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RESEARCH ARTICLE

Trends and determinants of preterm birth and neonatal mortality in Ghana (2008–2022): a WHO antenatal care guidelines analysis

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ABSTRACT

Background: Preterm birth and neonatal mortality continue to pose significant public health challenges in Ghana. This study explores their temporal trends and associated determinants from 2008 to 2022.

Methods: Birth record data from the Ghana Demographic and Health Surveys (2008, 2014, and 2022) were used to analyse trends and determinants in neonatal mortality and preterm birth aligned with World Health Organization antenatal care (ANC) guidelines using Pearson's Chi-square test and multivariate logistic regression with statistical significance at $P < 0.05$ and 95 % confidence intervals (*CI*).

Results: Preterm birth rate and neonatal mortality rate decreased from 13.0 % to 9.1 % and 27.6 to 23.7 per 1000 live births from 2008 to 2022 respectively. Lack of iron supplementation (odds ratio [*OR*]1.127, 95 % *CI*: 1.047 to 1.967) a nutritional intervention maternal assessments (moderate/severe anaemia (*OR* 1.423, 95 % *CI*: 1.178 to 2.051), preventive measures (Untreated malaria (*OR* 1.449, 95 % *CI*: 1.104 to 2.411) or deworming (*OR* 1.267, 95 % *CI*: 0.970 to 1.645) were associated with increased preterm birth risk. Attending < 8 ANC visits raised the odds of preterm birth (*OR* 1.24, 95 % *CI*: 1.03 to 1.257) and neonatal mortality (*OR* 1.583, 95 % *CI*: 1.120 to 2.480).

Conclusion: Despite reductions in preterm birth and neonatal mortality rates, substantial gaps in antenatal care remain. Strengthening the implementation of World Health Organization ANC guidelines is critical to reducing preterm birth and neonatal mortality in Ghana.

1. Introduction

1.1. Burden of adverse birth outcomes

Adverse birth outcomes, including preterm birth and neonatal mortality, remain critical public health concerns in Ghana and across sub-Saharan Africa.[1] These conditions contribute substantially to neonatal morbidity and mortality, with sub-Saharan Africa accounting for 65 % of all global preterm births and approximately 41 % of neonatal deaths in 2020.[2] In Ghana, despite ongoing maternal and newborn health interventions, neonatal mortality continues to be unacceptably high, with a reported prevalence of 18 deaths per 1000 live births in 2017.[3,4] Preterm birth that leads to immature organ systems, impaired immune responses, and metabolic instability, is associated with long-term neurological and developmental complications.[5] Antenatal care (ANC) plays a pivotal role in improving birth outcomes by providing timely assessments, preventive interventions, and essential support services throughout pregnancy.

1.2. The world health organization (WHO) ANC guidelines and its relevance to Ghana

The 2016 WHO ANC guidelines recommends a holistic approach that includes five interrelated domains: (1) maternal nutrition; (2) maternal and foetal assessment; (3) disease prevention; (4) management of common pregnancy symptoms; and (5) health system interventions to enhance care quality and utilization.[6,7] Adherence to this guidelines is crucial in preventing complications that lead to preterm birth and neonatal mortality, particularly in low-resource settings.[8–10]

Maternal nutrition is widely recognized as a critical determinant of healthy pregnancy outcomes.[11] The nutritional status of the foetus primarily depends on the mother's dietary intake, and it has long been rec-

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ognized that deficiencies in essential nutrients can result in congenital malformations and adverse health outcomes for both the mother and her child. Therefore, maternal undernutrition can lead to restricted foetal growth, heightening the likelihood of neonatal mortality and, among surviving infants, increasing the risk of stunted growth by the age of two.[12]

Furthermore, excess body weight increases the likelihood of complications such as gestational diabetes, delivering large-for-gestational-age infants, and preeclampsia. Therefore, it is important for women who are overweight, obese, or diabetic to consume diets rich in vegetables, polyunsaturated and essential fats, and fiber-containing carbohydrates. Ensuring sufficient intake of key micronutrients, including iron, calcium, folate, vitamin D, and carotenoids, is also vital for supporting both pregnancy and lactation.[13,14]

Maternal and foetal assessment plays an important role in early detection and prevention of pregnancy related complications. Screening and monitoring during pregnancy are essential approaches employed by healthcare professionals to detect high-risk pregnancies, such as those involving gestational diabetes, preeclampsia, foetal growth restriction, or congenital anomalies. These strategies enable timely, targeted interventions and tailored follow-up care, while also supporting the continuous assessment of foetal well-being in both low- and high-risk cases.[15–17]

Disease prevention during pregnancy is essential to safeguarding the health and wellbeing of both the mother and the developing foetus. It helps minimize the risk of complications that can lead to adverse pregnancy outcomes, including preterm birth, low birth weight, congenital anomalies, maternal morbidity, and mortality. Avoiding infectious diseases,[18] having tetanus toxoids,[19] prevention therapies to malaria, urinary tract infections prevention[20] are identified as major preventive methods.

Managing common physiological symptoms in pregnancy such as nausea, heartburn, constipation, and fatigue is essential to improve maternal comfort, ensure adequate nutrition, prevent complications, and support positive pregnancy outcomes.[21,22] It enhances the quality of antenatal care and promotes maternal wellbeing.

Health system interventions are vital for achieving positive pregnancy outcomes as they ensure timely access to quality antenatal care, skilled birth attendance, emergency obstetric services, and follow-up care. Strengthening health systems improves early detection and management of complications, promotes equitable service delivery, and supports the implementation of evidence-based guidelines ultimately reducing maternal and neonatal morbidity and mortality.[22] Adherence to the recommendations outlined in the 2016 WHO ANC guidelines plays a critical role in reducing the risk of adverse pregnancy outcomes.[23–27]

Despite its global relevance, and reported high prevalence of adverse birth outcome in Ghana, limited research has explored the implementation of this guidelines in Ghana and its effect on pregnancy outcomes.[28] Therefore, this study aims to provide a comprehensive analysis of the trends aligned with the 2016 WHO ANC guidelines in extreme preterm birth, and neonatal mortality in Ghana from 2008 to 2022, identifying key risk factors and healthcare gaps.

2. Methodology

2.1. Data source

Three birth-record datasets (2008, 2014, and 2022; comprising 2023 data) were obtained from the Ghana Demographic and Health Surveys (DHS), part of the global DHS Program, which provides open-access, nationally representative data. The Ghana DHS employs a two-stage stratified cluster sampling design based on the Ghana Population and Housing Census to ensure representativeness across urban and rural areas and administrative regions. Data are collected through face-to-face interviews using standardized questionnaires administered to women aged 15–49 years.

Each survey includes detailed information on maternal and child health, antenatal and postnatal care, fertility, family planning, nutrition, and household characteristics. For this study, variables related to antenatal care components, maternal health conditions, preventive interventions, and birth outcomes were extracted. To ensure comparability across the 2008, 2014, and 2022 surveys, variable definitions were harmonized using DHS recode manuals, and only indicators with consistent measurement and coding across all rounds were included in the analysis. These three survey years represent the most recent nationally representative datasets with complete maternal and neonatal health indicators; continuous annual data were not available, as the Ghana DHS is conducted periodically rather than annually.

Missing data were assessed for all variables, and those with > 50 % missingness were excluded for variables retained in the analysis, cases with missing values were removed using listwise deletion.

The dependent variable was constructed using information on the child's age at death, duration of pregnancy in completed months, month of pregnancy termination, and the child's survival status at the time of the survey. Based on these parameters, two major birth outcomes including preterm births (duration of pregnancy < 9 months) neonatal deaths (deaths occurring within the first month of life) were coded as 1 and 2 respectively and term or normal births were coded as 0. Independent variables were selected based on the 2016 WHO ANC guidelines and encompassed five key domains: (1) Nutritional interventions: provision of iron tablets or syrup during pregnancy was considered a key nutritional intervention. To assess dietary intake, foods commonly consumed by mothers were categorized into three groups: carbohydrate-rich foods (bread, rice, noodles, potatoes, pasta, yam, and cassava), protein-rich foods (eggs, beef, pork, chicken, lamb, fish, and shellfish), and vitamin-rich foods (papaya, mangoes, and other fruits). These classifications were based on self-reported consumption patterns recorded in the Ghana DHS food frequency module. (2) Maternal assessments, included blood pressure monitoring, blood testing, urine testing. Maternal anaemia status was categorised as mild, moderate, severe or not anaemic were also analysed under maternal assessments. (3) Using medication for malaria, tetanus toxoids, drugs for intestinal parasites were studied under preventive interventions. (4) As direct data on interventions for pregnancy symptoms such as vomiting, constipation, and muscle cramps were unavailable, receiving antenatal care or not was indirectly used as a proxy indicator for managing these common physiological symptoms including nausea, vomiting, constipation and bloating.[29] (5) Health system interventions encompassed antenatal care provided by government or private clinics and whether the number of antenatal visits exceeded eight or more.

Additionally, sociodemographic factors known to influence positive pregnancy outcomes were studied. Maternal age at first birth was categorized into two groups including adolescent mothers (10–19 years) and adult reproductive age mothers (20–40 years).

2.2. Data analysis

Descriptive statistics, including frequencies and percentage distributions, were applied to summarize the key sociodemographic characteristics of the women participating in the study. Data from Ghana DHS birth records were analysed at 3 time points—2008, 2014 and 2022. Thereby the improvement or adaptations of interventions were studies across the years to study the adaptation by participants. To examine the significances of adverse birth outcomes and the selected independent variables, Pearson's Chi-square test was utilized. Factors associated with preterm birth and neonatal mortality against normal births were studied using multivariate logistic regression analysis, we conducted multivariate logistic regression analysis using Stata (Multiprocessor version18.5). The outcome variable was the occurrence of preterm birth, a neonatal mortality or a normal birth recorded from 2008 to 2022. Therefore, Neonatal mortality rate and preterm birth rates were calculated.

Table 1
Selected pregnancy outcomes in Ghana, 2008, 2014, and 2022 [*n* (%)].

Selected pregnancy outcomes	2008	2014	2022	*P*
Preterm birth	1545 (13.0)	2774 (12.0)	3231 (9.1)	< 0.001
Neonatal deaths	356 (3.0)	670 (2.9)	842 (2.3)	
Normal birth	9986 (84.0)	19,674 (85.1)	31,815 (88.6)	
Total births included in the study	11,887	23,118	35,888	

Data are from the Ghana Demographic and Health Surveys conducted in 2008, 2014, and 2022. *P*-values represent the significance of temporal trends, assessed using chi-square tests. Birth outcomes were classified as preterm (births before 37 completed weeks of gestation), neonatal deaths (deaths within 28 days of birth), and normal births (term live births surviving beyond 28 days).

Predictor variables were selected based on the 2016 WHO ANC guidelines, encompassing domains such as maternal assessment, physiological symptom management, nutrition, and health system interventions. Fixed effects were reported as adjusted odds ratios with 95 % confidence intervals, and statistical significance was determined at $P < 0.05$. A univariate logistic regression analysis was first performed, and variables with $P < 0.20$ were included in the multivariable model to avoid excluding potentially important predictors. Variable selection also considered theoretical relevance to adverse birth outcomes based on prior literature. Missing data were examined for each variable, and cases with incomplete key covariates were excluded using listwise deletion, as the proportion of missing data was < 5 %. Model diagnostics were conducted to assess goodness-of-fit using the Hosmer–Lemeshow test and to evaluate multicollinearity using the variance inflation factor, with all values below 2, indicating no evidence of multicollinearity and ensuring model stability.

2.3. Ethics approval and consent to participate

The study used secondary data obtained from the DHS program. All DHS surveys are approved by the Institutional Review Board of informed consent form and by the relevant national ethics committees in participating countries. The data are anonymized before public release. Permission to use the dataset for this analysis was granted by the DHS Program. Therefore, no additional ethical approval or informed consent was required for this secondary data analysis.

3. Results

3.1. Adverse birth outcomes in Ghana

The preterm birth rate declined from 13.0 % in 2008 to 12.0 % in 2014, and further to 9.1 % in 2022. Similarly, the neonatal mortality rate per 1000 live births decreased from 27.6 in 2008, to 26.3 in 2014, and to 23.7 in 2022 as shown in Table 1.

Fig. 1 presents the regional distribution of birth outcomes in Ghana based on 2022 Demographic and Health Survey data, showing the proportion of normal deliveries, preterm births, and neonatal deaths across all 16 administrative regions. Notably, the newly created regions such as Oti, Savannah, and North East exhibit higher proportions of preterm births and neonatal deaths, reflecting persistent geographic disparities in maternal and neonatal health outcomes despite national progress.

3.2. Nutritional interventions

Iron supplementation was provided to 91 % of participants, indicating strong coverage of this intervention. While most women consumed protein-rich foods (> 90 %) and carbohydrate staples (99 %), 69.2 % reported no consumption of vitamin-rich fruits, reflecting poor dietary diversity during pregnancy.

3.3. Maternal assessments

The coverage of essential maternal assessments blood pressure monitoring, blood testing, and urine analysis increased significantly since 2008, reaching 98 % by 2022. Similarly, 99 % of women reported foetal assessments, including monitoring of movements and heartbeat. Additionally, 81.8 % were asked about vaginal bleeding and received breastfeeding counselling, while 89.9 % were advised on appropriate dietary practices. Smoking status was routinely assessed, with 99 % identified as non-smokers.

Despite high coverage, anaemia persisted as a concern. In 2022, 20 % of pregnant women were diagnosed with moderate to severe anaemia, which was significantly associated with adverse birth outcomes as shown in Table 2.

3.4. Preventive and therapeutic interventions

A significant increase in the provision of malaria prophylaxis was observed over time, with coverage rising from 53.5 % in 2008 to 89.8 % in 2022, reflecting substantial progress in implementing intermittent preventive treatment during pregnancy. This improvement likely reflects strengthened national malaria control strategies, integration of intermittent preventive treatment during pregnancy within routine ANC services, and expanded distribution of insecticide-treated nets. However, despite these gains, gaps remain in timely initiation and completion of the recommended number of doses, particularly among women in rural and low-education groups.

The treatment of intestinal parasites also improved from 37.4 % in 2008 to 54.1 % in 2022, indicating moderate progress in addressing helminth infections that contribute to maternal anaemia and poor fetal growth. Yet, the pace of improvement remains slow, suggesting limited awareness, stock availability, or underutilization of deworming services during ANC visits.

In contrast, tetanus vaccination coverage remained suboptimal, with 70.9 % of women in 2022 reporting receipt of no doses or only a single dose—below the WHO-recommended two-dose minimum during pregnancy. This persistent gap points to missed opportunities for preventive immunization within ANC programs and highlights the need for improved tracking and follow-up systems to ensure full immunization coverage.

3.5. Health system interventions

Most women (81.5 %) received ANC at government health centres, followed by 41.6 % at government hospitals, and only 4.9 % at polyclinics. Utilization of private hospitals, maternity homes, and community health services was minimal. Attendance at eight or more ANC visits increased from 24.3 % in 2014 to 35.1 % in 2022 yet remained below WHO targets.

Women attending fewer than eight visits were more likely to experience preterm birth and neonatal mortality, highlighting the importance of sustained ANC contact. The predominance of public-sector use and low uptake of community-based services suggest continued access disparities, particularly among rural populations. Analysis of sociodemo-

Table 2
Trends in the uptake of selected WHO antenatal care model recommendations and sociodemographic characteristics in 2008, 2014, and 2022 [*n* (%)].

WHO ANC guidelines	2008	2014	2022	*P*
Maternal nutrition				
Given iron tablets/syrup				< 0.001
Yes	312 (14.68)	356(8.44)	465 (8.91)	
No	1813 (85.32)	3914 (91.66)	4749 (91.09)	
Carbohydrate rich food consumption				< 0.001
Yes	–	–	34,323 (99.04)	
No	–	–	331 (0.96)	
Protein rich food consumption				< 0.001
Yes	–	–	32,394 (93.53)	
No	–	–	2239 (6.47)	
Consumed vitamin rich foods				< 0.001
Yes	–	–	10,673 (30.80)	
No	–	–	23,977 (69.20)	
Maternal assessments				
Blood sample taken during pregnancy				< 0.001
Yes	1830 (88.75)	4071 (97.79)	5036 (98.46)	
No	232 (11.25)	92 (2.21)	79 (1.54)	
Urine sample taken during pregnancy				< 0.001
Yes	1816 (88.08)	4012 (96.37)	5038 (98.50)	
No	246 (11.92)	151 (3.63)	77 (1.50)	
Blood pressure taken during pregnancy				< 0.001
Yes	2000 (97.00)	4101 (98.51)	5031 (98.40)	
No	62 (3.00)	62 (1.49)	82 (1.60)	
Anaemia level				< 0.001
Severe	287 (2.48)	45 (0.39)	182 (1.04)	
Moderate	2192 (18.94)	1014 (8.72)	3287 (18.84)	
Mild	4465 (38.59)	3701 (31.82)	3925 (22.49)	
Not anaemic	4625 (39.99)	6873 (59.09)	10,056 (57.63)	
Smokes cigarettes				< 0.001
Yes	31 (0.26)	8 (0.03)	242 (0.80)	
No	11,851 (99.74)	23,104 (99.97)	34,394 (99.20)	
Preventive and therapeutic measures				
Tetanus injection				< 0.001
0–1 injections	727 (77.84)	1234 (68.11)	2009 (70.93)	
≥ 2 injections	207 (22.16)	578 (31.89)	823 (29.07)	
Given drugs for intestinal parasites during pregnancy				< 0.001
Yes	766 (37.41)	1817 (43.58)	2836 (54.80)	
No	1282 (62.59)	2350 (56.42)	2341 (45.20)	
Given medicine for malaria during pregnancy				< 0.001
Yes	1117 (53.48)	3633 (85.13)	4680 (89.84)	
No	971 (46.52)	634 (14.87)	529 (10.16)	
Interventions for physiological symptoms				
Obtained support for physiological symptoms				< 0.001
Yes	1076 (52.35)	1901 (45.68)	2126 (41.58)	
No	980 (47.65)	2262 (54.32)	2989 (58.42)	
Health system interventions				
ANC from government hospitals				< 0.001
Yes	1067 (51.88)	1901 (45.68)	2126 (41.58)	
No	989 (48.12)	2262 (54.32)	2989 (58.42)	
ANC from government polyclinic				< 0.001
Yes	705 (34.30)	1699 (40.80)	248 (4.85)	
No	1351 (65.70)	2464 (59.20)	4867 (95.15)	
ANC from government health centre				< 0.001
Yes	114 (5.54)	326 (7.83)	945 (18.48)	
No	1942 (94.46)	3837 (92.17)	4170 (81.52)	
ANC from government clinic				< 0.001
Yes	10 (0.49)	6 (0.14)	688 (13.45)	
No	2046 (99.51)	4157 (99.86)	4427 (86.55)	
ANC from private hospital				< 0.001
Yes	171 (8.32)	329 (7.90)	283 (5.54)	
No	1885 (91.68)	3834 (92.10)	4832 (94.46)	
ANC from private clinic				< 0.001
Yes	8 (0.39)	1 (0.02)	120 (2.35)	
No	2048 (99.61)	4162 (99.98)	4995 (97.65)	
ANC from maternity home				< 0.001
Yes	5 (0.24)	11 (0.26)	40 (0.78)	
No	2051 (99.76)	4152 (99.74)	5075 (99.22)	
ANC from community health services				< 0.001
Yes	57 (2.77)	46 (1.10)	5 (0.10)	
No	1999 (97.23)	4117 (98.90)	5110 (99.90)	
Number of ANC visits				< 0.001
< 8 visits	1581 (75.69)	3040 (71.16)	3378 (64.89)	
≥ 8 visits	507 (24.31)	1232 (28.84)	1827 (35.11)	

(*continued on next page*)

Table 2 (*continued*)

WHO ANC guidelines	2008	2014	2022	*P*
Sociodemographic features				
Age at first birth				< 0.001
10–20 years	6970 (58.64)	12,752 (55.15)	16,969 (48.95)	
≥ 21 years	4918 (41.36)	10,366 (44.85)	17,694 (51.05)	
Residence				< 0.001
Rural	7970 (67.05)	13,946 (60.31)	20,314 (58.63)	
Urban	3918 (32.95)	9172 (39.69)	14,349 (41.37)	
Education				< 0.001
No education	5112 (43.01)	9804 (42.41)	14,056 (40.55)	
Primary	2668 (22.45)	4713 (20.39)	6147 (17.75)	
Secondary	3913 (32.92)	8084 (34.97)	12,865 (37.12)	
Higher	195 (1.64)	517 (2.24)	1595 (4.60)	
Literacy				< 0.001
Cannot read	8941 (75.36)	17,019 (73.74)	24,040 (69.57)	
Able to read	2922 (24.64)	6062 (26.26)	10,499 (30.43)	
Wealth index				< 0.001
Poorest	3658 (30.77)	7509 (32.48)	11,015 (31.77)	
Poor	2634 (22.16)	5283 (22.84)	8766 (25.28)	
Middle	2211 (18.60)	4542 (19.65)	6484 (18.70)	
Rich	1937 (16.30)	3281 (14.19)	4921 (14.19)	
Richest	1448 (12.18)	2503 (10.82)	3477 (10.03)	

Data are from the Ghana Demographic and Health Surveys conducted in 2008, 2014, and 2022. Percentages (%) represent weighted pron the DHS sampling design. Statistical significance ($P < 0.001$) indicates trends over time assessed using chi-square tests. WHO: World Health Organization; ANC: Antenatal care. ANC indicators are presented in accordance with the WHO recommendations for eight or more ANC contacts (2016 WHO ANC guidelines). Variables reflect maternal nutrition, clinical assessments, preventive interventions, health system service utilization, and sociodemographic characteristics. –: The relevant data could not be identified for analysis.

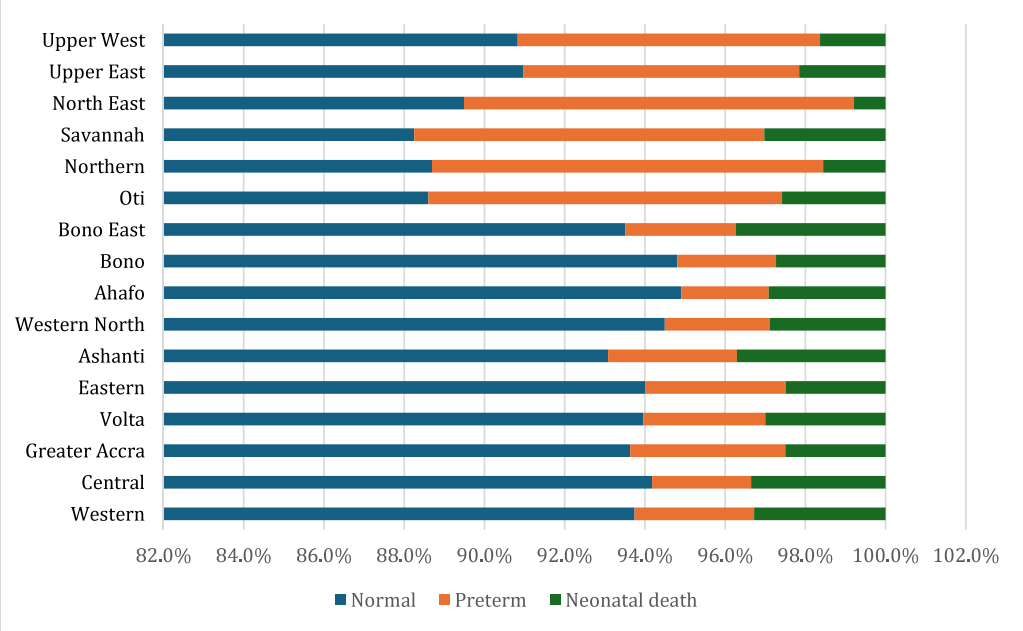

Fig. 1. Regional distribution of birth outcomes in Ghana (2022).

graphic features revealed that over 60 % of participants resided in rural areas, 42 % had no formal education, 20 % had only primary education, literacy was limited to 3 %, and nearly 50 % had their first birth before age 20. Table 3 examines the association between key WHO ANC guidelines recommendations and selected maternal/sociodemographic characteristics with adverse pregnancy outcomes (preterm birth and neonatal mortality) across 2008, 2014, and 2022.

3.6. Impact of 2016 WHO ANC guidelines-aligned interventions on preterm birth and neonatal mortality

Analysis of 2022 data, which included a small proportion of observations collected in early 2023, showed that interventions aligned with the 2016 WHO ANC guidelines were significantly associated with reduced risks of preterm birth and neonatal mortality. These included nutritional interventions (iron supplementations), maternal assessments (identifying moderate to severe anaemia) and preventive measures (treating malaria and intestinal parasites and administering tetanus toxoid) as well as health system interventions, particularly completing more than eight ANC visits.

Not taking iron supplements increased the preterm births by 1.27 times (95 % *CI*: 1.047 to 1.967) And women identified with moderate to severe anaemia increased the odds of preterm birth by 1.423 times (1.078 to 2.051). Similarly, not treating intestinal parasites increased the odds by 1.26 (95 % *CI:* 0.967 to 1.645) and not having drugs for malaria increased the odds by 1.449 times (1.104 to

Table 3
Adaptation of the WHO ANC guidelines across years 2008, 2014 and 2022 [*n* (%)].

WHO ANC guidelines	2008				2014				2022			
	Preterm	Neonatal deaths	Normal	*P*	Preterm	Neonatal deaths	Normal	*P*	Preterm	Neonatal deaths	Normal	*P*
Nutritional Interventions												
Given Iron tablets/syrup				0.55				0.524				0.022
No	5 (25.00)	6 (14.29)	292 (14.95)		6 (11.11)	5 (7.58)	350 (8.33)		5 (10.00)	11 (17.46)	454 (8.82)	
Yes	15 (75.00)	36 (85.71)	1661 (85.05)		48 (88.89	61 (92.42)	3853 (91.67)		45 (90.00)	52 (82.54)	4697 (91.18)	
Maternal Assessments												
Blood sample taken in pregnancy				< 0.001				< 0.001				0.537
No	18 (9.84)	4 (28.57)	41 (5.50)		18 (4.60)	0 (0.00)	92 (2.24)		3 (0.64)	2 (3.39)	77 (1.52)	
Yes	165 (90.16)	10 (71.43)	704 (94.50)		373 (95.40)	65 (100.00)	4006 (97.76)		465 (99.36)	57 (96.61)	4979 (98.48)	
Urine sample taken				0.001				< 0.001				0.358
No	22 (12.02)	3 (21.43)	42 (5.64)		22 (5.63)	0 (0.00)	151 (3.68)		9 (1.92)	3 (5.08)	75 (1.48)	
Yes	161 (87.98)	11 (78.57)	703 (94.36)		369 (94.37)	30 (100.00)	3947 (96.32)		459 (98.08)	56 (94.92)	4982 (98.52)	
Blood pressure taken				0.14				0.274				0.002
No	5 (2.73)	0 (0.00)	7 (0.94)		5 (1.28)	1 (1.54)	61 (1.49)		12 (2.56)	0 (0.00)	82 (1.62)	
Yes	178 (97.27)	14 (100)	738 (99.06)		386 (98.72)	64 (98.46)	4037 (98.51)		456 (97.44)	59 (100)	4972 (98.38)	
Anaemia level												
Moderate to Severe	277 (42.41)	39 (17.49)	177 (19.12)	< 0.001	164 (23.73)	31 (15.50)	121 (8.56)	< 0.001	263 (25.17)	49 (23.30)	345 (3.27)	< 0.001
Mild	155 (23.73)	85 (38.12)	353 (38.13)		197 (28.51)	48 (24.00)	427 (30.19)		282 (27.01)	54 (23.48)	438 (4.15)	
Not Anaemic	221 (33.84)	99 (44.39)	396 (42.75)		330 (47.76)	121 (60.50)	866 (61.24)		500 (47.84)	127 (55.22)	9784 (92.58)	
Smokes Cigarettes												
No	667 (99.26)	227 (100.00)	950 (100.0)		1300 (99.92)	418 (100.00)	2855 (99.93)	0.857	2092 (99.05)	484 (98.57)	3784 (99.42)	0.064
Yes	5 (0.74)	0 (0)	0 (0)		1 (0.08)	0 (0)	2 (0.07)		20 (0.95)	7 (1.43)	22 (0.58)	
Preventive and therapeutic measures												
Tetanus injections before birth												
0–1 injection	65 (75.58)	4 (80.00)	200 (73.00)	0.848	126 (74.12)	12 (75.00)	565 (65.39)	0.068	259 (54.53)	13 (76.47)	1833 (52.42)	0.101
≥ 2 injections	21 (24.42)	1 (20.00)	74 (27.00)		44 (25.88)	4 (25.00)	299 (34.61)		216 (45.47)	4 (23.53)	1664 (47.58)	
Drugs for intestinal parasites during pregnancy												
No	110 (60.77)	8 (61.54)	469 (64.09)	0.705	226 (58.70)	14 (45.16)	1236 (56.78)	0.323	217 (45.97)	8 (47.06)	2309 (45.11)	0.187
Yes	71 (39.23)	5 (38.46)	263 (35.91)		159 (41.30)	17 (54.84)	940 (43.22)		255 (54.03)	9 (52.94)	2806 (54.89)	
Given medicine for malaria												
No	79 (42.70)	5 (38.46)	299 (40.41)	0.838	261 (11.67)	4 (12.90)	261 (11.67)	0.994	60 (12.68)	3 (17.65)	281 (8.00)	0.001
Yes	106 (57.30)	8 (61.50)	441 (59.59)		1976 (88.33)	27 (87.10)	1976 (88.33)		413 (87.32)	14 (82.35)	3234 (92.00)	

(*continued on next page*)

Table 3 (*continued*)

WHO ANC guidelines	2008				2014				2022			
	Preterm	Neonatal deaths	Normal	*P*	Preterm	Neonatal deaths	Normal	*P*	Preterm	Neonatal deaths	Normal	*P*
Health systems interventions												
Number of ANC visits during pregnancy												
< 8 visits	185 (99.46)	13 (100.00)	739 (99.86)	0.875	369 (90.44)	31 (100.00)	1826 (81.24)	0.072	400 (84.39)	47 (74.60)	3331 (64.83)	0.005
≥ 8 visits	1 (0.54)	0 (0)	1 (0.14)		39 (9.56)	0 (0)	422 (18.76)		74 (15.61)	16 (25.40)	1811 (35.17)	
Interventions for physiological symptoms												
Obtained support for physiological symptoms												
No	79 (42.70)	6 (46.15)	323 (42.58)	0.068	225 (56.96)	17 (53.12)	1460 (54.45)	0.631	246 (55.91)	36 (57.13)	2241 (57.42)	0.167
Yes	106 (57.30)	7 (53.85)	436 (57.42)		170 (43.04)	15 (46.88)	1222 (45.55)		194 (44.09)	27 (42.86)	1662 (42.58)	
Socio demographic and other features												
Age of respondent at first birth												
10–20 years	364 (54.17)	110 (64.71)	390 (41.05)	< 0.001	695 (53.42)	447 (56.73)	12,081 (55.06)	< 0.001	953 (45.10)	445 (52.85)	16,165 (48.62)	< 0.001
≥ 21 years	308 (45.83)	60 (35.29)	560 (58.95)		606 (46.58)	341 (43.27)	9, 859 (44.94)		1159 (54.90)	397 (47.15)	17,068 (51.38)	
Type of place of residence												
Rural	487 (72.47)	115 (67.65)	418 (44.00)	< 0.001	803 (61.72)	466 (59.14)	13,236 (60.32)	< 0.001	1365 (64.63)	455 (54.04)	19,481 (58.56)	0.005
Urban	185 (27.53)	55 (32.35)	532 (56.00)		498 (38.28)	322 (40.86)	8704 (39.68)		747 (35.37)	387 (46.96)	13,772 (41.44)	
Wealth index												
Poorest to middle	520 (77.38)	130 (76.47)	455 (47.89)	< 0.001	980 (75.33)	253 (77.85)	1765 (61.71)	< 0.001	1643 (77.78))	640 (76.01)	25,066 (75.38)	0.364
Rich to richest	152 (22.62)	40 (23.53)	495 (52.11)		321 (24.77)	72 (22.15)	1095 (38.29)		469 (22.22)	202 (23.99)	8167 (24.62)	
Education												
No and primary	434 (64.58)	115 (67.65)	374 (39.37)	< 0.001	775 (59.57)	210 (64.62)	1270 (44.45)	< 0.001	1168 (55.29)	295 (62.64)	1508 (39.62)	< 0.001
Secendary and higher	238 (35.42)	55 (32.35)	576 (60.63)		526 (40.43)	115 (35.38)	1588 (55.55)		944 (4.71)	176 (37.36)	2298 (60.38)	

Data are derived from the Ghana Demographic and Health Surveys for 2008, 2014, and 2022. Percentages (%) represent estimates based on the DHS complex sampling design. The analysis follows the 2016 WHO ANC guidelines recommending a minimum of eight contacts during pregnancy. *P*-values represent the significance of associations or temporal trends assessed using chi-square tests. To improve statistical power and ensure meaningful comparisons, certain variables were recategorized. Specifically, the wealth index, Education were grouped into two categories to capture the socioeconomic gradient between disadvantaged and advantaged households while maintaining adequate subgroup sample sizes. This approach minimizes sparse data bias and highlights the broader inequality patterns relevant to maternal and child health outcomes. WHO: World Health Organization; ANC: Antenatal care.

Table 4
The association of selected independent variables against antenatal care model recommendations on adverse pregnancy outcomes in 2022.

WHO ANC guidelines	Preterm Birth (vs. Normal)		Neonatal mortality (vs. Normal)	
	OR (95 % *CI*)	*P*	*OR* (95 % *CI*)	*P*
Nutritional Interventions				
Given iron tablet/syrup				
No	Reference		Reference	
Yes	1.127 (1.047 to 1.967)	0.006	0.745 (0.350 to 1.587)	0.669
Consumed vitamin rich foods				
Yes	Reference		Reference	
No	0.660 (0.497 to 0.878)	0.004	0.636 (0.234 to 1.725)	0.235
Maternal Factors				
Anaemia level				
Not anaemic	Reference		Reference	
Severe to moderate anaemia	1.423 (1.178 to 2.051)	0.007	1.1 (0.589 to 1.422)	0.189
Preventive and therapeutic measures				
Tetanus injections before birth				
0–1 injection	0.758 (0.493 to 1.165)	0.214	1.286 (0.665 to 2.489)	0.628
≥ 2 injections	Reference		Reference	
Drugs for intestinal parasites during pregnancy				
No	1.267 (1.097 to 1.645)	0.003	0.751 (0.353 to 1.598)	0.258
Yes	Reference		Reference	
Given medicine for malaria				
No	1.449 (1.104 to 2.411)	0.002	1.301 (0.717 to 2.360)	0.352
Yes	Reference		Reference	
Interventions for physiological symptoms				
Obtained support for physiological symptoms				
Yes	Reference		Reference	
No	0.871 (0.556 to 1.201)	0.478	1.249 (0.651 to 2.396)	0.649
Health Systems interventions				
Number of ANC visits during pregnancy				
< 8 visits	1.24 (1.031 to 1.927)	0.002	1.583 (1.120 to 2.480)	0.003
≥ 8 visits	Reference		Reference	
Socio Demographic and other features				
Age of respondent at first birth				
10–20 years	1.265 (1.109 to 1.452)	0.008	0.987 (0.789 to1.023)	0.065
≥ 21 years	Reference		Reference	
Type of place of residence				
Rural	1.414 (1.182 to 2.077)	0.006	3.162 (1.342 to 7.451)	0.046
Urban	Reference		Reference	
Wealth index				
Poorest to middle	0.750 (0.432 to 1.304)	0.076	4.747 (1.390 to 10.208)	0.006
Rich to richest	Reference		Reference	
Education				
No and primary	1.360 (1.197 to 1.545)	0.005	1.465 (1.203 to 1.783)	0.002
Secendary and higher	Reference		Reference	

Data are derived from the Ghana Demographic and Health Surveys for 2008, 2014, and 2022. Percentages (%) represent estimates based on the Demographic and Health Surveys complex sampling design. The analysis follows the World Health Organization's 2016 Antenatal Care model recommending a minimum of eight contacts during pregnancy. p-values represent the significance of associations or temporal trends assessed using chi-square tests. To improve statistical power and ensure meaningful comparisons, certain variables were recategorized. Specifically, the wealth index, Education were grouped into two categories to capture the socioeconomic gradient between disadvantaged and advantaged households while maintaining adequate subgroup sample sizes. This approach minimizes sparse data bias and highlights the broader inequality patterns relevant to maternal and child health outcomes. WHO: World Health Organization; ANC: Antenatal care; *OR*: Odds ratio; *CI*: Confidence interval.

2.411) for preterm births. Women attending < 8 ANC visits were more likely to experience preterm births or neonatal deaths as indicated in Table 4.

3.7. Other risk factors

Sociodemographic factors also played a key role in adverse outcomes. Women living in rural areas had a significantly higher risk of preterm birth and neonatal death compared to urban residents (*OR*: 1.414; 95 % *CI*: 1.38 to 1.877; $P = 0.001$). In addition, women with no education or only primary education had higher rates of neonatal death, and those in the poor or poorest wealth categories were also more likely to experience neonatal mortality (*OR*: 4.747; 95 % *CI*: 1.39 to 10.208). Moreover, being under 20 years of age at the time of pregnancy was significantly associated with both preterm birth and neonatal death.

4. Discussion

This study assessed trends and determinants of preterm birth and neonatal mortality in Ghana from 2008 to 2022, structured around the 2016 WHO ANC guidelines.[29] The observed decline in preterm birth (from 13.0 % in 2008 to 9.1 % in 2022) and neonatal mortality (from 3.0 % to 2.3 %) aligns with national and regional trends reported in previous studies and DHS reports, reflecting gradual improvements in antenatal care coverage, facility-based deliveries, and newborn survival in Ghana over the past decade.[30] Marked regional disparities particularly in newly created and northern regions underscore persistent inequities in maternal and neonatal care, reinforcing the urgent need to strengthen early identification of high-risk pregnancies and ensure timely referral and management within the health system.

4.1. Nutritional interventions and maternal assessments

From 2008 to 2022, the proportion of women receiving iron tablets or syrup during pregnancy increased steadily from 85.3 % to 91.9 % ($P < 0.001$), reflecting substantial progress in the implementation of nutritional interventions within Ghana's antenatal care programs. This improvement aligns with WHO recommendations for universal iron–folate supplementation during pregnancy and likely contributes to reductions in maternal anaemia and improved pregnancy outcomes. By 2022, coverage of routine maternal and foetal assessments in Ghana had reached nearly 100 %, facilitating early detection of conditions such as anaemia in line with the core recommendations of the WHO ANC guidelines.[29] However, despite this high assessment coverage, moderate to severe anaemia remained prevalent and was significantly associated with adverse outcomes such as preterm birth and neonatal mortality findings consistent with previous studies.[31] This suggests that screening alone is insufficient to mitigate risk, likely due to persistent underlying nutritional deficiencies and limited access to effective treatment.

While iron supplementation coverage was relatively high (91 %), dietary assessments revealed significant shortfalls in the intake of fruits rich in essential vitamins. This pattern reflects broader trends observed across West Africa, where inadequate consumption of fruits and vegetables is common.[32] These findings underscore the need to complement existing supplementation programs with culturally appropriate, food-based nutritional interventions to address both macro- and micronutrient deficiencies more holistically. Moreover, the lower odds ratio observed for iron supplementation, despite its protective role, may reflect recall bias or misclassification within the self-reported Ghana DHS data. Women who experienced adverse outcomes might have underreported supplementation adherence, and such biases could attenuate the true effect. This highlights the importance of improving the accuracy of ANC intervention monitoring and differentiating between reported coverage and actual compliance in future studies.

4.2. Preventive measures and therapeutic gaps

Preventive measures, particularly malaria prophylaxis and deworming treatments, demonstrated positive trends from 2008 to 2022 reflecting enhanced integration of these services within Ghana's antenatal care (ANC) programs. However, tetanus toxoid immunisation remained a persistent gap. In 2022, over 70 % of women had received either no doses or only a single dose during pregnancy, despite global evidence that improved tetanus coverage contributed to a 96 % reduction in neonatal tetanus deaths between 1988 and 2015.[33] This shortfall indicates missed opportunities for maternal immunisation and underscores the need for stronger programmatic emphasis on complete tetanus protection during pregnancy.

Sustained and expanded deworming programs are equally critical, as intestinal parasitic infections are strongly linked to maternal undernutrition and anaemia, both of which heighten the risk of low birth weight, preterm birth, and neonatal morbidity.[34] To improve outcomes, strategies should include strengthening community outreach, integrating deworming into routine ANC visits, maintaining an uninterrupted drug supply, and training healthcare workers in screening and management of parasitic infections. Furthermore, establishing robust monitoring and accountability guidelines is essential to enhance coverage, particularly in rural and underserved areas.[35]

4.3. Health system service utilisation

Utilisation of ANC services has improved over the study period; however, by 2022, only 35.1 % of women had attended eight or more ANC contacts, falling significantly short of the WHO recommendation.[36] Inadequate ANC attendance limits opportunities for early detection and timely management of pregnancy-related complications, thereby increasing the risk of adverse outcomes for both mothers and neonates. This suboptimal coverage may have been further amplified by COVID-19–related disruptions, where lockdowns, mobility restrictions, fear of infection, and service interruptions reduced access to routine ANC services, potentially widening inequities and exacerbating risks in already vulnerable populations.

Evidence from prior studies in Ghana indicates that women from disadvantaged, rural, and less-educated backgrounds are particularly likely to underutilise ANC services.[10]

Low educational attainment and poor socio-economic status are strongly associated with reduced ANC uptake due to limited awareness of care benefits, constrained decision-making autonomy, and difficulties overcoming financial and logistical barriers. These persistent disparities underscore the urgent need for targeted policy interventions aimed at achieving equitable access to ANC services for vulnerable subpopulations. Although ANC coverage improved substantially after 2014, the decline in neonatal mortality appeared to plateau during the same period. This stagnation may reflect persistent quality-of-care challenges, including inadequate clinical follow-up, limited facility readiness, and variation in the quality of service delivery rather than access alone. Strengthening the content and continuity of ANC services is therefore critical to translating increased coverage into measurable reductions in neonatal deaths.

Recommended strategies include community-based health education tailored to low-literacy populations, provision of transport support, and integration of ANC services into existing community outreach structures. These efforts are essential not only to increase coverage but also to meet Sustainable Development Goal 3.1, which aims to reduce the global maternal mortality ratio to fewer than 70 deaths per 100,000 live births by 2030.[37] Aligning antenatal care interventions with Ghana's national maternal and newborn health strategies enhances policy coherence and strengthens implementation pathways that improve maternal and neonatal outcomes.

In parallel, strengthening access to and quality of facility-based delivery care in rural Ghana is equally critical. This requires investment in transportation infrastructure, deployment of skilled birth attendants, and upgrading of facility readiness ensuring the availability of essential drugs, clean delivery environments, and functioning equipment. Promoting respectful maternity care and delivering culturally sensitive health education can further increase community trust and service utilisation.[38]

Failure to consistently implement these essential interventions reflects underlying health system and operational inefficiencies that require urgent attention to improve maternal and neonatal health outcomes. Although Act 857 introduced important regulatory safeguards, persistent gaps in enforcement, monitoring capacity, and timely disciplinary actions indicate that legislative reform must be supported by strengthened institutional capacity, adequate resourcing, and robust accountability structures to meaningfully reduce medical negligence.[39]

These findings reinforce the multidimensional nature of antenatal care and the need for comprehensive, context-specific strategies that address not only clinical and nutritional needs but also structural and health system-level barriers, in line with 2016 WHO ANC guidelines.

In Ghana, regulatory guidelines can have a substantial influence on maternal health outcomes by governing the quality, standards, and accountability structures underpinning ANC delivery. Well functioning regulatory mechanisms enable consistent implementation of evidence based interventions across facilities, minimise variability in care, and strengthen system capacity to reduce preventable preterm birth and neonatal mortality.

4.4. Other risk factors

Sociodemographic inequalities played a significant role in shaping pregnancy outcomes in Ghana. Although the percentage of adolescent

pregnancies declined from 58.6 % in 2008 to 49.0 % in 2022, the absolute number more than doubled, highlighting the impact of a growing adolescent population. Adolescent pregnancies linked to biological immaturity, undernutrition, and psychosocial stress are further compounded by limited access to ANC and weak family or community support.[40–42] Contributing factors include poverty, child marriage, peer pressure, coerced sex, and the erosion of traditional protective practices.[43] With one in five girls married before 18, the need for culturally sensitive, multisectoral reproductive health strategies is critical.[44]

Education and literacy emerged as strong protective factors. Women with limited or no schooling were at substantially higher risk of adverse outcomes, underscoring how education enhances health literacy, critical decision-making, informed care-seeking, and autonomy in negotiating safer practices within relationships.[45] Higher educational attainment may also increase women's social capital and agency, reducing vulnerability to coercion and unequal power dynamics. Similarly, household wealth exerted a strong protective effect. Women in the poorest wealth quintile were more likely to experience neonatal death and preterm birth, as financial constraints limit access to timely and quality ANC, skilled birth attendants, and facility-based deliveries.[46] Increased economic resources can improve financial independence and bargaining power within relationships, lowering susceptibility to violence, improving service utilisation, and facilitating consistent uptake of preventive interventions.

Partner alcohol use, maternal stress, limited media exposure and weak social support can elevate physiological stress responses, reduce partner support for ANC utilisation, compromise decision-making autonomy, and restrict access to health information, all of which could increase the risk of preterm birth and neonatal adverse outcome.[47,48]

Geographic disparities also played a significant role. Rural residence was associated with higher risks likely due to limited access to skilled care, poor availability of emergency obstetric services, and greater reliance on home births, especially in the Northern Region where access to nutritious food and healthcare is most constrained.[41,46,49–51] These socio-economic and geographic inequities continue to undermine efforts to reduce maternal and neonatal mortality, particularly among the most vulnerable populations.

To accelerate progress, Ghana must adopt equity-driven, multisectoral policies that strengthen both the quality and reach of antenatal and delivery care. This includes ensuring that each ANC contact delivers the full WHO-recommended package of services, addressing tetanus immunisation and nutritional gaps, and expanding access to adolescent reproductive health services. Targeted investments in rural health infrastructure, transportation, and female education are equally essential. These interventions should be embedded within a broader national guideline supporting universal health coverage and aligned with the Sustainable Development Agenda 2030.[52]

4.5. Limitations

This study has several limitations. Due to data availability, only a subset of variables within each domain of the 2016 WHO ANC guidelines could be analyzed. Comprehensive data on certain indicators, particularly detailed maternal nutritional intake, were limited, constraining the assessment of temporal trends and their associations with pregnancy outcomes. The analysis relied on self-reported information, which may be affected by recall bias, especially regarding the number of ANC visits and receipt of counselling and by potential underreporting due to social desirability or fear of disclosure. As a result, the true prevalence of some outcomes may be underestimated. Furthermore, although low birth weight and congenital anomalies are recognized adverse birth outcomes, this study focused on a selected subset due to data constraints. These limitations should be considered when interpreting the findings and their implications for antenatal care policy and program planning in Ghana.

4.6. Recommendations

To improve pregnancy outcomes and achieve the SDG 3.1 targets by 2030, Ghana must prioritize interventions aligned with the 2016 WHO ANC guidelines. This includes strengthening the coverage and follow-up of maternal and fetal assessments, expanding preventive services such as tetanus immunization and iron–folic acid supplementation, and promoting adequate maternal nutrition through culturally appropriate counselling and support programs. Ensuring at least eight ANC contacts—particularly in underserved and rural regions—remains essential for improving continuity of care.

To enhance feasibility in Ghana's resource-constrained context, future interventions should emphasize cost-effective and scalable approaches that can be integrated into existing health-system structures. Leveraging community health workers, task-shifting strategies, and digital health tools may improve efficiency and reach. Additionally, addressing sociodemographic disparities through adolescent reproductive health education, expanded access to formal education for girls, and investments in rural health infrastructure and community-based outreach is critical. These integrated, equity-focused, and sustainable strategies are vital to reducing preterm births and neonatal mortality while advancing maternal and child health in Ghana.

5. Conclusion

This study highlights both progress and persistent challenges in reducing preterm birth and neonatal mortality in Ghana (2008–2022) within the 2016 WHO ANC guidelines. While maternal assessments, preventive measures and health system utilisation have improved over the years gaps remain in many areas. Addressing these issues requires equity-focused, multisectoral strategies that strengthen antenatal care, enhance preventive and nutritional support, and invest in rural health systems and female education. Full implementation of the WHO ANC guidelines is vital to improving maternal and newborn outcomes.

Ethics approval and consent to participate

The study used secondary data obtained from the DHS program. All DHS surveys are approved by the Institutional Review Board of informed consent form and by the relevant national ethics committees in participating countries. The data are anonymized before public release. Permission to use the dataset for this analysis was granted by the DHS Program. Therefore, no additional ethical approval or informed consent was required for this secondary data analysis.

CRediT authorship contribution statement

Kasuni H.M. Akalanka: Writing – original draft, Methodology, Formal analysis, Conceptualization. **Kelly Lin:** Writing – review & editing, Conceptualization. **Jing Sun:** Conceptualization, Methodology, Data curation, Writing – review & editing, Supervision.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request. Data access is subject to approval by the DHS Program.

References

1. Chawanpaiboon S, Vogel JP, Moller AB, et al. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health*. 2019;7(1):e37-e46. doi:10.1016/S2214-109X(18)30451-0.
2. Ohuma EO, Moller AB, Bradley E, et al. National, regional, and global estimates of preterm birth in 2020, with trends from 2010: a systematic analysis. *Lancet*. 2023;402(10409):1261-1271. doi:10.1016/S0140-6736(23)00878-4.
3. Afulani PA. Determinants of stillbirths in Ghana: does quality of antenatal care matter? *BMC Pregnancy Childbirth*. 2016;16(1):132. doi:10.1186/s12884-016-0925-9.
4. Azaare J, Kolekang AS, Agyeman YN. Maternal health care policy intervention and its impact on perinatal mortality outcomes in Ghana: evidence from a quasi-experimental design. *Public Health*. 2023;222:37-44. doi:10.1016/j.puhe.2023.06.035.
5. Volpe JJ. Brain injury in premature infants: a complex amalgam of destructive and developmental disturbances. *Lancet Neurol*. 2009;8(1):110-124. doi:10.1016/S1474-4422(08)70294-1.
6. Genie YD, Kebede BF, Silesh Zerihun M, Tilahun Beyene D. Morbidity and mortality patterns of preterm low birthweight neonates admitted to referral hospitals in the Amhara region of Ethiopia: retrospective follow-up study. *BMJ Open*. 2022;12(7):e054574. doi:10.1136/bmjopen-2021-054574.10.9745/GHSP-d-13-00176.
7. Pisacreta E, Mannella P. Molecular and endocrine mechanisms involved in preterm birth. *Gynecol Endocrinol*. 2022;38(5):368-378. doi:10.1080/09513590.2022.2053519.
8. Hodgins S, D'Agostino A. The quality-coverage gap in antenatal care: toward better measurement of effective coverage. *Glob Health Sci Pract*. 2014;2(2):173-181. doi:10.9745/GHSP-d-13-00176.
9. Lattof SR, Tunçalp Ö, Moran AC, et al. Developing measures for WHO recommendations on antenatal care for a positive pregnancy experience: a conceptual framework and scoping review. *BMJ Open*. 2019;9(4):e024130. doi:10.1136/bmjopen-2018-024130.
10. Lattof SR, Moran AC, Kidula N, et al. Implementation of the new WHO antenatal care model for a positive pregnancy experience: a monitoring framework. *BMJ Glob Health*. 2020;5(6):e002605. doi:10.1136/bmjgh-2020-002605.
11. Odhiambo JF, Pankey CL, Ghnenis AB, Ford SP. Areview of maternal nutrition during pregnancy and impact on the offspring through development: evidence from animal models of over- and undernutrition. *Int J Environ Res Public Health*. 2020;17(18):6926. doi:10.3390/ijerph17186926.
12. Black RE, Victora CG, Walker SP, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*. 2013;382(9890):427-451. doi:10.1016/S0140-6736(13)60937-X.
13. Mate A, Reyes-Goya C, Santana-Garrido Á, Vázquez CM. Lifestyle, maternal nutrition and healthy pregnancy. *Curr Vasc Pharmacol*. 2021;19(2):132-140. doi:10.2174/1570161118666200401112955.
14. Jain S, Maheshwari A, Jain SK. Maternal nutrition and fetal/infant development. *Clin Perinatol*. 2022;49(2):313-330. doi:10.1016/j.clp.2022.02.005.
15. Haws RA, Yakoob MY, Soomro T, Menezes EV, Darmstadt GL, Bhutta ZA. Reducing stillbirths: screening and monitoring during pregnancy and labour. *BMC Pregnancy Childbirth*. 2009;9(Suppl 1):S5. doi:10.1186/1471-2393-9-S1-S5.
16. Yakoob MY, Menezes EV, Soomro T, Haws RA, Darmstadt GL, Bhutta ZA. Reducing stillbirths: behavioural and nutritional interventions before and during pregnancy. *BMC Pregnancy Childbirth*. 2009;9(Suppl 1):S3. doi:10.1186/1471-2393-9-S1-S3.
17. Holness N. High-risk pregnancy. *Nurs Clin North Am*. 2018;53(2):241-251. doi:10.1016/j.cnur.2018.01.010.
18. Kriebs JM. Infectious diseases in pregnancy: issues of screening, prevention, and treatment. *J Perinat Neonatal Nurs*. 2008;22(3):214-220. doi:10.1097/01.JPN.0000333922.07458.e0.
19. Thwaites CL, Beeching NJ, Newton CR. Maternal and neonatal tetanus. *Lancet*. 2015;385(9965):362-370. doi:10.1016/S0140-6736(14)60236-1.
20. Habak PJ, Carlson K, Griggs JRP. *Urinary Tract Infection in Pregnancy*. Treasure Island (FL): StatPearls Publishing LLC; 2025.
21. Festin M. Nausea and vomiting in early pregnancy. *BMJ Clin Evid*. 2014;2014:1405.
22. Body C, Christie JA. Gastrointestinal diseases in pregnancy: nausea, vomiting, hyperemesis gravidarum, gastroesophageal reflux disease, constipation, and diarrhea. *Gastroenterol Clin North Am*. 2016;45(2):267-283. doi:10.1016/j.gtc.2016.02.005.
23. Simoncic V, Deguen S, Enaux C, Vandentorren S, Kihal-Talantikite W. A comprehensive review on social inequalities and pregnancy outcome-identification of relevant pathways and mechanisms. *Int J Environ Res Public Health*. 2022;19(24):16592. doi:10.3390/ijerph192416592.
24. Amjad S, MacDonald I, Chambers T, et al. Social determinants of health and adverse maternal and birth outcomes in adolescent pregnancies: a systematic review and meta-analysis. *Paediatr Perinat Epidemiol*. 2019;33(1):88-99. doi:10.1111/ppe.12529.
25. Goldenberg RL, Culhane JF, Iams JD, Romero R. Epidemiology and causes of preterm birth. *Lancet*. 2008;371(9606):75-84. doi:10.1016/S0140-6736(08)60074-4.
26. Geelhoed D, Agadzi F, Visser L, et al. Maternal and fetal outcome after severe anemia in pregnancy in rural Ghana. *Acta Obstet Gynecol Scand*. 2006;85(1):49-55. doi:10.1080/00016340500334794.
27. Annan RA, Gyimah LA, Apprey C, et al. Predictors of adverse birth outcomes among pregnant adolescents in Ashanti Region, Ghana. *J Nutr Sci*. 2021;10:e67. doi:10.1017/jns.2021.58.
28. Dwomoh D. Geospatial analysis of determinants of neonatal mortality in Ghana. *BMC Public Health*. 2021;21(1):492. doi:10.1186/s12889-021-10473-w.
29. Kazma JM, van den Anker J, Allegaert K, Dallmann A, Ahmadzia HK. Anatomical and physiological alterations of pregnancy. *J Pharmacokinet Pharmacodyn*. 2020;47(4):271-285. doi:10.1007/s10928-020-09677-1.
30. WHO Guidelines Approved by the Guidelines Review Committee. *WHO recommendations on antenatal care for a positive pregnancy experience*. Geneva: World Health Organization; 2016.
31. Dadzie D, Boadu RO, Engmann CM. Twum-Danso NAY. Evaluation of neonatal mortality data completeness and accuracy in Ghana. *PLoS One*. 2021;16(3):e0239049. doi:10.1371/journal.pone.0239049.
32. Helegbe GK, Aryee P, Mohammed BS. Preterm delivery and neonatal deaths among anaemic pregnant women in the bolgatanga metropolis of ghana. *Anemia*. 2023;2023:9865224.
33. Talebi S, Kianifar HR, Mehdizadeh A. Nutritional requirements in pregnancy and lactation. *Clin Nutr ESPEN*. 2024;64:400-410. doi:10.1016/j.clnesp.2024.10.155.
34. Giles ML, Gunatilaka A, Cole S, Kollmann T. The non-specific effects of maternal immunization on birth outcomes: the evidence, mechanisms, and the implications. *Int J Gynaecol Obstet*. 2023;162(1):13-17. doi:10.1002/ijgo.14795.
35. Taghipour A, Ghodsian S, Jabbari M, Olfatifar M, Abdoli A, Ghaffarifar F. Global prevalence of intestinal parasitic infections and associated risk factors in pregnant women: a systematic review and meta-analysis. *Trans R Soc Trop Med Hyg*. 2021;115(5):457-470. doi:10.1093/trstmh/traa101.
36. McClure EM, Meshnick SR, Mungai P, et al. The association of parasitic infections in pregnancy and maternal and fetal anemia: a cohort study in coastal Kenya. *PLoS Negl Trop Dis*. 2014;8(2):e2724. doi:10.1371/journal.pntd.0002724.
37. Aboagye RG, Osborne A, Salihu T, Wongnaah FG, Ahinkorah BO. Regional disparities and socio-demographic factors associated with eight or more antenatal care visits in Ghana. *Arch Public Health*. 2024;82(1):192. doi:10.1186/s13690-024-01364-8.
38. Seidu AA, Okyere J, Budu E, Duah HO, Ahinkorah BO. Inequalities in antenatal care in Ghana, 1998–2014. *BMC Pregnancy Childbirth*. 2022;22(1):478. doi:10.1186/s12884-022-04803-y.
39. Cofie LE, Barrington C, Singh K, Sodzi-Tettey S, Akaligaung A. Birth location preferences of mothers and fathers in rural Ghana: implications for pregnancy, labor and birth outcomes. *BMC Pregnancy Childbirth*. 2015;15:165. doi:10.1186/s12884-015-0604-2.
40. EAA Felix Nyante, Addy Alfred, Mensah George Benneh. Ghana's Health Professions Regulatory Bodies Act, 2013 (Act 857) and its adequacy in governing healthcare delivery and medical negligence issues. *Int J Multidiscip Res*. 2024;6(1):11993. doi:10.36948/ijfmr.2024.v06i01.11993 .
41. Lambonmung A, Acheampong CA, Langkulsen U. The effects of pregnancy: a systematic review of adolescent pregnancy in ghana, liberia, and nigeria. *Int J Environ Res Public Health*. 2022;20(1):605. doi:10.3390/ijerph20010605.
42. Amoadu M, Ansah EW, Assopiah P, et al. Socio-cultural factors influencing adolescent pregnancy in Ghana: a scoping review. *BMC Pregnancy Childbirth*. 2022;22(1):834. doi:10.1186/s12884-022-05172-2.
43. Gyimah LA, Annan RA, Apprey C, et al. Dietary diversity and its correlates among pregnant adolescent girls in Ghana. *PLoS One*. 2021;16(3):e0247979. doi:10.1371/journal.pone.0247979.
44. Kons K, Biney AAE, Sznajder K. Factors associated with adolescent pregnancy in sub-saharan africa during the COVID-19 pandemic: a review of socioeconomic influences and essential interventions. *Int J Sex Health*. 2022;34(3):386-396. doi:10.1080/19317611.2022.2084199.
45. de Groot R, Kuunyem MY, Palermo T. Child marriage and associated outcomes in northern Ghana: a cross-sectional study. *BMC Public Health*. 2018;18(1):285. doi:10.1186/s12889-018-5166-6.
46. Anarwat SG, Salifu M, Akuriba MA. Equity and access to maternal and child health services in Ghana a cross-sectional study. *BMC Health Serv Res*. 2021;21(1):864. doi:10.1186/s12913-021-06872-9.
47. Patel KK, Saroj RK, Kumar M. Prevalence and determinants of adverse pregnancy outcomes among women in india: a secondary data analysis. *Indian J Community Med*. 2021;46(3):434-437. doi:10.4103/ijcm.IJCM_569_20.
48. Sarkodie AO. Factors influencing under-five mortality in rural- urban Ghana: an applied survival analysis. *Soc Sci Med*. 2021;284:114185. doi:10.1016/j.socscimed.2021.114185.
49. Kumi-Kyereme A, Amo-Adjei J. Effects of spatial location and household wealth on health insurance subscription among women in Ghana. *BMC Health Serv Res*. 2013;13:221. doi:10.1186/1472-6963-13-221.
50. Dalinjong PA, Wang AY, Homer CSE. Are health facilities well equipped to provide basic quality childbirth services under the free maternal health policy? Findings from rural Northern Ghana. *BMC Health Serv Res*. 2018;18(1):959. doi:10.1186/s12913-018-3787-1.
51. Lee BX, Kjaerulf F, Turner S, et al. Transforming our world: implementing the 2030 agenda through sustainable development goal indicators. *J Public Health Policy*. 2016;37:13-31 Suppl 1. doi:10.1057/s41271-016-0002-7.
52. Dwomoh D, Iddi S, Afagbedzi SK, et al. Impact of urban slum residence on coverage of maternal, neonatal, and child health service indicators in the greater accra region of ghana: an ecological time-series analysis, 2018–2021. *J Urban Health*. 2024;101(Suppl 1):45-56. doi:10.1007/s11524-023-00812-0.