

ADOLESCENT MATERNAL AGE AND PRETERM BIRTH AT A GHANAIAAN DISTRICT HOSPITAL: THE MEDIATING ROLE OF ANTENATAL CARE ATTENDANCE

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ABSTRACT

OBJECTIVE: Maternal age (MA) is associated with preterm birth (PTB), but whether adolescent age independently predicts this risk after accounting for social and clinical factors remains unclear. We assessed whether adolescent MA (≤ 19 years) independently predicts PTB and gestational age (GA) at delivery in a Ghanaian district hospital population and identified modifiable factors accounting for any observed association.

METHODS: This retrospective cohort study analysed singleton vaginal births at a district hospital in Ghana (2018–2023; $n=2,343$ after exclusions). Bivariable (Mantel-Haenszel) and multivariable logistic (PTB) and linear (GA) regression analyses examined associations between MA, ANC attendance, and outcomes, supplemented by sensitivity and mediation analyses.

RESULTS: Adolescents had higher unadjusted odds of PTB than older women (crude OR=2.30, 95% CI 1.63–3.26; $p<0.001$). After adjustment, adolescent age was independently associated with neither PTB (adjusted OR=1.21, 95% CI 0.56–2.60; $p=0.62$) nor GA (coefficient=-0.15; $p=0.34$). ANC attendance showed the strongest independent association with both outcomes (PTB: OR=0.79 per visit; GA: coefficient=0.10; both $p<0.001$). Higher education was independently associated with shorter GA and higher PTB odds. Mediation analysis was consistent with a partially mediated pathway from adolescent age through reduced ANC attendance to shorter GA (indirect effect=-0.065 weeks, 95% CI -0.128 to -0.008). When haemoglobin was omitted as a covariate, the analytic sample increased from 1,028 to 1,677 and adolescent age became significantly associated with shorter GA (coefficient=-0.31; $p=0.01$).

CONCLUSIONS: Adolescent age was associated with higher crude odds of PTB but was not an independent predictor after adjustment. Reduced ANC attendance may partly explain the association with shorter GA, although longer pregnancies also allow more visits to accumulate, so the causal contribution of ANC remains uncertain.

KEYWORDS: adolescent pregnancy; preterm birth; gestational age; antenatal care.

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INTRODUCTION

The length of human gestation is shaped by a mix of biological, genetic and methodological influences, and estimating it precisely is not straightforward. Dating based on the last menstrual period (LMP) is frequently imprecise because of irregular cycles, uncertain timing of ovulation and recall bias, whereas early ultrasound offers a more reliable estimate. Because neonatal risk differs meaningfully across the five weeks conventionally labelled as “term”^{1,2,20}, the American College of Obstetricians and Gynecologists (ACOG) revised the term-pregnancy classification into early term (37 weeks 0 days–38 weeks 6 days), full term (39 weeks 0 days–40 weeks 6 days), late term (41 weeks 0 days–41 weeks 6 days) and postterm (≥ 42 weeks)². Preterm birth (PTB), defined as delivery before 37 completed weeks, accounts for roughly 11% of births worldwide and remains a leading cause of death among children under five⁴; reported prevalence ranges from 5% to 18%, with substantial downstream effects on neonatal morbidity, mortality and long-term development⁵. Surviving preterm infants carry an elevated burden of cerebral palsy, cognitive impairment, respiratory distress and sensory deficits⁴, and while the extremely preterm (22–27 weeks) face the highest risk, even late preterm (34–36 weeks) and early-term (37–38 weeks) infants fare worse than those born at full term⁴.

More than four in five of the world’s PTBs occur in low- and middle-income countries⁶, and the sub-Saharan African burden is considerable: Rwanda alone records an estimated 35,000 preterm deliveries and 2,600 under-five deaths from prematurity-related complications each year⁷. Across the region, adolescent childbearing has been consistently linked to a higher risk of preterm birth, low birthweight and perinatal death, alongside maternal complications such as pre-eclampsia/eclampsia²⁴. Maternal age (MA) more broadly is a recognised risk factor, with both teenage and advanced-age pregnancies carrying elevated PTB risk⁸. The World Health Organization (WHO)

defines teenage pregnancy as occurring between ages 10 and 19, a group at higher risk than women aged 20–24¹⁷, while advanced MA is separately associated with placenta praevia, intrauterine growth restriction, fetal death, gestational diabetes, hypertensive disorders and caesarean delivery⁴. In one Canadian cohort, rising MA was estimated to account for as much as 36% of the increase in PTB rates over time¹¹. Gestational duration is further shaped by fetal sex, parity and genetic factors: a biparietal-diameter-based study found that women under 20 carried measurably shorter pregnancies than those aged 20–34, plausibly reflecting their higher PTB rates¹. Because precise GA estimation underlies all of this, a discrepancy exceeding seven days between LMP and ultrasound dating is itself a strong predictor of PTB².

In Ghana, approximately 128,000 babies are born preterm annually, with an estimated 8,400 dying before the age of five from direct complications of prematurity^{12,13}. Hospital-based studies have reported PTB prevalences of 18.9% at Korle-Bu Teaching Hospital in Accra and 4.7–9.0% at Cape Coast Teaching Hospital, with advanced maternal age, inadequate antenatal care (ANC) utilisation, hypertensive disorders of pregnancy, and preterm premature rupture of membranes identified as key determinants^{12,13}. Despite this documented burden, evidence on whether adolescent MA independently predicts gestational duration after accounting for modifiable clinical and social factors remains limited in the Ghanaian context, particularly at the district-facility level where most deliveries occur. Unlike high-income settings characterised by delayed childbearing, countries like Ghana plausibly follow different demographic trends.

We used secondary data from a district hospital in Ghana to assess whether $MA \leq 19$ years independently predicts GA at delivery and PTB, and to identify modifiable factors that may account for any observed associations. We hypothesised that adolescent MA (≤ 19 years) would be independently associated with shorter gestational duration and higher odds of PTB

after adjustment for social and clinical covariates, and that any observed association would be partly explained by modifiable factors, particularly ANC utilisation. We tested: H0 – adolescent maternal age (≤ 19 years) is not independently associated with PTB or GA at delivery after adjustment for social and clinical covariates; H1 – adolescent maternal age is independently associated with PTB and/or GA at delivery after adjustment. The pre-specified sensitivity, diagnostic and mediation analyses reported below were conducted to test and probe this a priori hypothesis, rather than as exploratory post-hoc analyses.

MATERIALS AND METHODS

Study Design

We conducted a retrospective cohort study using delivery records from 2018 to 2023 at a district hospital in Ghana. The study examined the association between MA (exposure) and GA at delivery and PTB (outcomes). The exposed group comprised adolescent mothers (MA ≤ 19 years); the unexposed (reference) group comprised women aged >19 years, combining the 20–34 and ≥ 35 -year bands.

Study Site

This study was conducted at the maternity/labour ward of Kade Government Hospital, which serves as the main referral centre for Kwaebibirem Municipality in Ghana's Eastern Region. The facility has 85 beds and manages approximately 60–80 deliveries per month. It serves a municipal catchment population of 127,434, including 31,114 women of reproductive age.

Study Population

Women who gave birth at Kade Government Hospital between January 2018 and December 2023 and who fulfilled the inclusion criteria below were eligible. Of 3,735 institutional birth records in the maternity register for this period, 2,343 met these criteria (see Eligibility Criteria).

Eligibility Criteria

Inclusion criteria: singleton, live births; gestational age (GA) 27–44 completed weeks; vaginal birth, whether spontaneous or assisted (e.g. vacuum/forceps); maternal age recorded and biologically plausible; and no documented congenital anomaly. Exclusion criteria: records were sequentially excluded for: multiple gestation ($n=51$); non-live birth/stillbirth ($n=164$); GA outside 27–44 completed weeks or missing ($n=229$); implausible or missing MA ($n=6$); documented congenital anomaly ($n=8$); cesarean delivery ($n=856$); and unrecorded or ambiguous mode of delivery ($n=78$, mode of delivery unconfirmed). This yielded a final analytic cohort of $n = 2,343$ singleton, live vaginal births, including both spontaneous and assisted (e.g. vacuum/forceps) deliveries, with confirmed GA between 27 and 44 completed weeks.

The lower GA bound of 27 completed weeks was set just below Ghana's recognised clinical threshold of viability (~ 28 weeks)²³, to accommodate the ± 1 –2-week dating uncertainty inherent to LMP-based GA estimation while still excluding pregnancy losses conventionally classified as second-trimester miscarriage (< 22 weeks) or stillbirth (already excluded above). Reported survival among Ghanaian preterm infants rises sharply around this threshold, (from roughly 28% below 28 weeks to 47% at 28 weeks in one Ghanaian tertiary-hospital cohort)¹³, supporting 27 weeks as a defensible lower boundary for a liveborn analytic cohort rather than an artefact of miscarriage. The upper bound of 44 weeks was set as the physiologically plausible maximum for a confirmed live, singleton gestation; values beyond this range were treated as probable dating or recording error rather than true postterm delivery.

Sampling

A total (census) sampling approach was used: all delivery records in the register for the 2018–2023 period that met the eligibility criteria above were included, rather than a randomly selected subset (non-probability, total-population sampling).

Post hoc power analysis ($n=2,343$, $R^2=0.062$, $\alpha=0.05$) indicated power exceeding 99% to detect the observed effect size.

Data Collection Period and Procedure

Data covered deliveries between January 2018 and December 2023. Trained research assistants abstracted data directly from the hospital's birth/delivery registers using a structured abstraction tool. The tool was pretested at a hospital outside the study area before the main data collection, to identify and resolve ambiguities in variable definitions and recording. During abstraction, a subsample of records was independently double-entered by a second research assistant; discrepancies between entries were resolved by joint review against the original register entry and, where necessary, by consensus with the study supervisor, following a pre-agreed set of decision rules for ambiguous or illegible entries.

Variables

Outcome variables: PTB, a binary variable defined as delivery before 37 completed weeks; and GA at delivery, a continuous variable measured in completed weeks.

Exposure variable: MA, dichotomised as adolescent (≤ 19 years) versus adult (> 19 years, reference).

Covariates: area of residence (urban/rural), maternal education, occupation (formal/informal), gravidity, parity, ANC attendance (number of visits), IPTp-SP uptake, maternal haemoglobin concentration, systolic and diastolic blood pressure, birthweight, and fetal sex.

Operational definitions: GA at delivery was categorised, following ACOG criteria, as preterm (< 37 weeks 0 days), early term (37 weeks 0 days–38 weeks 6 days), full term (39 weeks 0 days–40 weeks 6 days), late term (41 weeks 0 days–41 weeks 6 days), and a linear regression model².

Data Management and Statistical Analysis

Data were entered and cleaned in Epi Info 3.5.4. Descriptive statistics summarised baseline

characteristics. GA was analysed in two complementary, non-interchangeable ways: as a continuous outcome (completed weeks) for the linear regression model (Table 6), and, separately, in categorical form (PTB, early term, term/postterm) for descriptive summaries (Table 1) and group comparisons (ANOVA/Kruskal-Wallis, Table 4). GA was categorised as PTB (< 37 weeks), early term (37–38 weeks 6 days), and term/postterm (≥ 39 weeks), and distributions were examined across MA groups (≤ 19 , 20–34, and ≥ 35 years). Differences in mean GA across MA groups were assessed using one-way ANOVA (Kruskal-Wallis as sensitivity), and pairwise independent *t*-tests for stratified comparisons. Bivariable associations between adolescent age and PTB were assessed via crude odds ratios (ORs, 95% CI), with Mantel-Haenszel (MH) methods used for stratum-adjusted ORs and effect modification.

Two multivariable regression models were fitted using the same a priori covariate set – MA (≤ 19 vs > 19 years), ANC attendance, education, maternal haemoglobin concentration, occupation, residence, fetal sex, and systolic and diastolic BP: (1) a logistic regression model with PTB (< 37 weeks, binary) as the outcome, treated as the principal model given PTB's clinical actionability as the study's binary endpoint; and (2) a linear regression model with GA at delivery (weeks, continuous) as a complementary outcome for finer-grained information across the full gestational range. Additional analyses addressed the following:

- (i) variance inflation factors (VIF) to assess multicollinearity¹⁴;
- (ii) residual diagnostics (Shapiro-Wilk, Breusch-Pagan) with HC3-robust standard errors as a sensitivity check for the linear model;
- (iii) bootstrap resampling (1,000 iterations) to internally validate coefficient stability;
- (iv) a sensitivity model treating MA as continuous, including a quadratic term, to test for nonlinearity;
- (v) a MA $\times$ hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) interaction term to test for effect modification;
- (vi) a mediation analysis (product-

of-coefficients method¹⁵, with 2,000-resample bootstrap CIs for the indirect effect¹⁶ exploring the pathway from adolescent age through ANC attendance to GA; and (vii) because haemoglobin concentration was the single largest source of missing data, a sensitivity regression excluding haemoglobin was fitted on the larger resulting complete-case sample, to test sensitivity to sample size. Analyses were conducted in Python (pandas, statsmodels, scipy), with statistical significance set at $\alpha = 0.05$.

Ethical Considerations

Ethical approval was obtained from the University of Health and Allied Sciences Research Ethics Committee (URO47/0226), granted on April 7, 2026. Institutional access to the data was granted by

the Regional Director of Health Services through the hospital's Medical Superintendent. All data were anonymised to ensure confidentiality.

RESULTS

Descriptive analyses

Among the 2,343 delivery records meeting inclusion criteria, 17.5% were adolescents (≤ 19 years), 67.1% were in the age group of 20–34 years, and 15.5% were ≥ 35 years. Overall, 7.1% of deliveries were preterm (< 37 weeks), 22.6% occurred at 37–38 weeks, and 70.3% at ≥ 39 weeks. PTB was most frequent among adolescents (12.7%) and least frequent among women aged ≥ 35 years (5.0%), a pattern consistent across residence, education, occupation, and parity strata. [Table 1]

Table 1: Distribution of gestational age categories by maternal age group and selected maternal and pregnancy characteristics (n=2,343)

Characteristic	≤ 19 years			20–34 years			≥ 35 years		
	< 37 wks, N(%)	37–38 wks, N(%)	≥ 39 wks, N(%)	< 37 wks, N(%)	37–38 wks, N(%)	≥ 39 wks, N(%)	< 37 wks, N(%)	37–38 wks, N(%)	≥ 39 wks, N(%)
Urban	16 (9.5)	50 (29.8)	102 (60.7)	41 (5.0)	172 (20.9)	611 (74.2)	9 (5.4)	21 (12.6)	137 (82.0)
Rural	35 (15.1)	69 (29.7)	128 (55.2)	54 (7.4)	178 (24.6)	493 (68.0)	8 (4.1)	31 (16.1)	154 (79.8)
<JHS	36 (11.2)	88 (27.5)	196 (61.3)	67 (6.1)	251 (22.8)	783 (71.1)	16 (4.9)	45 (13.8)	266 (81.3)
SHS	14 (17.7)	27 (34.2)	38 (48.1)	24 (7.1)	75 (22.1)	241 (70.9)	2 (10.0)	4 (20.0)	14 (70.0)
Tertiary	0 (0.0)	2 (100.0)	0 (0.0)	5 (4.3)	29 (24.8)	83 (70.9)	0 (0.0)	3 (27.3)	8 (72.7)
Formal	3 (7.0)	15 (34.9)	25 (58.1)	5 (3.9)	32 (25.0)	91 (71.1)	0 (0.0)	4 (36.4)	7 (63.6)
Informal	34 (12.7)	79 (29.6)	154 (57.7)	76 (5.8)	298 (22.9)	926 (71.2)	18 (5.3)	42 (12.3)	281 (82.4)
Para 1	50 (12.4)	119 (29.5)	234 (58.1)	50 (5.8)	213 (24.5)	605 (69.7)	1 (3.4)	7 (24.1)	21 (72.4)
Para 2+	2 (33.3)	2 (33.3)	2 (33.3)	47 (6.7)	143 (20.3)	513 (73.0)	17 (5.1)	45 (13.5)	272 (81.4)

n = number of women in each category; N = total number of women in the study sample; % = row percentage.

Bivariable analyses (adolescent age and PTB)

Adolescents had substantially higher odds of PTB than older women (crude OR = 2.30, 95% CI 1.63–3.26; $p < 0.001$). Table 2 restates this association with adolescent and non-adolescent PTB rates shown within each stratum level. Mantel–Haenszel (MH)-adjusted ORs across residence, education, occupation, and parity strata (2.20–2.44) were consistent with the crude estimate, indicating minimal confounding by these factors and no significant effect modification. [Table 2]

Table 2: Bivariable (Mantel–Haenszel) analysis of the association between adolescent maternal age (≤ 19 years vs > 19 years) and preterm birth, stratified by selected maternal characteristics (n=2,343)

Characteristic	Level	Adolescent (≤ 19 y) PTB, n/N (%)	Non-adolescent (> 19 y) PTB, n/N (%)
Residence	Urban	16/168 (9.5)	50/991 (5.0)
	Rural	35/232 (15.1)	62/918 (6.8)
	MH-adjusted OR (95% CI): 2.27 (1.60–3.23); MH $\chi^2 = 21.69$, $p < 0.001$		
Education	<JHS	36/320 (11.2)	83/1428 (5.8)
	SHS	14/79 (17.7)	26/360 (7.2)
	Tertiary	0/2 (0.0)	5/128 (3.9)
	MH-adjusted OR (95% CI): 2.20 (1.55–3.14); MH $\chi^2 = 19.89$, $p < 0.001$		
Occupation	Informal	34/267 (12.7)	94/1641 (5.7)
	Formal	3/43 (7.0)	5/139 (3.6)
	MH-adjusted OR (95% CI): 2.37 (1.59–3.53); MH $\chi^2 = 18.76$, $p < 0.001$		
Parity	0–2	51/403 (12.7)	76/1253 (6.1)
	≥ 3	1/6 (16.7)*	39/681 (5.7)
	MH-adjusted OR (95% CI): 2.44 (1.64–3.64); MH $\chi^2 = 20.33$, $p < 0.001$		

MH = Mantel–Haenszel; PTB = preterm birth; JHS = Junior High School. *The adolescent parity ≥ 3 subgroup is very small (n=6); the corresponding cell should be interpreted with caution.

Multivariable logistic regression analysis (principal model – PTB)

Given that PTB is the binary, clinically actionable outcome named in the study objective, a multivariable logistic regression model was fitted as the principal analysis. After adjustment, adolescent age (≤ 19 years) was not independently associated with PTB (adjusted OR = 1.21, 95% CI 0.56–2.60, $p = 0.623$). ANC attendance showed the strongest independent (inverse) association with PTB (OR = 0.79 per additional visit, 95% CI 0.71–0.87, $p <$

0.001). Both SHS (OR = 2.22, 95% CI 1.10–4.45, $p = 0.025$) and tertiary education (OR = 7.51, 95% CI 1.90–29.78, $p = 0.004$), relative to JHS or below, were independently associated with higher, (not lower), odds of PTB, reflecting the counter-intuitive education finding in the linear model below. Diastolic and systolic BP, occupation, residence, fetal sex, and haemoglobin concentration were not independently associated with PTB (Pseudo $R^2 = 0.082$; $n = 1,028$). [Table 3]

Table 3: Multivariable logistic regression analysis of factors associated with preterm birth (principal model; n=1,028)

Characteristic	Variable	Adjusted OR	95% CI	p-value
Age	≤19 yrs (Ref: >19 yrs)	1.21	0.56-2.60	0.623
ANC visits	Per additional visit	0.79	0.71-0.87	<0.001
Education (SHS vs JHS)	SHS vs JHS (Ref)	2.22	1.10-4.45	0.025
Education (Tertiary vs JHS)	Tertiary vs JHS (Ref)	7.51	1.90-29.78	0.004
Diastolic BP	Per 1 mmHg increase	1.01	0.97-1.04	0.738
Haemoglobin conc.	Per 1 g/dL increase	0.86	0.70-1.05	0.141
Occupation (Informal/Formal)	Informal vs Formal (Ref)	2.47	0.69-8.87	0.165
Residence (Urban/Rural)	Rural vs Urban (Ref)	1.26	0.70-2.25	0.446
Sex of fetus (M/F)	Male vs Female (Ref)	1.22	0.69-2.17	0.486
Systolic BP	Per 1 mmHg increase	0.99	0.97-1.02	0.532

ANC = antenatal care; BP = blood pressure; CI = confidence interval; JHS = Junior High School; OR = odds ratio; ref = reference category; SHS = Senior High School. Outcome: preterm birth (yes=1, reference=no); adjusted odds ratios from multivariable logistic regression (n=1,028).

One-way ANOVA / Kruskal-Wallis (gestational age by maternal age group)

Mean GA at delivery was 39.04 ± 1.84 weeks overall, lower among adolescents (38.61 ± 2.09 weeks) than women aged 20–34 (39.08 ± 1.80 weeks) and ≥35 years (39.35 ± 1.62 weeks). Overall ANOVA confirmed significant differences across MA groups (F = 16.94, p < 0.001). Stratified analyses showed these differences persisted across residence, occupation, and parity strata, but not among women with tertiary education or formal employment. [Table 4]

Table 4: Comparison of mean gestational age across maternal age groups by selected characteristics (one-way ANOVA and Kruskal-Wallis)

Characteristic	≤19 yrs, mean(SD)	20-34 yrs, mean(SD)	≥35 yrs, mean(SD)	ANOVA F (p)	Kruskal-Wallis χ^2 (p)
Urban	38.82 (1.81)	39.18 (1.74)	39.28 (1.72)	3.62 (0.027)	9.71 (0.008)
Rural	38.45 (2.27)	38.98 (1.87)	39.45 (1.47)	14.61 (<0.001)	26.17 (<0.001)
<JHS	38.75 (2.02)	39.11 (1.84)	39.41 (1.63)	10.26 (<0.001)	23.93 (<0.001)
SHS	38.13 (2.28)	38.99 (1.77)	38.55 (1.82)	6.94 (0.001)	9.99 (0.007)
Tertiary	38.00 (0.00)	39.02 (1.53)	38.82 (0.60)	0.55 (0.579)	3.22 (0.200)
Formal	38.51 (2.12)	39.00 (1.57)	39.09 (1.38)	1.40 (0.248)	1.59 (0.451)
Informal	38.66 (2.07)	39.11 (1.76)	39.37 (1.63)	11.94 (<0.001)	24.89 (<0.001)
Para 1	38.63 (2.09)	38.96 (1.79)	39.24 (1.53)	4.83 (0.008)	7.87 (0.020)
Para 2+	37.17 (1.94)	39.23 (1.81)	39.36 (1.63)	4.93 (0.007)	9.85 (0.007)

Yrs = years; SD = standard deviation; ANOVA = analysis of variance; F = F-statistic; χ^2 = chi-square statistic; p = p-value; JHS = Junior High School; SHS = Senior High School; Para = parity. Mean gestational age is in completed weeks.

Independent two-sample t-tests

Pairwise comparisons confirmed significantly shorter mean GA among adolescents relative to older women, particularly in rural residents and informally employed women; differences were not significant among formally employed women. [Table 5]

Table 5: Pairwise comparison of mean gestational age across maternal age groups (selected strata)

Characteristic	≤19 vs 20-34 t (p)	20-34 vs ≥35 t (p)	≤19 vs ≥35 t (p)
Urban	-2.39 (0.018)	-0.65 (0.514)	-2.38 (0.018)
Rural	-3.19 (0.002)	-3.70 (<0.001)	-5.44 (<0.001)
Formal	-1.39 (0.170)	-0.21 (0.839)	-1.10 (0.282)
Informal	-3.34 (0.001)	-2.52 (0.012)	-4.58 (<0.001)
Para 1	-2.75 (0.006)	-0.96 (0.345)	-2.02 (0.051)
Para 2+	-2.60 (0.048)	-1.17 (0.242)	-2.75 (0.039)

t = independent two-sample t-statistic; *p* = p-value. Age groups are in years. A negative *t* means the first-named age group had a lower mean gestational age.

Multivariable linear regression analysis (complementary model – GA)

A parallel linear regression model, with GA at delivery (weeks) as a continuous outcome, was fitted to complement the principal logistic model with finer-grained information across the full gestational range. Adolescent age was, consistently with the logistic model, not independently associated with GA after adjustment ($\beta = -0.152$, SE = 0.158, $p = 0.336$). ANC attendance again showed the strongest independent association with GA ($\beta = 0.103$, SE = 0.018, $p < 0.001$). SHS ($\beta = -0.608$, $p < 0.001$) and tertiary education ($\beta = -0.735$, $p = 0.010$) were

independently and inversely associated with GA. Haemoglobin concentration showed a modest positive association ($\beta = 0.088$, $p = 0.030$). Diastolic BP, systolic BP, occupation, residence, and fetal sex were not independently associated with GA. The model explained 6.2% of the variability in GA ($R^2 = 0.062$, adjusted $R^2 = 0.053$; $F(10,1017) = 6.72$, $p < 0.001$), on a complete-case sample of $n = 1,028$. [Table 6]

Table 6: Multivariable linear regression analysis of factors associated with gestational age at delivery (complementary model; n=1,028)

Characteristic	Variable	β coefficient	Std. error	t / F	p-value
Age	≤ 19 yrs (Ref: >19 yrs)	-0.152	0.158	-0.96	0.336
ANC visits	Per additional visit	0.103	0.018	5.77	<0.001
Education (SHS vs JHS)	SHS vs JHS (Ref)	-0.608	0.141	-4.31	<0.001
Education (Tertiary vs JHS)	Tertiary vs JHS (Ref)	-0.735	0.283	-2.59	0.010
Diastolic BP	Per 1 mmHg increase	-0.005	0.006	-0.80	0.423
Haemoglobin conc.	Per 1 g/dL increase	0.088	0.041	2.18	0.030
Occupation (Informal/Formal)	Informal vs Formal (Ref)	0.070	0.235	0.30	0.767
Residence (Urban/Rural)	Rural vs Urban (Ref)	-0.112	0.107	-1.05	0.296
Sex of fetus (M/F)	Male vs Female (Ref)	0.083	0.105	0.79	0.428
Systolic BP	Per 1 mmHg increase	0.005	0.005	0.99	0.323
CONSTANT		37.554	0.635	59.12	<0.001

Yrs = years; Ref = reference category; ANC = antenatal care; SHS = Senior High School; JHS = Junior High School; BP = blood pressure; mmHg = millimetres of mercury; conc. = concentration; g/dL = grams per decilitre; M = male; F = female; β = regression coefficient; Std. error = standard error; t = t-statistic; p = p-value. The dependent variable is gestational age in completed weeks; Δ is the change in weeks for each category or unit increase.

Diagnostic and sensitivity analyses addressed key methodological considerations. Variance inflation factors for all covariates were below 2.0, indicating no meaningful multicollinearity. Residuals departed from normality and showed mild heteroscedasticity, as expected for a left-skewed duration outcome; re-estimating the linear model with heteroscedasticity-robust (HC3) standard errors produced an identical pattern of results. Bootstrap resampling (1,000 iterations) confirmed that the ANC and education associations were stable (CIs excluding zero), while the adolescent age, blood pressure, occupation, residence, and fetal sex coefficients were not (CIs spanning zero). Modelling MA continuously revealed a significant positive linear association with GA across the full age range ($\beta = 0.0285$ weeks per year, $p < 0.001$; model $R^2 = 0.073$), with no evidence of nonlinearity (quadratic term $p = 0.998$). An interaction term between adolescent age and hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) was not significant ($p = 0.948$), providing no evidence of effect modification.

A mediation analysis of the pathway from adolescent age through ANC attendance to GA

found that adolescents attended significantly fewer ANC visits (path a: $\beta = -0.629$ visits, $p = 0.024$), that ANC attendance was significantly associated with longer GA (path b: $\beta = 0.103$, $p < 0.001$), and that the resulting indirect effect (-0.065 weeks) was statistically significant by bootstrap (95% CI -0.128 to -0.008), despite non-significant total ($p = 0.176$) and direct ($p = 0.336$) effects – a pattern compatible with partial mediation. However, because ANC visits were counted at delivery and therefore accumulate with gestation, this indirect association cannot be interpreted as causal mediation. Because both principal models used complete cases only ($n = 1,028$ of 2,343; 56% reduction), and haemoglobin accounted for the largest share of missingness, a sensitivity regression excluding haemoglobin was fitted on the larger resulting sample ($n = 1,677$). In this larger sample, adolescent age was independently and significantly associated with shorter GA ($\beta = -0.313$, SE = 0.125, $p = 0.013$), in the biologically expected direction, indicating the primary models' null finding partly reflects reduced power from haemoglobin-driven attrition, not true absence of effect. [Table 7]

Table 7: Summary of sensitivity, diagnostic, and mediation analyses

Diagnostic / sensitivity check	Result	Interpretation
Variance inflation factors (VIF)	All covariates VIF < 2.0 (highest: tertiary education, 1.91)	No meaningful multicollinearity among model covariates
Residual normality (Shapiro-Wilk)	W=0.92, p<0.001	Residuals depart from normality (expected for a left-skewed duration outcome)
Heteroscedasticity (Breusch-Pagan)	LM=23.2, p=0.010	Mild heteroscedasticity present
Robust (HC3) standard errors	Coefficients and significance pattern unchanged vs. OLS	Substantive conclusions are not an artifact of variance misspecification
Bootstrap validation (1,000 resamples)	ANC and education effects stable (95% CI excludes 0); adolescent age, BP, occupation, residence, sex unstable (CI includes 0)	ANC and education associations are statistically stable; this does not establish causality
Continuous maternal age (linear)	$\beta=0.0285$ weeks/year, p<0.001; $R^2=0.073$	A genuine, gradual positive association with age exists across the full range
Continuous maternal age (quadratic term)	$\beta=0.000$, p=0.998	No evidence of a nonlinear age-GA relationship
Adolescent age x hypertension interaction	$\beta=0.035$, p=0.948	No evidence of effect modification by hypertensive status
Mediation analysis (age → ANC → GA)	Indirect effect = -0.065 weeks (bootstrap 95% CI -0.128 to -0.008); direct effect n.s. (p=0.34); total effect n.s. (p=0.18)	Indirect association via ANC is statistically significant; causal mediation cannot be confirmed because ANC visits accumulate with gestation
Cross-model consistency (logistic vs linear)	Adolescent age n.s. in both PTB (OR=1.21, p=0.62) and GA ($\beta=-0.15$, p=0.34) models; ANC and education significant in both	Null adolescent-age finding and positive ANC/education findings replicate across outcome scale and model family
Missing-data sensitivity (haemoglobin excluded)	Complete-case n rises from 1,028 to 1,677; adolescent age becomes significant ($\beta=-0.313$, p=0.013), correct biological direction	Primary model's null adolescent-age finding partly reflects reduced power from haemoglobin-driven attrition, not firm evidence of no effect

W = Shapiro-Wilk test statistic; LM = Lagrange multiplier statistic; HC3 = heteroscedasticity-consistent standard errors (type 3); OLS = ordinary least squares; ANC = antenatal care; BP = blood pressure; GA = gestational age; PTB = preterm birth; OR = odds ratio; β = regression coefficient; R^2 = coefficient of determination; CI = confidence interval; n.s. = not statistically significant; p = p-value.

DISCUSSION

Adolescent maternal age (≤ 19 years) was not an independent predictor of either preterm birth or gestational age at delivery once ANC attendance, education and other maternal characteristics were adjusted for, despite adolescents carrying more than double the crude risk of preterm birth. This pattern, (a strong crude association that attenuates to the null after adjustment), points to modifiable factors, rather than age itself, as the more actionable target for reducing preterm birth among adolescents in this population. This finding is consistent with results from high-income and African settings^{3,4,7,11}, and is biologically plausible: incomplete physiological maturation, nutritional vulnerability, reduced ANC utilisation, stigma, and limited social support have all been proposed as mechanisms underlying the elevated unadjusted risk among adolescents^{17-19,24}. Mediation analysis was consistent with part of the adolescent age-GA relationship operating through reduced ANC attendance, in line with evidence that adequate ANC improves fetal surveillance and timely management of pregnancy complications^{17,18}. This is consistent with qualitative evidence on adolescent ANC-seeking behaviour in Ghana, which describes distinct individual, family and health-system barriers, (including stigma, financial constraints and negative provider attitudes), that delay ANC initiation and reduce completed visits relative to older women²⁵. Because mediation assumptions cannot be fully verified in observational studies, these findings should be regarded as hypothesis-supporting rather than definitive.

The ANC findings need careful interpretation. The register recorded the total number of ANC visits completed by delivery, and a woman whose pregnancy ends at 32 weeks has had fewer weeks in which to attend than one who delivers at 40 weeks. Part of the association between ANC attendance and both GA and PTB may therefore reflect pregnancy duration itself rather than a protective effect of ANC, and both directions may operate together; this could also contribute to the graded

association observed between visit count and GA. The same issue affects the mediation analysis, since the mediator was measured at the same point as the outcome rather than before it. These results should therefore not be read as showing that each additional visit lengthens pregnancy by a fixed amount, nor that the ANC association is spurious. Modelling MA continuously suggested a modest, graded association with GA across the full reproductive age range, indicating that the conventional adolescent cutoff may understate a broader age-related gradient in gestational duration. Higher maternal education was independently associated with shorter GA and higher PTB odds, a finding that contrasts with the protective association between maternal education and adverse birth outcomes reported in global and recent sub-Saharan African studies²⁶⁻²⁸. Because this pattern was consistent across both regression models, it is unlikely to represent a modelling artefact. Possible explanations include residual confounding, referral bias, or greater healthcare engagement resulting in earlier medically advised delivery. However, the small tertiary-education subgroup and wide confidence intervals warrant cautious interpretation, and this finding should be regarded as hypothesis-generating. Neither systolic nor diastolic BP showed an independent association with GA. Across diagnostic, bootstrap and sensitivity analyses, the ANC and education associations were consistently robust, whereas the null adolescent-age finding was comparatively less stable, and its reversal on the haemoglobin-exclusion sensitivity analysis (Table 7) suggests the principal null result may partly reflect reduced statistical power from haemoglobin-driven missingness rather than a true absence of effect.

Further limitations include mixed methods of GA estimation (LMP and ultrasound), with the register not recording which method was used for individual pregnancies, potentially introducing GA misclassification^{5,6,8}. The retrospective single-centre design may limit generalisability beyond similar district hospitals, and exclusion of caesarean deliveries limits applicability to operative births. The register also lacked a marker of medically

indicated PTB and could not identify repeat pregnancies, preventing adjustment for within-mother clustering. Residual confounding cannot be excluded. In addition, the register recorded only total ANC visits at delivery, not GA at booking or visits completed by a fixed GA, so ANC exposure could not be measured independently of pregnancy duration. Strengths include the large sample, six-year study period, use of routine clinical data, and comprehensive diagnostic, sensitivity, and cross-model validation analyses.

CONCLUSION

Adolescent MA was associated with a substantially higher crude risk of PTB, but this association was not independent after adjustment for ANC attendance and other maternal characteristics. Findings were consistent with a partially mediated pathway through reduced ANC attendance, although this may partly reflect the accumulation of visits over longer pregnancies. Sensitivity analyses also suggest that the null direct association may partly reflect limited power due to missing haemoglobin data. Improving ANC access and utilisation among adolescents remains an important strategy in this population, although this study cannot establish the causal contribution of visit frequency to pregnancy duration.

Ethical considerations. Ethical approval was obtained from the Research Ethics Committee of the University of Health and Allied Sciences, Institute of Health Research (Protocol No. URO47/0226; approved 7 April 2026). Institutional permission was granted by the Regional Director of Health Services through the management of Kade Government Hospital. The study used anonymised secondary data from routine birth registers; therefore, individual informed consent was waived in accordance with the ethics approval. All data were de-identified before analysis to ensure confidentiality.

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Author Contributions Statement. Brainard Ayisi Asare conceptualised and designed the study, supervised data collection, and conducted the statistical analysis. Grace Asare contributed to study design, data interpretation, and manuscript preparation. Both authors reviewed, read, and approved the final manuscript and consent to its publication.

Data availability. The datasets generated and/or analysed during the current study are not publicly available, as they are facility-based birth registry records maintained at Kade Government Hospital subject to institutional data protection policies, but de-identified data are available from the corresponding author on reasonable request and with permission from the hospital administration.

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