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Out of sight, out of mind? Evidence from cross-sectional surveys on hidden caesarean sections among women with stillbirths in Ghana, 2007 and 2017

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ABSTRACT

Background Caesarean section (CS) rates in women experiencing stillbirth have not been studied with nationally representative data. Two Ghana Maternal Health Surveys (GMHS) have captured pregnancy and mode of birth data for all women including those with stillbirths. We compared CS rates between women with live births and stillbirths, and identified socio-economic and pregnancy-related factors associated with CS in stillbirths.

Methods A population-based cross-sectional study was conducted in a pooled sample of 17 138 women who had given birth within 5 years preceding the 2007 and 2017 GMHS. CS rates were compared between women with stillbirths and very early neonatal deaths (SBVENDs) and women with live births who survived the first day. Bivariate and multivariable logistic regressions explored variables associated with CS. Effect modification of household's wealth and maternal educational level by birth outcome was assessed using multivariable logistic regression with interaction terms.

Results CS rate in women with SBVEND was 19.3% compared with 9.6% in women with live births who survived the first day (rate ratio 2.2; 95% CI 1.6 to 2.9). In multivariable analysis, attaining middle school compared with no formal education (adjusted OR, aOR 2.8; 95% CI 1.1 to 7.1), having had five or more births compared with nulliparity (aOR 3.7; 95% CI 1.3 to 10.7) and reporting prolonged or obstructed labour (aOR 3.3; 95% CI 1.3 to 8.3) were associated with CS in women with SBVEND. Higher household wealth and educational levels were associated with an increased risk of CS in both study groups, with no statistically significant difference in effect.

Conclusion Disaggregating CS rates by birth outcome revealed a high rate among women with SBVEND, twice the overall rate compared with live births. Exclusion of these 'hidden' CSs from rate calculations may lead to underestimation of (inter)national CS rates and potentially conceals CS overuse or misuse.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Caesarean section (CS) in women with stillbirth is generally contraindicated, as it exposes women to the risks of surgery without benefiting the child.
⇒ Population and facility-based studies show high CS rates in women experiencing stillbirth.

WHAT THIS STUDY ADDS

⇒ This study is the first to provide CS rates in women with stillbirth or very early neonatal death in a nationally representative sample.
⇒ We found a CS rate in Ghana in women with stillbirth or very early neonatal death of twice the rate in live births.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ We recommend that stillbirth data be used when calculating future national and global CS rates to include all women regardless of birth outcome in the denominator, instead of only women with live births.
⇒ Similar analysis should follow in nationally representative samples to unravel the scale of CS in women with stillbirth.

INTRODUCTION

Stillbirths are an important indicator of the quality of maternity care.[1] For international comparisons, the WHO defines stillbirth as the death of a fetus at or beyond a gestational age of 28 weeks and before birth.[2] Timely access to emergency caesarean section (CS), as part of comprehensive emergency obstetric care, may avert 75% of intrapartum stillbirths.[3] On the other hand, performing CS in women whose babies had already died at the time of deciding for surgery might be considered as surgery performed 'too much, too late'.[4] If performed without maternal indication, such procedures expose women to the risks of surgery without saving the life of the baby. This is important in all settings, but especially in sub-Saharan Africa, where 11 per 1000 women die following CS as a result of haemorrhage, sepsis and complications of anaesthesia.[5]

Little is known about CS rates in women experiencing stillbirth. Ninety-eight per cent of stillbirths happen in low-income and middle-income countries, where household surveys such as the Demographic and Health Surveys (DHSs) are the main source of data used to estimate national maternity care seeking and coverage of care.[1] Prior to 2022, in most of these household surveys women whose pregnancies ended in stillbirth were not asked about their maternity care-seeking and care content.[6] Therefore, for most stillbirths, no data pertaining to mode of birth are collected and CS in stillbirths are generally overlooked in calculations of national and global CS rates.[4]

Nevertheless, several smaller population-based and facility-based studies in sub-Saharan Africa, South America and South East Asia have included pregnancies ending in stillbirths in measurements of CS rates.[7–10] In facility-based studies from Zanzibar and Mozambique, more than 20% of women with stillbirth gave birth by CS, double the rates found in women with live births.[7 8] In terms of access to CS, this discrepancy in CS rates between live and stillbirths might indicate lack of timely emergency obstetric care, rather than no access at all.[11] This may be particularly relevant in women with a lower socioeconomic status, as they have a higher risk of stillbirth, while CS rates are generally found to be relatively low.[12 13]

The Ghana Maternal Health Surveys (GMHSs) are among the few DHS and household surveys that, in addition to live births, collected mode of birth data for women with stillbirths.[14–16] CS rates in women with stillbirths have not been reported in a nationally representative sample in Ghana. In this study, we used GMHS 2007 and 2017 to compare CS rates between women with stillbirths or very early neonatal deaths (SBVEND) and live births surviving the first day of life. Second, we aimed to identify socioeconomic and pregnancy-related factors associated with CS in women with stillbirths in Ghana. Finally, the effect of household wealth and maternal education on access to CS were compared between women with stillbirths and live births.

METHODS

This study was reported following the Strengthening the Reporting of Observational Studies in Epidemiology statement on reporting of cross-sectional studies (online supplemental file 1).[17]

Study design and data collection

A population-based cross-sectional study was conducted using data from GMHS 2007 and 2017.[18 19] GMHSs are cross-sectional, nationally representative household surveys, in which women of reproductive age (15–49 years) were interviewed about reproductive and maternal health topics, such as family planning, pregnancy, childbirth and postnatal care.[14 15] These were special surveys conducted in addition to the standard Ghana DHS survey with the main purpose to assess maternal mortality and causes of maternal deaths. We used GMHS, instead of standard DHS, because in this survey women with stillbirths were asked to answer questions about maternity care they received, including data about mode of birth. The standard DHS only included women with live births in the sample for maternity care questions. To date, in Ghana, only GMHSs for the years 2007 and 2017 were conducted.

To select samples of women of reproductive age for GMHS 2007 and 2017, two-stage stratified sampling procedures were performed (figure 1). First, clusters (geographical areas covering an estimated number of households) were selected using a predetermined sample size and probability proportional to size sampling in the ten administrative regions in Ghana, stratified in rural and urban areas. In GMHS 2007, half of the clusters were selected from three regions: Greater Accra, Ashanti and Eastern regions. This was due to a national programme aimed at reducing maternal mortality in these regions specifically. Second, a fixed number of households were selected in each cluster using systematic sampling. For GMHS 2007 and 2017, 10 370 and 25 062 women, respectively, were interviewed with response rates of 97% and 99%. Detailed description of sampling techniques and questionnaires can be found in the 2007 and 2017 GMHS reports.[14 15]

Participants

We included the most recent birth of all women who reported having given birth in the 5 years prior to GMHS 2007 or 2017, as maternity care data were collected only for women's most recent births. Multiple pregnancy (eg, twins) were considered as one birth in which mode of birth and birth outcome of the last born were used. Thereby, we maintained a one-to-one ratio of the number of mothers to births.

Study groups were defined according to birth outcome: women with SBVEND were compared with women with live births who survived the first day of life. VENDs are commonly defined as babies dying within the first day.[20] We combined women with SBVEND into one study group to reduce recall bias, because misclassification of stillbirths as VENDs are common in household surveys.[21 22] Up to one-fifth of stillbirths were previously found to be misclassified as VENDs.[21]

We defined stillbirth as a baby born dead at gestational age of 7 or more months and who had not cried, moved or breathed, based on responses to two questions in the pregnancy history: '*Was the baby born alive, born dead or did you have a miscarriage or abortion?*' and '*Did that baby cry, move or breathe when it was born?*'. VEND was defined as a baby born alive (who had cried, moved or breathed after birth), but where the mother responded 'no' and 'less than a day' when asked whether the child was still alive and how long it had been alive.

The sample of women with SBVEND and women with live births who survived the first day were used for calculation and comparison of CS rates. Women with SBVEND

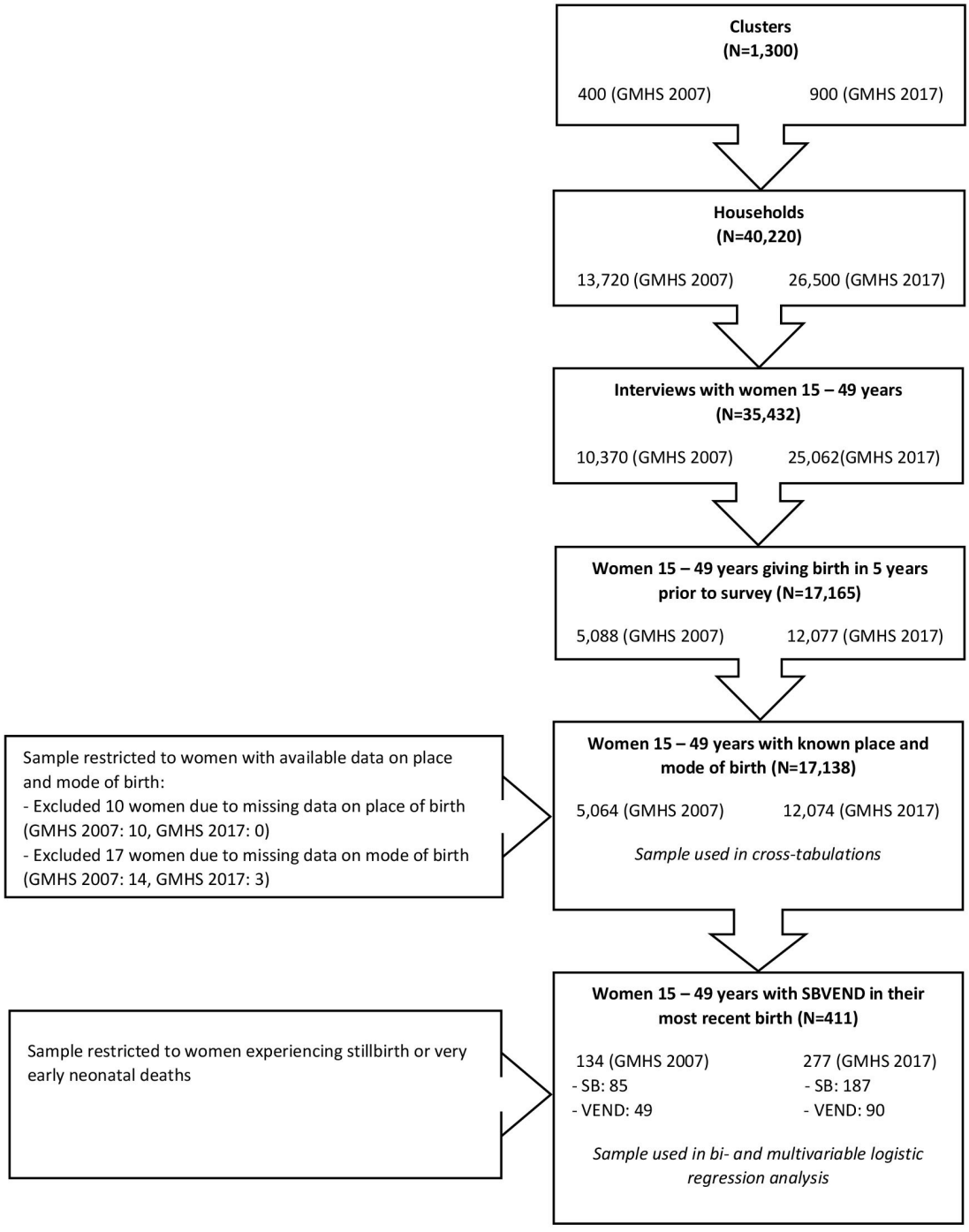

Figure 1 Flowchart with the derivation of the different study populations (unweighted). GMHS 2007 and 2017. GHMS, Ghana Maternal Health Survey; SB, stillbirth; SBVEND, stillbirth or VEND; VEND, very early neonatal deaths.

were analysed for factors associated with CS. Figure 1 shows the derivation of the different study populations displaying the unweighted number of participants.

Variables

The dependent variable was giving birth by CS. Women were asked where they had given birth and those giving birth in health facilities were subsequently asked if their child was '*delivered by caesarean (section), that is, did they cut your belly open to take the baby out?*'.

In addition to birth outcome, independent variables were considered based on their availability in both GMHS 2007 and 2017 and the effect of variables on CS in women with live births in previous studies.[23–28] We limited the number of included variables due to the small absolute number of CS in women with SBVEND, to maintain a ratio of one variable per five women.[29] In total, 17 variables were used, covering sociodemographic and pregnancy-related characteristics. Sociodemographic variables were ethnicity, region, place of residence, household's wealth

index, exposure to mass media, religion, marital status and maternal educational status. Pregnancy-related variables included maternal age and parity at index birth, history of perinatal death, multiple pregnancy, number of antenatal visits, antenatal care quality score, any peripartum complications, prolonged or obstructed labour and reduced fetal movements (online supplemental file 2). A number of categories per variable were limited to provide larger groups of women per category in accordance with our limited sample size. As two surveys were pooled in analysis, 'year of survey' was included as an additional variable.

Wealth index was a variable provided by DHS, generated from data on household assets, such as type of sanitation facilities available and households flooring material. Principal component analysis was used to assign a weight to each asset and, based on their score, households are divided in household wealth quintiles. We constructed 'exposure to mass media' as an additional variable, based on whether women read newspapers, listened to radio or watched television. No exposure at least once a week meant women were classified as 'little exposed', exposure to one out of three mass media as 'moderately exposed' and exposed to more than one classified as 'highly exposed'.[30] Additionally, an antenatal care quality score was constructed, composed of nine care items women during antenatal visits in the index pregnancy: measurement of maternal weight and blood pressure, analysis of urine and blood samples, education on danger signs and where to go for complications, if they received or were told to buy iron supplements, were given antihelminths and if they received tetanus vaccination. All nine items were scored binary, giving a maximum score of 9. Scores were dichotomised into low (0–7) and high[8 9] antenatal care quality. Cut-off was based on a mean antenatal care quality score of 7.4 from a prior analysis of GMHS 2017, with scores above average being considered high and scores below or equal to the mean being low.[31] Details of variables and their categorisation are available in online supplemental file 2.

Analysis

Analyses were performed using IBM SPSS Statistics, V.28. Data from GMHS 2007 and 2017 questionnaires were pooled to increase the sample size for analysis of the limited absolute number of CS in women with SBVEND. Women's sampling weights were applied to adjust for disproportionate sampling due to non-proportional allocation of selected households to regions and response rates. Sampling weights were denormalised to account for the difference in population size between surveys, using population data from the World Bank and the household population sample distribution from the corresponding GMHS (see online supplemental file 3).[14 15 32] SPSS complex sampling package was used to account for the GMHS's complex sampling design, implementing women's geographical area and cluster when calculating . GMHS survey reports did not provide information on cluster location. Therefore, in the complex sampling package, the 2007 and 2017 clusters were considered to be different, whereas geographical areas (strata) were considered similar. Apart from numbers regarding the study population in figure 1, all tables display weighted sample sizes.

We calculated the percentage and 95% CI of women that received four or more antenatal care visits (antenatal care coverage rate) and gave birth in facilities (facility birth rate), all births ending in SBVEND (SBVEND rate) and occurring by CS (CS rate). CS rates were stratified by birth outcome: SBVEND or liveborn surviving the first day. CS rates were compared between study groups using χ^2 tests to provide rate ratios (RR).

For women experiencing SBVEND, bivariate logistic regressions provided crude ORs (cOR) for each independent variables' category compared with a reference category. If five or fewer women per cell were observed, categories were collapsed.[33] Subsequently, multivariable logistic regression was used to identify risk factors for CS in women experiencing SBVEND. Multivariable analysis included independent variables based on statistical significance in bivariate logistic regression. Instead of p values below 0.05, variables with Wald F tests' p values below 0.25 in bivariate analysis were considered statistically significant, as to prevent exclusion of negatively correlated variables with a positive effect on outcome.[34] Pearson correlations above 0.8 or variance inflation factors higher than 4 were used to detect collinearity. The following independent variables were included: residence, wealth index, exposure to mass media, religion, current marital status, educational status, parity, history of perinatal death, multiple pregnancy, number of antenatal visits, antenatal care quality score, presence of peripartum complications, prolonged or obstructed labour and reduced fetal movements. To reduce overfitting, we used backward elimination based on p values to include eight independent variables in the final model, having a minimum of ten CS per included variable.[35] Adjusted ORs were provided (aOR). In bivariate and multivariable analyses, independent variables with an OR having a CI not containing the value 1 were considered statistically significant.

To assess effect modification by birth outcome (SBVEND or live birth who survived the first day) of household's wealth quintiles and maternal educational level on CS rates, we compared cORs using multivariable logistic regression with interaction terms. cORs were calculated for both independent variables' categories compared with reference categories in women with live births who survived the first day. These cORs were compared with cORs in women with SBVEND using multivariable logistic regression with interaction terms. aORs were provided as an effect size. Wald F tests of model effects were performed and p values below 0.05 indicated statistical significance.

As a sensitivity analysis, subgroup analysis was done in women with stillbirths. Bivariate and multivariable

logistic regression were performed similarly to the methodology described earlier. In assessing effect modification, women with VEND were included in the live births group. Online supplemental file 4 includes details on this analysis.

Missing data

Ten out of 17 165 women were excluded due to missing data on place of birth. Additionally, 17 women were excluded due to missing data on mode of birth. For each independent variable, missing values were less than 3%. Due to the limited number of women reporting SBVEND, missing values were manually imputed based on related variables to retain sample size. Online supplemental file 2 includes a detailed description of handling missing values.

Patient and public involvement

The importance of investigating use of CS and its associated morbidity in women with SBVEND was highlighted by clinical observations and informal conversations during clinical work by the authors with postpartum women in high-income and low-income settings. Patients were not actively involved in the design of our analysis of the GMHS data. However, prior to participation in GMHS, women were informed on the wide range of health topics of the survey and use of their responses to inform healthcare.[14] Specific components of the research partnership are defined in the author reflexivity statement (online supplemental file 5).

RESULTS

The final analysis included 17 138 women who had given birth in the 5 years prior to the surveys (table 1). Of those women, 411 reported experiencing SBVEND (2.6%, 95% CI 2.3% to 2.9%). Overall stillbirth rate was 1.7% or 17 stillbirths per 1000 total births, while the rate of VEND was 0.9% or 9 per 1000 total births. A higher SBVEND rate was found in women giving birth in facilities (3.0%; 95% CI 2.6% to 3.4%) compared with women giving birth at home (1.9%; 95% CI 1.4% to 2.4%). Of all women giving birth, 83.6% stated they had at least four antenatal care visits in the index pregnancy (95% CI 82.3 to 84.8). The pooled percentage of births occurring in health facilities was 67.7% (95% CI 65.4% to 69.9%).

In total, 9.9% of women reported giving birth by CS (95% CI 9.2 to 10.5). This was higher in the GMHS

Table 1 Stillbirth and very early neonatal death (SBVEND), antenatal care coverage, facility birth and CS rates (weighted)

	GMHS 2007 (N=7819)		GMHS 2017 (N=9319)		Total (N=17 138)	
	Cases/total births	% (95% CI)	Cases/total births	% (95% CI)	Cases/total births	% (95% CI)
SBVEND, antenatal care coverage and facility birth rates in the GMHS 2007 and 2017						
SBVEND in total	199/7819	2.5 (2.1 to 3.1)	249/9319	2.7 (2.3 to 3.1)	447/17 138	2.6 (2.3 to 2.9)
SB in total	130/7819	1.7 (1.3 to 2.2)	160/9319	1.7 (1.4 to 2.1)	290/1 7 138	1.7 (1.4 to 2.0)
VEND in total	69/7819	0.9 (0.6 to 1.2)	88/9319	0.9 (0.7 to 1.2)	157/17 138	0.9 (0.8 to 1.1)
SBVEND in home/other	60/3566	1.7 (1.2 to 2.4)	43/1972	2.2 (1.6 to 3.0)	103/5538	1.9 (1.4 to 2.4)
SBVEND in facility	139/4253	3.3 (2.6 to 4.1)	206/7347	2.8 (2.4 to 3.3)	345/11 600	3.0 (2.6 to 3.4)
In public facility	120/3399	3.5 (2.8 to 4.5)	189/6298	3.0 (2.5 to 3.5)	309/9697	3.2 (2.8 to 3.7)
In private facility	19/854	2.2 (1.2 to 3.9)	17/1049	1.6 (0.9 to 2.8)	36/1903	1.9 (1.3 to 2.8)
Antenatal care coverage	5991/7819	76.6 (74.2 to 78.9)	8337/9319	89.5 (88.5 to 90.3)	14328/17 138	83.6 (82.3 to 84.8)
In SBVEND	141/199	71.0 (61.2 to 79.2)	211/249	85.1 (79.5 to 89.3)	353/447	78.8 (73.4 to 83.4)
Births in facility	4253/7819	54.4 (50.4 to 58.3)	7347/9319	78.8 (77.0 to 80.5)	11600/17 138	67.7 (65.4 to 69.9)
In public facility	3399/7819	43.5 (39.9 to 47.1)	6298/9319	67.6 (65.7 to 69.4)	9697/17 138	56.6 (54.4 to 58.7)
In private facility	854/7819	10.9 (9.3 to 12.7)	1049/9319	11.3 (10.1 to 12.5)	1903/17 138	11.1 (10.2 to 12.1)
CS rates in the GMHS 2007 and 2017						
CS in total	513/7819	6.6 (5.7 to 7.5)	1175/9319	12.6 (11.7 to 13.5)	1688/17 138	9.9 (9.2 to 10.5)
CS in liveborn	481/7620	6.3 (5.5 to 7.2)	1121/9070	12.4 (11.5 to 13.3)	1602/16 691	9.6 (8.9 to 9.3)
CS in SBVEND	32/199	16.2 (10.5 to 24.3)	54/249	21.7 (16.2 to 28.4)	86/447	19.3 (15.1 to 24.3)
CS in SB	24/130	18.4 (10.9 to 29.4)	39/160	24.2 (17.3 to 32.6)	63/290	21.6 (16.2 to 28.1)
CS in VEND	8/69	12.1 (5.1 to 26.0)	15/88	17.3 (9.2 to 30.2)	23/157	15.0 (9.0 to 23.9)
CS in facility	513/4253	12.1 (10.6 to 13.7)	1175/7347	16.0 (15.0 to 17.1)	1168/11 600	14.6 (13.7 to 15.5)
In public facility	417/3399	12.3 (10.7 to 14.0)	994/6298	15.8 (14.6 to 17.0)	1411/9697	14.5 (13.6 to 15.6)
In private facility	96/854	11.3 (8.1 to 15.4)	181/1049	17.3 (14.7 to 20.2)	277/1626	14.6 (12.5 to 16.9)

GMHS 2007 and 2017.
CS, caesarean section; GMHS, Ghana Maternal Health Survey; SB, stillbirth; VEND, very early neonatal death.

2017—12.6% (95% CI 11.7% to 13.5%) compared with 6.6% (95% CI 5.7% to 7.5%) in the GMHS 2007. Table 1 shows that in the pooled study population 9.6% of women with live births who survived the first day (95% CI 8.9 to 9.3) and 19.3% of women with SBVEND (95% CI 15.1 to 24.3) gave birth by CS.

RRs of CS in women with SBVEND compared with women with live births who survived the first day

Among women with SBVEND, overall CS rate was 2.2 (95% CI 1.6 to 2.9) times higher than in women with live births who survived the first day (table 2). The highest prevalence of CS in women with SBVEND was found in multiple gestation births (29.3%), those with prolonged or obstructed labour (46.3%) or with reduced fetal movements (32.8%).

When examined according to sociodemographic and maternal characteristics, women with SBVEND had higher risks for caesarean birth than women with live births surviving the first day for most categories (table 2). They had a considerably higher risk of CS if they were of Mole-Dagbani ethnicity (RR 3.2; 95% CI 1.4 to 7.6), from the Northern regions (RR 3.1; 95% CI 1.2 to 7.7), of middle wealth (RR 3.1; 95% CI 1.8 to 5.4), of Muslim faith (RR 3.6; 95% CI 2.0 to 6.3) or belonged to other non-Christian religions or were areligious (RR 5.5; 95% CI 1.7 to 14.1), if they had some primary education (RR 3.7; 95% CI 1.9 to 7.2) or had five or more births (RR 3.6; 95% CI 2.2 to 5.9).

Bivariate and multivariable logistic regression of variables' association with CS in women with SBVEND

Table 3 shows the results of both bivariate and multivariable analyses of variables' association with CS in the 447 women experiencing SBVEND. Independent variables providing cORs with a CI not containing the value 1 in bivariate analysis were being from a household in the richest two wealth quintiles (cOR 2.9; 95% CI 1.4 to 5.9), being highly exposed to mass media (cOR 3.0; 95% CI 1.1 to 7.9), having had five or more births (cOR 2.6; 95% CI 1.1 to 6.6), having had four or more antenatal care visits (cOR 4.3; 95% CI 1.3 to 14.3) and having had prolonged or obstructed labour (cOR 4.3; 95% CI 1.8 to 10.2). In multivariable regression, having attained middle school level education (aOR 2.8; 95% CI 1.1 to 7.1), having had five or more births (aOR 3.7; 95% CI 1.3 to 10.7) and reporting having had prolonged or obstructed labour (aOR 3.3; 95% CI 1.3 to 8.3) were associated with CS in women experiencing SBVEND.

Multivariable logistic regression with interaction terms evaluating effect modification by birth outcome of household wealth status and maternal educational level on CS

Women with SBVEND who were from households in the median wealth quintile had an cOR of 2.2 (95% CI 1.0 to 4.8) of having CS as compared with women in the poorest two quintiles (table 4). In women with live births, this cOR was 1.7 (95% CI 1.4 to 2.1). When comparing these cORs using multivariable analysis with interaction terms, no statistically significant effect modification by birth outcome was found, providing an aOR of 1.3 (95% CI 0.6 to 3.0). Additionally, women with SBVEND who were from the richest two quintiles had an cOR of 2.9 (95% CI 1.4 to 5.9) of having CS as compared with women in the poorest two quintiles. In women with live births, this cOR was 3.9 (95% CI 3.3 to 4.6), which did not differ with statistical significance from the cOR found in women with SBVEND (aOR 0.7, 95% CI 0.4 to 1.6). The overall Wald F p value for effect modification of household's wealth status by birth outcome was 0.33, indicating no statistically significant difference in wealth's effect on CS between SBVEND and live births.

Regarding maternal educational level, women with SBVEND having attained secondary or higher education had an cOR of 2.6 (95% CI 1.0 to 6.7) of having CS as compared with women with no formal education (table 4). In women with live births who survived the first day, this cOR was 5.1 (95% CI 4.1 to 6.4). In multivariable analysis with interaction terms, these cORs did not differ with statistical significance (aOR 0.5, 95% CI 0.2 to 1.3). The effect of education on having CS was also found to be similar between study groups when comparing women with primary or middle education with women without formal education. This provided a Wald F p value 0.17, indicating no statistical significant effect modification by birth outcome of maternal educational level on CS.

Subgroup analysis

Two-hundred and twenty-nine women with stillbirths were included in a subgroup analysis (online supplemental file 4). Bivariate logistic regression showed cORs similar to women with SBVEND. AORs differed from women with SBVEND, with multiple pregnancy (aOR 3.6, 95% CI 1.6 to 8.4) and higher number of antenatal care visits (aOR 3.9, 95% CI 1.3 to 11.8) having statistically significant positive associations with CS.

DISCUSSION

To our knowledge, this is the first nationally representative study on CS rates in women with stillbirths. We found a CS rate of 19% among women with SBVEND, more than double the rate of women with live births who survived the first day of life. Disaggregating CS rates by birth outcome revealed much higher use of CS among women experiencing SBVEND, which otherwise would have remained hidden. This difference in rates between women with stillbirths and live births may potentially indicate CS overuse or misuse and exclusion of these hidden CS from CS rate calculations may lead to underestimation of national and global CS rates.

In women with intrauterine fetal deaths, CS should only be performed to manage severe maternal complications of pregnancy. In the absence of maternal indications, women should not be exposed to the risks of surgery without the option to save the life of the child.

Table 2 Caesarean section (CS) rates in women with stillbirth or a very early neonatal deaths and women with live births who survived the first day (N=17 138) (weighted)

	Stillbirths and very early neonatal deaths (N=447)			Live births who survived the first day (N=16691)			
	CS N	Total N	CS rate %	CS N	Total N	CS rate %	RR (95% CI)*
Total	86	447	19.3	1602	16691	9.6	2.2 (1.6 to 2.9)
Year of survey							
2007	32	198	16.2	481	7621	6.3	2.8 (1.7 to 4.8)
2017	54	249	21.7	1121	9070	12.4	1.9 (1.4 to 2.7)
Ethnicity							
Akan	47	243	19.3	864	7717	11.2	1.9 (1.3 to 2.7)
Ewe	12	49	24.6	261	2147	12.1	2.3 (1.0 to 5.3)
Mole-Dagbani	10	56	18.5	163	2515	6.5	3.2 (1.4 to 7.6)
Other	17	99	17.0	314	4312	7.3	2.5 (1.3 to 5.1)
Region							
Coastal	36	163	21.9	800	6939	11.5	2.1 (1.3 to 3.4)
Middle	43	225	19.3	602	6636	10.1	2.0 (1.4 to 3.0)
Northern	7	58	12.0	129	3116	4.1	3.1 (1.2 to 7.7)
Residence							
Rural	38	243	15.4	566	9680	5.8	2.8 (1.8 to 4.4)
Urban	49	205	23.8	1036	7011	14.8	1.8 (1.2 to 2.6)
Household's wealth index							
Poor	20	177	11.1	340	7153	4.8	2.4 (1.4 to 4.2)
Middle	22	101	21.7	261	3343	7.8	3.1 (1.8 to 5.4)
Rich	45	170	26.4	1001	6195	16.2	1.8 (1.2 to 2.8)
Exposure to mass media							
Little exposed	10	81	12.1	250	4380	5.7	2.2 (0.9 to 5.3)
Moderately exposed	24	187	13.0	525	6276	8.4	1.6 (1.0 to 2.6)
Highly exposed	52	179	29.0	827	6034	13.7	2.5 (1.6 to 3.7)
Maternal age							
<20	3	39	8.1	120	1846	6.5	1.3 (0.2 to 6.5)
20–35	54	261	20.6	1108	11578	9.6	2.4 (1.7 to 3.4)
>35	30	148	20.0	374	3266	11.4	1.9 (1.1 to 3.3)
Religion							
Christian	61	327	18.7	1338	12562	10.7	1.9 (1.3 to 2.7)
Muslim	20	81	24.2	230	2946	7.8	3.6 (2.0 to 6.3)
Other	5	38	14.1	34	1183	2.9	5.5 (1.7 to 14.1)
Current marital status							
Married or living together	72	361	20.0	1365	14171	9.6	2.3 (1.6 to 3.1)
Not married or living together	14	86	16.2	237	2520	9.4	1.8 (0.9 to 3.5)
Maternal educational status							
None	13	116	10.8	219	4784	4.6	2.4 (1.4 to 4.6)
Primary	32	93	24.1	244	3289	7.4	3.7 (1.9 to 7.2)
Middle	35	172	20.4	700	6398	10.0	2.0 (1.3 to 3.1)
Secondary or higher	16	66	24.3	439	2221	19.8	1.3 (0.6 to 2.6)
Parity							
0	10	94	10.3	456	3783	12.1	0.8 (0.4 to 1.7)
1–4	47	226	20.7	947	10114	9.4	2.5 (1.7 to 3.6)

Continued

Table 2 Continued

	Stillbirths and very early neonatal deaths (N=447)			Live births who survived the first day (N=16691)			
	CS N	Total N	CS rate %	CS N	Total N	CS rate %	RR (95% CI)*
≥5	30	128	23.4	199	2794	7.1	3.6 (2.2 to 5.9)
History of perinatal death							
No	56	323	17.3	1373	14985	9.2	2.0 (1.4 to 2.9)
Yes	30	124	24.4	229	1705	11.6	2.0 (1.2 to 3.2)
Multiple pregnancy							
No	75	408	18.3	1526	16324	9.3	2.1 (1.6 to 2.9)
Yes	11	39	29.3	76	367	20.7	1.5 (0.6 to 3.6)
No of antenatal care visits							
None	2	35	4.6	9	492	1.7	2.7 (0.3 to 21)
1–3	4	60	7.5	68	2224	3.1	2.5 (0.5 to 12.3)
≥4	80	352	22.7	1525	13957	10.9	2.4 (1.8 to 3.3)
Antenatal care quality score							
Low (0–7)	25	165	15.2	373	5531	6.7	2.4 (1.4 to 4.1)
High (8–9)	61	282	21.6	1229	11160	11.0	2.2 (1.6 to 3.0)
Peripartum complications							
No	44	283	15.5	1084	13528	8.0	2.1 (1.4 to 3.0)
Yes	42	164	25.8	518	3163	16.4	1.7 (1.1 to 2.7)
Prolonged or obstructed labour							
No	67	406	16.5	1475	16295	9.1	1.9 (1.4 to 2.7)
Yes	19	41	46.3	127	396	32.1	1.7 (0.8 to 3.6)
Reduced fetal movements							
No	79	426	18.6	1592	16650	9.6	2.1 (1.6 to 2.8)
Yes	7	21	32.8	10	41	23.8	1.3 (0.5 to 3.3)

Ghana Maternal Health Survey 2007 and 2017.
*RR dividing the CS rate in women with stillbirth or very early neonatal deaths by the CS rate in women with live births surviving the first day.
RR, rate ratio.

When fetal heart sounds were heard, stillbirth or neonatal death following CS could have followed difficult clinical judgement and a reasonably well-founded attempt to save the child's life that did not succeed. Considering such attempts as 'too much, too late' would disregard the complexity of clinical decision-making during obstetric emergencies and would wrongly suggest all CS in women with VEND are avoidable. However, even when death follows a genuine attempt to save the baby's life, some CS or deaths might have been prevented by adequate fetal heart rate monitoring, timely usage of assisted-vaginal birth and prompt performance of high-quality surgery to reduce the decision-to-incision interval. Therefore, use of CS in women with SBVEND may serve as an indicator of insufficient quality of emergency obstetric care.

Similar to our study, high CS rates in women with SBVEND were reported in facility-based studies in low-resource settings. In Mozambique, women experiencing stillbirth in health facilities had a CS rate of 43%, compared with 17% in live births.[8] A CS rate of 26% among stillbirths was found in a referral hospital on Zanzibar, which was double the rate found among live births.[7] Population-based studies, such as the Global Network study, reported lower CS rates, probably due to the inclusion of stillbirths born from 20 weeks' gestation onward.[9 10] These 'early' stillbirths are much less likely to be born by CS. Notably, in the Global Network study, 90% of non-macerated stillbirths were born by CS, suggesting fetal death had occurred shortly before surgery.[9]

Among women living in the Northern region, who are Muslim or belonged to the Mole-Dagbani ethnic group, CS rates were three times higher among SBVEND compared with live births. These characteristics are common to the same group of women, as the people of Dagbon are mainly situated in Northern Ghana and are predominantly Muslim.[36] The high CS rates in this group among women with SBVEND could be explained by limited access to care due to fewer health facilities and doctors in northern regions of Ghana.[37] Inaccessibility of emergency obstetric care is supported by a higher

Table 3 Bivariate and multivariable logistic regression of variables associated with caesarean section (CS) in women with stillbirth or a very early neonatal deaths (N=447) (weighted)

	Stillbirths and very early neonatal deaths (N=447)			
	CS (N=86)	VB (N=361)	cOR (95% CI)	aOR (95% CI)
Year of survey				
2007	32	166	1	
2017	54	195	1.4 (0.8 to 2.7)	
Ethnicity				
Akan	47	196	1	
Ewe	12	37	1.4 (0.5 to 3.5)	
Mole-Dagbani	10	46	1.0 (0.5 to 3.5)	
Other	17	82	0.8 (0.4 to 1.9)	
Region				
Coastal	36	127	1	
Middle	43	182	0.8 (0.4 to 1.6)	
Northern	7	51	0.5 (0.2 to 1.4)	
Residence*				
Rural	38	205	1	
Urban	49	156	1.7 (0.9 to 3.1)	
Household's wealth index*				
Poor	20	157	1	
Middle	22	79	2.2 (1.0 to 4.8)	
Rich	45	125	2.9 (1.4 to 5.9)	
Exposure to mass media*				
Little exposed	10	71	1	1
Moderately exposed	24	163	1.1 (0.4 to 3.0)	1.0 (0.3 to 2.8)
Highly exposed	52	127	3.0 (1.1 to 7.9)	2.1 (0.8 to 5.8)
Maternal age				
<35	57	243	1	
≥35	30	118	1.1 (0.6 to 2.0)	
Religion*				
Christian	61	266	1	1
Muslim, other religions, areligious	25	95	1.2 (0.6 to 2.2)	1.7 (0.8 to 3.8)
Current marital status*				
Married or living together	72	289	1	1
Not married or living together	14	72	0.8 (0.4 to 1.7)	0.6 (0.3 to 1.3)
Maternal educational status*				
None	13	103	1	1
Primary	32	71	2.6 (1.0 to 6.6)	2.7 (1.0 to 7.6)
Middle	35	137	2.1 (1.0 to 4.4)	2.8 (1.1 to 7.1)
Secondary or higher	16	50	2.6 (1.0 to 6.7)	3.3 (0.9 to 13.1)
Parity*				
0	10	84	1	1
1–4	47	179	2.3 (1.0 to 5.1)	2.3 (0.9 to 6.0)
≥5	30	98	2.6 (1.1 to 6.6)	3.7 (1.3 to 10.7)
History of perinatal death*				
No	56	267	1	
Yes	30	94	1.5 (0.8 to 3.0)	

Continued

Table 3 Continued

	Stillbirths and very early neonatal deaths (N=447)			
	CS (N=86)	VB (N=361)	cOR (95% CI)	aOR (95% CI)
Multiple pregnancy*				
No	75	333	1	1
Yes	11	28	1.8 (0.7 to 4.7)	1.9 (0.7 to 4.8)
No of antenatal visits*				
<4	6	89	1	1
≥4	80	272	4.3 (1.3 to 14.3)	3.8 (0.5 to 31.4)
Antenatal care quality score*				
Low (0–7)	25	140	1	
High (8–9)	61	221	1.5 (0.8 to 2.9)	
Peripartum complications*				
No	44	239	1	
Yes	42	122	1.9 (1.0 to 3.5)	
Prolonged or obstructed labour*				
No	67	339	1	1
Yes	19	22	4.3 (1.8 to 10.2)	3.3 (1.3 to 8.3)
Reduced fetal movements*				
No	79	347	1	
Yes	7	14	2.1 (0.6 to 7.7)	

Ghana Maternal Health Survey 2007 and 2017.
*Factors associated with CS in women having stillbirths and very early neonatal deaths with a Wald F-test p<0.25.
aOR, adjusted OR; cOR, crude OR; VB, vaginal birth.

maternal mortality ratio in the Northern compared with the middle and coastal regions.[15] Limited access to surgery might, apart from an absolute reduction in CS, lead to CS being performed too late, resulting in higher risks of stillbirth or perinatal asphyxia with VEND.[11]

Contrary to the increased risk of CS in multiparous women who experienced SBVEND in our study, previous findings show multiparity to be associated with reduced risks of CS in women with live births.[28] This difference might be explained by differing indications for CS

Table 4 Multivariable logistic regression with interaction terms assessing effect modification by birth outcome of household's wealth status and maternal educational level on caesarean section (CS) rates (N=17 138) (weighted)

	Stillbirths and very early neonatal deaths (N=447)			Live births who survived the first day (N=16691)			Wald F* and aOR (95% CI)†
	CS (N=86)	VB (N=361)	cOR (95% CI)	CS (N=1602)	VB (N=15089)	cOR (95% CI)	
Household's wealth index							0.33
Poor	20	157	1	340	6813	1	
Middle	22	79	2.2 (1.0 to 4.8)	261	3082	1.7 (1.4 to 2.1)	1.3 (0.6 to 3.0)
Rich	45	125	2.9 (1.4 to 5.9)	1001	5194	3.9 (3.3 to 4.6)	0.7 (0.4 to 1.6)
Maternal educational status							0.17
None	13	103	1	219	4565	1	
Primary	32	71	2.6 (1.0 to 6.6)	244	3045	1.7 (1.3 to 2.1)	1.6 (0.6 to 4.0)
Middle	35	137	2.1 (1.0 to 4.4)	700	5698	2.6 (2.1 to 3.1)	0.8 (0.4 to 1.8)
Secondary or higher	16	50	2.6 (1.0 to 6.7)	439	1782	5.1 (4.1 to 6.4)	0.5 (0.2 to 1.3)

Ghana Maternal Health Survey 2007 and 2017.
*Wald F p value serving as a measure of statistical significance. A p<0.05 is considered statistically significant.
†aOR and 95% CIs serve as a measure of effect size of effect modification by birth outcome.
aOR, adjusted OR; cOR, crude OR; VB, vaginal birth.

between nulliparous and multiparous women. Considering all CS performed in nulliparous, most are due to prolonged labour, while in multiparous women higher percentages are due to (pre)eclampsia, placental abruption and placenta praevia.[38] The latter indications have higher risks of SBVEND.

The relationship between prolonged labour and CS is easily understood, prolonged labour being an obstetric condition that may result in uterine rupture, stillbirth or perinatal asphyxia. In obstructed labour, CS and symphysiotomy are the only methods available to give birth. When a fetal heart rate is present, such invasive procedures might be justified after informed consent has been provided by the mother. When fetal death has been confirmed, however, alternative options for birth could be considered, such as induction of labour or assisted vaginal birth in case of prolonged labour, and destructive operative vaginal birth in case of obstructed labour. These options may reduce CS rates in women experiencing fetal death, protecting them from its morbidity and mortality.

In Ghana, higher wealth status and educational level were associated with an increased prevalence of CS in women with live births.[13 39] In the current study, similar associations were seen in both women with live births and SBVEND, with higher CS rates among the richest two wealth quintiles and higher education levels. The effect of wealth and educational level on CS did, however, not differ with statistical significance between study groups. This suggests that more CS rates are performed in women from richer households, whether the child is alive after birth or not. Questions could be raised about the necessity of many of these CS, possibly being a form of 'too much, too soon' or, even worse, 'too much, too late'.[4 40] We were unable to differentiate between emergency and elective CS, as the GMHS 2007 questionnaire did not include questions regarding type of CS.

Limitations

Our study is limited by the small absolute number of stillbirths after CS. To increase sample size and provide meaningful CI, we pooled datasets from GMHS 2007 and 2017. Doing so, however, creates a reference population that is harder to interpret, as characteristics of women in Ghana might have changed over time. We assume that, although population characteristics may have changed, their effect on CS did not. Therefore, variables should have similar effects in regression analysis.

Other limitations were related to the unavailability in the GMHS questionnaires of variables important for our outcome, including timing, birth weight and gestational age of stillbirths, whether CS occurred before or after the onset of labour (which was only available in the 2017 survey) and whether women had given birth by CS previously. Stillbirths could not be classified as antepartum or intrapartum, since questionnaires did not include information about presence of fetal heart rate or skin maceration (a proxy used to estimate timing of stillbirths). Nevertheless, even when GMHS would have included questions on stillbirth's birth weight, gestational age and timing of death, data from household surveys regarding these topics are often incomplete and lack criterion or convergent validity.[22 41] Women may have not been made aware of these details by their health provider or may not recall them.[22]

Also, there is a risk of residual confounding due to collapsing of independent variables' categories.[42] Categories at risk are ethnicity and religion variables' 'other' categories, as they combine varying categories with potential dissimilar effects on having CS.

Implications and future research

DHS using the newly updated DHS-8 questionnaire, which adopts a full pregnancy history capturing data on healthcare use during pregnancy and mode of birth for all births, including stillbirths, will enable analyses similar to ours for all other countries. This may reveal the scale of hidden CS in women with SBVEND.[43] We recommend that this data be used when calculating future (inter) national CS rates to include all women regardless of birth outcome in the denominator, instead of only women with live births. Based on our findings, we would also encourage separate reporting of CS rates for live births and stillbirths to assess the appropriateness of CS use.

In addition to household surveys, facility-based studies are needed to further understand CS use in women with SBVEND. High-quality facility data collection and health-facility registers may provide information on the cause and timing of fetal death, timing of CS, use of fetal heart rate monitoring and use of labour augmentation with oxytocin. Also, by using facility registries, women do not have to recount the experience of losing a child in great detail, as this may aggravate their fear, pain and grief.[44] Strengthening of facility-based data collection and documentation, and performing perinatal death reviews in women with CS may improve CS usage by enhancing professional learning and increasing accountability.

To reduce the number of unnecessary CS in women with stillbirths, in addition to deepening our understanding of explanatory factors through facility-based and community-based studies, we urge clinicians to consider alternative options for birth, such as induction of labour and assisted vaginal birth. Based on our findings, performance of CS in women from Northern regions with presumed limited access to care, but also in women with a high socioeconomic status requires particular scrutiny for being well indicated and performed in a timely manner. Electronic fetal heart rate monitoring may aid the clinician in such timely use.[45] If fetal death occurs, we advocate for the use of national, or, where these are unavailable, international guidelines in its management before, during and after birth.[46]

CONCLUSION

Analysis of a pooled sample from GMHS 2007 and 2017 showed a CS rate of 19.3% in women in Ghana with

SBVEND, double the rate in women with live births who survived the first day of life. These CS rates are currently excluded from CS rate calculations and inclusion might lead to an increase of facility-based, national and global CS rates. Future stillbirth data from household surveys and facility-based studies may reveal the exact scale of CS use in women with stillbirth and increase our understanding of why and when the decision for surgery is made. With these insights, unnecessary CS may be prevented and, instead, CS can be used for the right reasons at the right time.

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Contributors SZ drafted the study protocol, receiving feedback from all coauthors. AC and LB provided input on methodology, data analysis and kept record of progress. TKB provided critical interpretation of results in the context of Ghana. All authors were involved in drafting the manuscript and approved the final draft for submission. SZ serves as the guarantor and accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Authorisation to access the publicly available GMHS datasets was granted by the DHS programme after registration of the study. Procedures and questionnaires for DHS surveys have been reviewed by the Inner City Fund Institutional Review Board for compliance with US legislation, while the Ghana Health Service Ethical Review Committee ensured compliance with Ghanian legislation. All questionnaires from 2007 and 2017 included a consent statement introducing the aim of the survey and voluntary participation. Verbal consent was gained by the interviewer prior to participation in both surveys.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. Data are available at the DHS programme (see https://dhsprogram.com/). Authorisation to access the publicly available GMHS datasets has to be granted by the DHS programme after registration.

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SUPPLEMENTARY FILE 1 – STROBE STATEMENT – CHECKLIST CROSS-SECTIONAL STUDIES

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3,4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3,4
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	-
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4,5, Supp 2
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	5,6
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7, Fig 1
		(b) Give reasons for non-participation at each stage	6, 7
		(c) Consider use of a flow diagram	Fig 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	7
		(b) Indicate number of participants with missing data for each variable of interest	6, Supp 2

Outcome data	15*	Report numbers of outcome events or summary measures	7, 8
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7, 8
		(*b*) Report category boundaries when continuous variables were categorized	-
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	-
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	8, 9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9, 10
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10
Generalisability	21	Discuss the generalisability (external validity) of the study results	10
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

SUPPLEMENTARY FILE 2 – CONSTRUCTION OF (IN)DEPENDENT VARIABLES AND THEIR MISSING VALUES

Overview of variables with corresponding questions from the Ghana Maternal Health Surveys (GMHS) 2007 and 2017, collapsing of categories and missing values

Study groups

Women with stillbirth

In GMHS 2007, women with stillbirth in their most recent birth were identified in the *women's file* using variables Q220C$01-16 (computed birth status). Q220C was used instead of Q220 (birth status as circled by the interviewer), as it accounted for Q221 ("Did that baby cry, move or breathe when it was born?"), Q230 ("How many months did this pregnancy last?") and the presence of absence of sections 3, 4 and 5 of the questionnaire. In some cases, this led to recoding of pregnancy outcome. Q220C number 01 to 16 were manually scanned for a 1 (indicating born alive) or a 2 (indicating born death), and the highest birth order was selected as this represented the most recent birth.

In GMHS 2017, women with stillbirth in their most recent birth were identified in the *birth file* using variable PREGOUT (pregnancy outcome); a variable created by DHS combining Q212C ("Was the baby born alive or born dead, or did you have a miscarriage or abortion?"), Q 212D ("Did that baby cry, move or breathe when it was born?) and Q220AC ("How many months did this pregnancy last?"). Variable Q403 (line number) indicated whether the birth was the most recent live or stillbirth.

Women with very early neonatal death

In GMHS 2007, women with very early neonatal death, a baby not surviving the first day of life, were identified in the *women's file* using Q220C$01-16 (computed birth status) (see *women with stillbirth*). When birth status indicated live birth, age at death was computed from Q227U$01-16 (Age at death (units)) indicating days/months/years, and Q227N$01-16 (Age at death (number)) indicating the number of units. Women saying their child age of death was 0 days were included.

In GMHS 2017, women with very early neonatal death were identified in the *birth file* using variable Q220U (Age of death (units)) indicating days/months/years and Q220N (Age of death (number)), indicating the number of units. Women saying their child age of death was 0 days were included.

Women with livebirth who survived the first day of life

In GMHS 2007, women with a liveborn surviving the first day of life were identified using Q503 (line number) to indicate all most recent births ending in live or stillbirth. The earlier identified women with stillbirth or very early neonatal death were subtracted.

In GMHS 2017, women with a liveborn surviving the first day of life were identified using Q403 (line number) to indicate all most recent births ending in live or stillbirth. The earlier identified women with stillbirth or very early neonatal death were subtracted.

Dependent variable

Caesarean section

Constructed with variables Q542 (delivery by caesarean section) in GMHS 2007 and Q433A (delivery by caesarean section) in GMHS 2017.

Missing values: in GMHS 2007, 14 out of 5,088 women had missing values for mode of birth. In GMHS 2017, three out of 12,077 women had missing values for mode of birth.

Handling of missing values: women with missing values for caesarean section were excluded from analyses.

Independent variables

Ethnicity

Constructed with variables Q112 (ethnicity) in 2007, and Q123 (ethnicity) in 2017. Original categories were merged to create larger groups (see table S1).

Missing values: In GMHS 2007, two women (<0.1%) had missing values for Q112.

Handling missing values: women with missing values for ethnicity were categorized as 'other'.

Region

Constructed with variables QREGION in GMHS 2007 and 2017. Original categories were merged to create larger groups (see table S1).

Missing values: there were no missing values.

Place of residence

Constructed with variables QURBRUR (urban/rural) in GMHS 2007 and QTYPE (urban/rural) in GMHS 2017.

Missing values: there were no missing values.

Household's wealth index

Constructed with variables QHWLTHI (wealth index quintile) in GMHS 2007 and 2017. Extracted from household database. Original categories were merged to create larger groups (see table S1).

Missing values: there were no missing values.

Exposure to mass media

Constructed with variables Q108 (reads newspaper), Q109 (listens to radio), Q110 (watches television) in GMHS 2007 and 2017. Variables were combined, where no exposure to mass media at least once a week meant women were classified as 'little exposed', exposure to one out of three mass media once a week as 'moderately exposed' and those exposed to more than one mass medium once a week were classified as 'highly exposed'.

Missing values: in GMHS 2007, 24 (0.5%) women had missing values: 11 for Q108, 5 for Q109 and 8 for Q110. In GMHS 2017

Handling of missing values: missing values in 2007 were categorized with help of variables QH13A (electricity), QH13B (radio), QH13C (television) and Q106 (highest educational level). Women with missing values for Q108 were considered to read a newspaper at least once a week when educational level was secondary or higher. Women with missing values for Q109 and Q110 were considered to listen to radio or watch television at least once a week when having electricity and a radio or television.

Maternal age during birth of last child

Constructed with variables Q103C (woman, individual file) and Q224C$01-16 (child, individual file) in GMHS 2007, Q215C (CMC child, birth file) and Q105C (CMC woman, individual file) in GMHS 2017

Century month codes (CMC) were used. The CMC of women's date of birth was subtracted from date of birth of child and divided by twelve. In 2007, Q503 (line number of last live or stillbirth) was used to select the correlating child's CMC from Q224C$01-16.

Missing values: there were no missing values.

Religion

Constructed with variables Q111 (religion) in GMHS 2007, and Q122 (religion) in GMHS 2017. Original categories were merged to create larger groups (see table S1).

Missing values: in GMHS 2007, three women (0.1%) had missing values for Q111.

Handling of missing values: women with missing values for religion were categorized as 'other' (see table S2 and S3).

Marital status

Constructed with variables Q701 (currently in union), Q702 (ever married or lived together) and Q703 (current marital status) in GMHS 2007 and 2017.

Missing values: there were no missing values.

Maternal educational status

Constructed with variables Q105 (ever attended school) and Q106 (highest educational level) in GMHS 2007, and Q107 (ever attended school) and Q108 (highest educational level) in GMHS 2017. Original categories were merged to create larger groups (see table S1).

Missing values: in GMHS 2007, one woman (<0.1%) had a missing value for Q105.

Handling of missing values: one woman with a missing value for Q105 was categorized as having 'no education' based on Q601$01-14 (not having heard of 12 out of 13 contraceptive methods) and Q108 (not reading newspaper) (see table S2 and S3).

Parity

Constructed with variables Q214 (total number of pregnancies), Q209 (number of miscarriages) and Q211 (number of abortions) in GMHS 2007, and Q207F (number of stillbirths) and Q208A (number of live births) in GMHS 2017.

In GMHS 2007, Q209 and Q214 were subtracted from Q211 to provide the number of pregnancies ending in live and stillbirths. In GMHS 2017, Q207F and Q208A were summed up. The index pregnancy was not included in the parity number.

Missing values: there were no missing values.

History of perinatal death

Constructed with variables Q213 (number of stillbirths), Q220C$01-16 (computed birth status), Q227U$01-16, Q227N$01-16 and Q503 (line number) in GMHS 2007, and PREGOUT (pregnancy outcome) Q427 (weighed at birth), Q220U (unit of age of death) and Q220N (number of age of death) in GMHS 2017

History of perinatal death was defined as having a stillbirth (loss of a pregnancy after 7 months of pregnancy and prior to birth) or early neonatal death (death of a child in 7 days after birth) prior to the most recent birth.

For prior stillbirths in GMHS 2007, Q213 was used. When it was more than one, women were considered to have a history of stillbirth. When Q213 counted one, the most recent birth outcome had to be inspected (see *study groups, women with stillbirth* above) to see whether this considered the index pregnancy, and, therefore, should not be considered as history. For prior early neonatal death, Q227U/N$01-16 were used. Every death within one week after birth (Q227U=1 and Q227N<7) was selected, using 'sort ascending/descending' command in SPSS. The line number of the death was compared to Q503 and excluded when similar so that the index pregnancy was not included as history.

For prior stillbirths in 2017, Q207F was used. When Q207F was more than one, women were considered to have a history of stillbirth. When it was one, PREGOUT was used to see whether the index pregnancy ended in stillbirth, and, therefor should not be considered as history. For prior early neonatal death, the birth file was used. All live births dying within one week (Q220U=1 and Q220U<7) were selected and births with maternity

care data available would be excluded. A variable was created, indicating early neonatal death. Subsequently, the birth file was merged with the women's file.

Missing values: there were no missing values.

Multiple gestation

Constructed with variables Q219$01-16 (single or multiple birth) and Q503 (line number of last live or stillbirth) in GMHS 2007, and Q212B (single or multiple birth) in GMHS 2017.

In GMHS 2007 individual file, multiple birth were selected from Q219 using 'sort ascending/descending' command in SPSS. A new variable was created, wherein the line number of multiple births were compared with Q503 and coded 1=multiple birth if they were identical.

In GMHS 2017, Q212B was used from the birth file and merged with the individual file.

Missing values: there were no missing values.

Peripartum complications, prolonged or obstructed labour and reduced fetal movements.

Peripartum complications – problems just before, during or after giving birth – were documented as string variables, so women could choose more than one available answer: Q530 (problems just before, during or after delivery) in GMHS 2007, and Q431C (suffered from any problem before/after delivery) Q431D (problems suffered before/after delivery) in GMHS 2017. To include women who had more than one complication during their last pregnancy, several dummy variables (0=no, 1=yes) were created: any peripartum complication, hypertensive disorder of pregnancy, peripartum bleeding, peripartum infection, prolonged or obstructed labour and reduced fetal movements.

Women with any string value other than P (no problem) in GMHS 2007 and any string value in GMHS 2017 were considered to have had a complication, and were categorized as such.

Women with string values including a J (prolonged labour), K (obstructed labour) or O (fistula) were categorized as having reported prolonged or obstructed labour.

Women with string values including a H (baby's movement was low) were categorized as having reduced fetal movements.

Missing values: in GMHS 2007, one woman (<0.1%) had missing values for Q530.

Handling of missing values: women were categorised based on Q509 in GMHS 2007 or Q411 in GMHS 2017 (problems when first receiving antenatal care). If data were not available, they were categorized as not having had peripartum complications

Number of antenatal visits

Constructed with variables Q512 (antenatal visits during pregnancy) in 2007, and Q405 (received antenatal care for pregnancy) and Q412 (antenatal visits during pregnancy) in 2017.

Missing values: in GMHS 2007, four women (0.1%) had missing values and 21 women (0.4%) chose *don't know* for Q512. In GMHS 2017, 25 women (0.2%) chose *don't know* for Q 412.

Handling of missing values: women who had received antenatal care (Q405=1), but did not know the number of visits (Q512/Q412=98) or had missing values, were categorized as having 1 – 3 antenatal care visits.

Antenatal care quality score

Constructed with variables Q513A (weight), Q513B (blood pressure), Q513C (urine sample), Q513D (blood sample), Q514 (signs of complications), Q515 (sources of care for complications), Q516 (tetanus injection), Q523 (iron tablet), Q525 (anthelmintic) in GMHS 2007, and Q413A (weight) , Q413B (blood pressure), Q413C

(urine sample), Q413D (blood sample), Q413E (signs of complications), Q413F (sources of care for complications), Q414 (tetanus injection), Q420 (iron tablet) and Q422 (anthelmintic) in GMHS 2017.

Variables were coded as dummy variables (0=No, 1=Yes), and summed up to provide a score of 0 – 9.

Missing values: in GMHS 2007, 44 women (0.9%) had missing values for components of antenatal care quality score. In GMHS 2017, 350 women (2.9%) had missing values for components of antenatal care quality score.

Handling of missing values: women not knowing if they received above mentioned antenatal services or having missed values, were considered as not having received a service (see table S2 and S3).

Birth attendant

Constructed with string variable Q526 (assistance at delivery) in GMHS 2007, and Q429 (assistance at delivery) in GMHS 2017.

For GMHS 2007, string variables where recoded into categorical variables: doctor, nurse, other. If string values included assistants from separate categories, the category with the lowest number was selected. For instance, if a doctor and nurse were said to have assisted, the woman would be categorized as having been assisted by a doctor.

Missing values: in GMHS 2007, 9 women (0.2%) had missing values for Q526.

Handing of missing values: women with missing values for birth attendant were categorized according to Q527 (place of birth) and Q542 (caesarean section) in 2007. If women gave birth in a private facility or by caesarean section, they were categorized as being assisted by a doctor. If they gave birth in a public facility, they were categorized as being assisted by a nurse. If women gave birth at home, they were categorized as being assisted by 'other' (see table S2 and S3).

Table S1. Collapsed independent variables; their question, original and merged categories and reference category. GMHS 2007 and 2017

* = option only available in GMHS 2017

Variable	Question	Original categories	Collapsed categories	Reference
Ethnicity	*"To which ethnic group do you belong?"*	Akan Ga/Dangme Ewe Guan Mole-Dagbani Grussi Gruma Hausa Other	Akan Ga/Dangme Ewe Mole-Dagbani Other	Akan
Region	Based on location of survey	Western Central Greater Accra Volta Eastern Ashanti Brong Ahafo Northern Upper East Upper West	Coastal (Western, Central, Greater Accra, Volta) Middle (Eastern, Ashanti, Brong Ahafo) Northern (Northern, Upper East, Upper West)	Coastal
Household's wealth status	Composite measure of a household's cumulative living standard	Lowest Second Middle Fourth Highest	Poor (Lowest, Second) Middle Rich (Fourth, Highest)	Poor
Religion	*"What is your religion?"*	Catholic Protestant Methodist Presbyterian Pentacostal Other Christian Muslim Traditional/spiritualist No religion	Christian (Catholic, Protestant, Methodist, Presbyterian, Pentacostal, Other Christian) Muslim Other (traditional/spiritualist, no religion)	Christian
Marital status	Several questions regarding current or previous marriages	Currently married Living together Widowed Divorced Separated Not in union	Together (currently married, living together) Not together (widowed, divorced, separated, not in union)	Together
Maternal education	*"What is the highest level of school you attended?"*	None Primary Middle JSS/JHS* Secondary SSS/SHS* Higher	None Primary Middle, JSS/JHS Secondary, SSS/SHS, higher	None

Table S2. Missing values in GMHS 2007

Independent variables	**Number of missing values or *don't know* responses (N=5,064)**	**%**
Ethnicity	Missing 2	<0.1
Region	0	
Place of residence	0	
Household's wealth index	0	
Exposure to mass media	Missing 24	0.5
- Radio	Missing 11	0.2
- Television	Missing 5	0.1
- Newspaper	Missing 8	0.2
Maternal age during birth of last child	0	
Religion	Missing 3	0.1
Marital status	0	
Maternal educational status	1	<0.1
- Ever attended school	1	<0.1
- Highest educational level	0	
Parity	0	
History of perinatal death	0	
Multiple gestation	0	
Peripartum complications	1	<0.1
Number of antenatal visits	Missing 4, *don't know* 21	0.1, 0.4
Antenatal quality score	Missing 44	0.9
- Blood pressure	0	
- Urine Sample	Missing 1	<0.1
- Blood sample	Missing 2	<0.1
- Weight	0	
- Complications	0	
- Where to go	Missing 2	<0.1
- Tetanus	0	
- Iron tablets	0	
- Drugs for intestinal parasites	Missing 40	0.8
Birth attendant	Missing 9	0.2

Table S3. Missing values in GMHS 2017

Independent variables	**Number of missing values or *don't know* responses (N=12,074)**	**%**
Ethnicity	0	
Region	0	
Place of residence	0	
Household's wealth index	0	
Exposure to mass media	0	
- Radio	0	
- Television	0	
- Newspaper	0	
Maternal age during birth of last child	0	
Religion	0	
Marital status	0	
Maternal educational status	0	
Parity	0	
History of perinatal death	0	
Multiple gestation	0	
Peripartum complications	0	
- Suffered from any problem?	0	
- Which problem?	0	
Number of antenatal visits	Missing 25	0.2
- Received antenatal care	0	
- How many visits	*Don't know* 25	
Antenatal quality score	350	2.9
- Blood pressure	0	
- Urine Sample	0	
- Blood sample	0	
- Weight	0	
- Complications	*Don't know* 23	0.2
- Where to go	*Don't know* 1	<0.1
- Tetanus	*Don't know* 49	0.4
- Iron tablets	*Don't know* 15	0.1
- Drugs for intestinal parasites	*Don't know* 319	2.6
Birth attendant	0	

SUPPLEMENTARY FILE 3 – DHS data weight de-normalization and pooling. GMHS 2007 and 2017

DHS applies sample weights to adjust for disproportionate sampling and non-responders. Individual weights are "normalized" to make the total number of unweighted cases equal to the total number of weighted cases on a national level.(1) Sample weights are normalized by dividing each individual weight by the ratio of the sum of all weights to the size of the sample:

$$NSw = DSw / (\Sigma (Dsw) / Snumber)$$

NSw is the normalized sample weight
DSw is the de-normalized or original sample weight
Σ (Dsw) is the sum of all original sample weights or the size of the reference population.
Snumber is the number of women in the sample

When pooling data from the Ghana Maternal Health Surveys (GMHS) 2007 and 2017, we decided to de-normalize sample weights prior to combining datasets, to account for the difference in population size in 2007 and 2017. To de-normalize weights, individual sample weights were divided by the sampling fraction. We calculated the sampling fraction by dividing the study sample of women aged 15 – 49 years by the total population of women aged 15 – 49 years in Ghana, for each study separately. To estimate the total number of Ghanian women aged 15 – 49 years during the study period, we used population size data from The World Bank. The total population was multiplied with the fraction of the total population of women aged 15 - 49 years, as provided by the GMHS study reports. (2, 3) The following equation was used:

$$Sf = Ti / (Tp \times Fp)$$

Sf is the sampling fraction
Ti is the number of interviewed women aged 15-49 years in GMHS
Tp is the total de facto population of woman
Fp is the fraction of the total population of women aged 15-49 years.

In GMHS 2007, Ti was 10,370.(2) Tp was 11,385,621.(4) Fp was 45,2%.(2) This provided a Sf of 0.00201503966.

In GMHS 2017, Ti was 25,304.(3) Tp was 14,366,665.(4) Fp was 47,2%.(3) This provided a Sf of 0.00373156675.

Pooling of data from GMHS 2007 and 2017 provides a unweighted sample size of 17,138 women who had given birth. De-normalized weights of individual women were normalized once again, multiplying each individual weight by 17,138 and subsequently divided by the sum of all individual weights combined: 5,698,422.46. Applying This gave provided a normalized sample size of 17,138 women: 7,819 in 2007 and 9,319 in 2017.

[1]. Ren R. Note on DHS standard weight de-normalization. Source: https://userforum.dhsprogram.com. Accessed: 16-10-2022
[2]. Ghana Statistical Service (GSS), Ghana Health Service (GHS), and Macro International. 2009. Ghana Maternal Health Survey 2007. Calverton, Maryland, USA: GSS, GHS, and Macro International.
[3]. Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF. 2018. Ghana Maternal Health Survey 2017. Accra, Ghana: GSS, GHS, and ICF.
[4]. World Bank Data. Population, female - Ghana. World Development Indicators. World Bank Group. 2019. [cited 2022 17-5-2022]; Available from: https://data.worldbank.org/indicator/SP.POP.TOTL.FE.IN?locations=GH

SUPPLEMENTARY FILE 4 – Subgroup analysis: women with stillbirths (N=290)

Similar to women with SBVEND, a subgroup analysis was performed in women with stillbirths. Women with very early neonatal deaths were excluded from bivariate and multivariable logistic regression.

Bivariate logistic regressions provided crude odds ratios (cOR) for each independent variables' category compared to a reference category. If five or fewer women per cell were observed, categories were collapsed.

Subsequently, multivariable logistic regression was used to identify risk factors for CS in women with stillbirth. The multivariable analysis included independent variables based on statistical significance in bivariate logistic regression. Instead of p-values below 0.05, variables with Wald F tests' p-values below 0.25 in bivariate analysis were considered statistically significant. Pearson correlations above 0.8 or Variance Inflation Factors higher than 4 were used to detect collinearity.

The following independent variables were included: residence, wealth index, exposure to mass media, religion, current marital status, educational status, multiple pregnancy, number of antenatal visits, antenatal care quality score, presence of peripartum complications and prolonged or obstructed labour. To reduce overfitting, we used backward elimination based on p-values to include six independent variables in the final model, having a minimum of ten caesarean sections per included variable. Adjusted ORs were provided (aOR). In bivariate and multivariable analyses, independent variables with an OR having a CI not containing the value 1 were considered statistically significant.

To assess effect modification by birth outcome (stillbirth or live birth) of household's wealth quintiles and maternal educational level on CS rates, we compared cORs using multivariable logistic regression with interaction terms. cORs were calculated for both independent variables' categories compared to a reference category in women with live births who survived the first day. These cORs were compared to cORs in women with live births using multivariable logistic regression with interaction terms. Adjusted ORs were provided as an effect size. Wald F tests of model effects were performed and p-values below 0.05 indicated statistical significance.

Bivariate and multivariable logistic regression of variables associated with caesarean section in women with stillbirth (N=290)(weighted). Ghana Maternal Health Survey 2007 and 2017

CS = caesarean section, VB = vaginal birth, OR = crude odds ratio, aOR = adjusted odds ratio, CI = confidence interval

* Factors associated with CS in women having stillbirths and very early neonatal deaths with a Wald F-test p-value <0.25

	Stillbirths (N=290)			
	CS (N=63)	VB (N=227)	OR (95% CI)	aOR (95% CI)
Year of survey				
2007	24	106	1	
2017	39	121	1.4 (0.7 – 3.0)	
Ethnicity				
Akan	37	126	1	
Ewe	7	24	1.0 (0.3 – 3.0)	
Mole-Dagbani	7	31	0.8 (0.3 – 2.2)	
Other	12	46	0.9 (0.3 – 2.3)	
Region				
Coastal	26	68	1	
Middle	29	129	0.6 (0.3 – 1.3)	
Northern	7	30	0.6 (0.2 – 1.7)	
Residence*				
Rural	25	120	1	
Urban	37	108	1.6 (0.8 – 3.4)	
Household's wealth index*				
Poor	13	96	1	
Middle	15	46	2.4 (1.0 – 5.7)	
Rich	34	86	2.9 (1.2 – 7.0)	
Exposure to mass media*				
Little exposed	7	42	1	1
Moderately exposed	19	101	1.2 (0.4 – 3.3)	1.4 (0.4 – 4.2)
Highly exposed	37	84	2.8 (1.1 – 7.5)	2.5 (0.8 – 7.3)
Maternal age				
<35	44	149	1	
≥35	19	79	0.8 (0.4 – 1.7)	
Religion*				
Christian	43	188	1	1
Muslim, other religions, areligious	19	50	1.6 (0.8 – 3.4)	2.5 (1.0 – 6.5)
Current marital status*				
Married or living together	51	180	1	1
Not married or living together	12	47	0.9 (0.4 – 2.1)	0.4 (0.2 – 1.2)
Maternal educational status*				
None	8	57	1	1
Primary	15	44	2.3 (0.8 – 7.0)	2.9 (0.9 – 9.9)
Middle	25	99	1.8 (0.8 – 4.2)	2.3 (0.7 – 7.3)
Secondary or higher	14	28	3.6 (1.2 – 10.5)	4.1 (1.1 – 15.4)
Parity				
0	9	58	1	
1-4	35	113	2.0 (0.8 – 4.9)	
≥5	19	57	2.2 (0.8 – 6.0)	
History of perinatal death				
No	51	189	1	
Yes	12	38	1.2 (0.5 – 2.9)	
Multiple pregnancy*				
No	51	208	1	1
Yes	12	19	2.5 (0.9 – 6.8)	3.6 (1.6 – 8.4)
Number of antenatal visits*				
<4	6	67	1	1
≥4	57	160	3.9 (1.2 – 13.2)	3.9 (1.3 – 11.8)
Antenatal care quality score*				
Low (0-7)	16	98	1	
High (8-9)	47	129	2.2 (1.0 – 4.6)	
Peripartum complications*				
No	30	136	1	
Yes	33	91	1.6 (0.8 – 3.3)	
Prolonged or obstructed labour*				
No	51	208	1	
Yes	11	19	2.3 (0.8 – 6.4)	

Reduced fetal movements				
No	56	213	1	
Yes	7	14	1.9 (0.5 – 6.8)	

Multivariable logistic regression with interaction terms assessing effect modification by birth outcome of household's wealth status and maternal educational level on caesarean section rates (N=17.138)(weighted). Ghana Maternal Health Survey 2007 and 2017

CS = caesarean section, VB = vaginal birth, OR = crude odds ratio, aOR = adjusted odds ratio, CI = confidence interval
***** Wald F p-value serving as a measure of statistical significance. P-value <0.05 is considered statistically significant.
****** aOR and 95% confidence intervals serve as a measure of effect size of effect modification by birth outcome.

	Stillbirths (N=290)			**Live births (N=16,848)**			
	CS (N=63)	VB (N=227)	OR (95% CI)	CS (N=1,626)	VB (N=15,222)	OR (95% CI)	Wald F* and aOR (95% CI)**
Household's wealth index							0.36
Poor	13	96	1	346	6,873	1	
Middle	15	46	2.4 (1.0 – 5.7)	268	3,116	1.7 (1.4 – 2.1)	1.4 (0.6 – 3.4)
Rich	34	86	2.9 (1.2 – 7.0)	1,012	5,233	3.8 (3.3 – 4.5)	0.8 (0.3 – 1.8)
Maternal educational status							0.53
None	8	57	1	223	4,610	1	
Primary	15	44	2.3 (0.8 – 7.0)	252	3,071	1.7 (1.3 – 2.2)	1.4 (0.6 – 3.5)
Middle	25	99	1.8 (0.8 – 4.2)	710	5,736	2.6 (2.1 – 3.1)	0.7 (0.2 – 2.2)
Secondary or higher	14	28	3.6 (1.2 – 10.5)	441	1,805	5.0 (4.1 – 6.3)	1.4 (0.5 – 4.2)

SUPPLEMENTARY FILE 5 – Author reflexivity statement

Structured reflexivity statement to be completed with manuscript submissions from international research partnerships involving researchers from high- and low-to-middle-income countries.[1] This describes 15 questions that should be addressed by corresponding authors on behalf of an international research partnership. The questions are intentionally open-ended and designed to address specific components of equitable research partnership. It may be that not all questions can be addressed (e.g. a small project with minimal or no funding) but researchers should be able to describe individual components that they have considered when developing their partnership.

Q1. How does this study address local research and policy priorities?

Caesarean section (CS) rates are an important indicator of the quality of maternity care, but only include women with live births in the denominator.[2] National CS rates in low- and middle-income countries are derived from the Demographic Health Survey (DHS), a population-based household survey, which, prior to 2022, did not capture mode of birth data for women reporting stillbirths. The Ghana Maternal Health Survey (GMHS) 2007 and 2017 are two of the few population-based surveys capturing maternity care data for women with stillbirths.[3, 4] The GMHS were intended to serve as a source of data on maternal health and death for policymakers and the research community.

We performed a secondary analysis of GMHS data to unveil CS rates in women experiencing stillbirth and the associated factors. Analyses were done with the help of co-author TB, consultant obstetrician gynaecologist at the Korle-Bu Teaching Hospital in Accra, who, at the time, was finalizing his PhD at the Julius Centre in Utrecht, the Netherlands.[5]

As CS is generally contra-indicated in women with stillbirth, our findings may inform policy-makers on where and why these CS happen, and aid in intervention development to improve accessibility to and timely use of CS. This is in alignment with the Sustainable Development Goals 3.1 and 3.2 supported by the Ghanian government.

Q2. How were local researchers involved in study design?

This study was a secondary analysis of data obtained from the DHS program.[6] Data collection for the GMHS was done as a collaborative effort between the Ghana Statistical Service (GSS), Ghana Health Service of the Ministry of Health and the DHS program, using local interviewers and supervisors and provide their training. For a detailed description of the data collection methods, see the GMHS reports. [3,4]

Q3. How has funding been used to support the local research team(s)?

As our study was a secondary analysis of GMHS data, no funding has been used to support local research teams. The DHS program is funded by United States Agency for International Development.

Q4. How are research staff who conducted data collection acknowledged?

The research staff working on GMHS 2007 and 2017 have been acknowledged in the “Acknowledgements” section of our manuscript.

Q5. How have members of the research partnership been provided with access to study data?

GMHS data are already made publicly available by the Ghana Statistical Service. [5] All members of the research partnership had access to these data.

Q6. How were data used to develop analytical skills within the partnership?

Data analysis was conducted by the primary author (SZ). He received formal training on DHS data analysis and interpretation from co-authors AC and LB.

Q7. How have research partners collaborated in interpreting study data?

GMHS data and findings were reviewed and discussed among all authors through in person discussions and by email. SZ, AC and LB worked on the manuscript during the "Write your paper based on Demographic and Health Survey (DHS) data on reproductive and child health" course on DHS data analysis at the Institute of Tropical Medicine in Antwerp, Belgium. TB provided critical insights related to interpretation of findings for the Ghanian context, such as interpretation of regional differences in CS rates and its associated factors, and to develop feasible recommendations. The DHS program has provided approval for use of GMHS data, but did not collaborate in data interpretation.

Q8. How were research partners supported to develop writing skills?

Within the research team, senior academic co-authors (LB, JR, TA) supported SZ by providing several rounds of feedback to develop and refine writing skills.

Q9. How will research products be shared to address local needs?

The study will be published as open access and shared with the DHS Program. Findings will be discussed at Korle Bu teaching hospital in Ghana among obstetrics & gynaecology residents and staff members, and presented to the Ghana Medical Association.

Q10. How is the leadership, contribution and ownership of this work by LMIC researchers recognised within the authorship?

The leadership, contribution, and ownership of this work by LMIC researchers is acknowledged through the 4th author (TB) within the authorship. TB provided critical interpretation of results in the context of Ghana, which is acknowledged in the contributor statement in the manuscript.

Q11. How have early career researchers across the partnership been included within the authorship team?

The first (SZ), second (AC) and third author (TB) are early career researchers. SC is a predoctoral researcher, while AC and TB are postdoctoral researchers.

Q12. How has gender balance been addressed within the authorship?

Two authors identify as female and four authors as male.

Q13. How has the project contributed to training of LMIC researchers?

The DHS program provided training for interviewers and supervisors as preparation for data collection. Our secondary analysis did not implement training for LMIC researchers.

Q14. How has the project contributed to improvements in local infrastructure?

The project has not directly contributed to an improved infrastructure.

Q15. What safeguarding procedures were used to protect local study participants and researchers?

We used secondary anonymized data which have gone through rigorous procedures for data collection and quality. We abided by the DHS program stipulations on data storage and reporting.

During data collection through the DHS program, data were anonymous and stored on a password-protected computer in the GSS central office. DHS interviewers were trained prior to and supervised during data collection. Approval to use DHS data is granted by the DHS program after an application had been reviewed.

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