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Trends and population-attributable risk estimates for predictors of early neonatal mortality in Nigeria, 2003–2013: a cross-sectional analysis

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ABSTRACT

Objectives To assess trends in early neonatal mortality (ENM) and population-attributable risk (PAR) estimates for predictors of ENM in Nigeria.

Design, setting and participants A cross-sectional data on 63 844 singleton live births within the preceding 5 years from the 2003, 2008 and 2013 Nigeria Demographic and Health Surveys were used. Adjusted PARs were used to estimate the number of early neonatal deaths attributable to each predictor in the final multivariable Cox regression model.

Main outcome measures ENM, defined as the death of a live-born singleton between birth and 6 days of life.

Results The ENM rate slightly declined from 30.5 (95% CI 26.1 to 34.9) to 26.1 (CI 24.3 to 27.9) during the study period. Approximately 36 746 (CI 14 656 to 56 920) and 37 752 (CI 23 433 to 51 126) early neonatal deaths were attributable to rural residence and male sex, respectively. Other significant predictors of ENM included small neonates (attributable number: 25 884, CI 19 172 to 31 953), maternal age <20 years (11 708, CI 8521 to 17 042), caesarean section (6312, CI 4260 to 8521) and birth order ≥4 with a short birth interval (≤2 years) (18 929, CI 12 781 to 25 563)).

Conclusions To improve early neonatal survival in Nigeria, community-based interventions are needed for small neonates, and to promote delayed first pregnancy, child spacing and timely referral for sick male neonates and caesarean delivery.

Strengths and limitations of this study

- ► The nationally representative household data used for this study met the basic criteria for estimating population-attributable risk (PAR), such as random selection of the population of interest and exposure data detailed with minimal bias.
- ► Estimates provided in this study were population based, which increases the validity, and can be generalisable to the Nigerian population (with >350 ethnic groups with different cultures, religions and lifestyles).
- ► Restriction of the study to births within a 5-year period prior to the survey dates lessened recall bias relating to the dates of birth and death, and bias resulting from changes in household characteristics.
- ► The PAR estimates may have been underestimated or overestimated because of residual confounding due to potential early neonatal mortality (ENM) risk factors, such as birth asphyxia, gestational age, jaundice, sepsis, maternal hypertension and HIV.
- ► The PAR was estimated based on the assumption that there was a causal relationship between the risk factors identified in the study and ENM.

INTRODUCTION

Early neonatal mortality (ENM) refers to deaths of newborns between 0 and 6 days of age and remains a global public health concern, especially in sub-Saharan African countries, including Nigeria. Nearly 40% of deaths in newborns ≤27 days old occur in sub-Saharan Africa and the majority of these deaths occur in the first 1 week of age.[1] A huge number of these deaths are preventable with optimal healthcare,[2] such as those attributable to prematurity, which contributes to approximately 31% of neonatal deaths.[3]

In 2015, there were approximately 250 000 neonatal deaths in Nigeria,[1] and about 78% of neonatal deaths occurred during the early neonatal period, based on data from the 2013 Nigeria Demographic and Health Survey (NDHS).[4] Despite immense contributions to the reduction in the under-five mortality rate, governmental interventions to address the high ENM rate are inadequate. An example of this gap is the integrated maternal, newborn and child health framework, adopted in 2011,[5] which lacked clear details on the appropriate and effective implementation of crucial elements of newborn care, such as kangaroo mother care, newborn resuscitation and neonatal sepsis treatment. Such interventions are particularly necessary at the community level because nearly two-thirds of deliveries occur at home.[4] In Nigeria, as in many other developing countries, concerted

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efforts to address child mortality have focused on deaths after the postneonatal period. Studies have shown that the causes of death differ greatly between the early (0–6 days), late (7–27 days), and postneonatal (1–59 months) periods.[6] The inattention to the early period may explain why the under-five mortality rate in Nigeria has remained greater than 100 deaths per 1000 live births for more than 3 decades.[1 4]

Presently, there is neither estimation nor surveillance of the early neonatal mortality rate (ENMR) in Nigeria. ENM data are gathered and recorded in the NDHSs but the data are combined with stillbirths data (defined as fetal death at 28 weeks' gestation or later) and described as perinatal mortality.[4] It has been suggested that such amalgamation could hinder surveillance of trends, mask reporting differences, induce systematic misclassification and encumber effective solutions.[7]

In the past, studies relating to ENM in Nigeria mostly reported perinatal mortality,[8–10] with the exception of the study by Dahiru,[11] which specifically investigated ENM. Limitations of this study are that it included multiple births and the total number of early neonatal deaths exceeded that estimated by the 2013 NDHS by a factor of 4.[11] It is possible that the mortality estimates reported by Dahiru[11] may have been overestimated or underestimated because live births that occurred more than 5 years before data collection were included in the study, which is inconsistent with the most recent NDHS data. In addition, previous reviews in both developed and developing countries, including Nigeria, indicated that twins, triplets and other higher-order multiple births were more than twice as likely to die during infancy compared with singletons.[12–14] Prior to the current study, no population-based studies examined the trends in singleton ENMR, or population-attributable risk (PAR) estimates adjusted for independent risk factors associated with ENM in Nigeria.

This study investigated trends in ENMR and assessed possible demographic, socioeconomic and proximate factors influencing singleton ENM using data about live births during 5-year periods in the NDHSs from 2003 to 2013. Adjusted PAR proportions were also calculated to measure the ENM attributable to each significant independent risk factor in Nigeria. Estimates reported in this study will provide information that policy makers and public health researchers will be able to use to formulate effective, evidence-based interventions to substantially reduce ENM in Nigeria.

METHODS

A cross-sectional data from the 2003, 2008 and 2013 NDHSs were used for this study. Data regarding live births were reported by women aged 15–49 years old who participated in the surveys. The weighted number of reported live births that occurred during the 10-year study period was 247 772 (23 578, 104 808 and 119 386 from the 2003, 2008 and 2013 surveys, respectively). The NDHS final report included live births within the 5-year period prior to the interview date to minimise recall errors. The number of live births, including singletons and multiple births, reported from the NDHS was 6219, 28 107 and 31 828 from the 2003, 2008 and 2013 surveys, respectively. The statistical procedure used to estimate the number of live births is described elsewhere.[4 15 16]

Multiple births have a higher mortality risk than singletons and were excluded from this study. Trends in ENMR and the factors associated with ENM in Nigeria were investigated using singleton live births (n=5971, 27 147 and 30 726 from the 2003, 2008 and 2013 surveys, respectively). Data from all three surveys were combined for the analysis of characteristics associated with early neonatal death because few singleton deaths were reported during the early neonatal period for each survey year.

Study variables

The outcome variable for this study was ENM, defined as the death of a live-born singleton between birth and 6 days of life. A 'case' was defined as a neonate who died in the first week of life and a 'non-case' was defined as a neonate who was alive at the end of the early neonatal period.

The conceptual framework proposed by Mosley and Chen[17] was used in this study to identify and classify the factors that potentially influence ENM in Nigeria (figure 1). This model is considered to be the most comprehensive and systematic conceptual framework for analysing childhood mortality,[18 19] particularly in developing countries. As presented in figure 1, all of the potential study variables that were available in the NDHS data set were grouped into community-level factors, socioeconomic factors and proximate factors.

Statistical analysis

The distribution of all of the characteristics of early neonates that are listed in figure 1 was assessed separately for each survey year. The ENMRs were then calculated using the approach described by Rutstein and Rojas.[20] Estimation of the crude HRs and adjusted HRs (aHR) that accounted for factors related to ENM was examined by univariate and multivariable analyses, respectively, using Cox proportional hazards regression models. A hierarchical modelling approach was used for the multivariable analyses.[21] Each level factor (figure 1) was entered into the model separately to investigate their association with ENM. Initially, variable representing the year of survey and the community-level factor were entered, and a stepwise backward elimination procedure was carried out to identify factors significantly related to ENM at a 5% significance level were retained. In the second model, five socioeconomic-level factor variables were examined with the community factor variables that were significantly associated with ENM, and those variables with p values <0.05 were retained. In the final model, a similar method was employed for the proximate factor variables, which were examined with those variables significantly associated with ENM in the second model. The magnitude

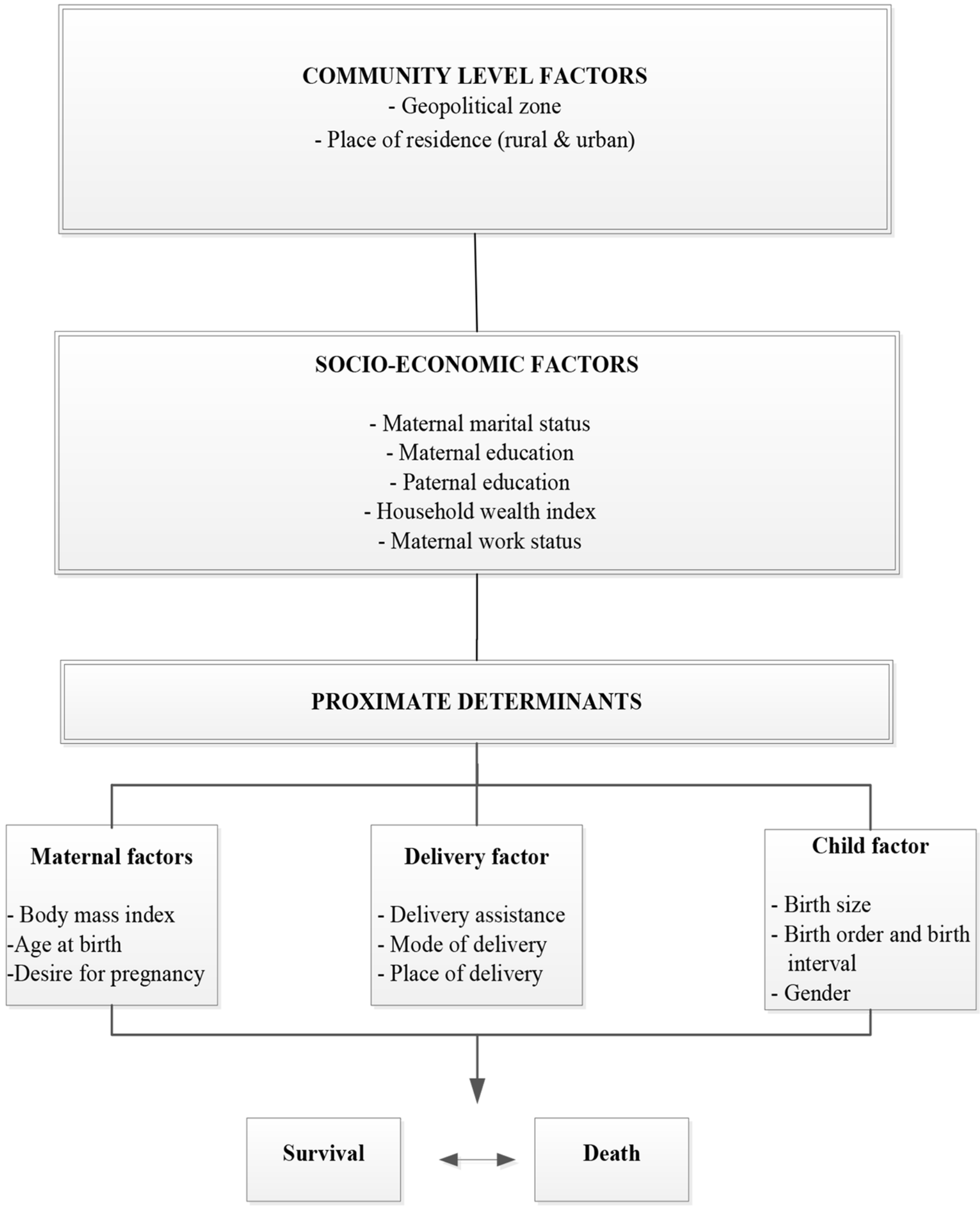

Figure 1 Conceptual framework for analysing factors influencing death of neonates (≤6 days old) in Nigeria, 2003–2013 (adapted from Mosley and Chen[17]).

of the risk associated with ENM for each of the significant variables was measured by the HR and associated 95% CI. All analyses were conducted using STATA/MP, V.13 (StataCorp).

Adjusted PAR proportions and 95% CI were obtained using an approach that was similar to that described by Stafford *et al*.[22] The PAR estimates were used to extrapolate the total number of early neonatal deaths in the general population that were attributable to each independent variable that was retained in the final multivariable Cox regression model, under the assumption that the relationships were causal. The projected total risk was calculated by using the PAR estimates and the yearly estimated number of early neonatal deaths (using NDHS's most recent neonatal mortality rate,[4] current estimated crude birth rate[23] and estimated general population).[24]

RESULTS

Trends in ENM

There were 1749 early neonatal deaths of (singleton) neonates ≤6 days old during the study period. One-third (n=572, 32.7%) of these deaths occurred <24 hours after birth and 517 (29.6%) occurred on the first day (figure 2A).

The overall ENMR for singleton live-born infants between 2003 and 2013 was approximately 27.4 per 1000 live births (95% CI 26.1 to 28.7). A decreasing trend in ENMR was observed during the study period (figure 2B) from 30.5 per 1000 live births in 2003 to 28.2 per 1000 in 2008 to 26.1 per 1000 in 2013.

The distribution of the independent variables and the ENMR for each category are shown in table 1. The ENMR

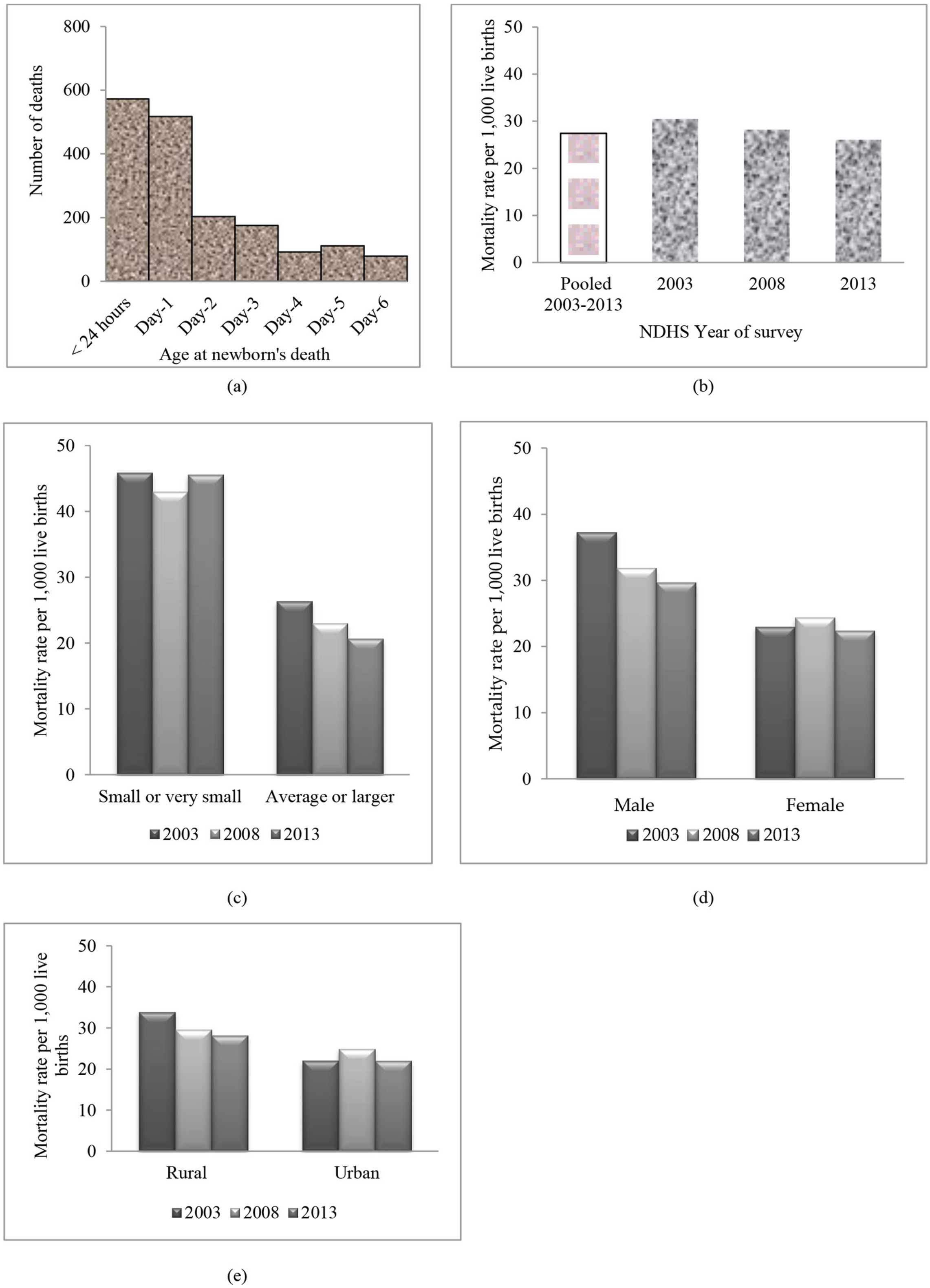

Figure 2 Distribution of and trends in early neonatal deaths per 1000 live births (singleton) by year of survey, newborn body size at birth, sex and place of residence in Nigeria, 2003–2013. (A) Distribution of early newborn deaths between birth and 6 days. (B) Early neonatal mortality rate. (C) Mother's perceived newborn body size at birth. (D) Newborn sex. (E) Newborn place of residence. NDHS, Nigeria Demographic and Health Survey.

for early neonates born to mothers from poor households decreased 25% (from 35.6 to 27.4 per 1000 between 2003 and 2013, respectively). There was a 16% decrease for early neonates whose mothers had no formal education (from 30.7 to 26.3 per 1000 between 2003 and 2013, respectively). The ENMR for early neonates who were

Table 1 Distribution of independent variables and the ENMR for each category of proximate, socioeconomic and community variables in Nigeria, 2003–2013

Characteristic	2003 n (%)	2003 ENMR (95% CI)	2008 n (%)	2008 ENMR (95% CI)	2013 n (%)	2013 ENMR (95% CI)
Residence type						
Urban	38 (21.0)	22.1 (15.1–29.1)	201 (26.2)	24.9 (23.1–30.0)	235 (29.3)	22.0 (19.2–24.8)
Rural	144 (79.0)	33.9 (28.3–39.4)	565 (73.8)	29.6 (30.3–35.4)	566 (70.7)	28.2 (25.9–30.6)
Geographical region						
North Central	30 (16.6)	35.1 (22.5–47.6)	84 (13.7)	22.7 (17.9–27.6)	94 (11.7)	22.6 (18.0–27.2)
North East	49 (27.2)	34.5 (24.8–44.1)	124 (16.4)	27.9 (23.0–32.8)	147 (18.3)	27.0 (22.6–31.3)
North West	54 (29.6)	26.0 (19.1–33.0)	229 (31.5)	26.8 (23.4–30.3)	310 (38.8)	27.1 (24.1–30.1)
South East	9 (4.8)	24.8 (8.6–41.0)	97 (9.5)	37.2 (29.8–44.5)	76 (9.5)	28.1 (21.8–34.5)
South West	28 (15.2)	37.2 (23.4–51.0)	120 (12.9)	34.1 (28.0–40.2)	71 (8.8)	25.2 (19.3–31.1)
South South	12 (6.6)	23.7 (10.3–37.1)	112 (16.1)	25.8 (21.0–30.6)	103 (12.9)	24.8 (20.0–29.6)
Household wealth index						
Poor	95 (52.3)	35.6 (28.4–42.8)	370 (48.3)	29.5 (26.5–32.5)	394 (49.2)	27.4 (24.7–30.1)
Middle	71 (39.1)	30.8 (23.7–38.0)	271 (35.3)	27.1 (23.8–30.3)	294 (36.7)	26.3 (23.3–29.3)
Rich	16 (8.6)	16.0 (8.2–23.8)	126 (16.4)	27.4 (22.6–32.2)	113 (14.2)	22.0 (17.9–26.1)
Mother's education						
No education	95 (52.5)	30.7 (24.5–36.9)	337 (43.9)	26.6 (23.7–29.4)	399 (49.8)	26.3 (23.7–28.9)
Primary	52 (28.4)	36.8 (26.8–46.8)	197 (25.8)	31.5 (27.1–35.9)	172 (21.4)	29.3 (24.9–33.7)
Secondary or higher	35 (19.1)	23.9 (16.0–31.8)	232 (30.3)	28.3 (24.6–31.9)	230 (28.7)	23.7 (20.7–26.8)
Mother's working status						
Not working	83 (45.9)	37.2 (29.2–45.2)	251 (33.4)	26.7 (23.4–30.0)	251 (33.6)	26.0 (22.7–29.2)
Working	98 (54.1)	26.2 (21.0–31.4)	501 (66.6)	29.3 (26.7–31.8)	497 (66.4)	25.2 (23.0–27.4)
Mother's age						
<20	19 (10.5)	43.9 (24.1–63.6)	68 (8.8)	46.2 (35.2–57.2)	62 (7.8)	39.5 (29.7–49.4)
20–29	80 (44.1)	26.0 (20.3–31.7)	335 (43.7)	25.6 (22.8–28.3)	383 (47.9)	26.1 (23.5–28.7)
30–39	68 (37.4)	34.9 (26.6–43.2)	273 (35.6)	27.9 (24.6–31.2)	259 (32.3)	22.7 (20.0–25.5)
40–49	15 (8.0)	29.4 (14.5–44.2)	92 (11.9)	33.1 (26.3–39.8)	96 (12.0)	31.3 (25.0–37.5)
MBMI						
MBMI >18.5	163 (89.5)	32.1 (27.2–37.0)	682 (89.0)	29.0 (26.8–31.2)	741 (92.6)	26.6 (24.7–28.6)
MBMI ≤18.5	16 (8.6)	20.9 (10.7–31.2)	72 (9.5)	23.5 (18.1–28.9)	51 (6.4)	19.8 (14.3–25.2)
Wanted pregnancy						
Wanted then	155 (87.2)	30.4 (25.6–35.2)	640 (89.2)	26.8 (24.7–28.9)	705 (92.6)	25.3 (23.4–27.1)

Continued

Table 1 Continued

Characteristic	2003 n (%)	2003 ENMR (95% CI)	2008 n (%)	2008 ENMR (95% CI)	2013 n (%)	2013 ENMR (95% CI)
Wanted later	11 (6.0)	20.7 (8.5–32.9)	40 (5.6)	24.0 (16.5–31.4)	42 (5.5)	20.9 (14.6–27.2)
Wanted no more	12 (6.8)	39.5 (17.1–61.8)	37 (5.1)	32.2 (21.8–42.5)	14 (1.8)	29.5 (14.0–44.9)
Father's education						
No education	74 (42.1)	31.2 (24.1–38.3)	260 (34.9)	25.8 (22.7–29.0)	310 (40.2)	25.1 (22.3–27.9)
Primary	45 (25.7)	32.7 (23.2–42.3)	179 (24.1)	30.7 (26.2–35.2)	161 (20.9)	28.5 (24.1–32.9)
Secondary or higher	57 (32.2)	28.0 (20.8–35.3)	304 (40.9)	29.3 (26.0–32.6)	300 (38.9)	25.1 (22.3–28.0)
Mother's perceived baby size						
Average or larger	133 (77.3)	26.4 (21.9–30.9)	525 (76.6)	23.0 (21.1–25.0)	532 (72.5)	20.7 (18.9–22.4)
Small or very small	39 (22.7)	45.9 (31.5–60.3)	161 (23.4)	43.0 (36.4–49.7)	202 (27.5)	45.6 (39.3–51.9)
Sex						
Female	67 (37.0)	23.0 (17.5–28.5)	326 (42.6)	24.4 (21.8–27.1)	341 (42.6)	22.4 (20.0–24.8)
Male	114 (63.0)	37.3 (30.4–44.1)	440 (57.4)	31.9 (28.9–34.8)	460 (57.4)	29.7 (27.0–32.4)
Birth order/birth interval						
First	59 (32.4)	46.3 (34.5–58.1)	191 (24.9)	35.8 (30.7–40.9)	221 (27.6)	36.1 (31.4–40.9)
Second or third rank, interval ≤2 years	14 (7.7)	25.5 (12.1–38.9)	107 (14.0)	40.3 (32.7–48.0)	92 (11.5)	33.3 (26.5–40.1)
Second or third rank, interval >2 years	27 (15.0)	20.4 (12.7–28.1)	121 (15.8)	18.8 (15.4–22.1)	137 (17.1)	18.9 (15.8–22.1)
Fourth or higher rank, interval ≤2 years	42 (23.2)	20.3 (14.2–26.5)	203 (26.5)	21.7 (18.7–24.6)	201 (25.2)	18.6 (16.1–21.2)
Fourth or higher rank, interval >2 years	39 (21.7)	51.4 (35.3–67.5)	145 (18.9)	43.3 (36.2–50.3)	150 (18.7)	39.2 (33.0–45.5)
Place of birth						
Home	116 (66.5)	59.2 (48.4–70.0)	411 (56.5)	24.2 (21.9–26.6)	470 (62.1)	24.1 (21.9–26.2)
Health facility	59 (33.5)	14.9 (11.1–18.7)	317 (43.5)	32.0 (28.4–35.5)	287 (37.9)	26.4 (23.4–29.5)
Mode of delivery						
Non-caesarean	178 (98.8)	30.7 (26.2–35.3)	727 (95.3)	27.3 (25.3–29.3)	747 (94.7)	25.1 (23.3–26.8)
Caesarean section*	2 (1.2)	19.8 (7.6–47.2)	36 (4.7)	79.6 (53.6–105.7)	42 (5.3)	72.8 (50.8–94.8)
Delivery assistance						
Health professional	57 (33.3)	28.8 (21.3–36.3)	328 (45.2)	31.7 (28.3–35.2)	312 (56.0)	27.2 (24.2–30.2)
Non-health professional	114 (66.7)	29.4 (24.0–34.8)	397 (54.8)	24.1 (21.8–26.5)	245 (44.0)	22.2 (19.4–24.9)

The sum of percentages does not equal 100 for some factors because of missing values.
*Caesarean section is a combination of elective and emergency procedures.
ENMR, early neonatal mortality rate; MBMI, mother's body mass index; n, number of early neonatal deaths.

not delivered by a health professional decreased over the study period (17% decrease from 2003 to 2008 and 8% decrease from 2008 to 2013).

Risk factors associated with ENM (0–6 days)

Multivariable analysis indicated that early neonates born to mothers in rural areas had a significant elevated ENM (aHR=1.31, CI 1.11 to 1.54) compared with those in urban areas (table 2). There was a significant increased risk of ENM among men (aHR=1.44, CI 1.25 to 1.65) and early neonates delivered by caesarean section (CS) (aHR=2.81, CI 2.07 to 3.84). Other groups of neonates at increased risk for ENM included those with small perceived birth size (aHR=2.12, CI 1.82 to 2.47), younger mothers (aHR=2.83, CI 2.04 to 3.91), or fourth or higher birth order and ≤2 years since the most recent birth (aHR=1.87, CI 1.51 to 2.32).

PAR for factors associated with ENM

The estimated proportion of ENM in the study population that was attributable to living in rural areas was 17.3% (CI 6.88 to 26.7) (table 3), and 17.7% (CI 11.1 to 23.9) of ENM was attributable to male sex. There were 6312 (CI 4260 to 8521) early neonatal deaths attributed to CS annually in Nigeria.

DISCUSSION

Findings from this study indicated a modest decrease in ENMR from 2003 to 2013; however, it was slower compared with the change in postneonatal mortality rates during the same period of time.[25] A substantial decreasing temporal trend in ENMR was noted for early neonates born to mothers from poor households. There was no significant change in ENMR for newborns perceived as small by their mothers. The risk of early neonatal death in Nigeria from 2003 to 2013 was significantly influenced by community-level and proximate-level factors but not by socioeconomic factors. Community-level and proximate-level factors that affected the ENMR included being perceived as small by their mothers (a proxy for low birth weight), delivered by CS, male sex, residing in a rural area and higher (≥4) birth order with a short (≤2 years) birth interval, after adjusting for potential confounding factors.

The strengths of this study are as follows: (1) the NDHS data met the basic criteria for estimating PAR, such as random selection of the population of interest and exposure data detailed with minimal bias; (2) credible PAR values and 95% CIs were generated for each risk factor that affected ENM; (3) restriction of the study to births within a 5-year period prior to the survey dates lessened recall bias relating to the dates of birth and death and bias resulting from changes in household characteristics; (4) estimates provided in this study were population based, which increases the validity, and can be generalisable to the Nigerian population (with >350 ethnic groups with different cultures, religions and lifestyles); and (5) to my knowledge, this is the first study from Nigeria to investigate trends in singleton ENM and PAR for risk factors associated with ENM using nationally representative data.

There are a number of limitations of this study, including: (1) the PAR estimates may have been underestimated or overestimated because of residual confounding due to potential ENM risk factors, such as birth asphyxia, gestational age, jaundice and sepsis as well as maternal medical condition prior to child birth (infection, HIV and hypertension); (2) the NDHS is usually conducted once every 5 years and is the major source of nationally representative data, but is time consuming and expensive; (3) under-reporting of early neonatal deaths may have occurred because only surviving women participated in the survey; (4) information on the medical status of the newborns and causes of death were not included in the NDHS data; (5) the effect of small-scale geographical inequality was not adjusted for in the analyses. However, intracluster correlation, which is an appropriate approach, was taken into consideration; and (6) the PAR was estimated based on the assumption that there was a causal relationship between the risk factors identified in the study and ENM.

The PAR estimates from this study indicated that, annually in Nigeria, 25 884 deaths of newborns within the first week of life were attributable to low birth weight (measured by the mother's perceived size of the newborn). Every year in Nigeria, there are nearly 6 million low birthweight newborns.[26] Low birth weight has many causes, including poor diet, restricted food intake and lifestyle during pregnancy,[27–29] which affect the fetus. Use of medications that were not prescribed or herbs[30] may also affect the fetal growth. This is a particular concern for mothers residing in rural communities where cultural beliefs and perceptions are influential and functional health institutions are lacking. For example, a recent review of self-medication among pregnant women in Uyo, Nigeria, found that approximately 28% of pregnant mothers only used drugs prescribed during antenatal care visits.[31] Small neonates remain a critical problem. No temporal changes were observed in ENMR among small neonates, highlighting the urgent need for effective public health interventions to improve their health. Such interventions should include educating pregnant women and their family members on nutrition and the adverse effects of non-prescription drugs or herbs during pregnancy. Educating mothers on the benefits of early initiation of and exclusive breastfeeding, and skin-to-skin contact (or kangaroo mother care) and management of small neonates at home may also decrease risk of dying in the first week of life.

Infectious diseases, respiratory distress syndrome and late development of fetal lung maturity in the first week of life are plausible explanations for the elevated mortality risk for men compared with women.[32–34] This study found that >37 000 early neonatal deaths were attributed to male sex, annually. There is an urgent need for public health managers to continue to educate women and family members, particularly their husbands or partners, about

Table 2 Distribution of independent variables and HRs for each category of the variables associated with ENM in Nigeria, 2003–2013

Variable	n* (%†)	Unadjusted‡ HR (95% CI)	Adjusted‡ HR (95% CI)
Year of survey			
2003	182 (10.4)	*Ref*	*Ref*
2008	766 (43.8)	0.87 (0.70–1.07)	0.89 (0.72–1.11)
2013	801 (45.8)	0.73 (0.58–0.91)	0.76 (0.61–0.96)
Residence type			
Urban	474 (27.1)	*Ref*	*Ref*
Rural	1275 (72.9)	1.40 (1.20–1.65)	1.31 (1.11–1.54)
Geopolitical zone			
North Central	208 (11.9)	*Ref*	
North East	320 (18.3)	1.12 (0.90–1.40)	
North West	594 (33.9)	1.01 (0.81–1.25)	
South East	182 (10.4)	1.13 (0.86–1.50)	
South West	218 (12.5)	1.19 (0.93–1.54)	
South South	227 (13.0)	0.83 (0.62–1.09)	
Household wealth index			
Rich	354 (20.2)	*Ref*	
Middle	684 (39.1)	1.18 (0.98–1.42)	
Poor	711 (40.6)	1.36 (1.13–1.64)	
Mother's education			
Secondary or higher	497 (28.4)	*Ref*	
Primary	421 (24.1)	1.19 (0.98–1.43)	
No education	831 (47.5)	1.10 (0.93–1.29)	
Mother's working status			
Not working	585 (34.8)	*Ref*	
Working	1097 (65.1)	0.91 (0.79–1.04)	
Mother's age			
<20	149 (8.5)	3.54 (2.73–4.59)	2.83 (2.04–3.91)
20–29	798 (45.6)	1.08 (0.93–1.25)	1.05 (0.88–1.25)
30–39	599 (34.3)	*Ref*	*Ref*
40–49	203 (11.6)	1.12 (0.88–1.43)	1.10 (0.87–1.41)
MBMI			
MBMI >18.5		1586 (90.7)	*Ref*
MBMI ≤18.5		139 (8.0)	0.84 (0.67–1.06)
Wanted pregnancy at the time			
Wanted then	1499 (85.7)	*Ref*	
Wanted later	93 (5.3)	0.90 (0.66–1.21)	
Unwanted	63 (3.6)	1.52 (1.05–2.20)	
Father's education			
Secondary or higher	661 (37.8)	*Ref*	
Primary	386 (22.1)	1.15 (0.97–1.36)	
No education	644 (36.8)	1.03 (0.88–1.20)	
Birth rank and birth interval			
Two or three children, interval >2	285 (16.3)	*Ref*	*Ref*

Continued

Table 2 Continued

Variable	n* (%†)	Unadjusted‡ HR (95% CI)	Adjusted‡ HR (95% CI)
First child	470 (26.9)	1.80 (1.47–2.20)	1.48 (1.19–1.84)
Two or three children, interval ≤2	213 (12.2)	1.50 (1.17–1.93)	1.50 (1.17–1.93)
Four or more children, interval >2	446 (25.5)	1.16 (0.95–1.41)	1.18 (0.95–1.46)
Four or more children, interval ≤2	334 (19.1)	1.91 (1.54–2.36)	1.87 (1.51–2.32)
Child sex			
Female	735 (42.0)	*Ref*	*Ref*
Male	1014 (58.0)	1.42 (1.24–1.63)	1.44 (1.25–1.65)
Mother's perceived baby size			
Average or larger	1191 (68.1)	*Ref*	*Ref*
Small or very small	401 (23.0)	2.16 (1.86–2.51)	2.12 (1.82–2.47)
Delivery assistance			
Health professional	697 (39.9)	*Ref*	
Non-health professional	756 (43.2)	0.87 (0.76–1.00)	
Mode of delivery			
Non-caesarean	1652 (94.4)	*Ref*	*Ref*
Caesarean section§	80 (4.6)	2.39 (1.76–3.25)	2.81 (2.07–3.84)
Place of delivery			
Health facility	662 (37.9)	*Ref*	
Home	998 (57.0)	0.85 (0.74–0.98)	

*Number of early neonatal deaths between 2003 and 2013.
†The sum of percentages does not equal 100 for some factors because of missing values.
‡Missing values were excluded from the model.
§Caesarean section is a combination of elective and emergency procedures.
ENM, early neonatal mortality; MBMI, mother's body mass index; Ref, reference category.

the advanced care needed in a referral hospital to treat breathing problems during the first week of life. This finding also supports the adequate provision of nasal continuous positive airways equipment and surfactant therapy in paediatric intensive care units, especially in hospitals and primary health centres in the rural communities.

This study found that 6312 deaths in the first week of life are attributable to CS, annually. A conceivable explanation for this finding could be linked to aversion to, and fear and misconception of CS among pregnant women in Nigeria,[35 36] resulting in late presentation to healthcare facilities for emergency CS with life-threatening complications.[37] A previous study in Nigeria found that over 80% of neonates delivered through emergency CS died during the early neonatal period.[38] There is a need for community promotional programmes to train community health workers, traditional birth attendants and women on safe delivery practices and detection of early obstetric complications for timely referral.

Results from this study suggested that approximately 11 708 early neonatal deaths annually in Nigeria were attributable to young (<20 years) maternal age. Physical immaturity, inexperience in child rearing, poor nutrition and inadequate use of maternal health services have been linked to ENM among neonates born to younger mothers[39] and are associated with adverse pregnancy outcome, such as low birth weight and prematurity.[40] This finding strongly supports interventions targeting women younger than 20 years old to delay their first pregnancy, which would contribute to improvement in ENM statistics in Nigeria.

The PAR proportions from the current study showed that >18 000 early neonatal deaths were attributable to high birth order (≥4) with shorter birth intervals (≤2 years). Short intervals between births may adversely affect maternal health and well-being, which may lead to economic resource competition and inadequate care given to infants.[41] This large number of early neonatal deaths in this study indicates that family planning services remain crucial. Public health interventions that increase awareness and promote the benefits of birth spacing would reduce ENM.

Findings from this study are consistent with the rural–urban differences in infant mortality that were previously reported in Rwanda[42] and Burkina Faso.[43] The estimated

Table 3 Estimated PAR and estimated yearly number of deaths for each of the factors significantly associated with early ENM in Nigeria, 2003–2013

Variable	n*†	aHR‡	PAR§ (95% CI)	Yearly projected ENM that could be avoided or treated, k¶ (95% CI)
Residence type				
Urban	27.1	*Ref*		
Rural	72.9	1.31	17.3 (6.88–26.7)	36 746 (14 656–56 920)
Mother's age				
<20	8.5	2.83	5.50 (3.62–7.52)	11 708 (8521–17 042)
20–29	45.6	1.05	—	
30–39	34.3	*Ref*		
40–49	11.6	1.10	—	
Birth rank and birth interval†				
Two or three children, interval >2	16.3	*Ref*		
First child	26.9	1.48	8.72 (3.91–13.4)	18 584 (8521–27 693)
Two or three children, interval ≤2	12.2	1.5	4.07 (1.54–6.75)	8663 (4260–14 912)
Four or higher, interval >2	25.5	1.18	—	
Four or higher, interval ≤2	19.1	1.87	8.89 (5.74–12.2)	18 929 (12 781–25 563)
Child sex				
Female	42	*Ref*		
Male	58	1.44	17.7 (11.1–23.9)	37 752 (23 433–51 126)
Mother's perceived baby size†				
Average or larger	68.1	*Ref*		
Small or very small	23	2.12	12.2 (9.28–15.2)	25 884 (19 172–31 953)
Mode of delivery†				
Non-caesarean	94.4	*Ref*		
Caesarean section**	4.6	2.81	2.96 (1.86–4.29)	6312 (4260–8521)

*Weighted proportion of neonates who died during early neonatal period (0–6 days).
†Proportion varies between groups due to missing values.
‡The adjusted model included place of residence; geopolitical zone; household wealth index; mother's education, working status, age, body mass index, desire for pregnancy; father's education; child sex; place of birth; delivery assistance; mode of delivery; child's body size at birth; and birth order and birth interval. — PAR was not obtained because factors were not significantly associated with ENM.
§PAR and was obtained using similar formula described by Stafford et al,[22] that is, PAR = *×((aHR−1)/aHR).
¶Derived based on PAR, estimated general population, crude birth rate and NDHS's most recent reported neonatal mortality rate.
**Caesarean section is a combination of elective and emergency procedures.
aHR, adjusted HRs; ENM, early neonatal mortality; PAR, population-attributable risk; Ref, reference category.

PAR indicated that slightly less than 40 000 early neonatal deaths could have been averted if rural areas had health facilities, educational and transport services, sources of water and sanitation, and access to skilled health personnel who were comparable to those in urban areas.

CONCLUSION

The study described a modest decline in ENMR in Nigeria from 2003 to 2013. The findings suggest that community-based participatory interventions approach with community leaders, health volunteers and women leaders is needed to collaborate with existing community health workers. Such interventions should target small newborns, and address delaying early pregnancy, child spacing and timely referral, particularly for sick male neonates and birth requiring CS, to improve ENM in Nigeria. The aforementioned interventions have been successfully implemented in low-income and middle-income countries that share similar characteristics with Nigeria, for example, a cluster-randomised controlled trial conducted in rural communities in Nepal and India indicated that participatory women's group reduced neonatal mortality by 30% and 32%, respectively.[44 45]

Contributors OKE conceptualised the study, carried out the literature review, conducted the analysis, interpreted the data, and drafted and critically reviewed the manuscript.

Competing interests None declared.

Patient consent This study was based on existing public domain survey data sets with all identifier information removed. Therefore, patient consent is not required.

Ethics approval The author communicated with MEASURE DHS, ICF International, Rockville, MD, USA, through email, and access was granted to download and use the NDHS data sets for this study.

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