Journal of Biosocial Science (2024), 56: 2, 357–375
doi:10.1017/S0021932023000305

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

Disentangling the link between social determinants of health and child survival in Nigeria during the Sustainable Development Goals era: a hierarchical path analysis of time-to-event outcome

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(Received 17 November 2022; revised 10 October 2023; accepted 16 November 2023; first published online 14 December 2023)

Abstract

While social determinants of health have been perennially linked to child survival in resource-limited countries, the precise and tested pathways to effect are not clearly understood. The objective of this study was therefore to identify the critical pathways as posited a priori in a model through which social factors (at maternal, household, and community levels) determine neonatal, infant, and under-five mortalities in Nigeria. Using a novel analytic approach (hierarchical path modelling for predicting accelerated failure time) to estimate (in)direct and total effects of social determinants of child survival, we analysed 30,960 live births (weighted data for representativeness), obtained from the 2016/2017 Nigeria Multiple Indicator Cluster Survey. There were three outcome variables: time until occurrence of neonatal, infant, and under-five mortalities. The independent variables were layered factors related to child, maternal, household and community. Geographical region, rurality of residence, infrastructural development, maternal education, contraceptive use, marital status, and maternal age at birth were found to operate more indirectly on neonatal, infant, and under-five survival. Child survival is due to direct effects of child's sex (female), gestational type (singleton), birth spacing (children whose mothers delivered at least two years apart), and maternal age at delivery (20–34 years). According to the path coefficients, the indirect effects of geographical regions are the most influential determinants of child survival, accounting for 30% (neonatal), 37.1% (infant) and 39.9% (under-five) of the total effects. This study offers comprehensive set of factors, and linked pathways, at the maternal, household, and community levels that are associated with child survival in Nigeria. To accelerate progress towards Sustainable Development Goal targets for child survival and reduce geographical inequities, stakeholders should implement more impactful policies that promote maternal education, contraceptive use and improve living conditions of women (especially in rural areas of northern Nigeria). Future research should focus on identifying the most effective interventions for addressing these social determinants of child survival in Nigeria.

Keywords: Social determinants of health; path analysis; parametric survival analysis; Sustainable Development Goals; neonatal mortality; infant mortality; under-five mortality; Nigeria

Introduction

Child survival, a critical indicator of a societal well-being and public health, continues to emerge as a global priority as articulated in the Sustainable Development Goal 3 (SDG-3), which aims to reduce global and country-level neonatal and under-five mortality rates to 12 deaths and 25 deaths per 1,000 live births by 2030, respectively (UNICEF 2022). While progress has been made in reducing under-five mortality rate (U5MR) by 59%, from 93 deaths per 1000 live births in 1990 to 38 in 2021, about 15,000 under-five children continue to die everyday worldwide (UNICEF 2022). According to a recent global report, 5 million under-five deaths were recorded in 2021 (UNICEF 2022). Based on the current trend, it was estimated that 40 million under-five children will die between 2021 and 2030 (UNICEF 2022).

Child survival rates vary significantly across different regions, with sub-Saharan Africa historically experiencing higher child mortality rates compared to other regions. In 2021, the under-five mortality rate in sub-Saharan Africa was 74 deaths per 1,000 live births, indicating a greater risk of child mortality in the region (UNICEF 2022). Conversely, there are regions where child survival rates are comparatively better. For instance, the mortality rate for children born in Europe, Australia, and New Zealand was only 4 deaths per 1,000 live births (UNICEF 2022). This indicates that the child mortality rate in sub-Saharan Africa is approximately 19 times higher than in the regions of Europe, Australia, and New Zealand.

Given the present high rates and slow decline of childhood mortality in sub-Saharan Africa, many countries in the region will continue to have high neonatal, infant, and under-five mortalities beyond 2030 (ending of SDG era) (You et al. 2015). Although child survival has marginally improved in Nigeria, the country ranks second globally on the neonatal and under-five mortality burden league tables (UNICEF 2022). As reported by the United Nations, Nigeria contributed 17% to the global burden of 5 million under-five deaths, which is equivalent to 111 deaths per 1,000 live births in 2021 (UNICEF 2022). In Nigeria, little progress has been made towards achieving child survival and social inclusion targets of SDG-3 and 10, respectively, because there is little evidence to guide policymakers on appropriate interventions (National Bureau of Statistics 2015). Nigeria faces numerous challenges in ensuring the survival of its children, including inadequate healthcare infrastructure, limited access to essential prenatal services, and socioeconomic disparities (Adeyanju, Tubeuf, and Ensor 2017; Adedini et al. 2014). These factors, combined with issues such as malnutrition, infectious diseases, and limited healthcare financing, contribute to the persistent struggle for child survival in the country (Akombi-Inyang Blessing 2021; UNICEF 2022).

In order to address the persistent challenges and improve child survival in Nigeria, it is imperative to understand the complex interplay of factors at various levels. This includes examining the social, economic, cultural, and environmental factors that impact child survival. By comprehensively analysing these factors, policymakers and stakeholders can develop targeted interventions and policies that address the specific needs of children and their communities. By adopting a holistic approach and implementing evidence-based strategies, Nigeria can make significant progress towards achieving the SDG 3 (good health and well-being) and SDG 10 (reduced inequality) and ensuring a brighter future for its children.

While social determinants of health have been perennially linked to child survival in resource-limited countries, the precise and tested pathways to outcome are not clearly understood. Empirical demonstration of pathways from social determinants to child survival provides clearer guidance and efficiency in using finite resources, and in implementation of more impactful policies during the SDG era. Previous studies (Kayode et al. 2017; Boco 2014; Antai 2011; Akinyemi, Bamgboye, and Ayeni 2015; Adebowale, Morakinyo, and Ana 2017; Abu, Madu, and Ajaero 2015) in this area have recognized social factors that are associated with poor survival outcomes among under-five children; however, it remains unclear to which degree they are attributed to childhood deaths. Most of these studies have not reported results that separate

https://doi.org/10.1017/S0021932023000305 Published online by Cambridge University Press

associations into direct (i.e., non-mediated) and indirect (i.e., mediated) effects, effectively delineating mechanisms or pathways from determinants to outcome. Path analysis – a variant of structural equation model (SEM) – is an extension of multiple regression that simultaneously tests a priori logical sequence of assumptions of association among variables. Path analysis provides a graphical summary of the structural and logical relationships between the explanatory variables and outcome variable.

Unlike multivariable regression models, path analysis delineates pathways to outcome, in this case a chain of factors that leads to child survival (Jeon 2015). Other studies have demonstrated independent variables of child survival through path analysis in resource-limited countries (Ricci et al. 2019; Abdelkhalek and Bolla 2020; Kananura et al. 2017; Nguyen and Nguyen 2020; Naghavi-Behzad et al. 2014). These studies, however, have used ecological data (Ricci et al. 2019; Abdelkhalek and Bolla 2020; Nguyen and Nguyen 2020) or are hospital-based (Naghavi-Behzad et al. 2014), limiting inferences that can be drawn at individual level or to a wider population, respectively. Previous study in sub-Saharan Africa showed, however, that poverty and maternal illiteracy are indirectly associated with child mortality, whereas child's nutritional status has direct association with child mortality (Ricci et al. 2019). Also, Kananura *et al.* (2017) argued that among eastern Ugandan newborns, maternal age, religion, maternal education, and antenatal care (ANC) attendance have indirect effects on neonatal survival. Furthermore, the authors (Kananura et al. 2017) observed that low birth weight, previous history of newborn mortality, and teenage mothers have direct association with newborn deaths. For Nigeria, the pathways to outcome of social determinants of health on age-specific mortalities are largely unknown. To inform policy and programmatic actions, this study aimed to identify the critical pathways as posited a priori in a model through which social factors (maternal, household and community) may affect neonatal, infant, and under-five survival in Nigeria while addressing the SDGs 3 and 10.

Proposed path model

The conceptual path model was adapted from Mosley-Chen framework (Mosley and Chen 1984). The conceptual framework suggests that socioeconomic factors affecting child mortality are connected to a common set of biological and proximate mechanisms that directly impact a child's survival. According to this framework, socioeconomic factors indirectly influence child mortality through proximate factors such as maternal characteristics, environmental pollution, malnutrition, injuries, and health-seeking behaviours.

The framework provides a broad overview of the essential components for child health programmes, but it was transformed into a model to gain a more comprehensive understanding of the relationships between different factors that contribute to child survival. Furthermore, it was necessary to expand the factors considered in the original framework, as its scope was limited to 14 proximate determinants which were layered into five broad categories: maternal factors (age, parity, birth interval); environmental contamination (air, water, soil); nutrient deficiency (calories, protein, micronutrients); injury (accident, intentional); and personal illness control (health-seeking behaviour, medical treatment) (Mosley and Chen 1984). However, these variables did not capture all the relevant aspects of child health and survival, such as child's sex, multiple births, marital status, religion, and geography.

The adapted model describes the hypothesized pathways by which child, maternal, household, and community-level factors are associated with child survival in Nigeria (Figure 1). The model, particularly the selection of variables, is also informed by the authors' programmatic experience in child health, data availability, and evidence in the literature. Through directed acyclic graphs (DAGs) (Williams et al. 2018), the model conceptualizes that child-level factors (i.e., child's sex, birth order, gestation type – single/multiple, previous birth interval and maternal age at birth of the child) and maternal-level factors (maternal education, maternal wealth, frequency of ANC visits, skilled birth attendants during delivery, and place of delivery) would have direct effects on

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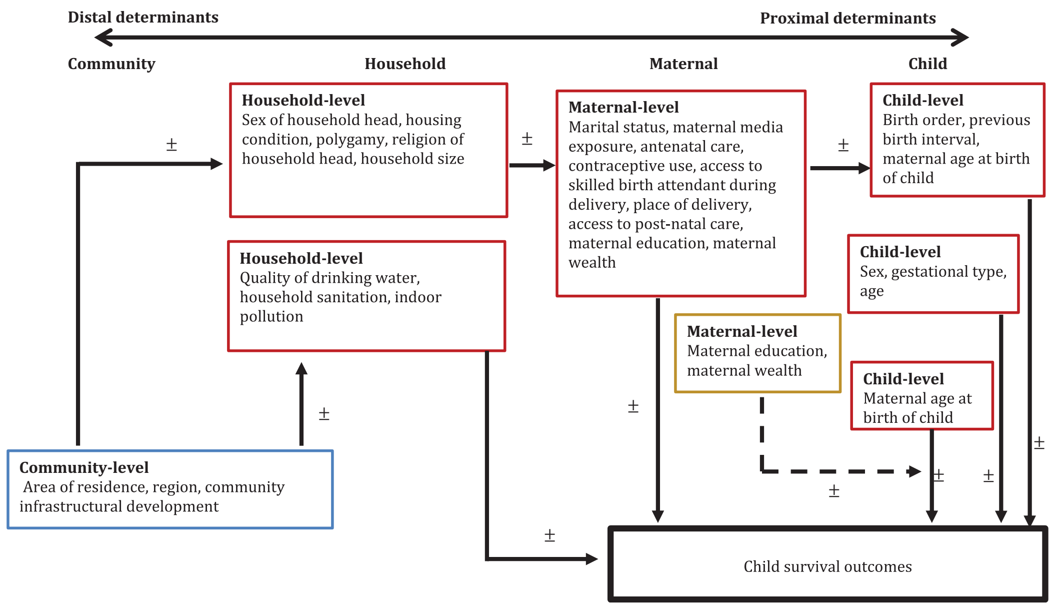

Figure 1. Conceptual model of child survival outcomes.
Legend: Mediators (variables in red boxes) and moderators (variables in orange box).

neonatal, infant, and under-five survival. Furthermore, the effects of community-level factors (i.e., region, area of residence and social infrastructural development) on child survival are mediated via child-level, maternal-level, and household-level factors. We postulated that household-level factors (such as sanitation, drinking water source and indoor pollution) and maternal-level factors would have direct effects on child survival. In addition, the influence of maternal age at birth on child survival is hypothesized to be moderated by maternal education and maternal wealth index. As depicted in Figure 1, the determinants closest to the outcome, proximal, are easier to control than the determinants farther from the outcome (distal) except for biological factors. However, the distal determinants have increased potentials for larger-scale impact and sustained change with population health interventions.

Methods

Data source

In the current analysis, we employed a cross-sectional cohort design (Hudson, Pope, and Glynn 2005). This design involved retrospectively evaluating data collected at a specific point in time to examine the historical exposures and outcomes within a defined time period for individuals belonging to the cohort. The beginning of the risk period is determined as the point at which an individual naturally becomes susceptible to a particular outcome, such as from birth until death.

This study utilized complete birth histories, as well as maternal and household datafiles from the 2016/2017 National Multiple Indicator Cluster Survey (MICS) (UNICEF MICS 2018). Like other resource-limited countries, MICS is a national representative population-based survey which was conducted in the 36 states and Federal Capital Territory (FCT), for monitoring progress towards SDG targets in Nigeria. The methodology used for MICS study has been described in the full report (UNICEF and NBS 2017). Data were collected through interviewer-administered questionnaires from 34,376 women aged 15–49 years in 33,901 households and 2,239 enumeration areas (i.e., primary sampling unit) through multi-stage stratified cluster sampling technique. The primary sampling units, otherwise referred to as the 'communities', are

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clusters of geographical and administratively distinct areas of homogenous households. The response rate was 95%. For this study and to minimize recall bias, our analysis was limited to all live births (unweighted population of 29,786) delivered by 18,497 women who resided in 16,151 households and 2,227 communities, within five years prior to survey commencement (i.e., prior to September 2016), regardless of the gestation type (single or multiple).

Outcome (endogenous) variables

The dependent variables are the time-to-death for neonates, infants and under-five children, which were derived from the original variables in 2016/2017 MICS dataset. The time-to-death variables, otherwise known as survival time, were derived from variables on survival status, age at death, and current age of living children. The survival times are as follows: (i) time to neonatal death – defined by survival time from birth to 27 days; (ii) time to infant death – defined by survival time from birth to one year of life; and (iii) time to under-five death – defined by survival time from birth to five years of life. Survival status was categorized as alive or right censored = 0 and dead = 1. Except for neonatal survival time that was reported in days, other outcome variables were reported in years.

Exposure (exogenous) variables

The independent variables are layered factors related to child, maternal, household and community. In relation to DAG, the proximate factors are the child-level factors, intermediate factors are the maternal- and household-level factors, and distal factors are community-level factors. We included the following variables, child-level factors (child's sex, gestation type, birth order, previous birth interval, maternal age at birth), maternal-level factors (maternal education, maternal wealth index, maternal media exposure, number of ANC visits, skilled birth attendants during delivery, institutional delivery, marital status, contraception use), household-level factors (sex of household head, quality of house, polygamy, access to drinking water, sanitation, indoor pollution, household size, religion of household head, and community-level factors (rurality of residence, region, infrastructural development). The covariates were considered as confounders and adjusted for in the statistical models. The operational definitions of all selected variables are presented in Table 1. For ease of data analysis and interpretation, the independent variables were dichotomized, except for frequency of ANC visits and household size which were discrete variables. Specifically, variables on maternal media exposure, housing condition index, and community infrastructural development were newly generated from the existing variables in the dataset. Housing condition index was extracted from the first component of a principal component analysis (PCA). It was computed from three variables – quality of the roof, exterior wall, and floor items; Kaiser–Meyer–Olkin measure of adequacy ranged from 0.6 to 0.8 and Bartlett's test of sphericity (p-$value$<0.001). The first component of PCA accounted for 67.7% of the total variance of the three variables. The community infrastructural development was measured, indirectly, by calculating the proportion of households with electricity in the community. The variable has two groups (low = 0, high = 1) based on median value.

Also, multiple levels of the individual variables on cooking fuel (proxy for indoor pollution), sanitation and source of drinking water were collapsed to generate new (separate) variables with two levels (i.e., improved/unimproved) – based on the standard classification by WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) (WHO, UNICEF, and JMP 2018). Maternal media exposure variable was generated by collapsing individual variables on accessibility to newspaper/magazine, radio and television. The three variables had a four-item scale measuring the frequency of exposures to the media items — almost every day, at least once a week, less than once a week, and not at all. The items were combined based on the best exposure score and recoded into four categories, where lowest score is no exposure and highest score is high exposure to mass media.

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Table 1. Characteristics of outcome variables and child, maternal, household and community-level determinants of under-five mortality, MICS Nigeria, 2016/2017

Variable	Mean (SD)/ *n* (%)	Incidence rate (95%CI) Per 1,000 child-years	Description
Outcome variables			
Under-5 mortality			Time-to-death from births to 5 years, censored/ alive = 0, died = 1
Total time at risk (per 1,000 child-years) (*N* = 30,960)	75139.6		
Failure variable (*N* = 30,924)			
Alive	28084 (90.8)		
Died	2840 (9.2)		
Infant mortality			Time-to-death from birth to 1 year of life, alive/ censored = 0, died = 1
Total time at risk (per 1,000 infant-years) (*N* = 30,960)	26938.7		
Failure variable (*N* = 30,924)			
Alive	28897 (93.5)		
Died	2027 (6.6)		
Neonatal mortality			Time-to-death from birth to 27 days of life, alive/ censored = 0, died = 1
Total time at risk (per 1,000 neonate days) (*N* = 30,960)	837769		
Failure variable (*N* = 30,924)			
Alive	29751 (96.2)		
Died	1174 (3.8)		
Child-level factors			
Child's sex (*N* = 30,959)			Male = 0, female = 1
Male	15725 (50.8)	40.5 (38.0–43.3)	
Female	15234 (49.2)	35.0 (32.7–37.5)	
Gestation type (*N* = 30,957)			Single = 0, multiple = 1
Single	29729 (96.0)	35.3 (33.6–37.1)	
Multiple	1228 (4.0)	105.5 (89.4–124.7)	
Birth order (*N* = 30,960)			≤3 = 0, >3 = 1
≤3	15793 (51.0)	32.1 (30.0–34.4)	
>3	15166 (49.0)	41.3 (41.3–47.0)	
Previous birth interval (*N* = 30,960)			Duration of child spacing in years*, first birth/ <2 years = 0, ≥2 = 1
First birth/ <2 years	12101 (30.1)	50.0 (46.8–53.5)	
≥2 years	18858 (60.9)	29.6 (27.7–31.7)	
Maternal age at birth (*N* = 30,960)			Mother's age at the birth of the child, <20/≥35 years = 0, 20–34 years = 1
<20 years	4320 (14.0)	51.8 (46.4–58.0)	
20–34 years	21338 (68.9)	33.8 (31.9–35.9)	
≥35 years	5302 (17.1)	42.9 (38.5–47.9)	

(*Continued*)

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Table 1. (*Continued*)

Variable	Mean (SD)/ *n* (%)	Incidence rate (95%CI) Per 1,000 child-years	Description
Maternal-level factors			
Maternal education (*N* = 30,959)			Highest educational level attained by mothers; none/primary = 0; secondary/technical/post-secondary = 1
None/primary	20,609 (66.6)	45.2 (43.0–47.7)	
Secondary	7981 (25.8)	24.3 (21.6–27.3)	
Post-secondary	2369 (7.7)	19.1 (14.7–25.2)	
Maternal wealth index (*N* = 30,960)			Poor = 0, middle/rich = 1
Poor	13912 (44.9)	48.6 (45.8–51.6)	
Middle	6068 (19.6)	39.9 (35.6–44.7)	
Rich	10980 (35.5)	23.4 (21.2–26.0)	
Maternal media exposure (*N* = 30,956)			Accessibility to newspaper/magazine or listening to the radio or watching television; no = 0, yes = 1
No	12394 (40.0)	47.3 (44.4–50.5)	
Yes	18561 (60.0)	31.6 (29.5–33.8)	
Number of ANC visits# (*N* = 20,775)			Frequency of ANC visits regardless of the personnel type; discrete
Mean (SD)	5.19 (11.2)	37.8 (36.1–39.6)	
Skilled birth attendants during delivery# (*N* = 20,786)			Delivery by type of personnel; none/unskilled/friend = 0, skilled birth attendants = 1
None/Unskilled	12714 (61.2)	51.1 (47.7–54.8)	
Skilled	8072 (38.8)	32.3 (29.0–36.0)	
Institutional delivery# (*N* = 20,783)			Place of delivery; home = 0, health facility = 1
Home	13358 (64.3)	49.3 (46.1–52.9)	
Health facilities	7425 (35.7)	33.3 (29.8–37.3)	
Marital status (*N* = 30,934)			Currently married/in relationship = 0, Never married/formerly married = 1
Currently married/in relationship	29748 (96.2)	37.6 (35.9–39.5)	
Never married/formerly married	1186 (3.8)	40.4 (31.6–52.3)	
Contraceptive use (*N* = 26,807)			Ever used a method to avoid pregnancy; yes = 0, no = 1
Yes	1947 (7.3)	22.3 (17.8–28.1)	
No	24860 (92.7)	41.6 (39.6–43.8)	
Household-level factors			
Sex of household head (*N* = 30,960)			Male = 0, female = 1
Male	29614 (95.7)	38.2 (36.4–40.1)	
Female	1346 (4.4)	29.6 (22.7–39.2)	
Housing condition (*N* = 30,960)			Housing material type based on the quality of the roof, exterior wall and floor; inadequate = 0, adequate = 1
Inadequate	13172 (42.6)	46.4 (43.7–49.4)	
Adequate	17788 (57.5)	31.5 (29.4–33.9)	

(*Continued*)

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Table 1. (*Continued*)

Variable	Mean (SD)/ *n* (%)	Incidence rate (95%CI) Per 1,000 child-years	Description
Polygamy (*N* = 30,960)			Husband/partner has other wives; yes = 0, no = 1
Yes	10880 (35.1)	44.3 (41.3–47.5)	
No	20079 (64.9)	34.3 (32.2–36.5)	
Household access to drinking water (*N* = 30,959)			Household source of drinking water; unimproved source = 0, improved source = 1
Unimproved	10820 (35.0)	47.0 (43.7–50.6)	
Improved	20139 (65.1)	32.9 (31.0–35.0)	
Household sanitation (*N* = 30,959)			Household members using improved toilet facility; unimproved = 0, improved = 1
Unimproved	159256 (51.4)	42.8 (40.4–45.4)	
Improved	15033 (48.6)	32.5 (30.2–35.2)	
Indoor pollution (*N* = 30,960)			Source of cooking fuel; polluting fuel = 0, clean fuel = 1
Polluting fuel	29120 (94.1)	39.1 (37.2–41.0)	
Clean fuel	1840 (5.9)	18.3 (14.2–24.0)	
Household size (*N* = 30,960)			
Mean (standard deviation)	7.8 (4.1)	37.8 (36.1–39.6)	Number of household members (Discrete)
Religion of household head (*N* = 30,960)			Household head religion affiliation; no religion = 0, any religion (Christianity, Islam, traditional/others) = 1
No religion	14 (0.04)	15.4	
Religious	30946 (99.7)	37.8 (39.6)	
Community-level factors			
Area (*N* = 30,960)			Urban = 0, rural = 1
Urban	9327 (30.1)	25.8 (22.9–29.2)	
Rural	21633 (69.9)	43.1 (41.0–45.4)	
Region (*N* = 30,960)			Geopolitical region where mothers reside; northern part (NC/ NE/ NW) = 0, Southern part = (SE/ SS/ SW) = 1
North-Central (NC)	5084 (16.4)	35.0 (31.3–39.2)	
North-East (NE)	6517 (21.1)	35.3 (31.1–40.2)	
North-West (NW)	12113 (39.1)	50.8 (47.7–54.2)	
South-East (SE)	1604 (5.2)	21.5 (17.8–26.1)	
South-South (SS)	2370 (7.7)	19.0 (15.8–22.9)	
South-West (SW)	3272 (10.6)	23.0 (19.4–27.5)	
Infrastructural development (*N* = 30,960)			Proportion of households with electricity in the community; low = 0, high = 1
Low	16235 (52.4)	45.3 (42.8–47.9)	
High	14724 (47.6)	29.7 (27.4–32.2)	

[#]Data available for only women with a live birth in the 2 years prior to the survey.
*Grouping was informed by the potential risks to child health.

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Statistical analysis

Cox proportional models – most popular modelling method for survival analysis – have been criticized as not suitable for path modelling because of its assumption of constant hazard ratios between categories over time (Lapointe-Shaw et al. 2018). Recently, however, path analysis that uses accelerated failure time data (parametric survival analysis) has been proposed to address this limitation. Hierarchical path analyses with accelerated failure times (parametric survival models) were performed to determine the pathways by which child, maternal, household and community-level factors might contribute to survival of neonates, infants, and under-five children in Nigeria. By fitting three separate models for the outcome variables, parametric survival model along binomial logit was fitted using generalized SEM (gsem) in Stata's version™ 15.1 SEM builder (StataCorp LLC. 2017). Data were assessed for quality – multicollinearity, completeness, maternal age heaping (Whipple's index) (Al Zalak and Goujon 2017), sex-birth ratio, and heaping of child death (displacement of age at death). Post-natal care variable was dropped because >70% of its values were missing. The following assumptions of path analysis with time-to-event outcome data were deemed to have been met: no multicollinearity (mean variance inflation factor (VIF) = 1.49), adequate sample size (Mitchell 1993) (ratio of observation to parameter was 1238:1), and non-proportionality of hazards (i.e., collapsibility of hazard ratio) (Lapointe-Shaw et al. 2018).

After preliminary analyses with the different types of parametric survival methods (i.e., Weibull, gamma, exponential, log-log and lognormal regressions), lognormal (accelerated failure time) model was observed to be appropriate in fitting the data based on lowest values of Bayesian Information Criterion and Akaike's Information Criterion.

We considered selected (literature- and practice-informed) moderating effects of maternal education and maternal wealth index on maternal age at birth by fitting the interaction terms. However, the interaction terms were not statistically significant; hence they were dropped from the model. The path coefficients (β) representing direct effects (i.e., associations between the proximate and outcome variables without the contribution of intermediate variables) and indirect effects (i.e., associations between the distal variables and outcome through intermediate variables) were obtained. The path coefficients of the direct effects were transformed exponentially into time ratios (TR) (Stata 2019), while those of indirect effects were transformed exponentially into odds ratios (OR) (Stata 2019). In fitting the re-specified parsimonious models (final models), the complete paths (i.e., direct and indirect) with statistical significance $\alpha \leq 5\%$ were retained. Also, all the exogenous variables that were retained were binary in scale. This similarity in scale allows for meaningful comparison of the contributions of the exogenous variables in the pathway. The strength of a complete path (i.e., indirect effect) was estimated as the product of the contributing coefficients in that pathway. The total effects were calculated by summing the effects of direct and indirect effects. The survey analysis procedures *(svy command)* in Stata™ software version 15.1 (StataCorp LLC. 2017) were used to account for the cluster sampling design (via Taylor linearization method of variance estimation), and sampling weights provided in the 2016/2017 MICS were applied to ensure representativeness of the sample. The survey analysis procedure allows us to account for the hierarchical nature of the data and appropriately address any clustering or dependency effects that may arise from the shared frailty within the maternal, household, or community units. Listwise deletion was utilized to treat missing data.

Ethical considerations. Ethical clearances were obtained earlier by the UNICEF MICS team from National Health Research Ethics Committee (NHREC), Nigeria before survey commencement. In addition, this study was exempted from ethical review by the University of Saskatchewan Behavioural Ethics Committee (ID# 904) as datasets were de-identified of the respondents' personal information (Government of Canada 2018). The participants' anonymity and confidentiality are assured. This study is reported as per the Strengthening the Reporting of Observational Studies in Epidemiology guidelines (EQUATOR, 2023).

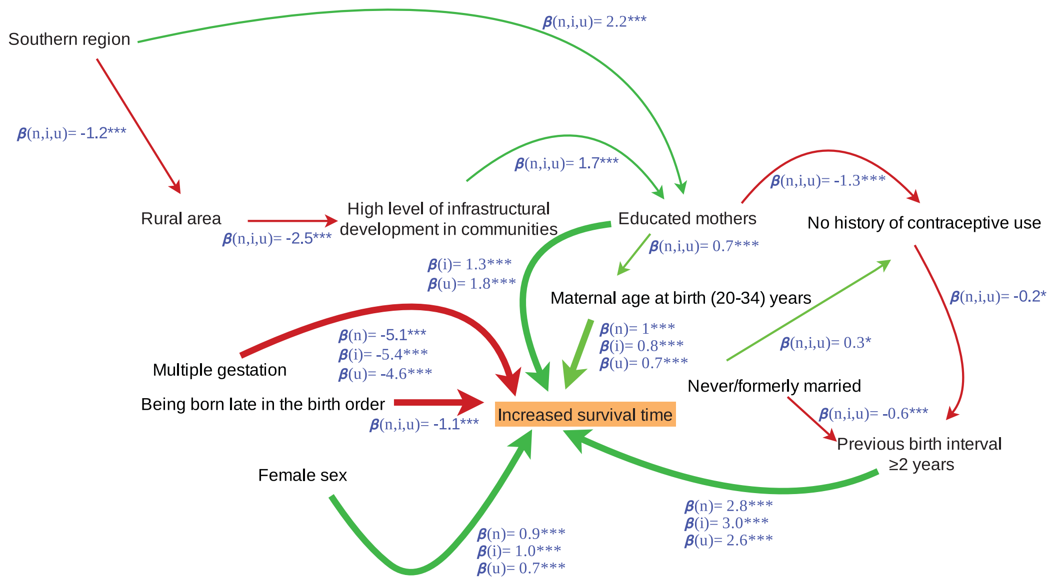

Figure 2. Omnibus hierarchical path diagram (re-specified model) showing path coefficients of social determinants of child survival in Nigeria, MICS 2016/2017.
Legend: Thick lines: Direct effect, thin lines: indirect effect; red line: inverse relationship, green line: positive relationship; β (n): path coefficient for neonates, β (i): path coefficient for infants, β (u): path coefficient for under-five children; ***significant at p-value <0.001, *significant at p-value <0.05.

Results

Table 1 describes the child, maternal, household, and community-level characteristics of participants. Of the weighted population of 30,960 live births in this study, 15,725 (50.8%) were males and 29,729 (96.0%) were singletons. More than half of the children, 21,338 (68.9%), were delivered when their mothers were 20–34 years old, and 4,320 (14%) were delivered by teenage mothers. About two out of three were children of mothers who delivered at home. Most of the children were delivered by mothers who were married or in relationship at the time of conducting the survey (96.2%). While 21,633 (69.9%) were children of women residing in rural areas, less than half of the children were of mothers who had at least secondary education (33.5%). The overall weighted time at risk for the study period was 75139.6 child-years.

During the neonatal period, 1,174 (3.8%) of the children died, incidence rate for neonatal mortality was 1.4 (95% confidence interval (CI): 1.3–1.5) per 1,000 neonate-days. Cumulatively, within one year, 2,027 (6.6%) had died, translating to 75.3 (95%CI: 71.3–79.5) per 1,000 infant-years for infant mortality. At fifth year, mortality rose to 2,840 (9.2%), i.e., 37.8 (95%CI: 36.1–39.6) per 1,000 child-years. Forty-three per cent of childhood deaths occurred during neonatal period, while 30.8% of deaths occurred during post-natal period.

The omnibus re-specified models of neonatal, infant, and under-five survival with the corresponding path coefficients are presented in Figure 2. The equivalent TRs of proximate determinants and ORs of distal determinants for the pathways are shown in Table 2.

Indirect effects

As shown in Table 3, geographical region, area of residence (urban/rural), infrastructural development, maternal education, contraceptive use, marital status, and maternal age at birth were found to operate more indirectly on neonatal, infant, and under-five survival. Geographical region had the greatest indirect effects on child survival (neonate: $\beta = 9.55$, infant: $\beta = 18.41$ and

Table 2. Final models (re-specified) of significant paths of association among variables, Nigeria MICS, 2016/2017

Endogenous variable	Exogenous variable	Exp (*β*) 95%CI
Direct effect		**Time ratio (95%CI)**
Neonatal survival	Child's sex (*Ref: Male*)	–
	Female	2.57 (1.57–4.23)
	Maternal age at birth *(Ref: <20/≥35 years)*	–
	20–34 years	2.74 (1.67–4.50)
	Gestation type *(Ref: Single)*	–
	Multiple	0.01 (0.003–0.02)
	Birth order *(Ref: ≤3)*	–
	>3	0.32 (0.19–0.55)
	Previous birth interval *(Ref: First birth/<2 years)*	–
	≥2 years	16.17 (9.90–26.42)
Infant survival	Child's sex (*Ref: Male*)	–
	Female	2.61 (1.69–4.03)
	Maternal age at birth *(Ref: <20/≥35 years)*	–
	20–34 years	2.24 (1.38–3.65)
	Gestation type *(Ref: Single)*	–
	Multiple	0.01 (0.002–0.01)
	Birth order *(Ref: ≤3)*	–
	>3	0.33 (0.20–0.55)
	Previous birth interval *(Ref: First birth/<2 years)*	–
	≥2 years	20.37 (12.77–32.49)
	Maternal education *(Ref: None/ primary)*	–
	More than primary	3.84 (2.29–6.43)
Under-five survival	Child's sex (*Ref: Male*)	–
	Female	1.94 (1.34–2.81)
	Maternal age at birth *(Ref: <20/≥35 years)*	–
	20–34 years	2.10 (1.42–3.09)
	Gestation type *(Ref: Single)*	–
	Multiple	0.01 (0.005–0.02)
	Birth order *(Ref: ≤3)*	–
	>3	0.34 (0.23–0.52)
	Previous birth interval *(Ref: First birth/<2 years)*	–
	≥2 years	13.43 (9.19–19.61)
	Maternal education *(Ref: None/ primary)*	–
	More than primary	6.32 (4.01–9.97)
Indirect effect		**Odds ratio (OR) 95%CI**
Area of residence *(Ref: Urban)*	Region *(Ref: Northern)*	–
Rural	Southern	0.30 (0.24–0.39)
Maternal education *(Ref: None/ primary)*	Region *(Ref: Northern)*	–
Post-primary	*Southern*	8.76 (7.55–10.15)
Maternal education *(Ref: None/ primary)*	Comm. Development *(Ref: Low)*	–
More than primary	High	5.46 (4.65–6.41)

(*Continued*)

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Table 2. (*Continued*)

Endogenous variable	Exogenous variable	Exp (β) 95%CI
Comm. Development *(Ref: Low)*	Area of residence *(Ref: Urban)*	–
High	Rural	0.08 (0.06–0.11)
Prev. birth interval (*Ref: First birth/ <2 years)*	Marital status *(Ref: currently married*	–
≥2 years	never/formerly married	0.56 (0.47–0.68)
Prev. birth interval (*Ref: First birth/ <2 years)*	Contraceptive use (*Ref: Yes)*	–
≥2 years	No	0.84 (0.73–0.97)
Contraceptive use *(Ref: Yes)*	Maternal education *(Ref: None/primary)*	–
No	More than primary	0.28 (0.27–0.34)
Contraceptive use *(Ref: Yes)*	Marital status *(Ref: currently married*	–
No	never/formerly married	1.37 (1.01–1.85)
Maternal age at birth *(Ref: <20/≥35 years)*	Maternal education *(Ref: None/primary)*	–
20–34 years	More than primary	1.98 (1.78–2.21)

Ref: reference; 95%CI: 95% confidence interval.

under-five: $\beta = 21.06$), followed by rurality of place of residence (neonate: $\beta = -5.56$, infant: $\beta = -10.72$ and under-five: $\beta = -12.26$). Compared to northern Nigeria, mother-child dyads in southern Nigeria were less likely to reside in rural areas (OR: 0.30, 95%CI: 0.24–0.39, *p-value*<0.001). As expected, those living in rural areas were less likely to access better social infrastructure in their communities (OR: 0.08, 95%CI: 0.06–0.11, *p-value* <0.001). Mothers who had access to better infrastructure were 5.5 times more likely to have post-primary education (OR: 5.5, 95%CI: 4.65–6.41, *p-value* <0.001). Sequentially, mothers with post-primary education were less likely not to have used contraceptives (OR: 0.28, 95%CI: 0.24–0.34, *p-value* <0.001). As anticipated, women with no history of contraceptive use were 16% less likely to have longer spacing between the current and previous birth (OR: 0.84, 95%CI: 0.73–0.97, *p-value* = 0.019). Figure 2 and Table 2 outline the other (less impactful) chains of indirect effects.

Direct effects

Child survival is due to direct effects of child's sex (female), gestational type (singleton), birth spacing (children whose mothers delivered at least two years apart), and maternal age at delivery (20–34 years).

Neonatal survival

The direct association from re-specified path diagram shows that previous birth interval ≥2 years had the highest positive effect ($\beta = 2.78$), while multiple births had the highest negative effect ($\beta = -5.06$) (Figure 2 and Table 3). As shown in Table 2, the survival time for neonates of mothers who had a previous birth interval ≥2 years was 16 times the survival time of first-born or with birth interval <2 years, 95%CI: 9.90–26.42, p-value <0.001. The survival time for neonates in multiple births decreased by 99% compared to singleton births, TR = 0.01 (95%CI: 0.003–0.02), p-value <0.001. In addition, the survival time for females increased by 2.57, compared to males, 95%CI: 1.57–4.23, p-value <0.001. Survival time increased for neonates whose mothers were 20–34 years, TR = 2.74 (95%CI: 1.67–4.50, p-value<0.001) and decreased for neonates born late in the birth order (>3rd birth order), TR = 0.32 (95%CI: 0.19–0.55, p-value<0.001). The complete pathway (both direct and indirect effects) with the greatest impact has $\beta = 3.71$, as notated in

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https://doi.org/10.1017/S0021932023000305 Published online by Cambridge University Press

Table 3. Path coefficients of direct, indirect, and total effects from social determinants to child survival

Variable	Neonatal survival time			Infant survival time			Under-five survival time		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
Child's sex (*Ref: Male*)	–			–			–		
Female	0.95		0.95	0.96		0.96	0.66		0.66
Maternal age at birth *(Ref: <20/≥35 years)*	–			–			–		
20-34 years	1.01		1.01	0.81		0.81	0.74		0.74
Gestation type *(Ref: Single)*	–			–			–		
Multiple	−5.06		−5.06	−5.38		−5.38	−4.56		−4.56
Birth order *(Ref: ≤3)*	–			–			–		
>3	−1.13		−1.13	−1.10		−1.10	−1.07		−1.07
Previous birth interval *(Ref: First birth/<2 years)*	–			–			–		
≥2 years	2.78		2.78	3.01		3.01	2.60		2.60
Maternal education *(Ref: None/ primary)*		–		–	–		–	–	
More than primary		1.31	1.31	1.35	1.22	2.57	1.84	1.09	2.93
Region *(Ref: Northern)*		–			–			–	
Southern		9.55	9.55		18.41	18.41		21.06	21.06
Area of residence *(Ref: Urban)*		–			–	–		–	
Rural		−5.56	−5.56		−10.72	−10.72		−12.26	−12.26
Community development *(Ref: Low)*		–			–			–	
High		2.23	2.23		4.28	4.28		4.91	4.91
Contraceptive use *(Ref: Yes)*		–			–			–	
No		−0.48	−0.48		−0.51	−0.51		−0.44	−0.44
Marital status *(Ref: currently married)*		–			–			–	
Never/formerly married		−1.77	−1.77		−1.90	−1.90		−1.65	−1.65
Overall effects	10.93	20.9	31.83	12.61	37.04	49.65	11.47	41.41	52.88

Ref: reference.

path 1, followed by path 2 ($\beta = 3.57$). The other significantly less impactful pathways are shown in re-specified path diagram (Figure 2).

$$\textit{Southern region} \xrightarrow{\beta=-1.2***} \textit{rural area} \xrightarrow{\beta=-2.5***} \textit{infrastructural development} \xrightarrow{\beta=1.7***} \textit{educated mothers} \xrightarrow{\beta=-1.3***} \textit{no hx of contraceptive use} \xrightarrow{\beta=-0.2*} \textit{birth interval} \geq \textit{2 years} \xRightarrow{\beta=2.8***} \textit{neonatal survival time} \quad (\textit{path 1})$$

*Legend: ⇒: Direct effect, →: indirect effect; β: path coefficient; ***significant at p-value < 0.001, *significant at p-value < 0.05*

$$\textit{Southern region} \xrightarrow{\beta=-1.2***} \textit{rural area} \xrightarrow{\beta=-2.5***} \textit{infrastructural development} \xrightarrow{\beta=1.7***} \textit{educated mothers} \xrightarrow{\beta=0.7***} \textit{maternal age at birth (20 - 34 years)} \xRightarrow{\beta=1***} \textit{neonatal survival time} \quad (\textit{path 2})$$

*Legend: ⇒: Direct effect, →: indirect effect; β: path coefficient; ***significant at p-value < 0.001*

Infant survival

Figure 2 presents the final (re-specified) path diagram and path three highlights the most impactful pathway that has the highest path-specific effect ($\beta = 7.14$) for infant survival. For the direct effects, infants of mothers who had longer spacing between the current and previous birth (birth interval ≥2 years) had longer survival time, compared to children whose mothers had shorter interval between births (birth interval <2 years), TR = 20.37 (95%CI: 12.77–32.49, p-value <0.001) (Table 2). Also, children delivered as part of multiple births were less likely to survive during infancy, compared to singletons, TR = 0.01 (95%CI: 0.002–0.01, p-value <0.001). Considering maternal age, infants delivered by women whose age was 20–34 years had longer survival time, TR = 2.24, (95%CI: 1.38–3.65, p-value = 0.001). Also, the survival time increased for female infants, (TR = 2.61, 95%CI: 1.69–4.03, p-value <0.001), and infants whose mothers had post-primary education (TR = 3.84, 95%CI: 2.29–6.43, p-value <0.001). However, infants born late in the birth order (fourth-born and above), were less likely to survive (TR = 0.33, 95% CI: 0.20–0.55, p-value <0.001).

$$\textit{Southern region} \xrightarrow{\beta=-1.2***} \textit{rural area} \xrightarrow{\beta=-2.5***} \textit{infrastructural development} \xrightarrow{\beta=1.7***} \textit{educated mothers} \xRightarrow{\beta=1.4***} \textit{infant survival time} \quad (\textit{path 3})$$

*Legend: ⇒: Direct effect, →: indirect effect; β: path coefficient; ***significant at p-value<0.001*

Under-five survival

From Table 2, children of mothers born more than two years apart survived longer (TR = 13.43, 95%CI: 9.19–19.61, p-value <0.001). Also, children delivered as part of multiple births had shorter survival time, compared to single births, TR = 0.01 (95%CI: 0.005–0.02, p-value <0.001). The survival time increased for female children (TR = 1.94, 95%CI: 1.34–2.81, p-value <0.001), children delivered by women aged 20–34 years (TR = 2.10, 95%CI: 1.42–3.09, p-value = 0.001), and children whose mothers had post-primary education (TR = 6.32, 95%CI: 4.01–9.97, p-value<0.001). However, children born late in the birth order (fourth-born and above) were less likely to survive (TR: 0.34, 95%CI: 0.23–0.52, p-value <0.001). The path 4 shows the highest path coefficient for under-five survival ($\beta = 9.18$).

$$\textit{Southern region} \xrightarrow{\beta=-1.2***} \textit{rural area} \xrightarrow{\beta=-2.5***} \textit{infrastructural development} \xrightarrow{\beta=1.7***}$$
$$\textit{educated mothers} \xRightarrow{\beta=1.8***} \textit{under}-5 \textit{ survival time} \quad (\textit{path } 4)$$

*Legend: ⇒: Direct effect, →: indirect effect; β: path coefficient; ***significant at p-value < 0.001*

Total effects

The greatest total positive effect was observed for geographical (southern) region, explaining 30-40% of the full effects of social determinants of health on child survival. Rurality had the greatest negative total effect on child survival, accounting for 17.47%, 21.59% and 23.19% of the full effects of determinants of neonatal, child and under-five survival, respectively. The indirect effects of the maternal, household, and community-level factors accounted for more than half of the full effects. The share of the indirect effects increases from 65.66% for neonates to 78.31% for under-five survival. No significant (in)direct effects of frequency of ANC visits, institutional delivery, skilled birth attendance during delivery, maternal wealth index, maternal media exposure, household sanitation, indoor air pollution, housing condition, quality of drinking water, religion, spousal age difference, polygamy, household size, sex of household health and polygamy were observed.

Discussion

We used a hierarchical path analysis with accelerated failure time approach to investigate the pathways through which child, maternal, household, and community-level factors influence neonatal, infant, and under-five survival in Nigeria. Indirect effects of maternal, household and community-level factors emerged as the major influencers of child survival. As a child grows older, the direct influence of proximal variables, primarily biological factors, diminishes, highlighting the growing significance of social factors during the later stages of a child's development. Among the exogenous variables, living in the southern region exhibited the most notable positive effect on child survival, whereas residing in rural areas of Nigeria had the strongest negative influence. Female children, those whose mothers delivered at least two years apart and aged 20–34 years had longer neonatal, infant, and under-five survival times. Maternal education had significant direct effects on infant and under-five survival, separately, but not on neonatal survival. Effects of maternal education on neonatal survival were mediated by maternal age at child's birth. During the first years of life, children delivered as part of multiple births, and those born late in the birth order, were less likely to survive. In addition, factors such as region, area of residence, infrastructure development, maternal education, contraceptive use, previous birth interval, maternal status, and maternal age at birth were found to operate indirectly on the neonatal, infant, and under-five survival.

This study offers comprehensive set of factors at the maternal, household, and community levels that are associated with child survival in Nigeria. The path analysis reveals that in the neonatal, infant, and under-five models, women from the northern areas of Nigeria were less likely to reside in urban cities and towns than those in the southern areas. This, in turn, limited their access to social infrastructure and acted as a barrier to maternal education. Without adequate education, women were less likely to use contraceptive methods. Women with no history of contraceptive use were less likely to delay pregnancy and have adequate spacing (≥2 years) between children, which, in turn, negatively impacted child survival. This is consistent with what has been observed previously (Biradar, Patel, and Prasad 2019; Morakinyo and Fagbamigbe 2017). With respect to birth interval, inadequate child spacing depletes maternal micronutrients (e.g., copper, zinc, ferritin, folate and magnesium) which are critical to child survival (Ezeh et al. 2015).

As observed from this study, the direct relationship between high maternal education level, and infant and under-five survival could be due to better health literacy and health-seeking behaviours

https://doi.org/10.1017/S0021932023000305 Published online by Cambridge University Press

for themselves and their children (Mosley 1985; Caldwell 1990; Akinyemi, Bamgboye, and Ayeni 2015; Morakinyo and Fagbamigbe 2017; Ezeh et al. 2015; Sanders et al. 2009; DeWalt et al. 2004). Similarly, empirical evidence from literature suggests that health prevention measures against childhood diseases (such as immunization) (Adeyinka et al. 2008). and prompt care of sick children are vital elements for child survival (Mosley and Chen 1984; Sanders et al. 2009; DeWalt et al. 2004). Furthermore, through an alternative pathway, the indirect effects of maternal education on neonatal, infant, and under-five survival were mediated by maternal age at birth. Our study found that women with higher levels of education were less likely to be teenage mothers, thereby reducing child mortality. This pattern aligns with findings from a previous study in Ghana, indicating that young women with limited education are more likely to engage in early sexual activity and face barriers to accessing reproductive health information (Asante et al. 2018). However, due to the nature of observational studies like ours, it is challenging to completely dismiss the possibility of reverse causality. It is conceivable that young women who became pregnant at an early age might subsequently drop out of school (Onyeka et al. 2011; Grant and Hallman 2008; Rosenberg et al. 2015). On this note, it is crucial to conduct additional studies to establish a chronological sequence of events through longitudinal studies and gather stronger evidence for causality.

Physiologic immaturity, low birth weight, prematurity, and infections may be considered important aetiological factors for childhood mortality among teenage mothers (Neal, Channon, and Chintsanya 2018); however, Adeyinka *et al.*, opined that it is an indication of the lack of critical and supportive care needed by teenage mothers in low-resource settings (Adeyinka et al. 2010). To a lesser extent, marital status exerted indirect effects on neonatal, infant, and under-five survival through previous birth interval. This study provides evidence to support that children delivered to never-married or formerly married women were less likely to use contraceptives, which in turn is associated with short birth spacing after a previous delivery.

Contrary to the findings from previous studies (Ezeh et al. 2015; Morakinyo and Fagbamigbe 2017), we did not find association between the frequency of ANC visits, skilled birth attendants during delivery, and child survival. It is possible that this observation could have been masked by inability to account for high-risk pregnancies and quality of care received during pregnancy and labour. Similarly, this study could not ascertain the timing of those interventions. These assumptions should be tested in future studies.

We recognize that model-driven path analysis provides evidence in support of, or lack thereof, a theoretical model, but it is not tantamount to causal inferences (Jeon 2015). From this perspective, our findings should be regarded as associations, albeit describing previously conceptualized structured pathways, and not causation. In addition, maternal recall bias/poor memory arising from self-report could not be completely overlooked. However, we expect that limiting our analysis to five years prior to the survey might have minimized its effect. As generalized structural equation modelling is at its nascent stage during the time of our analysis, goodness-of-fit tests were not available in Stata™ software (StataCorp LLC 2017). Hence, we could not assess model fit. Future research should be devoted to the development of model fit for generalized SEM. Despite these limitations, this study has some strengths. We have demonstrated the utility of a combined survival analysis with path analysis approach to explain the pathways of social determinants of health on child survival. Also, the study relied on a large dataset which comprised of representative national sample and high response rate; hence, findings are generalizable to under-five children in Nigeria and other settings with similar contexts. Nigeria is a culturally diverse nation with distinct regional variations in customs, traditions, beliefs, and practices. These cultural differences can significantly influence child survival outcomes. By recruiting participants from diverse regions in Nigeria, the study captures the heterogeneity of cultural and socioeconomic factors that can influence child survival. This approach ensures that the identified pathways are reflective of the broader population and increases the applicability of the results to different regions within Nigeria. Nonetheless, it is important to recognize that there might still be nuanced variations within regions that this study might not capture, and the need for further localized research to complement the study's findings. Path analysis with time-to-event outcome constitutes a relatively new area of research which is still evolving. This study adds to the few papers that utilized path analysis in population health research.

This study identified various factors that directly and indirectly affect neonatal, infant, and under-five survival. As a result, there are several policy and practice implications to consider. For instance, the identification of geographical region as an indirect factor influencing child survival suggests the need for targeted interventions in regions with higher child mortality rates (such as northern Nigeria). Policymakers should allocate resources and implement region-specific programmes or interventions to address the underlying factors contributing to poor child survival in these areas. Improving healthcare infrastructure in rural areas is a priority and may involve building healthcare facilities in hard-to-reach areas, training healthcare professionals, and implementing telemedicine to bridge the gap between rural communities and healthcare providers. Efforts should be made to enhance maternal education, especially in areas with lower educational attainment. Additionally, comprehensive family planning programmes should be implemented to promote contraceptive use, enabling women and their families to have better control over the timing and spacing of pregnancies. Communities should also be educated about the benefits of allowing birth spacing. To meet the needs of young mothers, the government should provide support and resources to ensure their well-being and that of their children. This could involve initiatives such as access to healthcare services, educational opportunities, and social support systems specifically tailored to meet the needs of young mothers.

Conclusion

In conclusion, our findings indicate child survival inequity in Nigeria, which might be independently due to multiple gestation, previous birth intervals, maternal education, birth order, child's sex, and maternal age at birth. Also, this study has highlighted the key pathways by which region, area of residence, infrastructural development, contraceptive use, and maternal status influence neonatal, infant, and under-five survival. Furthermore, the most influential determinants of child survival are geographical region and place of residence. In order to accelerate progress towards child survival targets of SDG-3 and reduce geographical disparities (SDG-10) in Nigeria, stakeholders should implement more impactful policies that promote maternal education, contraceptive use and improve living conditions of women in rural areas. Also, our findings indicate the need for community and facility-based interventions for neonates of teenage mothers.

Acknowledgements. This study was made possible by support for DAA through the College of Medicine Graduate Award (CoMGRAD) from the University of Saskatchewan, Canada. The content is solely the responsibility of the authors and does not necessarily reflect the official views of the College of Medicine, University of Saskatchewan.

Data availability. Data may be found at UNICEF MICS website (UNICEF MICS 2018).

Authors' contributions. DAA conceived the study, analysed and interpreted the data, and wrote the first draft of the paper. NM assisted in the design and data interpretation and critically reviewed the manuscript. NM supervised this study. All authors read and approved the final manuscript.

Competing interests. No potential conflict of interest was reported by the authors.

Funding. The authors received no specific funding for this work.

References

Abdelkhalek F and Bolla M (2020) Application of Structural Equation Modeling to Infant Mortality Rate in Egypt. In Application of Structural Equation Modeling to Infant Mortality Rate in Egypt. In: Skiadas C. and Skiadas C. (Eds.)

Demography of Population Health, Aging and Health Expenditures. The Springer Series on Demographic Methods and Population Analysis 50. pp. 89–99. Springer, Cham. https://doi.org/10.1007/978-3-030-44695-6_7.

Abu IN, Madu IA, and Ajaero CK (2015) The prevalence and determinants of under-five mortality in Benue State, Nigeria. *SAGE Open* **5**, 215824401561193. https://doi.org/10.1177/2158244015611938.

Adebowale SA, Mayowa Morakinyo O, and Rowland Ana G (2017) Housing materials as predictors of under-five mortality in Nigeria: Evidence from 2013 demographic and health survey. *BMC Pediatrics* **17**, 30. https://doi.org/10.1186/s12887-016-0742-3.

Adedini SA, Odimegwu C, Bamiwuye O, Fadeyibi O, and De Wet N (2014) Barriers to accessing health care in Nigeria: Implications for child survival. *Global Health Action* **7**, 1–10. https://doi.org/10.3402/GHA.V7.23499.

Adeyanju O, Tubeuf S, and Ensor T (2017) Socio-economic inequalities in access to maternal and child healthcare in Nigeria: Changes over time and decomposition analysis. *Health Policy and Planning* **32**, 1111–18.

Adeyinka DA, Oladimeji O, Adekanbi TI, Adeyinka FE, Falope Y and Aimakhu C (2010) Outcome of adolescent pregnancies in Southwestern Nigeria: A casecontrol study. *Journal of Maternal-Fetal and Neonatal Medicine* **23**. https://doi.org/10.3109/14767050903572166.

Adeyinka DA, Oladimeji O, Adeyinka F, and Aimakhu C (2008) Uptake of childhood immunization among mothers of under-five in Southwestern Nigeria. *The Internet Journal of Epidemiology* **7**, 1–9.

Akinyemi JO, Afolabi Bamgboye E, and Ayeni O (2015) Trends in neonatal mortality in Nigeria and effects of bio-demographic and maternal characteristics. *BMC Pediatrics* **15**, 36. https://doi.org/10.1186/s12887-015-0349-0.

Akombi-Inyang B (2021) Malnutrition among children is rife in Nigeria. What must be done. *The Conversation*. https://theconversation.com/malnutrition-among-children-is-rife-in-nigeria-what-must-be-done-164496.

Antai D (2011) Regional inequalities in under-5 mortality in Nigeria: A population-based analysis of individual- and community-level determinants. *Population Health Metrics* **9**, 6. https://doi.org/10.1186/1478-7954-9-6.

Asante K, Nketiah-Amponsah E, Andoh-Arthur J, Boafo IM, and Ampaw S (2018) Correlates of early sexual debut among sexually active youth in Ghana. *International Quarterly of Community Health Education* **39**, 9–17.

Biradar R, Kumar Patel K, and Bahadur Prasad J (2019) Effect of birth interval and wealth on under-5 child mortality in Nigeria. *Clinical Epidemiology and Global Health* **7**, 234–38.

Boco AG (2014) Assessing sex differentials in under-five mortality in Sub-Saharan Africa: A cross-national comparative analysis. *Canadian Studies in Population* **41**.

Caldwell J (1990) Cultural and social factors influencing mortality levels in developing countries. *The Annals of the American Academy of Political and Social Science* **510**, 44–59. https://doi.org/10.1177/0002716290510001004.

DeWalt DA, Berkman ND, Sheridan S, Lohr KN and Pignone MP (2004) Literacy and health outcomes. *Journal of General Internal Medicine* **19**, 1228–39.

EQUATOR Network (2023) The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies, https://www.equator-network.org/reporting-guidelines/strobe/.

Ezeh KO, Kingsley Agho E, Dibley John M, John Hall J and Andrew Page N (2015) Risk factors for postneonatal, infant, child and under-5 mortality in Nigeria: A pooled cross-sectional analysis. *BMJ Open* **5**, e006779. https://doi.org/10.1136/bmjopen-2014.

Government of Canada (2018) Interagency advisory panel on research ethics. http://www.pre.ethics.gc.ca/eng/policy-politique/initiatives/tcps2-eptc2/chapter2-chapitre2/#ch2_en_a2.4.

Grant MJ, and. Hallman KK (2008) Pregnancy-related school dropout and prior school performance in KwaZulu-Natal, South Africa. *Studies in Family Planning* 39, 369–82.

Hudson JI, Pope HG, and Glynn RJ (2005) The cross-sectional cohort study: An underutilized design. *Epidemiology* **16**, 355–59.

Jeon J (2015) The strengths and limitations of the statistical modeling of complex social phenomenon: Focusing on SEM, path analysis, or multiple regression models. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering* **9**, 1634–42.

Kananura RM, Wamala R, Ekirapa-Kiracho E, Tetui M, Kiwanuka SN, Waiswa P, and Atuhaire LK (2017) A structural equation analysis on the relationship between maternal health services utilization and newborn health outcomes: A cross-sectional study in Eastern Uganda. *BMC Pregnancy and Childbirth* **17**, 98. https://doi.org/10.1186/s12884-017-1289-5.

Kayode G, Grobbee D, Amoakoh-Coleman M, Ansah E, Uthman O, and Klipstein-Grobusch K (2017) Variation in neonatal mortality and its relation to country characteristics in Sub-Saharan Africa. *BMJ Global Health* **2**, A49.1–A49. https://doi.org/10.1136/bmjgh-2016-000260.130.

Lapointe-Shaw L, Bouck Z, Howell NA, Lange T, Orchanian-Cheff A, Austin PC, Ivers NM, Redelmeier DA, and Bell CM (2018) Mediation analysis with a time-to-event outcome: A review of use and reporting in healthcare research. *BMC Medical Research Methodology* **18**, 118. https://doi.org/10.1186/s12874-018-0578-7.

Mitchell RJ (1993) Path analysis: Pollination. In: Scheiner SM and Gurevitch J (Eds.), *Design and Analysis of Ecological Experiments*. Chapman and Hall, New York, pp. 211–31.

Morakinyo, OM and Fagbamigbe AF (2017) Neonatal, infant and under-five mortalities in Nigeria: An examination of trends and drivers (2003-2013). *PLOS ONE* **12**, e0182990. https://doi.org/10.1371/journal.pone.0182990.

Mosley WH (1985) Child survival: Research and policy. *World Health Forum* **6**, 352–60. http://apps.who.int/iris/bitstream/handle/10665/50068/WHF_1985_6%284%29_p352-360.pdf?sequence = 1&isAllowed = y.

Mosley WH, and Chen LC (1984) An analytical framework for the study of child survival in developing countries. *Population and Development Review* **10**, 25–45.

Naghavi-Behzad M, Ghojazadeh M, Mirnia K, Azami-Aghdash S, and Piri R (2014) Contributing death factors in very low-birth-weight infants by path method analysis. *Nigerian Medical Journal* **55**, 389–93.

National Bureau of Statistics (2015) The millennium development goals performance tracking survey 2015 report. http://www.ng.undp.org/content/dam/nigeria/docs/MDGs/UNDP_NG_2014MDGSurveyReport.pdf.

Neal S, Channon AA, and Chintsanya J (2018) The impact of young maternal age at birth on neonatal mortality: Evidence from 45 low and middle income countries. *PLOS ONE* **13**, e0195731. https://doi.org/10.1371/journal.pone.0195731.

Nguyen MP, and. Nguyen CM (2020) Dominant factors affecting regional inequality of infant mortality in Vietnam: A structural equation modelling analysis. *International Journal of Health Policy and Management*, **10**, 1–8. https://doi.org/10.34172/ijhpm.2020.59.

Onyeka IN, Miettola J, Ilika AL, and Vaskilampi T (2011) Unintended pregnancy and termination of studies among students in Anambra State, Nigeria: Are secondary schools playing their part? *African Journal of Reproductive Health* **15**, 109–15.

Ricci C, Carboo J, Asare H, Smuts CM, Dolman R, and Lombard M (2019) Nutritional status as a central determinant of child mortality in Sub-Saharan Africa: A quantitative conceptual framework. *Maternal & Child Nutrition* **15**, e12722. https://doi.org/10.1111/mcn.12722.

Rosenberg M, Pettifor A, Miller WC, Thirumurthy H, Emch M, Afolabi SA, Kahn K, Collinson M, and Tollman S (2015) Relationship between school dropout and teen pregnancy among rural South African young women. *International Journal of Epidemiology* **44**, 928–36.

Sanders LM, Federico S, Klass P, Abrams MA, and Dreyer B (2009) Literacy and child health. *Archives of Pediatrics & Adolescent Medicine* **163**, 131–40.

Stata (2019) Structural equation modeling reference manual release 16. https://www.stata.com/manuals/sem.pdf.

StataCorp LLC (2017) Stata survival analysis reference manual release 15. https://www.surveydesign.com.au/docs/manuals/stata15/st.pdf.

UNICEF (2022) Levels and trends in child mortality. https://data.unicef.org/resources/levels-and-trends-in-child-mortality/.

UNICEF, and **NBS** (2017) *Multiple Indicator Cluster Survey 2016-17, Survey Findings Report*. Abuja, Nigeria.

UNICEF MICS (2018) Datasets. http://mics.unicef.org/surveys.

WHO, **UNICEF**, and **JMP** (2018) JMP methodology: Update and SDG baselines. https://washdata.org/sites/default/files/documents/reports/2018-04/JMP-2017-update-methodology.pdf.

Williams TC, Bach CC, Matthiesen NB, Henriksen TB and Gagliardi L (2018) Directed acyclic graphs: A tool for causal studies in paediatrics. *Pediatric Research* **84**, 487–93. https://doi.org/10.1038/s41390-018-0071-3.

You D, Hug L, Ejdemyr S, Idele P, Hogan D, Mathers C, Gerland P, Rou New J, and Alkema L (2015) Global, regional, and national levels and trends in under-5 mortality between 1990 and 2015, with scenario-based projections to 2030: A systematic analysis by the UN inter-agency group for child mortality estimation. *The Lancet* **386**, 2275–86. https://doi.org/10.1016/S0140-6736(15)00120-8.

Zalak ZA, and Goujon A (2017) Assessment of the data quality in demographic and health surveys in Egypt. www.oeaw.ac.at/vid.

Cite this article: Adeyinka DA and Muhajarine N (2024). Disentangling the link between social determinants of health and child survival in Nigeria during the Sustainable Development Goals era: a hierarchical path analysis of time-to-event outcome. *Journal of Biosocial Science* **56**, 357–375. https://doi.org/10.1017/S0021932023000305