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Original Research Article

Socioeconomic Determinants of Infant Mortality in Northern Nigeria: A Multivariable Analysis of NDHS 2018 Data

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Abstract: Infant mortality remains a significant public health challenge in Nigeria, with the Northern region experiencing disproportionately high rates. This study investigates the socioeconomic determinants of infant mortality, focusing on maternal education and household wealth, using data from the 2018 Nigeria Demographic and Health Survey (NDHS). A total of 80,110 women aged 15–49 was analysed using multivariable logistic regression models to assess the independent effects of socioeconomic status on the likelihood of infant death. The results show that maternal education and wealth index are significantly associated with infant mortality. Women with higher education had 18% lower odds of experiencing infant mortality compared to those with no education. In comparison, those in the richest wealth quintile had 67% lower odds than the poorest. These findings underscore the critical role of socioeconomic factors in shaping infant survival outcomes and highlight the need for region-specific interventions in Northern Nigeria. The study contributes to the growing evidence that improving women's access to education and economic resources is fundamental to reducing infant deaths. Targeted policy actions addressing these social determinants can drive meaningful child health and survival progress.

Keywords: Infant Mortality, Maternal Education, Wealth Index, Northern Nigeria, Social Determinants of Health.

I. INTRODUCTION

Infant mortality remains one of the most pressing public health concerns in Sub-Saharan Africa, where it is estimated that at least one in nine children dies before reaching the age of five. A significant proportion of these deaths occur during the first year of life, marking infant mortality (IM) as a critical indicator of both child and maternal health status. Sub-Saharan Africa accounts for approximately 38 percent of global neonatal deaths, with a newborn death rate of 34 deaths per 1,000 live births (Estimates, 2015). Within this region, Nigeria contributes substantially to the high burden, exhibiting one of the highest infant mortality rates. The most recent estimates place Nigeria's infant mortality rate at 74 deaths per 1,000 live births, a statistic that underlines the magnitude of the problem and the need for targeted public health interventions (Pons-Duran et al., 2016). The problem of infant mortality in Nigeria is even more pronounced in the northern regions of the country, where deaths are recorded at disproportionately higher rates than in the south. Contributing factors are multifaceted, but growing evidence highlights the central role of socioeconomic variables such as maternal education and household wealth. These

variables significantly influence a mother's ability to access healthcare, adopt preventive health measures, and utilize available child survival services. According to Ezeh et al. (2015), higher maternal education correlates with greater awareness of good health practices, including antenatal care and immunization, which are crucial for infant survival. Similarly, Adewuyi et al. (2017) emphasized that poverty and limited economic opportunities reduce access to healthcare facilities, adequate nutrition, and safe living environments, all of which are necessary to ensure the survival of infants.

Despite the recognized importance of socioeconomic determinants in child survival, most existing studies in Nigeria have focused on national-level data or urban-rural differentials, often overlooking regional disparities. Studies such as those by Salawu et al. (2021) and Morakinyo and Fagbamigbe (2017) have documented significant differences in infant health outcomes based on location. However, there remains a dearth of focused research on the northern region of Nigeria, where infant mortality rates are among the highest in the country. This gap limits the capacity of public health policies to tailor interventions that effectively address the specific needs and vulnerabilities of populations in the North. Moreover, the interaction between wealth status and education may compound or mitigate risk factors in ways that vary by region. While maternal education improves health literacy and decision-making, its effect may be constrained by economic hardship, as pointed out by Ibrahim et al. (2019), who found that children born to poor, uneducated mothers were significantly more likely to die in infancy. The persistent regional inequities in Nigeria call for a deeper investigation into how socioeconomic determinants affect infant mortality in the Northern geopolitical zone. This paper seeks to fill that gap by examining the role of maternal education and household wealth in shaping infant mortality outcomes in Northern Nigeria. Using data from a nationally representative health survey provides a region-specific analysis to identify high-risk populations and inform the design of targeted public health strategies. By focusing on socioeconomic factors within a regional context, this study contributes to the growing body of literature advocating for more nuanced and equity-focused approaches to reducing infant mortality in Nigeria.

2. OBJECTIVES

- To investigate the relationship between socioeconomic factors, wealth index, maternal education, and infant mortality in Northern Nigeria.
- To quantify the influence of these variables using multivariable logistic regression based on NDHS 2018 data.
- To contribute to public health policy by identifying vulnerable subpopulations.

3. LITERATURE REVIEW

The literature on infant mortality in Sub-Saharan Africa consistently points to socioeconomic status as a critical determinant of infant health outcomes. Numerous studies have explored how factors such as maternal education, wealth index, and access to healthcare shape the survival probabilities of infants. One of the most consistent findings across multiple analyses is the significant association between maternal education and infant mortality. For example, Agho *et al.,* (2015) found that mothers with at least a secondary education had lower odds of experiencing child deaths than those with no formal education. This relationship is attributed to the enhanced health knowledge, improved care-seeking behavior, and greater autonomy in decision-making that education affords women.

The wealth index is another robust predictor of infant survival, often measured using composite scores based on household assets and living conditions. According to Adebowale (2017), children from wealthier households are significantly less likely to die before their first birthday. This is mainly because economic resources enhance a family's access to quality healthcare services, maintain adequate nutrition, and live in safer, more sanitary environments. Similarly, Ozodiegwu *et al.,* (2019) emphasized that the protective effect of wealth is significant in resource-limited settings, where public healthcare infrastructure may be weak or inaccessible.

Several studies have examined the interplay between maternal age, parity, and birth spacing and socioeconomic factors. Jaiyeola *et al.,* (2016) demonstrated that maternal education and income reduce infant mortality directly and influence reproductive behaviors such as the length of birth intervals, which in turn impact infant survival. Longer birth intervals are generally associated with better health outcomes for both the mother and child, likely due to reduced competition for maternal resources and increased maternal recovery time. This interaction suggests that socioeconomic variables may serve as direct and indirect infant mortality predictors. In regional analyses, Morakinyo and Fagbamigbe (2017) reported stark disparities in infant and child mortality across different zones of Nigeria, with the Northern region exhibiting significantly higher rates. These findings align with those of Salawu *et al.,* (2021), who noted that high-

risk birth behaviors, including short birth intervals and early maternal age at first birth, were more prevalent in the North and were compounded by low educational attainment and poverty. These regional trends underscore the importance of disaggregating national data to capture localized vulnerabilities that may be masked in aggregated analyses.

The influence of gender has also emerged as a recurring theme in the literature. Pongou (2013) hypothesized that biological and environmental factors might account for higher mortality among male infants. However, socioeconomic variables remain the dominant explanatory factors for the broader disparities observed in IM across populations. For instance, Kamal (2015) found that the adverse effects of low maternal education on neonatal mortality persisted even when controlling for child sex, highlighting the overarching influence of maternal socioeconomic characteristics.

Moreover, the compounding effect of multiple risk factors has been noted by several researchers. According to Ezeh *et al.,* (2015), the clustering of disadvantages, such as being young, uneducated, and poor, substantially increases the likelihood of infant death. This cumulative disadvantage theory suggests that addressing a single factor may not be sufficient; multidimensional interventions are needed to improve child survival outcomes in complex socioeconomic contexts. Despite the rich body of research, limited scholarship specifically analyzes the combined effects of maternal education and wealth index on infant mortality in Northern Nigeria. Most existing studies aggregate data across regions or focus on rural-urban divides without isolating regional disparities. Ibrahim *et al.,* (2019) highlight that such oversight can hinder effective policymaking because it fails to account for context-specific factors that shape health outcomes. Additionally, findings from studies such as those by Ozodiegwu *et al.,* (2019) and Adewuyi *et al.,* (2017) suggest that region-specific analyses are essential for crafting targeted health interventions that are both culturally appropriate and economically viable.

This gap in the literature presents a compelling case for regionally focused studies that explore how socioeconomic determinants operate in the specific sociopolitical and cultural context of Northern Nigeria. By narrowing the analytical focus to this high-burden region, new insights can be generated that inform more effective and equitable health policies to reduce infant mortality.

4. METHODOLOGY

This study employed a cross-sectional analytical design using secondary data from the 2018 Nigeria Demographic and Health Survey (NDHS). The NDHS is a nationally representative household survey that collects extensive data on population health indicators, maternal and child health, fertility patterns, and socioeconomic conditions. The methodology adopted in this study aligns with approaches recommended in previous demographic studies, such as those by Kamal (2015) and Fitzgerald et al. (1998), who used cross-sectional designs to assess mortality risks in developing country settings. The NDHS 2018 employed a two-stage stratified cluster sampling design to ensure representativeness across all regions of Nigeria. The first stage involved selecting enumeration areas (EAs) using probability proportional to size, while the second stage involved systematic sampling of households within each selected EA. This sampling approach, which is consistent with that used in similar national health surveys across low- and middle-income countries (LMICs), has been validated in studies such as those by Barfield et al. (2013) and Alonso et al. (2006) for generating reliable population-level health estimates.

The analytical sample for this study was restricted to women aged 15 to 49 years residing in Northern Nigeria who had given birth and had complete information on the variables of interest. Women residing in other geopolitical zones were excluded to maintain regional focus. Observations involving children older than 12 months or missing data on key predictors were also excluded, a procedure consistent with the sample refinement approaches adopted by Davanzo et al. (1983) and Adebowale (2017) in child survival studies. The primary outcome variable was infant mortality, defined as the death of a child before the age of one year, based on maternal reports. The independent variables of interest included maternal education, categorized into four levels (no education, primary, secondary, and higher), and wealth index, divided into five quintiles (poorest, poorer, middle, more affluent, richest). These classifications follow standardized coding protocols used in prior DHS-based studies, such as those conducted by Jaiyeola et al. (2016) and Ezeh et al. (2015).

The wealth index used in the NDHS was derived from household ownership of consumer goods, housing characteristics, and access to water and sanitation facilities. Principal component analysis (PCA) was used to compute asset scores, which were then used to categorize households into quintiles. This method has been widely accepted in global health research, including in the work of Pons-Duran *et al.,* (2016), as a robust proxy for household economic status in contexts where income data may be unreliable or unavailable. Data analysis used multivariable logistic regression models to estimate

the adjusted odds ratios (AORs) of infant mortality associated with maternal education and wealth index. The models controlled for potential confounders, including maternal age, child sex, maternal body mass index (BMI), and preceding birth interval, in line with the analytical frameworks utilized by Salawu *et al.,* (2021) and Morakinyo and Fagbamigbe (2017). The choice of logistic regression is consistent with studies by Adewuyi *et al.,* (2017) and Ozodiegwu *et al.,* (2019), who highlighted the model's appropriateness for binary outcome variables and cross-sectional survey data.

Multicollinearity among independent variables was assessed using the Variance Inflation Factor (VIF) scores, with a cut-off of 3, a practice supported by statistical guidelines in health research literature (Jaiyeola *et al.,* 2016). Influential observations were identified using Cook's distance, and observations exceeding a conservative threshold were flagged for sensitivity analysis. Although independence of observations was assumed, the survey's hierarchical sampling structure (e.g., children nested within mothers) suggests potential clustering. While this was not explicitly modeled, other researchers such as Pongou (2013) and Ibrahim *et al.,* (2019) have acknowledged this as a typical limitation of DHS-based analyses. All analyses used R version 4.0.5, leveraging the survey and stats packages to accommodate complex survey design features. Descriptive statistics were first used to characterize the sample, followed by multivariable regression analysis to test study hypotheses. Statistical significance was determined at the 5% level ($p < 0.05$), consistent with the standard thresholds used in global health literature (Sandhu, 2021; Davanzo *et al.,* 1983). This methodological approach, grounded in best practices and supported by previous research, allows for a robust and contextually relevant analysis of how maternal education and wealth status affect infant mortality in Northern Nigeria.

5. DATA ANALYSIS & RESULTS

This section presents the multivariable logistic regression analysis results that examined the associations between socioeconomic determinants, specifically maternal education and household wealth, and infant mortality in Northern Nigeria. The analysis was based on data from the 2018 Nigeria Demographic and Health Survey (NDHS), comprising 80,110 women respondents, of whom 7,270 (9%) reported the death of a child before the age of one. This outcome variable, infant mortality, was modelled against key explanatory variables while controlling for potential confounders such as maternal age, child sex, maternal body mass index (BMI), and preceding birth interval.

5.1 Descriptive Overview

The descriptive statistics reveal that most mothers in the sample had no formal education, with 66.4% falling into this category. Only 4.1% of the mothers had attained higher education. Regarding economic status, 59.6% of respondents were classified within the two lowest wealth quintiles (poorest and poorer), whereas only 7.5% belonged to the richest quintile. These figures reflect the profound socioeconomic disparities that characterize Northern Nigeria and set the stage for the subsequent analysis (Table 1)

Table 1: Frequency Table for each predictor of Infant Mortality

	Infant Mortality		
	No (N=72840)	Yes (N=7270)	Overall (N=80110)
Maternal Education			
No education	48020 (65.9%)	5203 (71.6%)	53223 (66.4%)
Primary	11515 (15.8%)	1141 (15.7%)	12656 (15.8%)
Secondary	10198 (14.0%)	746 (10.3%)	10944 (13.7%)
Higher	3107 (4.3%)	180 (2.5%)	3287 (4.1%)
Wealth index			
Poorest	23178 (31.8%)	2671 (36.7%)	25849 (32.3%)
Poorer	19680 (27.0%)	2205 (30.3%)	21885 (27.3%)
Middle	14377 (19.7%)	1368 (18.8%)	15745 (19.7%)
Richer	9918 (13.6%)	734 (10.1%)	10652 (13.3%)
Richest	5687 (7.8%)	292 (4.0%)	5979 (7.5%)

5.2 Infant Mortality by Wealth Index

One of the clearest findings from the descriptive data is the inverse relationship between household wealth and infant mortality. Figure 1 illustrates that the infant mortality rate is highest among mothers in the poorest wealth quintile (36.7%) and steadily declines to just 4.0% among those in the wealthiest quintile. This linear pattern underscores the protective role that economic resources play in child survival. This pattern

supports prior findings by Adebowale (2017), who observed that children born into wealthier Nigerian households enjoy significantly higher survival rates. Similar evidence from Salawu et al. (2021) indicates wealth enhances access to quality maternal health services, such as antenatal care, skilled birth attendance, and postnatal checkups.

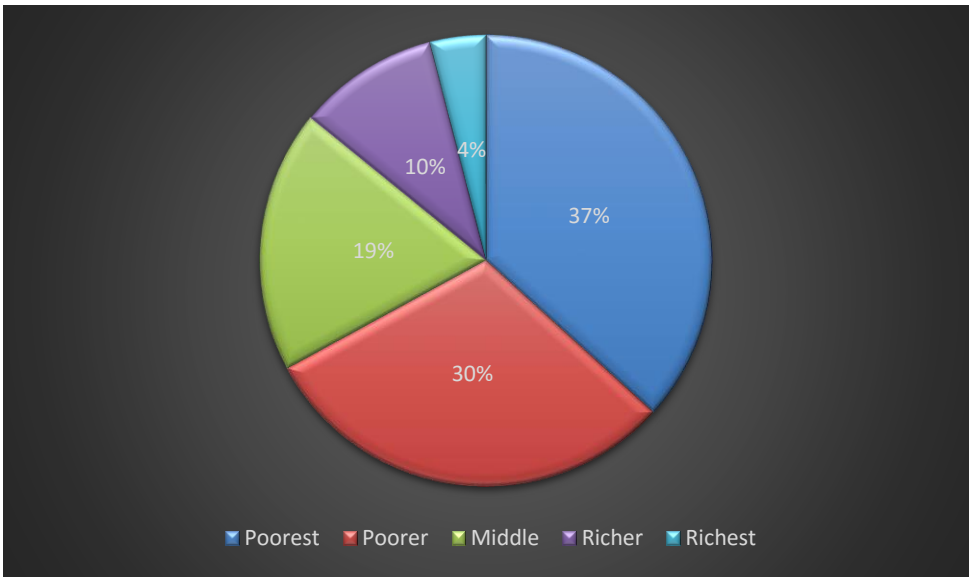

Figure 1: Infant Mortality by Wealth Index

5.3 Infant Mortality by Maternal Education

Education is another potent determinant of infant survival. As shown in Figure 2, the incidence of infant mortality was highest among women with no education (71.6%) and decreased progressively with higher levels of educational attainment. Women with primary education accounted for 15.7% of infant deaths, while those with higher education accounted for only 2.5%. These results align with the findings of Ezeh *et al.,* (2015), who reported that maternal education positively influences a mother's knowledge, behavior, and health-seeking practices. The strong link between maternal literacy and improved child health has also been emphasized in global health literature, including in studies by Pons-Duran *et al.,* (2016) and Kamal (2015).

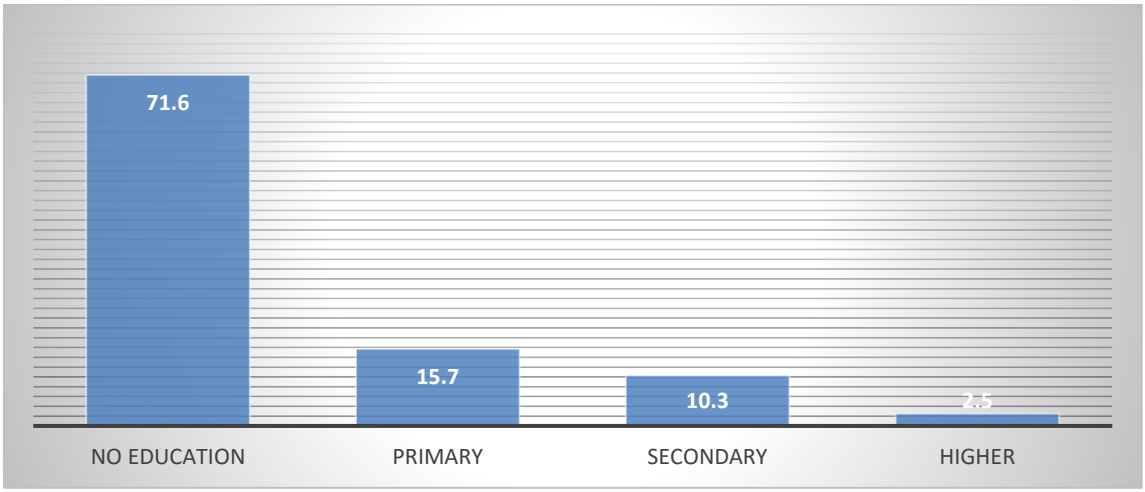

Figure 2: Infant Mortality by Maternal Education

5.4 Adjusted Multivariable Logistic Regression Results

A multivariable logistic regression analysis was conducted further to quantify the strength and direction of these associations. Adjusted odds ratios (ORs) were computed, controlling for maternal age, child sex, maternal BMI, and preceding birth interval.

Wealth Index and Infant Mortality: Figure 3 shows that compared to the poorest group (reference category), the odds of infant mortality decreased progressively across the wealth index with statistical significance noted in the Middle, Richer and Richest category:

- Poorer: OR = 0.95 (95% CI: 0.90–1.01)
- Middle: OR = 0.72 (95% CI: 0.67–0.77)
- Richer: OR = 0.52 (95% CI: 0.47–0.56)
- Richest: OR = 0.33 (95% CI: 0.28–0.37)

These findings mirror those of Ozodiegwu *et al.,* (2019), who demonstrated that household wealth significantly reduces the likelihood of neonatal and infant deaths across Sub-Saharan Africa. Notably, women in the wealthiest quintile had a 67% lower odds of reporting infant death compared to those in the poorest quintile.

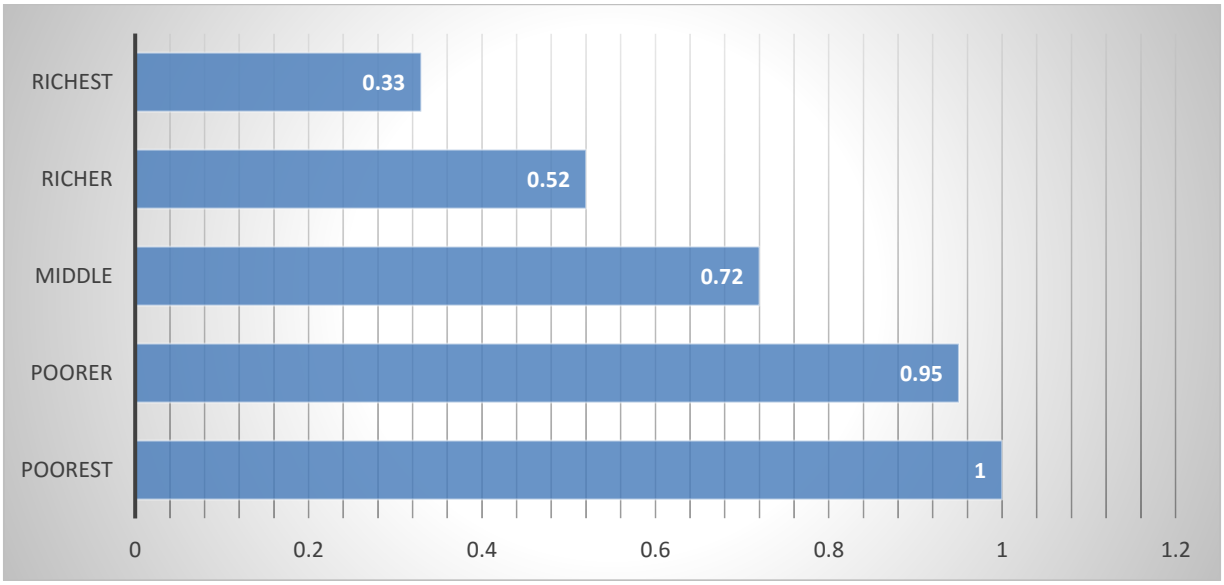

Figure 3: Odds Ratios of Infant Mortality by Wealth Index

Maternal Education and Infant Mortality

The analysis further revealed a strong negative association between maternal education and infant mortality (reference category: No education):

- Primary Education: OR = 0.99 (95% CI: 0.93–1.06)
- Secondary Education: OR = 0.84 (95% CI: 0.77–0.92)
- Higher Education: OR = 0.82 (95% CI: 0.69–0.96)

These results emphasize that education beyond the primary level significantly reduces the likelihood of infant death. Studies such as those by Morakinyo and Fagbamigbe (2017) support this, linking higher educational attainment with better health outcomes due to improved decision-making autonomy and health literacy.

5.5 Additional Covariate Results

While the primary focus of this paper is on socioeconomic determinants, additional covariates were included in the model to control for potential confounding (Table 2):

- **Maternal Age**: Older maternal age groups (25–29, 30–34, 35–39) were associated with lower infant mortality odds than the 15–19 reference group. These results support findings from Kamal (2015) and Fitzgerald et al. (1998), who found a U-shaped relationship between maternal age and child mortality.
- **Preceding Birth Interval**: Longer intervals (>2 years) were associated with significantly reduced risk of infant mortality (OR = 0.27; 95% CI: 0.24–0.31), consistent with the findings of Kozuki and Walker (2013).
- **Child Sex**: Female infants had 14% lower odds of mortality than males (OR = 0.86; 95% CI: 0.82–0.90), reflecting a pattern observed in multiple studies, including Pongou (2013) and Alonso et al. (2006), potentially due to biological resilience among female neonates.
- **Maternal BMI**: Women who were overweight had lower odds of infant mortality (OR = 0.75; 95% CI: 0.64–0.88) compared to those who were underweight, in line with Sandhu (2021), who suggested that maternal nutritional status plays a critical role in birth outcomes.

Table 2: Associations of Maternal age, Maternal education, Wealth index, Maternal BMI, Birth interval and Child sex with infant mortality in Northern Nigeria

Variables	OR (95% CI)
Age in 5-year groups[1]	
15-19	Ref
20-24	0.89 (0.72, 1.10)
25-29	**0.76 (0.63, 0.94)**
30-34	**0.76 (0.62, 0.93)**
35-39	**0.74 (0.61, 0.91)**
40-44	**0.79 (0.65, 0.97)**
Maternal Education[2]	
Primary	0.99 (0.93, 1.06)
Secondary	**0.84 (0.77, 0.92)**
Higher	**0.82 (0.69, 0.96)**
No Education	Ref
Wealth Index[3]	
Poorest	Ref
Poorer	0.95 (0.90, 1.01)
Middle	**0.72 (0.67, 0.77)**
Richer	**0.52 (0.47, 0.56)**
Richest	**0.33 (0.28, 0.37)**
Maternal BMI[2]	
Underweight	Ref
Normal	0.97 (0.85, 1.10)
Overweight	**0.75 (0.64, 0.88)**
Obese	0.86 (0.71, 1.03)
Preceding Birth Interval[4]	
≤ 11 months	Ref
1-2 years	**0.54 (0.47, 0.61)**
> 2 years	**0.27 (0.24, 0.31)**
Child sex[1]	
Male	Ref
Female	**0.86 (0.82, 0.90)**

5.6 Interpretation of Results

The analysis underscores the centrality of socioeconomic factors in influencing infant mortality in Northern Nigeria. Maternal education and household wealth exhibited strong, statistically significant associations with infant survival, even after controlling for other relevant predictors. This supports a growing body of literature suggesting that education and economic empowerment are not just ancillary social goals but fundamental determinants of population health (Barfield *et al.,* 2013; Davanzo *et al.,*1983). Moreover, the results reveal that the interaction between these factors is likely synergistic rather than additive. For instance, higher education in a low-income household may not be as protective as when combined with adequate wealth, and vice versa. These findings align with Ezeh *et al.,* (2015), who advocate for multidimensional strategies in reducing infant mortality, especially in socioeconomically disadvantaged regions.

[1] Significant coefficients and p values are in bold print; Assumptions(multicollinearity and undue influence). CI = confidence intervals; Ref = reference group.

[2] Adjusted for age (categorical) and wealth index (poorer, poor, middle, richer, richest); Significant coefficients and p-values are in bold print; Assumptions(multicollinearity and undue influence). CI = confidence intervals; Ref = reference group; OR = odds ratio.

[3] Adjusted for age (categorical) and education (primary, secondary, higher, no education); Significant coefficients and p values are in bold print; Assumptions(multicollinearity and undue influence). CI = confidence intervals; Ref = reference group; OR = odds ratio.

[4] Adjusted for wealth index (poorer, poor, middle, richer, richest) and education (primary, secondary, higher, no education); Significant coefficients and p values are in bold print; Assumptions(multicollinearity and undue influence). CI = confidence intervals; Ref = reference group; OR = odds ratio.

5.7 Summary of findings

The analysis reveals that maternal education and wealth index are independently and significantly associated with lower infant mortality in Northern Nigeria. These socioeconomic variables are central to understanding regional disparities in child survival and provide a critical lens through which public health interventions should be designed. The integration of illustrative data in Figures 1, 2, and 3 highlights these associations and provides accessible insights into the nature and strength of these relationships. These visual representations and statistical findings support the hypothesis that improving education and economic conditions for women can dramatically improve infant health outcomes.

6. Contributions to Research

This study makes several significant contributions to the growing body of literature on infant mortality and its determinants in Sub-Saharan Africa, particularly within Nigeria. By focusing on Northern Nigeria, a region characterized by persistently high rates of infant mortality and deeply rooted socioeconomic disparities, the research offers novel insights that are both region-specific and policy relevant.

Firstly, the study advances the understanding of how socioeconomic factors, namely maternal education and household wealth, distinctly influence infant survival in a high-burden region. While prior studies such as those by Adewuyi et al. (2017) and Ezeh et al. (2015) have identified these variables as key predictors at the national level, few have isolated their effects within Northern Nigeria. This regional focus fills a critical gap in the literature, where most analyses tend to aggregate data across diverse geopolitical zones, thereby masking localized patterns of vulnerability. By doing so, this study allows for a more nuanced understanding of how economic deprivation and educational disadvantages manifest uniquely in this part of the country.

Secondly, the study enhances methodological rigor in investigating infant mortality by employing a multivariable logistic regression model that adjusts for key demographic and biological confounders, including maternal age, BMI, child sex, and birth interval. This allows for a more precise estimation of the independent effects of socioeconomic status. The findings confirm and reinforce the multifactorial nature of infant mortality, echoing observations from studies such as Morakinyo and Fagbamigbe (2017), and underscore the necessity of integrated, multi-sectoral approaches to health policy.

This research contributes to the theoretical understanding of cumulative disadvantage in maternal and child health. By demonstrating that education and wealth independently reduce the risk of infant mortality, and that their protective effects are likely amplified when present simultaneously, the study aligns with the conceptual framework of social determinants of health. This supports the argument made by Ibrahim et al. (2019) and Salawu et al. (2021) that interventions must simultaneously address multiple layers of deprivation to be effective.

Finally, this study provides evidence that can be directly applied to health policy and planning. The statistical associations' clarity and the dataset's robustness offer reliable guidance for government agencies, NGOs, and international development partners looking to design targeted interventions. It positions maternal education and economic empowerment as social or developmental goals and fundamental strategies in public health programming. This study makes a timely and contextually grounded contribution to research and practice by uncovering the socioeconomic contours of infant mortality in one of Nigeria's most vulnerable regions.

7. RECOMMENDATIONS

Based on this study's findings, which highlight the profound influence of maternal education and household wealth on infant mortality in Northern Nigeria, several actionable recommendations are proposed. These recommendations are designed to inform health policy, guide programmatic interventions, and catalyze community-level change to reduce the burden of infant mortality in the region.

Scale Up Access to Quality Education for Girls and Women

The evidence from this study, in line with previous research by Agho *et al.,* (2015) and Jaiyeola *et al.,* (2016), demonstrates that maternal education significantly reduces the likelihood of infant death. Educational attainment enhances women's health literacy, autonomy in health-related decision-making, and ability to access and utilize healthcare services. Therefore, expanding access to quality primary and secondary education should be a central strategy in reducing infant mortality, especially in rural and underserved communities. Government initiatives such as free basic education policies must be strengthened with adequate funding, school infrastructure, and community mobilization to reduce cultural and economic barriers to girls' schooling.

Implement Conditional Cash Transfers Linked to Maternal and Child Health

Economic interventions are crucial given the strong inverse relationship between household wealth and infant mortality observed in this study and supported by Ozodiegwu *et al.,* (2019). Conditional cash transfer (CCT) programs that reward low-income families for attending antenatal care, delivering at health facilities, or completing childhood immunizations could effectively promote positive maternal and child health behaviors. These programs, already implemented in parts of Nigeria with moderate success, should be expanded and fine-tuned to reflect the unique socioeconomic context of Northern Nigeria.

Integrate Maternal Health Education into Community Health Platforms

Non-formal community education initiatives should be employed in areas with low formal education levels. These include maternal health workshops, peer education programs, and community outreach conducted by trained health workers or local NGOs. Studies by Kamal (2015) and Salawu *et al.,* (2021) have shown that such grassroots interventions can improve maternal knowledge and infant care practices, especially in conservative communities where formal schooling for women may be limited.

Strengthen and Subsidize Maternal Healthcare Services

Economic barriers often prevent poor women from accessing skilled birth attendants, safe delivery environments, or neonatal care. To mitigate this, governments and health agencies should ensure that maternal and child healthcare services are available and affordable. Subsidies, mobile clinics, and free maternal care policies should be scaled up in rural and peri-urban areas, building on the findings of Morakinyo and Fagbamigbe (2017), who emphasized the impact of healthcare access on child survival.

Promote Multisectoral Collaboration and Evidence-Based Policy

Lastly, policymakers must adopt a multisectoral approach that addresses the intersection of health, education, and poverty. Collaborations between the ministries of health, education, and women's affairs, as well as partnerships with local NGOs, religious institutions, and international donors, are essential for sustainable impact. Data from this study and similar research (e.g., Ezeh *et al.,* 2015) should be used to inform targeted, evidence-based policies that reflect the socioeconomic realities of Northern Nigeria. Reducing infant mortality in Northern Nigeria requires a combination of educational reform, economic support, healthcare accessibility, and community engagement. These recommendations are feasible and necessary for equitable child survival outcomes in the region.

8. Future Research Directions

While this study offers valuable insights into the socioeconomic determinants of infant mortality in Northern Nigeria, it also reveals several avenues for further inquiry. Future research can build on this work by addressing methodological limitations, deepening the contextual understanding of observed associations, and exploring new analytical frameworks that better capture the complex interplay of social determinants and infant health outcomes.

Longitudinal and Cohort-Based Studies

This study relied on cross-sectional data from the 2018 Nigeria Demographic and Health Survey (NDHS), which, while rich in scope, limits the ability to establish causal relationships between socioeconomic variables and infant mortality. Longitudinal studies that follow mothers and infants over time would allow for more robust analyses of how changes in household wealth, educational attainment, and health behaviors influence child survival. Davanzo et al. (1983) highlighted the utility of cohort analyses in uncovering temporal dynamics often obscured in cross-sectional datasets.

Disaggregated Analysis of Education and Health Literacy

Although this study demonstrated a significant inverse association between maternal education and infant mortality, future research should explore the specific mechanisms through which education confers protective benefits. For example, researchers could disaggregate educational attainment to examine the role of functional literacy, numeracy, and health knowledge. Studies by Kamal (2015) and Ezeh *et al.,* (2015) suggest that formal education alone may not fully capture the nuanced cognitive and behavioural competencies that influence maternal decision-making and child care practices.

Intersectional Analyses Incorporating Cultural and Gender Norms

Future studies should also consider how cultural beliefs, gender dynamics, and patriarchal norms intersect with socioeconomic status to affect infant health. Research in Northern Nigeria, such as that by Okereke *et al.,* (2019), has documented how gender roles, religious practices, and sociocultural barriers limit women's access to health services, even when financial or educational barriers are addressed. Incorporating qualitative and ethnographic methods

into future studies can yield a more holistic understanding of these constraints and how they shape maternal and infant health behaviors.

Geospatial and Infrastructure Mapping

Another valuable direction would be integrating geospatial analysis and infrastructure mapping with demographic data. Ibrahim *et al.,* (2019) argue that location-specific variables, such as distance to healthcare facilities, road access, and environmental hazards, play a significant role in infant survival. Overlaying NDHS data with geographic information systems (GIS) can help pinpoint underserved regions and guide targeted policy interventions.

Evaluating Policy Interventions and Program Effectiveness

Impact evaluations of existing and emerging interventions aimed at improving maternal and child health in Northern Nigeria are also needed. For instance, conditional cash transfer programs, school-feeding schemes, and community health worker initiatives are increasingly deployed to address social determinants of health. Future research should assess these programs' effectiveness, scalability, and cost-efficiency in reducing infant mortality. As Barfield *et al.,* (2013) emphasized, evidence-based policy requires rigorous monitoring and evaluation frameworks to determine what works, for whom, and under what conditions.

Multi-Variable Interaction and Mediation Analyses

Given the interdependence of socioeconomic variables, further research could explore how education and wealth interact or mediate each other's effects on infant mortality. Advanced statistical techniques such as structural equation modelling or path analysis can unpack these predictors' direct and indirect effects. Studies by Jaiyeola et al. (2016) and Salawu *et al.,* (2021) have laid the groundwork for this approach by demonstrating the need to go beyond single-variable associations.

Exploring Paternal and Household-Level Influences

Lastly, while maternal characteristics are critical, future research should incorporate paternal factors and broader household dynamics. The role of paternal education, income, and involvement in childcare remains underexplored in the Nigerian context. Including household-level variables such as spousal support, decision-making power, and family size could offer a more comprehensive perspective on the determinants of infant mortality. Future research should aim for depth, context sensitivity, and methodological innovation to advance our understanding of infant mortality. These directions will not only fill existing gaps in the literature but also provide actionable insights for policymakers and development practitioners working to reduce child mortality in Nigeria and similar contexts.

9. CONCLUSION

This study has examined the socioeconomic determinants of infant mortality in Northern Nigeria, focusing on maternal education and household wealth, using data from the 2018 Nigeria Demographic and Health Survey (NDHS). The analysis revealed strong, statistically significant associations between these two variables and the likelihood of infant mortality, even after adjusting for important demographic and biological covariates such as maternal age, child sex, maternal BMI, and preceding birth interval. The findings show that higher levels of maternal education are associated with lower odds of infant death, reflecting the critical role of education in enhancing maternal health literacy, improving care-seeking behaviors, and fostering greater autonomy in making health-related decisions. Similarly, household wealth was a decisive protective factor against infant mortality, supporting the notion that economic empowerment enables better access to healthcare services, nutrition, and living conditions conducive to child survival. These outcomes align with and reinforce previous research by scholars such as Adewuyi *et al.,* (2017), Ozodiegwu *et al.,* (2019), and Ezeh *et al.,* (2015), among others.

Concentrating on Northern Nigeria, this study addresses an important gap in the literature, which has often treated the country as a homogeneous unit despite its substantial regional disparities in health outcomes and socioeconomic status. The regionally focused approach offers new insights into localized vulnerabilities, enabling more targeted policy and intervention efforts. The findings underscore the necessity of region-specific strategies that consider both the educational and economic dimensions of maternal well-being as key levers for improving infant survival. Beyond identifying statistical associations, this study also contributes to theoretical and policy discourses by illustrating how the interaction of multiple social determinants creates compounded risk or resilience for infants. It highlights the importance of integrated approaches that simultaneously address education, income, and healthcare access. The study supports calls from researchers like Morakinyo and Fagbamigbe (2017) and Ibrahim *et al.,* (2019) for multidimensional public health strategies.

The policy implications are clear: Northern Nigeria's efforts to reduce infant mortality must go

beyond healthcare provision alone and incorporate broader social development initiatives. Expanding access to quality education for girls, implementing economic support programs for low-income households, and improving healthcare infrastructure are essential to achieving equitable health outcomes. Reducing infant mortality in Northern Nigeria requires a concerted effort across sectors and disciplines. This study adds to the empirical and conceptual foundations needed to inform such efforts and provides a platform for future research, evaluation, and policy innovation. The path forward must be informed by evidence, driven by equity, and grounded in the lived realities of the region's most vulnerable populations.

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