BMC Pregnancy and Childbirth

https://doi.org/10.1186/s12884-026-09213-y

Article in Press

Decomposition analysis and spatial change of age disparities in antenatal care utilisation among women with high-risk pregnancies in Nigeria

Received: 10 December 2024

Accepted: 3 May 2026

Published online: 12 May 2026

Cite this article as: Bolarinwa O., Oni T.O., Mohammed A. *et al.* Decomposition analysis and spatial change of age disparities in antenatal care utilisation among women with high-risk pregnancies in Nigeria. *BMC Pregnancy Childbirth* (2026). https://doi.org/10.1186/s12884-026-09213-y

Obasanjo Bolarinwa, Tosin Olajide Oni, Aliu Mohammed, Henderson Mitomoni & Akanni Akinyemi

Decomposition analysis and spatial change of age disparities in antenatal care utilisation among women with high-risk pregnancies in Nigeria

Obasanjo Bolarinwa[1,2*], Tosn Olajide Oni[3], Aliu Mohammed[4] , Henderson Mitomoni[5], Akanni Akinyemi[3]

[1]Department of Public Health, York St John University, London, United Kingdom.

[2]Demography and Population Studies Programme, Schools of Public Health and Social Sciences, University of the Witwatersrand, Johannesburg, South Africa

[3]Department of Demography and Social Statistics, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

[4]Department of Health, Physical Education and Recreation, University of Cape Coast, Cape Coast, Ghana

[5]African Institute for Development Policy, Lilongwe, Malawi.

*Corresponding Author

Email addresses:

*OAB: bolarinwaobasanjo@gmail.com

TOO: tosnooni@gmail.com

AM: mohammedaliu39@yahoo.com

HM: hendmitomonih@gmail.com

AA: akakanni2@gmail.com

Abstract

Background

Despite global efforts to reduce maternal deaths and stillbirths, these remain critical issues in low- and middle-income countries, particularly in sub-Saharan Africa. Nigeria faces a disproportionately high burden, exacerbated by

suboptimal receipt of essential antenatal care (ANC) content, especially among high-risk groups like young women (<18 years) and women of advanced maternal age (>35 years). Thus, this study examined the age disparities in the receipt of Optimal ANC content among women with high-risk pregnancies in Nigeria.

Methods

This study analysed data from the 2003, 2008, 2013, and 2018 Nigeria Demographic and Health Surveys (NDHS). Using multi-stage sampling, data were collected from women aged 15–49 years, focusing on those with high-risk pregnancies (below 18 or above 35 years). The analysis included descriptive statistics, spatial mapping of optimal ANC utilisation using Bayesian models, and a multivariate non-linear decomposition model to explore age disparities in the receipt of optimal ANC content. Weighted analysis accounted for survey design complexity, with statistical assessments performed using Stata 17.0 and spatial analysis in R.

Results

Receipt of optimal ANC content among women with high-risk pregnancies in Nigeria remained low but showed a gradual increase from 2003 to 2018. In 2003, the rate of receipt was negligible across all states, and by 2008, Sokoto recorded the highest rate at 21%. Women of advanced maternal age consistently reported higher receipt of optimal ANC content, rising from 1% in 2003 to 48.7% in 2018, compared with younger mothers whose rate increased from 0% to 38% over the same period. Decomposition analysis revealed disparities were largely explained by socio-demographic factors, with education (16.5%) and marital status (38%) being the strongest contributors.

Conclusions and recommendations

This study shows persistently low receipt of optimal ANC content among women with high-risk pregnancies in Nigeria, with adolescents particularly disadvantaged. Targeted interventions should prioritise youth-friendly ANC services, community-based outreach in rural areas, and conditional cash transfers to reduce financial barriers. Expanding educational programmes for women with limited schooling and strengthening health system equity policies are also essential in improving access. Future studies should investigate age-specific disparities in pregnancy outcomes, regional barriers to ANC quality, and the effectiveness of adolescent-friendly models.

Keywords: High-risk pregnancies, Antenatal care utilisation, Maternal health disparities, Nigeria, DHS

Background

Nigeria remains one of the few countries with an extremely high number of maternal deaths and stillbirths in the world, accounting for 28.5% [1] and 8.7% [2] of all maternal deaths and stillbirths, respectively. Despite efforts to improve maternal health outcomes, preventable complications during pregnancy and childbirth remain widespread, particularly among women with high-risk pregnancies [3]. Antenatal care (ANC) is a critical intervention for minimising maternal health risks as it ensures early detection of complications and timely diagnosis and treatment of pregnancy risk factors such as hypertension, haemorrhage, and sepsis [4, 5]. However, persistent socio-demographic disparities exist in access and utilisation of ANC services in Nigeria, which continue to undermine maternal and newborn health, contributing to the country's high burden of maternal and newborn morbidity and mortality [6, 7].

Optimal ANC utilisation, defined by timely initiation, adherence to recommended visits, and receipt of essential ANC content or components, including screening, health promotion, disease prevention, and treatment, has been shown to significantly reduce maternal and newborn morbidity and mortality [8-11]. However, evidence suggests that ANC services remain underutilised in Nigeria, with many women failing to meet the recommended eight visits, initiate ANC during the first trimester, or receive all the essential ANC content during attendance [7, 11, 12]. Disparities in access and utilisation of optimal ANC in Nigeria persist across age groups, socio-economic strata, and geographic locations [11]. These inequalities are particularly concerning for women with high-risk pregnancies, including those with young (<18 years) or advanced maternal age (>35 years), pre-existing medical conditions (e.g., hypertension, diabetes), adverse obstetric histories (multiple pregnancies, previous caesarean section), and pregnancy-related complications (e.g., preeclampsia, gestational diabetes), all of whom require close monitoring and care to prevent adverse pregnancy and childbirth outcome [8, 13, 14].

Although previous studies investigated ANC utilisation in Nigeria [15-17], these studies largely examined the general determinants of ANC utilisation, often focusing on coverage and frequency of visits, with limited attention to age-related disparities and their spatial variations, particularly among women with high-risk pregnancies. Besides, while optimal ANC utilisation encompasses multiple dimensions [8], few studies have specifically analysed

the receipt of essential ANC content as a distinct measure of quality and equity in ANC service delivery. This gap is particularly significant because suboptimal receipt of essential ANC content compromises the overall effectiveness of care, even in cases where the recommended frequency of contacts has been met [18, 19]. Therefore, the current study employs decomposition analysis and spatial approaches to investigate the age disparities in the receipt of optimal ANC content among women with high-risk pregnancies in Nigeria.

Methods

Study design

We analysed data from the 2003, 2008, 2013, and 2018 Nigeria Demographic and Health Survey (NDHS) [20-24]. Written permission was obtained from "MEASURE DHS", the implementer and primary owner of the Demographic Health Survey (DHS) dataset, which was surveyed in many countries within low-middle-income countries (LMICs). The DHSs are implemented with cross-sectional designs using multi-stage sampling procedures that draw on the most recent census data of individual countries as sampling frames. The 2018 DHS used the 36 states and the Federal Capital Territory of Nigeria as the sampling strata, and the Local Government areas within each state were used as clusters. Eligible respondents were selected within each cluster, stratified into urban and rural, thus making the NDHS nationally representative [23, 24]. The NDHS datasets are categorised into many recode files, such as infant (< age 1), child (1-5 years), men (11-54 years), women (15-49 years), couples, and household recodes. Further details on the methods used for implementing DHS are available on www.dhsprogram.com.

Data source

We analysed data from the women's recode file of the 2003, 2008, 2013, and 2018 NDHS. The recode contains information obtained from 41,821 women of reproductive age (15-49 years). In the recode file is information on women's socio-economic and demographic characteristics, birth history, sexual activity, family planning, antenatal care service utilisation, fertility, and child and maternal health, amongst others [23].

Target population and sample

The study targeted women whose age, according to the WHO [25, 26], makes them susceptible to high pregnancy risks. These are women aged below 18 and those above 35, but who still had births in the year that preceded the survey. Given that the pregnancy for the referenced birth occurred at least

one year earlier, the categorisation of women into high-risk pregnancies on the basis of the women's current age refers to women with a birth in the last year whose current age is either less than 19 or greater than 36 [25, 26]. A weighted sample of 1,287 women who met these inclusion criteria and provided information on their utilisation of ANC services while pregnant with the referenced birth was created as a 'subpop' and used for analysis.

Variables and their Measurements

Outcome variable

The outcome variable is receipt of optimal ANC content. It refers to women's receipt of specific care packages or use of specific health services while pregnant with their most recent birth. They are (i) tetanus injection, measured as whether or not women received at least 3 (complete) or less than 3 (incomplete); (ii) iron tablet/syrup (received or not); (iii) sulfadoxine/pyrimethamine (FANSIDAR) (received or not); and (iv) drug for intestinal parasites (received or not). Others are whether or not the respondents' blood and urine were collected and screened for malaria, low blood count and any other health issue during the referenced pregnancy. These care packages and health services represent the minimum intervention recommended by the WHO for pregnant women in developing countries [25] and the pregnancy-related care indices captured in the DHSs. Women whose blood and urine samples were screened and who received all the other four care items were regarded as those who received 'optimal ANC content' (coded as '1'), while women who did not receive either blood or urine screening services were deemed to have received below optimal ANC content (coded as '0'), irrespective of other care package received. Pregnant women's utilisation of urine and blood screening was considered a basic requirement for optimal ANC content because they serve as baseline services, the results of which would determine the number of interventions that pregnant women would require [25].

Explanatory variables

The principal explanatory variable was maternal age, which refers to women's age in the previous year when they got pregnant with the referenced birth. Women whose current age was below 19 years (i.e. below 18 at the time of the pregnancy) were grouped as 'young age risk', while those whose current age was above 36 years (i.e. above 35 at the time of the pregnancy) were grouped as 'old age risk'. This age grouping is at the instance of the WHO's categorisation of women getting pregnant at ages below 18 and above 35 as

women with high-risk pregnancies [25, 26]. Another set of explanatory variables is spatial factors, which refer to the respondent's region of residence, type of place of residence (urban or rural), and state of residence, which were used for spatial analysis. Other explanatory variables are the women's socio-economic and demographic characteristics, which include their educational levels, marital status, level of income and preceding birth interval.

The explanatory variables were used as captured in the standard DHS, but with modifications in the levels of measurement of some of the variables. Wealth status was derived from the DHS wealth index, which is a composite measure of household socio-economic status. It is constructed using principal component analysis of household assets and characteristics, including ownership of durable goods (e.g. television, bicycle), housing materials, water source, and sanitation facilities, rather than direct income or employment measures. Households are ranked into quintiles (poorest, poorer, middle, richer, richest), which were recategorised in this study into 'poor', 'middle', and 'rich' for analysis [23, 24]. Women in legal marital relationships were grouped as 'married', those living with partners without being in a legal relationship were 'cohabiting', those never married were 'single', and the rest were grouped as 'others'. 'Preceding birth interval' refers to the space between the respondents' previous birth and the referenced birth. Women with only one birth history were grouped as 'na', those with less than 36 months of space were grouped as '<3 years' and others as '3+ years'. Women who chose 'not at all' as a response to all the questions on the frequency of listening to the radio, watching television and reading newspapers were grouped as having 'no' media access, while others were grouped as 'yes'. Birth order was 'first' if the referenced birth was the respondent's firstborn and '2nd+' if otherwise.

Data analysis

The spatial analysis examined the predicted percentage of women who received ANC content optimally. A Bayesian model was run for each year to generate 'posterior estimates', which vary from the point estimate of more standard frequentist approaches [27]. The model includes a spatial random effect that smoothens the data according to the spatial structure [28]. The percentages plotted on the maps were derived from the mean of the posterior distribution at the state level.

The first level of analysis was the descriptive presentation of all the study variables, and this entails frequency tabulations and percentage distributions. Other levels of analysis involve a multivariate non-linear decomposition

model, similar to the Fairlie and Blinder-Oaxaca methods, which were employed to decompose the age disparities in antenatal care utilisation [29]. A Decomposition analysis is a statistical technique used to explain differences in an outcome between two groups [30]. It separates the observed gap into two components: (1) the portion explained by differences in measurable characteristics such as education, wealth, or residence, and (2) the unexplained portion, which reflects differences in how those characteristics influence the outcome or the effects of unobserved factors. Spatial mapping was conducted for each survey wave (2003, 2008, 2013, and 2018) to estimate and compare state-level variation in optimal ANC content utilisation over time. For each year, a Bayesian hierarchical model was fitted with optimal ANC utilisation as the outcome, incorporating fixed covariates and a spatially structured random effect to account for geographic dependence between neighbouring states. Temporal comparisons were undertaken by harmonising variables across waves and examining changes in posterior state-level estimates over time. An adjacency matrix enabled information sharing across contiguous states, improving stability in areas with small samples. [28].

The data were appropriately weighted and adjusted to reflect the complex survey design, with no signs of multicollinearity detected based on the variance inflation factor. Statistical analyses were conducted using Stata software version 17.0 (StataCorp, College Station, TX, USA), with spatial analysis performed in R.

Ethical considerations

The DHS study protocols and questionnaires are reviewed and approved by the Ethical Review Board of ICF before use. At the country level, as in the case of the NDHS, the protocols were reviewed and approved by the Federal Ministry of Health to ensure compliance with standard ethical procedures. To use the dataset for this study, we obtained written authorisation from the measures DHS. The dataset analysed is publicly available at https://dhsprogram.com.

Results

The percentage of women who received optimal ANC content in 2003 was negligible across all states. Receipt of optimal ANC content increased marginally in 2008, with the highest increase (21%) recorded in Sokoto state. Bauchi was the only state that recorded a decline in the receipt of optimal ANC content in 2008. In 2013, receipt of optimal ANC content increased to 40% in Zamfara, and many other states registered an increase despite the decline in

other states, including Sokoto. By 2018, receipt of optimal ANC content ranged from 26% in Anambra state to 73% in Ebonyi. Despite the variations over the years, all the states recorded an increase in the receipt of optimal ANC content between 2003 and 2018, but the remaining geographical variations require attention (Figure 1).

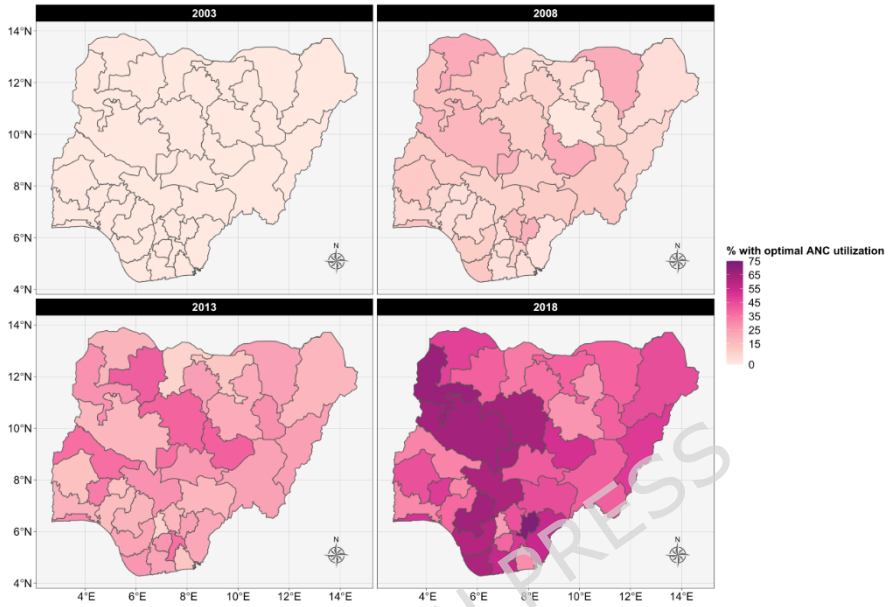

Figure 1: Spatial change in receipt of optimal ANC content among women with high-risk pregnancies in Nigeria from 2003 to 2018.

Table 1 presents the basic characteristics of the respondents used for the DHS series from 2003 to 2018. The results show that respondents used in the NDHS 2013 had the lowest average age (29.5 ± 11.7 years) and the lowest proportion of women with no formal education (72.3%). The majority of all the respondents were married (92.1%), with approximately 2% cohabiting. With the exception of NDHS 2003, Islam was the religion most practised by at least 64% of the respondents across the survey years. No less than half of the respondents across all survey years were poor, with approximately one-quarter (25%) being rich. The proportion residing in rural areas decreased from 78.6% in NDHS 2003 to 66.1% in NDHS 2018. More than three-fifths (68.1%) of the respondents were experienced mothers, as they reported the referenced pregnancy to be their second or more births. Meanwhile, a maximum of 41% of the mothers across survey years adhered to the WHO-recommended birth spacing interval of at least 3 years, with NDHS 2003 being the lowest (34.2%) and NDHS 2018 being the highest (40.9%). Across survey years, the northwest region had the highest proportion (e.g. 47% in 2013) of respondents, while the southeast region had the least (i.e. 7.4%). The

proportion of respondents with access to the media was much higher in NDHS 2003 (70.1%) than in NDHS 2018 (56.2%). Asked about the place of delivery of the referenced pregnancy, less than 30% reported having delivered at a health facility, although with a slight improvement from 24.7% in 2003 to 32.4% in 2018.

Table 1: Distribution of respondents by selected socio-demographic characteristics

		DHS 2003 (N=302) **n (%)**	DHS 2008 (N=1257) **n (%)**	DHS 2013 (N=1279) **n (%)**	DHS 2018 (N=1287) **n (%)**	Total (N=4124) **n (%)**
Highest level of education	No Education	218 (72.3)	720 (57.3)	758 (59.3)	740 (57.5)	2436 (59.1)
	Primary	46 (15.2)	283 (22.5)	262 (20.5)	236 (18.3)	826 (20.0)
	Secondary	34 (11.2)	218 (17.3)	228 (17.8)	255 (19.8)	734 (17.8)
	Tertiary	4 (1.4)	35 (2.8)	31 (2.4)	57 (4.4)	127 (3.1)
Mean age (in years)		29.5 ± 11.7	32.1 ± 11.6	31.9 ± 11.5	32.1 ± 11.2	31.8 ± 11.5
Marital status	Single	17 (5.5)	54 (4.3)	54 (4.2)	42 (3.3)	167 (4.0)
	Married	272 (90.3)	1164 (92.7)	1179 (92.2)	1180 (91.7)	3796 (92.1)
	Cohabiting	4 (1.5)	20 (1.6)	22 (1.7)	33 (2.5)	79 (1.9)
	Others	8 (2.7)	18 (1.4)	23 (1.8)	32 (2.5)	81 (2.0)
Religion	Christianity	41 (13.6)	428 (34.3)	364 (28.5)	370 (28.7)	1204 (29.2)
	Islam	28 (9.3)	798 (63.9)	890 (69.9)	908 (70.5)	2624 (63.7)
	Others	232 (77.1)	23 (1.8)	24 (1.9)	9 (0.7)	289 (7.0)
Wealth status	Poor	154 (51.0)	694 (55.2)	738 (57.7)	666 (51.8)	2252 (54.6)
	Middle	66 (21.7)	244 (19.4)	238 (18.6)	293 (22.8)	840 (20.4)
	Rich	82 (27.3)	319 (25.4)	303 (23.7)	328 (25.5)	1032 (25.0)
Type of place of residence	Urban	65 (21.4)	268 (21.3)	338 (26.4)	437 (33.9)	1107 (26.8)
	Rural	237 (78.6)	989 (78.7)	941 (73.6)	850 (66.1)	3017 (73.2)
Birth order	First	124 (41.2)	367 (29.2)	410 (32.0)	415 (32.3)	1316 (31.9)
	2^{nd} +	177 (58.8)	890 (70.8)	869 (68.0)	872 (67.7)	2808 (68.1)
	na	124 (41.2)	368 (29.3)	414 (32.4)	417 (32.4)	1323 (32.1)

Preceding birth interval	<3 years	74 (24.6)	401 (31.9)	348 (27.2)	343 (26.7)	1167 (28.3)
	3+ years	103 (34.2)	487 (38.8)	517 (40.5)	527 (40.9)	1634 (39.6)
Region	North Central	27 (8.9)	156 (12.4)	139 (10.9)	145 (11.3)	467 (11.3)
	North East	79 (26.3)	259 (20.6)	223 (17.5)	250 (19.5)	812 (19.7)
	North West	132 (43.7)	458 (36.5)	601 (47.0)	578 (44.9)	1769 (42.9)
	South East	8 (2.8)	90 (7.2)	94 (7.4)	110 (8.6)	303 (7.4)
	South South	37 (12.4)	141 (11.2)	110 (8.6)	98 (8.6)	386 (9.4)
	South West	18 (5.9)	152 (12.1)	111 (8.7)	106 (8.2)	388 (9.4)
Media Access	No	89 (29.9)	457 (36.8)	510 (39.9)	564 (43.8)	1620 (39.5)
	Yes	208 (70.1)	783 (63.2)	769 (60.1)	723 (56.2)	2483 (60.5)
Place of delivery	Non-health facility	227 (75.3)	919 (73.1)	894 (70.0)	870 (67.6)	2911 (70.6)
	Health facility	75 (24.7)	338 (26.9)	384 (30.0)	417 (32.4)	1213 (29.4)

Figure 2 shows that none of the young mothers received optimal ANC content in 2003. Only about 1% of old mothers received optimal ANC content during the period. The rate of receipt of optimal ANC content increased to 9.1% among old mothers and 6.7% among young mothers in 2013. From 2013 to 2018, receipt of optimal ANC content increased steadily, with older mothers sustaining a consistently higher access rate than younger mothers.

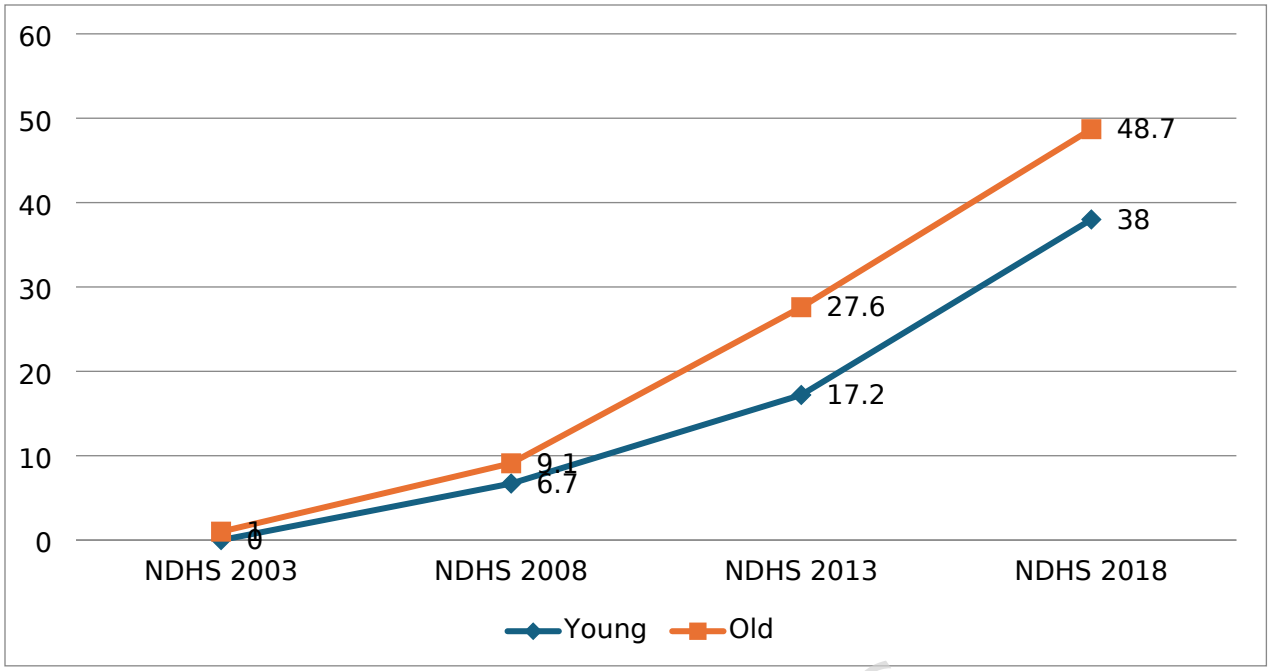

Fig. 2: Prevalence (%) of receiving Optimal ANC content among young and old who are at high-risk pregnancies across the NDHS waves

Table 2 shows the relationships between the background characteristics and receipt of ANC content, decomposed into old and young respondents. The results show that older mothers (27%) received more optimal ANC content than younger mothers (18.8%). Birth order was significantly associated with the rate of receiving optimal ANC content among both young ($\chi 2=27$, $p<0.05$) and old mothers ($\chi^2=12$, $p<0.05$), as they were more likely to receive optimal ANC content during their first pregnancy. Also, both young and old mothers who had at least 3 years of birth spacing had a higher rate of receiving optimal ANC content than mothers with shorter birth spacing (i.e. <3 years). Marital status had no significant association with receiving optimal ANC content among both categories of mothers. Among young mothers, 43.8% of those with a tertiary level education compared with only 13.2% of those with no education received optimal ANC content ($\chi^2=205$, $p<0.05$). A similar trend was observed among old mothers, with more of those having a tertiary level education (53.6%) than those having no formal education (19.1%) receiving optimal ANC content ($\chi^2=222$, $p<0.05$). Receipt of optimal ANC content was significantly higher among urban residents for both young and old mothers ($\chi^2=100$, $p<0.05$ and $\chi^2=316$, $p<0.05$, respectively). However, access to the media had no significant influence on the receipt of optimal ANC content among young mothers.

Table 2: Cross-tabulation of antenatal care utilisation by socio-demographic characteristics among young and old women

		Young age pregnancy risks (N=1575)			Old-age pregna (N=2549	
		ANC Utilisation			ANC Utiliza	
		Below optimal **n (%)**	Optimal **n (%)**	χ^2 (***p***)	Below optimal **n (%)**	
Birth order	First	1029 (79.7)	262 (20.3)	27* (***0.00***)	13 (49.4)	1
	2nd +	250 (87.9)	34 (12.1)		1849 (73.3)	6
Preceding birth interval	Na	1035 (79.8)	262 (20.2)	24* (***0.03***)	13 (51.1)	1
	<3 years	208 (88.1)	28 (12.0)		693 (74.5)	2
	3+ years	35 (85.1)	6 (14.9)		1156 (72.6)	4
Marital status	Single	121 (78.4)	33 (21.6)	7 (***0.44***)	10 (78.0)	
	Married	1098 (81.4)	251 (18.6)		1791 (73.2)	6
	Cohabiting	32 (77.9)	9 (22.1)		28 (73.2)	1
	Others	28 (90.2)	3 (9.8)		33 (64.7)	1
Highest level of education	No Education	862 (86.8)	131 (13.2)	205* (***0.00***)	1167 (80.9)	2
	Primary	204 (80.2)	50 (19.8)		396 (69.3)	1
	Secondary	212 (65.0)	114 (35.0)		240 (58.7)	1
	Tertiary	1 (56.2)	9057 (43.8)		58 (46.4)	6
Religion	Christianity	247 (73.9)	87 (26.1)	105* (***0.00***)	624 (71.7)	2
	Islam	891 (81.1)	207 (18.9)		1093 (71.6)	4
	Others	140 (98.7)	2 (1.3)		141 (95.8)	
Wealth status	Poor	838 (85.0)	148 (15.0)	77* (***0.00***)	1064 (84.1)	2
	Middle	246 (78.2)	68 (21.8)		380 (72.3)	1
	Rich	195 (71.1)	79 (28.9)		418 (55.2)	3
Type of place of residence	Urban	202 (68.5)	93 (31.5)	100* (***0.00***)	448 (55.1)	3
	Rural	1077 (84.1)	204 (15.9)		1414 (81.4)	3
Region	North Central	121 (83.3)	24 (16.7)	134* (***0.00***)	221 (68.5)	1
	North East	330 (82.7)	69 (17.3)		315 (76.3)	9
	North West	626 (82.6)	132 (17.4)		756 (74.7)	2
	South East	35 (49.3)	36 (50.7)		146 (62.8)	8
	South South	103 (85.3)	18 (14.7)		218 (82.1)	4
	South West	64 (78.5)	18 (21.5)		207 (67.8)	9
Mass Media Access	No	588 (83.5)	116 (16.5)	12 (***0.05***)	768 (83.9)	1
	Yes	684 (79.2)	180 (20.8)		1079 (66.7)	5
DHS series	2003	155 (100.0)	0	516* (***0.00***)	146 (99.0)	
	2008	426 (93.3)	31 (6.7)		728 (90.9)	
	2013	402 (82.8)	84 (17.2)		574 (72.4)	2
	2018	297 (62.0)	182 (38.0)		415 (51.3)	3
Total		**81.2**	**18.8**		**73.0**	

*significant at p< 0.05

Table 3 shows that education, wealth status and region of residence were significantly associated with receipt of optimal ANC content among young mothers. The likelihood of receiving optimal ANC content increased consistently from 0.54 (CI: 0.10-0.97) among young mothers with primary education to 0.92 (CI: 0.46-0.98) among those with secondary education. Results on the influence of wealth status show that young mothers from rich households were 63% (CI: 0.17-0.82) more likely than their counterparts from poor households to receive optimal ANC content. Besides wealth, the results show that sociodemographic factors such as marital status, type of place of residence and media access had a significant influence on receipt of optimal ANC content among older mothers. Specifically, married older mothers were about twice as likely as their unmarried counterparts to receive optimal ANC content. Also, for older women, living in rural areas was significantly associated with reduced likelihood of receiving optimal ANC content 34% (coef.= -0.34; CI: -0.58 -0.09). Unlike younger women, the results also show that media access had a significant influence on the receipt of optimal ANC among older women.

Table 3: Multivariate logit models showing effects on antenatal care utilisation among old and young mothers

		Women with young age pregnancy risks (N=1575)		Women with old-age pregnancy risks (N=2549)	
		Coef.	95% CI	Coef.	95% CI
Birth order	First	RC		RC	
	2nd +	-14.2	-1732.2 – 1703.9	-14.2	1543.1 1514.8
Preceding birth interval	Na	RC		RC	
	<3 years	13.9	-1704.2 – 1731.9	13.4	-1515.5 1542.4
	3+ years	14.0	-1704.2 – 1731.9	13.4	-1515.5 1542.4
Marital status	Single	RC		RC	
	Married	0.18	-0.38 – 0.75	1.99*	1.13 2.86
	Cohabiting	-0.22	-1.10 – 0.66	1.98	-0.04 3.99
	Others	-0.58	-1.86 – 0.69	2.22*	0.24 4.19
Highest level of education	No Education	RC		RC	
	Primary	0.54*	0.10 0.97	0.71*	0.41 1.01
	Secondary	0.92*	0.46 0.98	0.82*	0.44 1.19
	Tertiary	2.73	-0.22 5.68	0.95*	0.42 1.47
Religion	Christianity	RC		RC	
	Islam	-0.04	-0.57 0.49	0.26	-0.07 0.58
	Others	-0.68	-2.45 1.08	-0.41	-1.43 0.60
Wealth status	Poor	RC		RC	
	Middle	0.26	-0.13 0.65	0.56*	0.27 0.85

	Rich	0.63*	0.17 0.82	1.11*	0.78 1.44
Type of place of residence	Urban	RC		RC	
	Rural	-0.31	-0.71 0.08	-0.34*	-0.58 -0.09
Region	North Central	RC		RC	
	North East	0.39	-0.16 0.93	0.19	-0.18 0.55
	North West	0.17	-0.38 0.71	0.04	-0.32 0.39
	South East	0.81*	0.06 0.87	-0.28	-0.73 0.17
	South South	-0.41	-1.15 0.34	-1.14*	-1.60 -0.68
	South West	-0.51	-1.31 0.30	-0.60*	-1.02 -0.19
Media Access	No	RC		RC	
	Yes	0.32	-0.00 0.65	0.51*	0.26 0.77
DHS series	2003	IO	IO	RC	
	2008	RC		2.53*	0.47 4.60
	2013	-2.38	-2.82 -1.93	3.88*	1.83 5.94
	2018	-1.11	-1.44 -0.78	4.92*	2.86 6.98

Note: *significant at p<o.o5; CI: confidence intervals; RC: reference category; IO: insufficient observations

Table 4 presents results on the decomposition analysis of receiving optimal ANC content between young and old mothers. Briefly stated, a decomposition coefficient due to *differences in characteristics* (E) indicates the amount of differences in receiving optimal ANC content that is attributable to differences in the socio-demographic characteristics, such as education, media access, etc., among the young and old women. On the other hand, a decomposition coefficient due to *differences in coefficients* (C) shows the differences in receiving optimal ANC content that occurred (e.g. due to experiences, beliefs about ANC, etc.) even if both sets of women had the same socio-demographic characteristics. The results show that overall, 23.8% of the disparities in receipt of optimal ANC content were attributable to differences in the socio-demographic characteristics of young and old women. The multivariable decomposition analysis shows that having a spacing of at least 3 years between births contributed to about 2.7% of the higher receipt of optimal ANC content among older mothers. Being married significantly contributed to about 38% of the higher rate of receiving optimal ANC content among old and young mothers. In addition, being educated up to the tertiary level contributed to about 16.5% of the higher levels of receiving optimal ANC content among older mothers. Additionally, having access to the media significantly contributed to the differences in receipt of optimal ANC content among young and old mothers.

Table 4: Decomposition of disparity in receiving optimal ANC content between young and old mothers

		Due to differences in characteristics (E)	Due to differences in coefficients (C)

		Coefficients	Percent (%)	Coefficients	Percent (%)
% total explained the disparity			**23.8**		**76.2**
Birth order	First	Ref		Ref	
	2nd +	-2.26	-32.12	-0.01	-17.1
Preceding birth interval	Na	Ref		Ref	
	<3 years	0.55	783	-0.00	-3.3
	3+ years	1.60**	2.7	-0.00	-14.1
Marital status	Single	Ref		Ref	
	Married	0.26**	37.6	0.11**	12.2
	Cohabiting	-0.004	-5.95	0.01	9.4
	Others	-0.000	-0.45	0.01***	9.2
Highest level of education	No Education	Ref		Ref	
	Primary	0.01	14.6	0.00	6.1
	Secondary	0.01	-19.2	-0.01	-8.1
	Tertiary	0.01**	16.5	-0.00	-0.1
Religion	Christianity	Ref		Ref	
	Islam	-0.01	-11.6	0.05*	77.9
	Others	0.01	13.8	0.01	12.7
Wealth status	Poor	Ref		Ref	
	Middle	0.00	2.0	0.01	13.7
	Rich	0.02***	26.8	0.02	24.9
Type of place of residence	Urban	Ref		Ref	
	Rural	0.01	15.7	-0.02*	-23.6
Region	North Central	Ref		Ref	
	North East	-0.001	-2.0	-0.01	-20.2
	North West	-0.001	-1.9	-0.02	-23.7
	South East	-0.002	-2.6	-0.01	-11.7
	South South	-0.01	-7.1	-0.01	-9.0
	South West	-0.01	-10.5	-0.00	-2.3
Mass Media Access	No	Ref		Ref	
	Yes	0.01***	7.4	-0.03*	39.7

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Discussion

In this study, we found a persistently low prevalence of receiving optimal ANC content among women with high-risk pregnancies (specifically those of young or advanced maternal age) in Nigeria, with younger women particularly disadvantaged. The average receipt of optimal ANC content was higher among older women (27%) compared to younger women (18.8%). Also, we observed a steady increase in the receipt of optimal ANC content over the survey years, rising from 1% in 2003 to 48.7% in 2018 among older women, and from 0% in 2003 to 38% in 2018 among younger women. Socio-economic factors such as education and wealth were significantly associated with receipt of optimal ANC

content among both age groups, while marital status, place of residence, and media access influenced receipt among older women. Regional disparities in the receipt of optimal ANC content were more pronounced among younger women, highlighting the spatial dimension of inequalities in maternal healthcare in Nigeria.

This study found that the majority of women with high-risk pregnancies in Nigeria did not receive optimal ANC content. The low prevalence of receiving optimal ANC content highlights a critical gap in maternal healthcare services in Nigeria, as a mere attendance at ANC visits does not guarantee that women benefit from the full package of recommended interventions. The current findings support previous studies that reported that while ANC coverage has improved in many low- and middle-income countries, the quality and completeness of services remain inadequate, with many women missing essential preventive and diagnostic components [31, 32]. This discrepancy underscores the need to shift policy focus from just increasing ANC attendance to ensuring that women consistently receive the full package of the essential ANC content, which is vital in reducing maternal and neonatal morbidity and mortality [31, 33]. Meanwhile, the observed steady increase in receipt of optimal ANC content among both young and older women since 2003 could be attributed to the impact of the various interventions to scale up ANC uptake among pregnant women in Nigeria over the past few decades [34, 35]. Nonetheless, the current findings highlight the need for further efforts to provide optimal ANC content to all pregnant women in Nigeria, particularly those at high risk due to young or advanced maternal age.

The findings also revealed a persistent age-related disparity in maternal healthcare quality in Nigeria, with the average receipt of optimal ANC content being higher among older women (27%) compared to younger women (18.8%). This finding aligns with previous evidence in Nigeria that maternal age influences access to components of ANC [36], with adolescents often facing socio-cultural, low health literacy, and economic barriers that reduce their ability to receive comprehensive ANC services [37]. In contrast, previous pregnancy experiences, increased exposure to maternal and child health information, and greater autonomy in healthcare decision-making might have contributed to increased receipt of optimal ANC content among older women [7]. These findings highlight the need for age-sensitive ANC interventions that prioritise younger women and ensure they have equitable access to the full package of ANC content during visits.

Further, the results revealed that socio-economic factors, such as education and wealth, were significantly associated with the receipt of optimal ANC content among both younger and older women with high-risk pregnancies in Nigeria. Previous studies have shown that women's educational attainment enhances health literacy and decision-making capacity, thereby increasing the likelihood of receiving comprehensive ANC services [38, 39]. Similarly, wealth status influences affordability and access to quality maternal healthcare services, with poorer women often having limited access to the full ANC package [40]. Therefore, interventions aimed at promoting the receipt of optimal ANC content among women with high-risk pregnancies in Nigeria need to target those with limited or no formal education, as well as the poor.

Also, the current findings show that marital status, place of residence, and media access influenced receipt of optimal ANC content among older women, reflecting the importance of household support and information exposure in influencing health-seeking behaviours among the women [41]. Conversely, geographical disparities in the receipt of optimal ANC content were more pronounced among younger women, with those in the South East being more likely to receive optimal ANC content. Available evidence shows that geographic and regional disparities influence the receipt of optimal ANC content in Nigeria [11], emphasising the impact of geographic inequalities and the effectiveness of localised healthcare systems. Meanwhile, a previous study that investigated barriers to ANC use in Nigeria revealed that the South East region has the least non-users of ANC (14.3%) [42], which potentially contributes to their increased receipt of optimal ANC content. Besides, studies have shown that regional disadvantage, particularly in northern Nigeria, significantly limits access to comprehensive ANC services, with younger women disproportionately affected due to socio-cultural constraints and lower autonomy [36, 43]. Previous findings from SSA suggested that geographic disparities in healthcare delivery remain a significant barrier to equitable receipt of ANC content [44, 45]. Thus, spatially targeted interventions are required to address the geographical inequalities in the receipt of optimal ANC content, particularly among younger women in Nigeria.

Strengths and limitations

This study used nationally representative datasets, thereby enhancing the generalisability of findings to women with high-risk pregnancies in Nigeria. Also, the inclusion of multiple survey years further allowed for trend analysis of optimal ANC content, which could guide future studies and monitoring of trends. However, the study has some limitations that need to be considered

when interpreting the current findings. First, the definition of optimal ANC was based on the receipt of WHO-recommended ANC interventions for pregnant women in developing countries, which may not fully capture context-specific variations. Second, a high-risk pregnancy was defined solely by advanced maternal age, although other factors such as parity, comorbidities, and obstetric history could also be relevant. Third, the reliance on self-reported data introduces the possibility of recall bias, particularly given the DHS recall period.

Additionally, the cross-sectional design of the study further limits causal inference, restricting interpretation to associations rather than causal relationships. Additionally, this study focuses specifically on antenatal care utilisation among women with high-risk pregnancies; therefore, the findings should not be generalised to overall health system performance or other areas of healthcare delivery. Finally, ecological issues may arise in state-level mapping due to varying cluster sample sizes, which could influence the precision estimates.

Implications for Maternal Health

The current findings highlight the need for maternal healthcare interventions and policies in Nigeria that are both age-sensitive and regionally targeted. Whilst ANC services in Nigeria are free, many women with high-risk pregnancies, particularly adolescents and those of advanced maternal age, do not receive optimal ANC care. Adolescents require adolescent-friendly services, including confidential counselling, peer support, and school-based reproductive health education, with special outreach in northern Nigeria, where socio-cultural barriers are strongest. For older women, especially those unmarried or in rural areas, interventions should emphasise community-based education, mobile health clinics, and improve access to health information through radio and other media. To address financial barriers, conditional cash transfers or transport incentives for poor households could be assessed to improve uptake and access to optimal ANC content. Regional disparities must be addressed by strengthening primary healthcare systems in underserved areas, such as the northern regions, while sustaining service quality in areas with higher access to optimal ANC content, such as the South East.

Conclusion and recommendations for future studies

This study shows persistently low receipt of optimal ANC content among women with high-risk pregnancies in Nigeria, with adolescents particularly disadvantaged. Thus, addressing age and regional disparities in the receipt of

optimal ANC content requires targeted, context-specific interventions that go beyond ANC attendance to ensuring delivery of comprehensive ANC service to women with high-risk pregnancies in Nigeria. Future studies should investigate age-specific disparities in pregnancy outcomes, regional barriers to ANC quality, and the effectiveness of adolescent-friendly models.

Abbreviations

ANC: Antenatal Care; DHS: Demographic and Health Survey; FCT: Federal Capital Territory; HIV: Human Immunodeficiency Virus; ICF: ICF International; LMICs: Low- and Middle-Income Countries; NDHS: Nigeria Demographic and Health Survey; SSA: Sub-Saharan Africa; WHO: World Health Organisation; RC: Reference Category; IO: Insufficient Observations; CI: Confidence Intervals.

Acknowledgements
The authors are grateful to MEASURE DHS for granting access to the dataset used in this study.

Authors' contributions
OAB conceived and designed the study. OAB, OOO and AM drafted the manuscript, conducted the methodology, and performed the statistical analysis. HM and OAB performed the spatial analysis. AA supervised the overall study development and critically reviewed the manuscript for methodological and intellectual content. All authors read and approved the final version of the manuscript before submission.

Funding
There is no specific funding received for this study.

Availability of data and materials
The datasets utilised in this study can be accessed at https://dhsprogram.com/data/available-datasets.cfm.

Declarations

Ethics approval and consent to participate
Since the authors of this manuscript did not collect the data, we sought permission from the MEASURE DHS website and access to the data was provided after our request was assessed and approved on the 13th of February 2024. The Nigerian committee and the ethics Boards ethically accept the DHS surveys. Each participant gave either written or verbal consent during each of the surveys.

Consent for publication
Not applicable.

Competing interests

The authors declare no competing interests.

Author's details

[1]Department of Public Health, York St John University, London, United Kingdom; [2]Demography and Population Studies Programme, Schools of Public Health and Social Sciences, University of the Witwatersrand, Johannesburg, South Africa; [3]Department of Demography and Social Statistics, Obafemi Awolowo University, Osun State, Nigeria; [4]Department of Health, Physical Education and Recreation, University of Cape Coast, Cape Coast, Ghana; [5]African Institute for Development Policy, Lilongwe, Malawi

References

1. World Health Organisation: **Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division.** World Health Organization; 2023.
2. Hug L, You D, Blencowe H, Mishra A, Wang Z, Fix MJ, Wakefield J, Moran AC, Gaigbe-Togbe V, Suzuki E: **Global, regional, and national estimates and trends in stillbirths from 2000 to 2019: a systematic assessment.** *The Lancet* 2021, **398:**772-785.
3. Tukur J, Lavin T, Adanikin A, Abdussalam M, Bankole K, Ekott MI, Godwin A, Ibrahim HA, Ikechukwu O, Kadas SA: **Quality and outcomes of maternal and perinatal care for 76,563 pregnancies reported in a nationwide network of Nigerian referral-level hospitals.** *EClinicalMedicine* 2022, **47**.
4. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller A-B, Daniels J, Gülmezoglu AM, Temmerman M, Alkema L: **Global causes of maternal death: a WHO systematic analysis.** *The Lancet global health* 2014, **2:**e323-e333.
5. Tandu-Umba B, Mbangama MA, Kamongola KMB, Kamgang Tchawou AG, Kivuidi MP, Kasonga Munene S, Kambashi Meke I, Kapuku Kabasele O, Kondoli BJ, Kikuni KR: **Pre-pregnancy high-risk factors at first antenatal visit: how predictive are these of pregnancy outcomes?** *International Journal of Women's Health* 2014**:**1011-1018.
6. Tadese ZB, Sani J, Kebede SD, Kitil GW, Dube GN, Nimani TD: **Sociodemographic determinants and regional disparities of first-trimester antenatal care initiation among Nigerian women: a multilevel analysis of 2018 NDHS data.** *Frontiers in Global Women's Health* 2025, **6:**1502905.
7. Setlhare K, Ewemooje OS, Molefe WB, Adebola OG, Adebola FB: **Determinants of adequate antenatal care utilisation among Nigerian women.** *Discover Public Health* 2025, **22:**563.

8. World Health Organisation: *WHO recommendations on antenatal care for a positive pregnancy experience.* World Health Organisation; 2016.
9. Alem AZ, Yeshaw Y, Liyew AM, Tesema GA, Alamneh TS, Worku MG, Teshale AB, Tessema ZT: **Timely initiation of antenatal care and its associated factors among pregnant women in sub-Saharan Africa: A multicountry analysis of Demographic and Health Surveys.** *PloS one* 2022, **17:**e0262411.
10. Ayele BA, Holliday E, Chojenta C: **Determinants of antenatal care service utilisation in sub-Saharan Africa: an analysis of demographic and health surveys data (2015–2022).** *Archives of Public Health* 2025, **83:**189.
11. Adewuyi EO, Auta A, Adewuyi MI, Philip AA, Olutuase V, Zhao Y, Khanal V: **Antenatal care utilisation and receipt of its components in Nigeria: Assessing disparities between rural and urban areas—A nationwide population-based study.** *Plos one* 2024, **19:**e0307316.
12. Fagbamigbe AF, Idemudia ES: **Barriers to antenatal care use in Nigeria: evidences from non-users and implications for maternal health programming.** *BMC pregnancy and childbirth* 2015, **15:**95.
13. Zhang Y, Ding W, Wu T, Wu S, Wang H, Fawad M, Adane AA, Dai X, Zhu X, Xu X: **Pregnancy with multiple high-risk factors: a systematic review and meta-analysis.** *Journal of global health* 2025, **15:**04027.
14. Rajbanshi S, Norhayati MN, Nik Hazlina NH: **High-risk pregnancies and their association with severe maternal morbidity in Nepal: A prospective cohort study.** *PloS one* 2020, **15:**e0244072.
15. Nghargbu R, Olaniyan O: *Determinants of antenatal care utilisation in Nigeria.* African Development Bank; 2019.
16. Adewuyi EO, Auta A, Khanal V, Bamidele OD, Akuoko CP, Adefemi K, Tapshak SJ, Zhao Y: **Prevalence and factors associated with underutilisation of antenatal care services in Nigeria: A comparative study of rural and urban residences based on the 2013 Nigeria demographic and health survey.** *PloS one* 2018, **13:**e0197324.
17. Bolarinwa OA, Sakyi B, Ahinkorah BO, Ajayi KV, Seidu A-A, Hagan Jr JE, Tessema ZT: **Spatial patterns and multilevel analysis of factors associated with antenatal care visits in Nigeria: Insight from the 2018 Nigeria Demographic Health Survey.** In *Healthcare*. MDPI; 2021: 1389.
18. Abanga EA, Ziblim AM, Boah M: **Antenatal care quality and pregnancy outcomes in the northern region of Ghana: a mixed-methods analysis.** *BMC Pregnancy and Childbirth* 2025, **25:**810.
19. Khatri RB, Mengistu TS, Assefa Y: **Input, process, and output factors contributing to quality of antenatal care services: a scoping review of evidence.** *BMC Pregnancy and Childbirth* 2022, **22:**977.
20. Commission NP: **Nigeria demographic and health survey 2018.** NPC, ICF; 2019.

21. Commission NP: **Nigeria demographic and health survey 2013.** National Population Commission, ICF International; 2013.
22. Macro I, Commission NP: **Nigeria demographic and health survey 2008.** National Population Commission, ICF Macro; 2009.
23. Aliaga A, Ren R: *The optimal sample sizes for two-stage cluster sampling in demographic and health surveys.* ORC Macro; 2006.
24. DHS Program: **Collaboration yields new disability questionnaire module.** USAID; 2017.
25. Londero A, Rossetti E, Pittini C, Cagnacci A, Driul L: **Maternal age and the risk of adverse pregnancy outcomes: a retrospective cohort study.** *BMC Pregnancy and Childbirth* 2019, **19:**261.
26. **Adolescent pregnancy.** [https://www.who.int/news-room/fact-sheets/detail/adolescent-pregnancy]
27. Neal S, Channon AA, Chintsanya J: **The impact of young maternal age at birth on neonatal mortality: evidence from 45 low and middle income countries.** *PloS one* 2018, **13:**e0195731.
28. Moraga P: *Geospatial health data: Modeling and visualisation with R-INLA and shiny.* Chapman and Hall/CRC; 2019.
29. Rahimi E, Hashemi Nazari SS: **A detailed explanation and graphical representation of the Blinder-Oaxaca decomposition method with its application in health inequalities.** *Emerging Themes in Epidemiology* 2021, **18:**12.
30. De Boer P, Rodrigues JF: **Decomposition analysis: when to use which method?** *Economic Systems Research* 2020, **32:**1-28.
31. Benova L, Tunçalp Ö, Moran AC, Campbell OMR: **Not just a number: examining coverage and content of antenatal care in low-income and middle-income countries.** *BMJ global health* 2018, **3**.
32. Arsenault C, Jordan K, Lee D, Dinsa G, Manzi F, Marchant T, Kruk ME: **Equity in antenatal care quality: an analysis of 91 national household surveys.** *The Lancet Global Health* 2018, **6:**e1186-e1195.
33. Tunçalp O, Pena-Rosas JP, Lawrie T, Bucagu M, Oladapo OT, Portela A, Metin Gülmezoglu A: **WHO recommendations on antenatal care for a positive pregnancy experience—going beyond survival.** *BJOG: an international journal of obstetrics and gynaecology* 2017, **124:**860-862.
34. Federal Ministry of Health: **Antenatal care: An orientation package for health care providers.** Federal Ministry of Health, Nigeria; 2017.
35. Fagbamigbe AF, Olaseinde O, Setlhare V: **Sub-national analysis and determinants of numbers of antenatal care contacts in Nigeria: assessing the compliance with the WHO recommended standard guidelines.** *BMC Pregnancy and Childbirth* 2021, **21:**402.
36. Envuladu EA, Issaka AI, Dhami MV, Sahiledengle B, Agho KE: **Differential Associated Factors for Inadequate Receipt of Components and Non-Use of Antenatal Care Services among Adolescent, Young, and Older Women in Nigeria.** *International Journal of Environmental Research and Public Health* 2023, **20:**4092.

37. Oladele R, Ojo E, Okoduwa GE, Olajide OA, Olufadewa I, Adesina M: **Utilisation of antenatal care by young mothers and adolescents in Nigeria.** *Discover Public Health* 2024, **21:**206.
38. Lori JR, Kukula VA, Liu L, Apetorgbor VE, Ghosh B, Awini E, Lockhart N, Amankwah G, Zielinski R, Moyer CA: **Improving health literacy through group antenatal care: results from a cluster randomised controlled trial in Ghana.** *BMC Pregnancy and Childbirth* 2024, **24:**37.
39. Nwosu CO, Ataguba JE: **Socioeconomic inequalities in maternal health service utilisation: a case of antenatal care in Nigeria using a decomposition approach.** *BMC public health* 2019, **19:**1493.
40. Afulani PA: **Rural/urban and socioeconomic differentials in quality of antenatal care in Ghana.** *PloS one* 2015, **10:**e0117996.
41. He Q, Abdureyim M, He Z, Ma X, Huang M, Zhang T, Qi X, Hee J, Tang K: **Factors associated with age-specific maternal health-seeking behaviours among women: A Multiple Indicator Cluster Survey-based study in 10 African countries.** *Journal of global health* 2022, **12:**04095.
42. Fagbamigbe AF, Idemudia ES: **Barriers to antenatal care use in Nigeria: evidences from non-users and implications for maternal health programming.** *BMC pregnancy and childbirth* 2015, **15:**1-10.
43. Imo CK: **Influence of women's decision-making autonomy on antenatal care utilisation and institutional delivery services in Nigeria: evidence from the Nigeria Demographic and Health Survey 2018.** *BMC Pregnancy and Childbirth* 2022, **22:**141.
44. Belay DB, Fenta HM, Birhan NA, Rad NN, Chen D-G: **Spatial Disparities of Antenatal Care Utilization among Pregnant Women in Sub-Saharan Africa: Bayesian Geo-Additive Modelling Approach.** *Frontiers in Public Health* 2025, **13:**1517724.
45. Macharia PM, Joseph NK, Nalwadda GK, Mwilike B, Banke-Thomas A, Benova L, Johnson O: **Spatial variation and inequities in antenatal care coverage in Kenya, Uganda and mainland Tanzania using model-based geostatistics: a socioeconomic and geographical accessibility lens.** *BMC pregnancy and childbirth* 2022, **22:**908.