)	201 (14.2)	57 (4.0)	40 (2.8)
Total	71 758	819	17 780 (24.8)	7424 (10.4)	46 230 (64.4)	13 423 (18.7)	5032 (7.0)	2210 (3.1)

SBA, skilled birthing attendant.

neonatal mortality. Countries with the highest SBA coverage had the greatest associated reduction in mortality from delivering in a facility. Giving birth at home with a skilled birthing attendant was not associated with reduced mortality compared with births at home with no assistance.

Maternal report of the three life-threatening complications prolonged labour, infection and convulsions was strongly associated with early neonatal mortality (OR 1.7, OR 2.6 and OR 2.4, respectively). A dose-response was noted with increasing numbers of severe complications and the odds ratio of death, reaching 3.9 when all three complications were present.

Strengths and limitations

DHS use standardised questionnaires, limiting the risk of inter-country variation,³⁵ and are generally considered high-quality surveys. DHS are sometimes the only source of maternal and child health information available in developing countries.³⁵ However, in this report we have compared DHS data across nine countries at various times after 2005. Furthermore, only these nine countries representing three continents had data necessary for this analysis and there are large differences in place and attendance at birth among these countries. Also birth histories may contain errors, as women may not want to report information on non-surviving children, thus distorting the real entity of early neonatal mortality.^{36,37} Maternal recall of complications, especially infections, was noted to have problems in accuracy.^{38–42} One hospital study found accuracy of recall for infection had a sensitivity of 69.2 (95% CI 48.1–84.9), specificity of 77.2 (95% CI 73.2–80.8) and likelihood ratio of 3.0 (95% CI 2.2–4.1). In contrast, for reported

convulsions the sensitivity, specificity and likelihood were 96.4 (95% CI 79.8–99.8), 87.5 (95% CI 84.2–90.3) and 7.7 (95% CI 6.4–9.9), respectively.⁴³ Maternal recall is also influenced by health provider-patient communication^{44,45} and what health providers communicate by their capacity to diagnose severe complications accurately.

Another limitation is potential information bias when complications are reported after a neonatal death occurs. Women may be more likely to report complications if their babies die than if they survive. This can lead to an overestimation of any associations between complications and neonatal death.

One additional limitation of these data is the lack of information on women who died during or after childbirth, events which are likely to be associated with increased risk of early neonatal mortality. However, given the relative rarity of maternal deaths compared with the frequency of neonatal deaths, the impact is likely small.

The number of deaths for single country analyses were too small for meaningful interpretation. For example in Sao Tome and Principe and Philippines DHS analyses, there were only 12 and 47 early neonatal deaths, respectively. In models that contain several covariates, the results were not significant (Table 4) and analysis combining more than one obstetrical complications was not feasible (Table S1).

In our analysis, we were unable to explore the role of birthweight in the overall analysis, as weight at birth was missing for around 30% of the study population.

In our study population, 25% of the total live births at home without an SBA contributed to only 8% of the total complications reported. Under-reporting from this group of women is likely, as is the likely reporting bias related to

Table 2. Maternal characteristics in births with and without reported complications among 71 758 live births

	All births <i>N</i>	Births with no complications <i>n</i> (%)	Births with complications <i>n</i> (%)	χ^2
Maternal age (years)				
15–19	240	4697 (75.3)	1543 (24.7)	<0.001
20–24	16 991	12 701 (75.7)	4290 (25.2)	
25–29	18 143	13 729 (75.7)	4414 (24.3)	
30–34	14 391	10 988 (76.3)	3403 (23.6)	
35–39	9756	7622 (78.1)	2134 (21.9)	
40–44	4917	3848 (78.3)	1069 (21.7)	
45–49	1291	1041 (80.6)	250 (19.4)	
Birth order				
1	21 506	14 990 (69.7)	6516 (30.3)	<0.001
>1	50 252	39 651 (78.9)	10 601 (21.1)	
Preceding birth interval (months)				
<18	2707	2190 (80.9)	517 (19.1)	<0.001
18–23	5022	4080 (81.2)	942 (18.8)	
24–35	12 462	10 113 (81.1)	2349 (18.9)	
>35	30 061	23 225 (77.2)	6836 (22.8)	
Place of residence				
Urban	33 056	24 073 (72.8)	8983 (27.2)	<0.001
Rural	38 702	30 568 (79.0)	8134 (21.0)	
Education				
No education	14 617	12 543 (85.8)	2074 (14.2)	<0.001
Primary	21 693	16 098 (74.2)	5595 (25.8)	
Secondary	26 981	19 498 (72.3)	7483 (27.7)	
Higher	8464	6499 (76.8)	1965 (23.2)	
Wealth Index				
Poorest	19 249	15 066 (78.3)	4183 (21.7)	<0.001
Poorer	16 218	12 416 (76.6)	3802 (23.4)	
Middle	13 859	10 506 (75.8)	3353 (24.2)	
Richer	12 043	9070 (75.3)	2973 (24.7)	
Richest	10 389	7583 (73.0)	2806 (27.0)	
Place of delivery				
Home	17 780	16 401 (92.2)	1379 (7.8)	<0.001
Home with SBA	7424	5712 (76.9)	1712 (23.1)	
Health facility	46 230	32 252 (69.8)	13 978 (30.2)	

the highest percentage of complications reported among the richest wealth quintile (Table 2). Increased deaths among poorer women (and respective children) would exacerbate this reporting bias. Complications of infection and convulsions seem over-reported in Honduras and infection rates under-reported in Bangladesh (Table 1). Thus, reporting bias is a concern at country level.

Interpretations

Neonatal mortality especially in low-income countries is largely attributed to prematurity, asphyxia and infections, which often result from maternal complications such as

hypertensive disease, prolonged labour and peripartum sepsis.⁴⁶

A few previous reports found weak associations or no differences in neonatal mortality between births at home and in facilities.^{26,27,47} Two reports, in particular, have discussed at length the role of selection bias, confounding by obstetric complications in addition to poor quality of care. In our study, no significant difference was found in early neonatal mortality between home births by skilled and non-skilled attendants even after adjusting for maternal complications.

Adjusting for complications as a potential solution was considered but not done by others due to the low reliability of self-reported complications.^{48–50}

Quality of care is a known problem in many low- and middle-income countries.^{51–53} Newborns in low- and middle-income countries have a 20 times increased risk of acquiring a healthcare facility-acquired infection compared with those in high-income countries. Furthermore, healthcare facility-acquired infections may account for up to half of neonatal deaths.²⁷

Countries with the highest SBA coverage had the highest benefit from birth in facilities. This may be related to fewer late referrals and higher quality of care in these settings. Perhaps if countries with lower facility coverage could improve quality of care as has happened in the higher coverage countries, the protective effect of delivering in a facility might be vastly increased.

These findings are similar to another study reporting a 30.0% (OR 0.7, 95% CI 0.6–0.8) reduction in the adjusted odds of early neonatal mortality in communities where 80% of babies are born in facilities and progressive reduction of this protective effect with lower coverages.²⁷

A study from Bangladesh had data over 19 years and despite the fact that early neonatal mortality was higher for health facility births than for home births, this decreased over time as access to institutional delivery became more common.²⁴

No significant changes in neonatal adverse outcomes between attended and non-attended home births have been observed in other studies.^{54,55} The main reason for this could be closely linked to the definition of SBA that does not include an assessment of provider skills.⁴³ Poor performances due to unsatisfactory education and training of community health attendants in low-income countries are furthermore weakened by the lack of access to tests, medication and equipment necessary to reduce neonatal mortality.

Conclusions

Whereas several population-based studies of perinatal mortality in low- and middle-income countries examined the role of place and attendance at birth, we explored the role of intrapartum risk factors as a means to tease out the

Table 3. Odds ratios (95% Confidence Intervals) of early neonatal deaths for prolonged labour, infection and convulsions compared to births with no reported complications

Country, survey years	Prolonged labour		Infection		Convulsions	
	OR (95% CI) unadjusted	OR (95% CI) adjusted***	OR (95% CI) unadjusted	OR (95% CI) adjusted***	OR (95% CI) unadjusted	OR (95% CI) adjusted***
Bangladesh 2007	3.8 (2.0–6.9)	3.0 (1.4–5.6)	4.8 (2.2–10.4)	4.2 (1.8–8.9)	1.5 (0.4–3.4)	1.1 (0.2–4.5)
Colombia 2010	1.3 (0.8–2.1)	1.2 (0.7–2.0)	2.3 (1.2–4.4)	2.2 (1.2–4.2)	2.2 (0.7–7.3)	2.1 (0.5–6.5)
Honduras 2011	2.3 (1.3–4.2)	2.1 (1.3–3.5)	1.4 (1.0–2.9)	1.5 (0.9–2.4)	2.5 (1.4–4.2)	2.1 (1.3–3.6)
Indonesia 2012	0.7 (0.5–1.1)	0.8 (0.5–1.3)	1.9 (1.0–3.1)	2.0 (1.1–3.5)	2.3 (0.8–4.9)	2.2 (1.1–6.3)
Mali 2006	1.6 (0.9–2.3)	1.9 (1.1–2.7)	2.0 (1.0–3.0)	2.2 (1.2–3.4)	2.7 (1.8–5.0)	2.8 (1.6–4.7)
Niger 2006	2.1 (1.4–4.3)	2.0 (1.2–4.9)	2.8 (1.3–6.1)	2.6 (1.1–6.0)	5.1 (2.2–9.9)	5.0 (2.0–12.2)
Peru 2011	0.8 (0.3–2.0)	0.9 (0.6–2.1)	3.3 (1.8–7.4)	3.3 (1.2–7.6)	5.1 (1.5–16.8)	5.1 (1.8–17.1)
Philippines 2013	0.7 (0.3–1.5)	0.7 (0.4–1.7)	6.6 (2.9–15.1)	7.4 (2.9–19.3)	2.2 (0.8–6.3)	2.2 (0.9–8.1)
Sao Tome and Principe 2008/09	0.4 (0.1–3.6)	0.8 (0.2–5.6)	2.9 (0.4–17.8)	3.1 (0.4–27.2)	***	***
Pooled	1.3 (1.1–1.6)	1.7 (1.2–2.2)	2.2 (1.7–2.8)	2.6 (2.1–3.1)	2.3 (1.8–3.1)	2.4 (1.8–3.2)

*Pooled analysis adjusted for place of birth, wealth, maternal age, sex of infant, birth order, birth spacing, maternal education, rural/urban residence, sample unit and country as random effect.

**Single-country analysis adjusted for place of birth, wealth, maternal age, sex of infant, birth order, birth spacing, maternal education, rural/urban residence, and sample unit as random effect.

***Unable to calculate OR as zero cases in early neonatal mortality group.

Bold indicates significant values ($p < 0.01$).

Table 4. Adjusted odds ratios for early neonatal death for place and attendant at birth

	Non-SBA home versus home based with SBA births		Home based with SBA deliveries versus health facility based births		Non-SBA home deliveries vs health facility based births	
	OR (95% CI) ***	OR (95% CI) ***.***	OR (95% CI) ***	OR (95% CI) ***.***	OR (95% CI) ***	OR (95% CI) ***.***
Bangladesh 2007	0.8 (0.2–2.0)	0.9 (0.2–3.4)	0.6 (0.2–2.4)	0.7 (0.2–2.3)	0.5 (0.2–1.2)	0.5 (0.2–1.2)
Colombia 2010	0.6 (0.1–2.9)	1.8 (0.2–21.5)	2.2 (0.5–9.5)	2.2 (0.6–9.7)	2.1 (0.9–5.4)	2.3 (0.9–5.9)
Honduras 2011	1.3 (0.3–4.1)	1.1 (0.3–3.8)	1.6 (0.7–2.7)	1.7 (0.9–3.1)	1.9 (0.6–5.3)	2.2 (0.8–6.2)
Indonesia 2012	1.2 (0.6–2.2)	0.9 (0.4–1.6)	0.9 (0.6–1.4)	0.9 (0.5–1.6)	1.0 (0.6–1.8)	1.0 (0.6–1.9)
Mali 2006	1.0 (0.4–2.5)	1.2 (0.5–2.7)	1.0 (0.4–2.0)	1.2 (0.5–2.6)	0.9 (0.6–1.3)	1.2 (0.7–1.8)
Niger 2006	0.8 (0.3–1.4)	0.7 (0.2–1.3)	0.6 (0.3–1.5)	1.1 (0.4–3.5)	0.6 (0.2–1.3)	0.7 (0.2–3.3)
Peru 2011	1.9 (0.4–8.1)	2.4 (0.4–11.7)	1.7 (0.4–8.0)	1.8 (0.5–7.9)	3.3 (1.3–7.8)	3.4 (1.3–8.3)
Philippines 2013	2.4 (0.5–13.4)	1.9 (0.5–6.7)	0.4 (0.1–1.7)	0.4 (0.1–1.6)	0.7 (0.3–1.6)	0.7 (0.3–1.6)
Sao Tome and Principe 2008/09	0.2 (0.1–4.6)	0.3 (0.2–4.7)	3.0 (0.3–27.6)	3.0 (0.3–27.3)	0.8 (0.1–5.7)	1.2 (0.2–9.6)
Pooled	1.0 (0.6–1.5)	1.1 (0.5–1.8)	1.1 (0.5–1.7)	1.2 (1.0–1.5)	1.1 (0.8–1.4)	1.3 (1.1–1.5)

*Pooled analysis adjusted for household wealth, maternal age, sex of infant, maternal education, birth order, birth spacing, rural/urban residence, sample unit and country as random effect.

**Single-country analysis adjusted for household wealth, maternal age, sex of infant, maternal education, birth order, birth spacing, rural/urban residence, and sample unit as random effect.

***Pooled analysis adjusted for household wealth, maternal age, sex of infant, maternal education, birth order, birth spacing, rural/urban residence, sample unit and country as random effect, and for reported obstetric complications.

****Single-country analysis adjusted for household wealth, maternal age, sex of infant, maternal education, birth order, birth spacing, rural/urban residence, and sample unit as random effect, and for reported obstetric complications.

Bold indicates significant values ($p < 0.01$).

impact of referral bias. The high risks of early neonatal deaths associated with maternal complications during childbirth strengthen suggestions that efforts of SBAs at health facilities to improve performance in early detection and appropriate management of problems arising in labour, supported by effective referral mechanisms, will substantially contribute to reductions in early neonatal mortality.

Disclosure of interests

None declared. Completed disclosure of interests form available to view online as supporting information.

Contribution to authorship

SB, HS and MM contributed to the study conception and design. SB conducted the statistical analysis. SB and HS wrote the manuscript. SB, HS, MM and MT interpreted the data and approved the final submission.

Details of ethics approval

The institutional review board of ORC Macro (Calverton, MD, USA) and of each country approved the DHS data collection procedures including informed consent. This study used existing data obtained from ORC Macro through formal request mechanisms. As no interviews or identifying information were included, additional ethical review for the secondary analysis was not required.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Acknowledgements

None.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Odds ratios (95% Confidence Intervals) of early neonatal deaths versus one, two and three obstetrical complications associated compared to births with no complications. ■

References

- UNICEF. Committing to child survival: a promise renewed. Progress report 2013. New York, NY: United Nations Children's Fund, 2013.
- Rajaratnam JK, Marcus JR, Flaxman AD, Wang H, Levin-Rector A, Dwyer L, et al. Neonatal, post neonatal, childhood, and under-5 mortality for 187 countries, 1970–2010: a systematic analysis of progress towards Millennium Development Goal 4. *Lancet* 2010;375:1988–2008.
- Lozano R, Wang H, Foreman KJ, Rajaratnam JK, Naghavi M, Marcus JR, et al. Progress towards Millennium Development Goals 4 and 5 on maternal and child mortality: an updated systematic analysis. *Lancet* 2011;378:1139–65.
- Hill K, You D, Inoue M, Oestergaard MZ, for the Technical Advisory Group of United Nations Inter-agency Group for Child Mortality Estimation. Child mortality estimation: accelerated progress in reducing global child mortality, 1990–2010. *PLoS Med* 2012;9:e1001303.
- Alkema L, You D. Child mortality estimation: a comparison of UN IGME and IHME estimates of levels and trends in under-five mortality rates and deaths. *PLoS Med* 2012;9:e1001288.
- Hill K, Amouzou A. Trends in child mortality, 1960 to 2000. In: Jamison DT, Feachem RG, Makgoba MW, Bos ER, Baingana FK, Hofman KJ, et al., editors. *Disease and Mortality in Sub-Saharan Africa*, 2nd edn. Washington, DC: World Bank, 2006, Chapter 3.
- Wang H, Dwyer-Lindgren L, Lofgren KT, Rajaratnam JK, Marcus JR, Levin-Rector A, et al. Age-specific and sex-specific mortality in 187 countries, 1970–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2071–94.
- United Nations Department of International Economic and Social Affairs. *Mortality of Children Under Age 5: World Estimates and Projections, 1950–2025*. Herndon, VA: United Nations, 1998.
- Guillot M, Gerland P, Pelletier F, Saabneh A. Child mortality estimation: a global overview of infant and child mortality age patterns in light of new empirical data. *PLoS Med* 2012;9:e1001299.
- Gakidou E, Cowling K, Lozano R, Murray CJL. Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis. *Lancet* 2010;376:959–74.
- O'Hare B, Makuta I, Chiwaula L, Bar-Zeev N. Income and child mortality in developing countries: a systematic review and meta-analysis. *J R Soc Med* 2013;106:408–14.
- Mohan P. Inequities in coverage of preventive child health interventions: the rural drinking water supply program and the universal immunization program in Rajasthan, India. *Am J Public Health* 2005;95:241–4.
- Boerma JT, Bryce J, Kinfu Y, Axelson H, Victora CG, the Countdown 2008 Equity Analysis Group. Mind the gap: equity and trends in coverage of maternal, newborn, and child health services in 54 Countdown countries. *Lancet* 2008;371:1259–67.
- WHO. *Monitoring Maternal, Newborn and Child Health: Understanding Key Progress Indicators* (Accessed 1 September 2015). Geneva: WHO, 2011.
- WHO. *World Health Report 2005: Make Every Mother and Child Count*. Geneva: WHO, 2005.
- Wang H, Liddell CA, Coates MM, Mooney MD, Levitz CE, Schumacher AE, et al. Global, regional, and national levels of neonatal, infant, and under-5 mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;384:957–79.
- UNICEF. *The United Nations Inter-agency Group for Child Mortality Estimation (2015) Levels & Trends in Child Mortality: Report 2015*. New York, NY: UNICEF.
- Zupan J. Perinatal mortality in developing countries. *N Engl J Med* 2005;352:2047–8.
- Kusiako T, Ronsmans C, Van der Paal L. Perinatal mortality attributable to complications of childbirth in Matlab, Bangladesh. *Bull World Health Organ* 2000;78:621–7.
- Weiner R, Ronsmans C, Dorman E, Jilo H, Muhoru A, Shulman C. Labour complications remain the most important risk factors for perinatal mortality in rural Kenya. *Bull World Health Organ* 2003;81:561–6.

- 21 Lassi ZS, Bhutta ZA. Community-based intervention packages for reducing maternal and neonatal morbidity and mortality and improving neonatal outcomes. *Cochrane Database Syst Rev* 2015; (3):CD007754.
- 22 Sobel HL, Oliveros YE, Nyunt US. Secondary analysis of a national health survey on factors influencing women in the Philippines to deliver at home and unattended by a healthcare professional. *Int J Gynaecol Obstet* 2010;111:157–60.
- 23 World Health Organization. Reduction of maternal mortality: a joint WHO/UNFPA/UNICEF World Bank statement 68.2013. Geneva: WHO.
- 24 Ronsmans C, Chowdhury ME, Koblinsky M, Ahmed A. Care seeking at time of childbirth, and maternal and perinatal mortality in Matlab, Bangladesh. *Bull World Health Organ* 2010;88:289–96.
- 25 Inter-Agency Group for Safe Motherhood. The safe motherhood action agenda: priorities for the next decade. Report on the safe Motherhood Technical Consultation, 18–23 October 1997, Colombo.
- 26 Lohela TJ, Campbell OM, Gabrysch S. Distance to care, facility delivery and early neonatal mortality in Malawi and Zambia. *PLoS One* 2012;7:e52110.
- 27 Fink G, Ross R, Hill K. Institutional deliveries weakly associated with improved neonatal survival in developing countries: evidence from 192 Demographic and Health Surveys. *Int J Epidemiol* 2015;44:1879–88.
- 28 Sobel HL, Silvestre MA, Mantaring JB III, Oliveros YE, Nyunt US. Immediate newborn care practices delay thermoregulation and breastfeeding initiation. *Acta Paediatr* 2011;100:1127–33.
- 29 Rustein SO, Rojas G. *Guide to DHS Statistics*. Calverton, MD: ORC Macro, MEASURE DHS+, 2003.
- 30 Ananth CV, Berkowitz GS, Savitz DA, Lapinski RH. Placental abruption and adverse perinatal outcomes. *JAMA* 1999;282:1646–51.
- 31 Stata Corp. Statistical software: release 10SE [Computer program]. College Station, TX: Stata Corp., 2008.
- 32 Donner A, Klar N. Methods for comparing event rates in intervention studies when the unit of allocation is a cluster. *Am J Epidemiol* 1994;140:279–89.
- 33 Zanini RR, de Moraes AB, Giugliani ERJ, Riboldi J. Contextual determinants of neonatal mortality using two analysis methods, Rio Grande do Sul, Brazil. *Rev Saude Publica* 2011;45:79–89.
- 34 Titaley CR, Dibley MJ, Agho K, Roberts CL, Hall J. Determinants of neonatal mortality in Indonesia. *BMC Public Health* 2008;8:232.
- 35 Johnson K, Grant M, Khan S, Moore Z, Armstrong A, Sa Z. *Fieldwork-Related Factors and Data Quality in the Demographic and Health Surveys Program*. Calverton, MD: Macro International, 2009.
- 36 Curtis S. Assessment of the quality of data used for direct estimation of infant and child mortality in DHS-II surveys. Occasional Papers No. 3. Demographic and Health Surveys. [http://www.dhsprogram.com/pubs/pdf/OP3/OP3.pdf]. Accessed 13 August 2015.
- 37 Neal S. The measurement of neonatal mortality: how reliable is Demographic and Household Survey data? Working paper 25. ESRC Centre for Population Change, 2012 [http://www.cpc.ac.uk/publications/cpc_working_papers/pdf/2012_WP25_The_Measurement_of_Neonatal_Mortality_Neal.pdf]. Accessed 13 August 2015.
- 38 Liu J, Tuvblad C, Li L, Raine A, Baker LA. Medical record validation of maternal recall of pregnancy and birth events from a twin cohort. *Twin Res Hum Genet* 2013;16:845–60.
- 39 Sou SC, Chen WJ, Hsieh WS, Jeng SF. Severe obstetric complications and birth characteristics in preterm or term delivery were accurately recalled by mothers. *J Clin Epidemiol* 2006;59:429–35.
- 40 Filippi V, Ronsmans C, Gandaho T, Graham W, Alihonou E, Santos P. Women's reports of severe (near-miss) obstetric complications in Benin. *Stud Fam Plann* 2000;31:309–24.
- 41 Tomeo CA, Rich-Edwards JW, Michels KB, Berkey CS, Hunter DJ, Frazier AL, et al. Reproducibility and validity of maternal recall of pregnancy-related events. *Epidemiology* 1999;10:774–7.
- 42 Ronsmans C, Achadi E, Cohen S, Zazri A. Women's recall of obstetric complications in south Kalimantan, Indonesia. *Stud Fam Plann* 1997;28:203–14.
- 43 Souza JP, Cecatti JG, Pacagnella RC, Giavarotti TM, Parpinelli MA, Camargo RS, et al. Development and validation of a questionnaire to identify severe maternal morbidity in epidemiological surveys. *Reprod Health* 2010;7:16.
- 44 Stengel MR, Kraschnewski JL, Hwang SW, Kjerulff KH, Chuang CH. 'What my doctor didn't tell me': examining health care provider advice to overweight and obese pregnant women on gestational weight gain and physical activity. *Womens Health Issues* 2012;22:e535–40.
- 45 Gourlay A, Wringe A, Birdthistle I, Mshana G, Michael D, Urassa M. 'It is like that, we didn't understand each other': exploring the influence of patient-provider interactions on prevention of mother-to-child transmission of HIV service in rural Tanzania. *PLoS One* 2014;9:e106325.
- 46 Lawn JE, Cousens S, Zupan J. 4 million neonatal deaths: when? Where? Why? *Lancet* 2005;365:891–900.
- 47 Hatt L, Stanton C, Ronsmans C, Makowiecka K, Adisasmita A. Did professional attendance at home births improve early neonatal survival in Indonesia? *Health Policy Plan* 2009;24:270–8.
- 48 Bell J, Curtis SL, Alayon S. Trends in delivery care in six countries. [https://dhsprogram.com/pubs/pdf/AS7/AS7.pdf]. Accessed 14 August 2015.
- 49 Gleit DA, Goldman N, Rodriguez G. Utilization of care during pregnancy in rural Guatemala: does obstetrical need matter? *Soc Sci Med* 2003;57:2447–63.
- 50 Birthplace in England Collaborative Group. Perinatal and maternal outcomes by planned place of birth for healthy women with low risk pregnancies: the birthplace in England national prospective cohort study. *BMJ* 2011;343:d7400.
- 51 WHO Global Alert and Response. Health care-associated infections: fact sheet. World Health Organization [www.who.int/gpsc/country_work/gpsc_ccisc_fact_sheet_en.pdf]. Accessed 15 August 2015.
- 52 Obara H, Sobel H. Quality maternal and newborn care to ensure a healthy start for every newborn in the World Health Organization Western Pacific Region. *BJOG* 2014;121 (Suppl 4):154–9.
- 53 Montoya A, Calvert C, Filippi V. Explaining differences in maternal mortality levels in sub-Saharan African hospitals: a systematic review and meta-analysis. *Int Health* 2014;6:12–22.
- 54 Singh K, Brodish P, Suchindran C. A regional multilevel analysis: can skilled birth attendants uniformly decrease neonatal mortality? *Matern Child Health J* 2014;18:242–9.
- 55 Garces A, McClure EM, Chomba E, Patel A, Pasha O, Tshetu A, et al. Home birth attendants in low income countries: who are they and what do they do? *BMC Pregnancy Childbirth* 2012;12:34.