RESEARCH ARTICLE

Housing materials as predictors of under-five mortality in Nigeria: evidence from 2013 demographic and health survey

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Abstract

Background: Nigeria is among countries with high Under-Five Mortality (USM) rates worldwide. Both maternal and childhood factors have been linked to USM in the country. However, despite the growing global recognition of the association between housing and quality of life, the role of housing materials as predictors of USM remain largely unexplored in Nigeria. This study, therefore, investigated the relationship between housing materials and USM in Nigeria.

Methods: The study utilised the 2013 Nigeria Demographic and Health Survey data. A representative sample of 40,680 households was selected for the survey. The sample included 18,516 women of reproductive age who had given birth in the past 5 years prior the survey; with attention on the survival status of the index child (the most recent delivery). Data were analysed using descriptive statistics, Chi-square, Cox-proportional hazard and Brass 2-parameter models (α = 0.05).

Results: The hazard ratio of USM was 1.46 (C.I = 1.02–1.47, p < 0.001) and 1.23 (C.I = 1.24–1.71, p < 0.001) higher among children who lived in houses built with inadequate and moderate housing materials respectively than those in good housing materials. Under-five deaths show a downward trend (slope = −0.4871) relative to the housing materials assessment score. The refined USM rate was 143.5, 127.0 and 90.8 per 1000 live birth among women who live in houses built with inadequate, moderate and adequate housing materials respectively. Other predictors of USM were; the size of the child at birth, preceding birth interval, prenatal care provider, residence and education. Under-five death reduces with increasing maternal level of; education, wealth quintile, media exposure and housing material type and mostly experienced by Muslim women (6.0%), rural women (6.5%) and women residence in the North-West geopolitical zones (6.9%).

Conclusions: Living in houses built with poor housing materials promoted USM in Nigeria. Provision of sustainable housing by the government and the maintenance of existing housing stock to healthful conditions will play a significant role in reducing the burden of USM in Nigeria.

Keywords: Housing materials, Under-five mortality, Nigeria
Background

Housing is a key determinant of health and quality of life [1]. Housing is designed to provide shelter and protection from hazards resulting from the physical and social environments. It promotes physical and mental health and ensures the social and economic well-being and quality of life of individuals and households [2]. A person's home is an essential locus for everyday life [3]. Environmental living conditions, including housing conditions and their association with health have drawn the attention of public health scientists since ancient times [4].

Healthy housing has been defined as dwellings and premises that are built and maintained in ways that support the health of its occupants [5, 6]. In the year 1996, the United Nations Habitat conference that held in Istanbul defined healthy housing to include the provision of adequate physical, chemical, biological and mental conditions that supports health, comfort and privacy [7].

Researchers have established that good housing conditions are indispensable in improving household health. Poor housing and environmental conditions can predispose to adverse health problems, including infectious diseases (respiratory disorders), stress and depression [8]. The well-being of household occupants is a reflection of the building materials from which the house is built [9, 10]. One of the established ways through which housing influences health is by human exposure to poor housing conditions, lack of improved water sources, ineffective waste disposal methods, invasion by disease vectors and inappropriate food storage techniques [11].

Deficient and worsening housing conditions can trigger a range of diseases, including lung diseases, neurological disorders, mental and behavioural dysfunction, which mostly unduly affect children [12]. Children are predominantly susceptible to housing-related hazards than adults since they spend comparably more time indoors. They are seen as a risk group because they require a higher amount of air inhalation than adults, and their organs are not fully developed [13, 14]. Children also have larger surface area to total body mass, thus causing increased exposure to pollutants [15].

Child mortality is a core indicator for measuring the level of child health and well-being in all nations [16]. It is an important indicator of the performance of the health system of a country [17]. Since the beginning of the twentieth century, childhood mortality has been at the centre of health discourse. Health professionals and policy makers have reserved a unique interest in combating the increasing childhood mortality rates [18]. This interest has not only extended globally, it has led to the development of logical approaches to reducing child mortality by two-thirds among children under the age of 5 years between 1990 and 2015, as tagged in the United Nation's Millennium Development Goals (MDGs) [18].

With 133 of the 195 countries that adopted the MDGs failing in meeting the target of a two-thirds reduction in U5M rate, the United Nations in 2015 adopted the Sustainable Development Goals (SDGs) with the intention of safeguarding healthy lives and ensuring the well-being of all children. The goal 3 target 3.2 of the SDGs is to halt preventable deaths of newborns and under-fives by the year 2030 [19].

Under-five mortality rate is highest in sub-Saharan Africa with 1 child in 12 dying before 6 months, which translates to more than 12 times higher than the 1 in 147 average in developed countries [16]. India and Nigeria account for more than one-third of all under-five deaths globally [20]. Currently, Nigeria has the highest reported number of under-5 deaths in Africa [21] with about one million of them dying annually [22]. A number of factors are contributory to this high prevalence of under-five mortality in Nigeria [20, 23–32].

Provision of healthy housing and the continuous maintenance of existing housing stock in such a way as to support and promote human health remain a huge challenge in many countries [9, 33]. In sub-Saharan Africa more than 60% of urban dwellers live in slums [34], characterised with poor housing, insufficient space, unimproved water and sanitation. Though the association between living in healthy housing and good quality of life have been described in many developed nations, the links between housing and under-five mortality remain largely unexplored in developing nations [35].

While many studies and reports (including the 2013 report of the Nigeria Demographic and Health Survey) have indicated that the demographic characteristics of both mothers and children play an important role in a child survival [36], there is dearth of information on the role of housing materials in the causation of under-five child mortality while controlling for mother and child individual level factors. To this end, the present study seeks to advance the existing knowledge beyond the understanding of medical-related or personal characteristics by examining the influence of housing conditions and other environmental factors on under-five mortality in Nigeria.

Methods

Study area

The study was carried out in Nigeria, with a human population figure of above 180 million. Nigeria is characterised with high infant and childhood mortality. The maternal mortality ratio is also one of the highest among developing nations worldwide [36]. High fertility is a key factor for high under-five mortality across countries [37]. In Nigeria, the total fertility rate remains high (TFR = 5.5) [36]. Unfortunately, the contraceptive prevalence rate of 10% is still considered as low [36]. Nigeria
is seen on the global page as poverty stricken country with a striking gap between the rich and the poor. Administratively, Nigeria is made up of 36 states and the Federal Capital territory. Each state has local government areas (third level of government) which are further divided into localities. The country is also stratified into 6 geopolitical zones; North-Central, North-East, North-West, South-East, South-South and South-West. The reason being that Nigeria comprised approximately 400 ethnic groups and 450 dialects. There was the need for the government to unify similar groups into zones for effective allocation of resources. The inhabitants in each of the geopolitical zones are homogeneous and share similar socio-cultural characteristics and unique in other health-related characteristics like access to health care, environment, housing system etc.

Data collection
The Demographic and Health Surveys (DHS) and alike surveys that collect information on birth outcomes from women are one of the main bases for data collection on under-five mortality estimation in developing countries like Nigeria, where reliable and adequate vital registration system is lacking [17]. The 2013 Nigeria Demographic and Health Survey data were used for this study. The original data was collected to provide information on the population, health and fertility levels in Nigeria. A 3-stage stratified cluster design consisting of 904 clusters (372 in urban areas and 532 in rural areas) was used for sample selection. A representative sample of 40,680 households was selected for the survey and a fixed sample of 45 households was selected in each cluster. In this study, the sample used was 18,516 women of reproductive age who had given birth in the past 5 years prior the study. However, the attention was focused on the survival status of the index child, the most recent delivery the women had in the past 5 years prior the study.

Variable description
The dependent variable was childhood mortality and this was captured with the question on the survival status of the most recent birth (dead = 1 or alive = 0) in the last 5 years preceding the survey. Under-five mortality was defined as the death of a live-born child before its fifth birthday [27]. The main predictor was the type of housing materials. This was obtained as aggregate score based on information from roof materials (Improved – cement, roofing sheets, ceramic tiles; Unimproved – natural, no roof, palm leaf, sod, rudimentary, rustic mat, bamboo, cardboard), wall materials (Improved – cement, stone with cement, cement blocks, bricks; Unimproved – natural, no wall, palm/trunks, dirt, rudimentary, bamboo with mud) and floor materials (Improved – cement, ceramic tiles, vinyl asphalt strips, parquet, polished wood, finished; Unimproved – natural, earth, sand, dung, rudimentary, wood planks, palm, bamboo, others). The improved categories assumed a score of 1 while un-improved scored [36, 38]. The overall score (13-point maximum and 0-point minimum) for a woman was dis-aggregated into three categories: inadequate (<50% of the overall score), moderate (50% ≤ x < 75% of the overall score) and adequate (75% ≤ x ≤ 100%) of the overall score. They are based on quartile classification: 3rd quartile is 75% and 2nd quartile is 50%.

Other independent variables include mother’s age, highest educational level, religion, ethnicity, marital status, place of residence, region, wealth index and media exposure. others are; number of antenatal visits, tetanus injection, gender of a child, size at birth, birth order, preceding birth interval, prenatal care provider, delivery assistance, place of delivery, cooking fuel (Clean – electricity, liquefied petroleum gas, natural gas, biofuel; Un-clean/biomass – coal, charcoal, wood, straw/shrubs/grass, agricultural crop, animal dung, kerosene), source of water (Improved - piped into dwelling, public tap, borehole, protected well and spring, rain water and bottle water; Unimproved – other sources not listed as improved sources) and toilet facility (Improved – flush/pour flush to piped sewer system, septic tank or pit latrine, ventilated improved pit latrine, pit latrine with slab, composting toilet; Unimproved – other toilet types not listed as improved). We adapted the groupings of environmental factors documented in the 2013 Nigeria National Demographic Health Survey (NDHS) and the 2010 WHO and UNICEF document on progress on sanitation and drinking water [36, 39]. These variables were used as covariates during multivariate analysis to determine the association between housing materials and childhood mortality.

Data analyses
The dataset was weighted before data analyses. The weight is an inflation factor which extrapolates the sample to the target population [40]. Analysis of data was done at bivariate and multivariate levels using Chi-square, Cox proportional hazard model and Brass 2-parameter model. The Chi-square test was used to examine the relationship between child’s survival status and the independent variables at 5.0% level of significance. At the multivariate level of analysis, Cox proportional hazard model was used to detect the predictors of childhood mortality. The proportional hazards model assumes that the time to event and the covariates are related as: \[ \log \left( \frac{\gamma(t)}{\gamma_0(t)} \right) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_p x_{pi} \]
Where; \( \gamma(t) \) is the hazard rate for the \( i \)th case of a woman having lost her child before age five; \( \gamma_0(t) \) is the baseline hazard at time \( t \) when the death of the child occurs; \( \beta_i \) is the value of the \( j \)th regression coefficient; \( x_{ji} \) is the value of the \( i \)th case of the \( j \)th covariate.
Further analysis using an indirect method to ascertain the influence of housing materials on childhood mortality was done. Brass [41] reported that the probability of dying between birth and exact age (a) can be estimated as 
\[ q(x) = k(x) \times D(x) \]
where \( D(x) \) is the number of dead children in each age group and \( k(x) \) is a multiplier and is estimated as: \( k(x) = a(i) + b(i)(P_1/P_2) + C(i)(P_2/P_3) \). The number of non-surviving children for women in age groups 15–20, 20–25, 25–30,..., 45–50 were used to calculate childhood mortality at exact ages \( q(x) \); 1, 2, 3, 5, 10, 15 and 20. Regression equations which relate the multipliers \( k(x) \) to indices of fertility schedule were formulated from mathematical simulations [42]. The time reference to which the \( q(x) \) values refer were also formulated. Due to limitations in the estimates produced by this method, we further adjusted the childhood mortality using Brass 1-parameter model (\( Y = \alpha + \beta Y_s \)) where \( \beta = 1 \). This procedure made use of logit equation: 
\[ \text{logit}(q(x)) = \frac{1}{2} \log \left( \frac{1 - q(x)}{q(x)} \right) \]. This was transformed to Brass relational system of life tables; 
\[ \text{logit}(l(x)) = \alpha + \beta \text{logit}(l_s(x)) \]
usually transcribed as \( Y = \alpha + \beta Y_s \). The logit relational system smoothens the estimated values of \( l(x) \) (survival probability) in contrast to the values from the model life-table. Therefore, if \( \beta = 1 \), \( \hat{\alpha} = Y(x) - Y_s(x) \), thus generating; 
\[ Y(1) = \hat{\alpha} + Y_s(1); Y(2) = \hat{\alpha} + Y_s(2); \ldots; Y(20) = \hat{\alpha} + Y_s(20) \]. Estimate of \( \hat{\alpha} \) was obtained from the average values of \( x = 2, x = 3 \) and \( x = 5 \) which produce reliable values of \( l(x) \). Therefore, if \( \bar{Y} \) is the average of \( Y(2), Y(3) \) and \( Y(5) \) and \( \bar{Y}_s \) is the average of \( Y_s(2), Y_s(3) \) and \( Y_s(5) \), then \( \hat{\alpha} = \bar{Y} - \bar{Y}_s \). This produced the adjusted survival probabilities at childhood. The infant and under-five mortality were estimated using the models; infant mortality rate \( = \frac{q_i}{1.07 \times q_i} \) and under-five mortality rate \( = \frac{2q_5}{1.07 \times q_5} \) [43].

All analysis were done using SPSS version 20.0 and Excel software.

**Results**

In Table 1, the data shows that the percentage of women whose most recent under-five children died was highest among women aged 35–49 years (7.2%) and least between the age segment 25–34 years (4.7%) \( p < 0.001 \). The percentage of women who had lost their most recent child reduces with increasing level of education, increasing wealth quintile and level of media exposure. For instance, women who had high exposure to media had 4.5% deaths of their most recent under-five child compared to 6.7% reported by those with no media exposure.

Table 2 shows the results of the association between under-five survival status and maternal and child health-related characteristics. Under-five deaths was highest among women who did not attend any antenatal clinic during the child’s pregnancy (6.9%), who did not take

### Table 1  Socio-demographic characteristics of women according to deaths of under-five children

| Background characteristics | Death among under-5 children (%) | Total number of children | \( \chi^2 \)-value | \( p \)-value |
|---------------------------|---------------------------------|--------------------------|-------------------|-------------|
| Mother’s Age\(^a\)         |                                 |                          | 40.10             | <0.001      |
| 15–24                     | 5.9                             | 4746                     |                   |             |
| 25–29                     | 4.7                             | 4843                     |                   |             |
| 30–34                     | 4.7                             | 3830                     |                   |             |
| 35–49                     | 7.2                             | 5097                     |                   |             |
| Highest educational level\(^b\) |                               |                          | 48.97             | <0.001      |
| No education              | 6.7                             | 8532                     |                   |             |
| Primary                   | 6.1                             | 3747                     |                   |             |
| Secondary                 | 4.3                             | 5038                     |                   |             |
| Higher                    | 3.2                             | 1199                     |                   |             |
| Religion\(^c\)            |                                 |                          | 4.73              | 0.094       |
| Christian                 | 5.3                             | 7568                     |                   |             |
| Islam                     | 6.0                             | 10752                    |                   |             |
| Others                    | 5.5                             | 200                      |                   |             |
| Ethnicity\(^d\)           |                                 |                          | 34.42             | <0.001      |
| Hausa                     | 6.6                             | 7234                     |                   |             |
| Igbo                      | 6.1                             | 1916                     |                   |             |
| Yoruba                    | 3.5                             | 2236                     |                   |             |
| Others                    | 5.3                             | 7130                     |                   |             |
| Marital status\(^b\)      |                                 |                          | 11.15             | 0.004       |
| Never in union            | 6.9                             | 492                      |                   |             |
| Currently in union/living with a man | 5.6                             | 17445                    |                   |             |
| Formerly in union         | 8.6                             | 579                      |                   |             |
| Place of residence\(^e\)  |                                 |                          |                   |             |
| Urban                     | 4.0                             | 6157                     |                   |             |
| Rural                     | 6.5                             | 12359                    |                   |             |
| Geopolitical zones\(^e\)  |                                 |                          | 48.66             | <0.001      |
| North Central             | 4.2                             | 2783                     |                   |             |
| North East                | 6.3                             | 3692                     |                   |             |
| North West                | 6.9                             | 5816                     |                   |             |
| South East                | 6.6                             | 1568                     |                   |             |
| South South               | 5.1                             | 2179                     |                   |             |
| South West                | 3.8                             | 2478                     |                   |             |
| Media exposure\(^e\)      |                                 |                          | 26.55             | <0.001      |
| None                      | 6.7                             | 6318                     |                   |             |
| Low                       | 5.7                             | 6013                     |                   |             |
| Medium                    | 4.6                             | 4607                     |                   |             |
| High                      | 4.5                             | 1578                     |                   |             |

\(^a\)Significant at 0.1%; \(^b\)Significant at 1.0%
any tetanus injection (6.8%), whose prenatal care was provided by unskilled attendant (9.1%), who were not assisted by any attendant during delivery (6.9%) and those who delivered at their homes (6.4%).

The percentage of the most recent under-five children who had died was higher among males (6.2%) than female (5.2%) ($p < 0.001$).

The preceding birth interval was also found to be significantly associated with under-five death with children whose immediate senior sibling was born 7–23 months (7.2%) before their delivery experiencing highest deaths compared to those who left 24–35 months (5.8%), 36–59 months (4.6%) interval. Figure 1 shows the percentage distribution of under-deaths by building material assessment score.

The data as represented in Table 3 show that the type of cooking fuel, the source of drinking water, toilet facility and housing materials were significantly associated with childhood deaths ($p < 0.05$). However, variation exists in childhood deaths within these environmental factors. For example, women who used biomass had experienced higher under-five deaths (6.1%) than those using clean fuel (3.8%). Under-five death was lower among children of women who used improved sources (5.2%) as their drinking and cooking water than their counterparts using unimproved sources (6.3%). This pattern was similar to that of the improved and unimproved toilet facility. The results further show that women who lived in houses built with inadequate housing materials (7.1%) lost more of their under-five children compared to those who lived in houses built with adequate housing materials (4.4%) ($p < 0.001$).

### Table 2 Maternal and child health related characteristics according to deaths of under-five children

| Background characteristics | Death among under-5 children (%) | Total number of children | $\chi^2$-value | p-value |
|----------------------------|----------------------------------|--------------------------|----------------|---------|
| Number of antenatal visits* |                                  |                          | 30.62          | <0.001  |
| None                       | 6.9                              | 6266                     |                |         |
| 1–3                        | 6.0                              | 2346                     |                |         |
| 4+                         | 4.9                              | 9904                     |                |         |
| Tetanus injection*         |                                  |                          | 29.68          | <0.001  |
| None                       | 6.8                              | 7362                     |                |         |
| At least 1                 | 4.9                              | 11154                    |                |         |
| Sex of child*              |                                  |                          | 8.47           | 0.004   |
| Male                       | 6.2                              | 9347                     |                |         |
| Female                     | 5.2                              | 9169                     |                |         |
| Perceived size of baby at birth* |                    |                          | 26.53          | <0.001  |
| Small                      | 7.7                              | 2738                     |                |         |
| Average                    | 5.6                              | 7500                     |                |         |
| Larger than average        | 5.1                              | 8278                     |                |         |
| Birth order*               |                                  |                          | 61.86          | <0.001  |
| 1st                        | 6.2                              | 3302                     |                |         |
| 2–3                        | 4.3                              | 5707                     |                |         |
| 4–5                        | 5.0                              | 4416                     |                |         |
| 6+                         | 7.6                              | 5091                     |                |         |
| Preceding birth interval*  |                                  |                          | 28.25          | <0.001  |
| 7–23                       | 7.2                              | 2860                     |                |         |
| 24–35                      | 5.8                              | 5775                     |                |         |
| 36–59                      | 4.6                              | 4794                     |                |         |
| 60+                        | 4.7                              | 1743                     |                |         |
| 1st birth                  | 6.4                              | 3344                     |                |         |
| Prenatal care provider*    |                                  |                          | 43.25          | <0.001  |
| None                       | 6.9                              | 6266                     |                |         |
| Unskilled                  | 9.1                              | 176                      |                |         |
| Semi-skilled               | 7.0                              | 1434                     |                |         |
| Skilled                    | 4.8                              | 10640                    |                |         |
| Delivery assistance*       |                                  |                          | 36.52          | <0.001  |
| None                       | 6.9                              | 2264                     |                |         |
| Unskilled                  | 6.4                              | 8385                     |                |         |
| Semi-skilled               | 6.0                              | 1092                     |                |         |
| Skilled                    | 4.4                              | 6775                     |                |         |
| Place of delivery*         |                                  |                          | 28.060         | <0.001  |
| Home                       | 6.4                              | 11503                    |                |         |
| Others                     | 3.3                              | 30                       |                |         |
| Health facility            | 4.6                              | 6983                     |                |         |

*Significant at 0.1%
materials. This pattern was found across the models but in the last model, housing materials were found to be insignificantly associated with childhood mortality showing that socio-demographic factors are strongly important in the relationship between childhood mortality and housing materials. The identified predictors of childhood mortality are; the size of the child at birth, preceding birth interval, prenatal care provider, place of residence and education. The likelihood of childhood mortality was 0.82 (C.I = 0.72–0.92; \( p < 0.001 \)) lower among females than males, among children who were average (HR = 0.76; C.I = 0.64–0.90) or larger (HR = 0.71; C.I = 0.60–0.84, \( p < 0.001 \)) than average in size at birth than those who were small. The data further show that childhood mortality hazard was 1.35 (C.I = 1.13–1.62, \( p < 0.001 \)) more in the rural areas than the urban.

**Infant and under-five mortality rates by housing material type**

In Table 5, the data show that at different levels of housing materials type (inadequate, moderate and adequate), the refined childhood mortality probability increases as the age of child increases. For instance, among the group of women who live in houses built with inadequate housing material, the refined childhood mortality probability increases from 0.0778 among infants to 0.1613 among young adults. The data further show that infant mortality probability increases considerably as the level of housing materials type increases.

For instance, the probability of dying at exact age 1 year was highest among women who live in houses built with inadequate housing materials (0.0778) and least among their counterparts whose houses were built with adequate materials (0.0507). Figure 2 shows childhood probability of dying at age \( x \) according to housing materials. The estimated infant and under-five mortality rates which were obtained from the smoothed childhood mortality probabilities in Table 5 are displayed in Fig. 3.

**Discussion**

Housing and health are essential for human wellness and quality of life [44]. Poor housing conditions have been seen to represent a stern environmental health threat that is preventable [45]. Our study seeks to understand the effect of housing materials on under-five mortality in Nigeria.

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**Table 3** Environmental characteristics according to deaths of under-five children

| Environmental characteristics | Death among under-5 children (%) | Total number of children | \( \chi^2 \)-value | \( p \)-value |
|------------------------------|----------------------------------|--------------------------|-------------------|-------------|
| Cooking fuel \(^a\)          |                                  |                          | 28.25             | <0.001      |
| Clean                        | 3.8                              | 3340                     |                   |             |
| Biomass                      | 6.1                              | 15176                    |                   |             |
| Source of drinking water \(^a\) |                                  |                          | 9.64              | 0.002       |
| Improved                     | 5.2                              | 10339                    |                   |             |
| Unimproved                   | 6.3                              | 8177                     |                   |             |
| Toilet facility \(^a\)       |                                  |                          | 11.47             | 0.001       |
| Improved                     | 5.1                              | 9090                     |                   |             |
| Unimproved                   | 6.3                              | 9426                     |                   |             |
| Housing material \(^a\)      |                                  |                          | 50.91             | <0.001      |
| Inadequate                   | 7.1                              | 7035                     |                   |             |
| Moderate                     | 5.9                              | 3414                     |                   |             |
| Adequate                     | 4.4                              | 8067                     |                   |             |

\(^a\)Significant at 0.1%
### Table 4 Cox proportional hazard model of determinants of childhood mortality in Nigeria

| Background characteristics | Model 1 | Model 2 | Model 3 | Model 4 |
|----------------------------|---------|---------|---------|---------|
|                            | HR (95% CI) | HR (95% CI) | HR (95% CI) | HR (95% CI) |
| Housing material           |         |         |         |         |
| Inadequate                 | 1.46 (1.24–1.71) | 1.36 (1.16–1.60) | 1.25 (1.05–1.49) | 1.03 (0.82–1.27) |
| Moderate                   | 1.23 (1.02–1.47) | 1.20 (1.03–1.44) | 1.14 (0.94–1.37) | 0.94 (0.74–1.18) |
| Adequate                   | 1       | 1       | 1       | 1       |
| Sex of the child           |         |         |         |         |
| Male                       | 1       | 1       | 1       | 1       |
| Female                     | 0.82 (0.72–0.92) | 0.82 (0.72–0.92) | 0.80 (0.69–0.92) | 0.80 (0.69–0.92) |
| Size at birth              |         |         |         |         |
| Small                      | 1       | 1       | 1       | 1       |
| Average                    | 0.76 (0.64–0.89) | 0.76 (0.64–0.90) | 0.81 (0.66–0.98) | 0.77 (0.63–0.93) |
| Larger than average        | 0.69 (0.52–0.81) | 0.70 (0.59–0.83) | 0.77 (0.63–0.93) | 0.77 (0.63–0.93) |
| Prenatal care provider     |         |         |         |         |
| None                       | 1.11 (0.87–1.40) | 1.07 (0.81–1.40) | 1.07 (0.81–1.40) | 1.07 (0.81–1.40) |
| Unskilled                  | 1.78 (1.06–2.98) | 1.95 (0.99–3.82) | 1.95 (0.99–3.82) | 1.95 (0.99–3.82) |
| Semi-skilled               | 1.23 (0.97–1.57) | 1.28 (0.97–1.69) | 1.28 (0.97–1.69) | 1.28 (0.97–1.69) |
| Skilled                    | 1       | 1       | 1       | 1       |
| Delivery assistance        |         |         |         |         |
| None                       | 1.14 (0.79–1.66) | 0.93 (0.58–1.48) | 0.93 (0.58–1.48) | 0.93 (0.58–1.48) |
| Unskilled                  | 1.17 (0.83–1.65) | 0.96 (0.62–1.48) | 0.96 (0.62–1.48) | 0.96 (0.62–1.48) |
| Semi-skilled               | 1.14 (0.83–1.57) | 0.83 (0.55–1.23) | 0.83 (0.55–1.23) | 0.83 (0.55–1.23) |
| Skilled                    | 1       | 1       | 1       | 1       |
| Tetanus injection          |         |         |         |         |
| None                       | 1.05 (0.86–1.29) | 1.04 (0.82–1.32) | 1.04 (0.82–1.32) | 1.04 (0.82–1.32) |
| At least one               | 1       | 1       | 1       | 1       |
| Number of antenatal visits |         |         |         |         |
| None                       | 1.01 (0.32–3.15) | 1.02 (0.31–1.39) | 1.02 (0.31–1.39) | 1.02 (0.31–1.39) |
| 1–3                        | 1.05 (0.86–1.28) | 1.05 (0.83–1.32) | 1.05 (0.83–1.32) | 1.05 (0.83–1.32) |
| 4+                         | 1       | 1       | 1       | 1       |
| Toilet facility            |         |         |         |         |
| Improved                   | 1       | 1       | 1       | 1       |
| Unimproved                 | 1.04 (0.92–1.19) | 1.05 (0.92–1.20) | 1.04 (0.91–1.19) | 1.14 (0.97–1.33) |
| Birth order                |         |         |         |         |
| 1st                        | 1       | 1       | 1       | 1       |
| 2–3                        | 3.80 (1.94–7.42) | 3.80 (1.94–7.42) | 3.61 (1.46–8.88) | 3.61 (1.46–8.88) |
| 4–5                        | 4.44 (2.21–8.89) | 4.44 (2.21–8.89) | 3.80 (1.49–9.68) | 3.80 (1.49–9.68) |
| 6+                         | 6.47 (3.24–12.91) | 6.47 (3.24–12.91) | 4.93 (1.92–12.60) | 4.93 (1.92–12.60) |
| Cooking fuel               |         |         |         |         |
| Clean                      | 1       | 1       | 1       | 1       |
| Biomass                    | 1.31 (1.06–1.62) | 1.22 (0.99–1.51) | 1.16 (0.94–1.44) | 0.81 (0.56–1.18) |
| Place of delivery          |         |         |         |         |
| Home                       | 1       | 1       | 1       | 1       |
| Others                     | 0.94 (0.68–1.29) | 0.71 (0.09–5.11) | 0.71 (0.09–5.11) | 0.71 (0.09–5.11) |
| Health facility            | 0.47 (0.65–3.44) | 1.11 (0.74–1.66) | 1.11 (0.74–1.66) | 1.11 (0.74–1.66) |
Table 4 Cox proportional hazard model of determinants of childhood mortality in Nigeria (Continued)

| Age group      | 15–24 | 25–29 | 30–34 | 35–39 |
|----------------|-------|-------|-------|-------|
|                | 1     | 0.97 (0.76–1.22) | 0.95 (0.71–1.26) | 1.20 (0.89–1.62) |
| Source of drinking water |       |       |       |       |
| Improved       | 1     | 1.05 (0.93–1.20) | 1.04 (0.92–1.19) | 1.02 (0.90–1.17) |
| Unimproved     | 1.02 (0.88–1.18) | 1.02 (0.88–1.18) | 1.02 (0.88–1.18) | 1.02 (0.88–1.18) |
| Geopolitical zones |     |       |       |       |
| North Central  | 1.13 (0.69–1.84) | 1.13 (0.69–1.84) | 1.13 (0.69–1.84) | 1.13 (0.69–1.84) |
| North East     | 1.57 (0.96–2.55) | 1.57 (0.96–2.55) | 1.57 (0.96–2.55) | 1.57 (0.96–2.55) |
| North West     | 1.85 (1.11–3.05) | 1.85 (1.11–3.05) | 1.85 (1.11–3.05) | 1.85 (1.11–3.05) |
| South East     | 2.54 (0.87–7.37) | 2.54 (0.87–7.37) | 2.54 (0.87–7.37) | 2.54 (0.87–7.37) |
| South South    | 1.29 (0.77–2.13) | 1.29 (0.77–2.13) | 1.29 (0.77–2.13) | 1.29 (0.77–2.13) |
| South West     | 1     | 1     | 1     | 1     |
| Preceding birth interval |     |       |       |       |
| 7–23           | 1     | 1     | 1     | 1     |
| 24–35          | 0.81 (0.68–0.96) | 0.81 (0.68–0.97) | 0.82 (0.67–0.99) | 0.82 (0.67–0.99) |
| 36–59          | 0.64 (0.53–0.77) | 0.65 (0.53–0.78) | 0.64 (0.51–0.79) | 0.64 (0.51–0.79) |
| 60+            | 0.69 (0.53–0.89) | 0.70 (0.54–0.90) | 0.57 (0.41–0.79) | 0.57 (0.41–0.79) |
| 1st birth      | 4.39 (2.23–8.63) | 4.56 (2.31–8.99) | 4.56 (2.31–8.99) | 4.56 (2.31–8.99) |
| Place of Residence |     |       |       |       |
| Urban          | 1     | 1     | 1     | 1     |
| Rural          | 1.23 (0.87–2.54) | 1.23 (0.87–2.54) | 1.23 (0.87–2.54) | 1.23 (0.87–2.54) |
| Highest educational level |     |       |       |       |
| None           | 1.73 (0.85–3.52) | 1.73 (0.85–3.52) | 1.73 (0.85–3.52) | 1.73 (0.85–3.52) |
| Primary        | 1.94 (0.96–3.89) | 1.94 (0.96–3.89) | 1.94 (0.96–3.89) | 1.94 (0.96–3.89) |
| Secondary      | 1.51 (0.76–2.96) | 1.51 (0.76–2.96) | 1.51 (0.76–2.96) | 1.51 (0.76–2.96) |
| Tertiary       | 1     | 1     | 1     | 1     |
| Ethnicity      |     |       |       |       |
| Hausa/Fulani   | 0.99 (0.79–1.25) | 0.99 (0.79–1.25) | 0.99 (0.79–1.25) | 0.99 (0.79–1.25) |
| Igbo           | 0.69 (0.26–1.79) | 0.69 (0.26–1.79) | 0.69 (0.26–1.79) | 0.69 (0.26–1.79) |
| Yoruba         | 0.82 (0.46–1.45) | 0.82 (0.46–1.45) | 0.82 (0.46–1.45) | 0.82 (0.46–1.45) |
| Others         | 1     | 1     | 1     | 1     |
| Media exposure |     |       |       |       |
| None           | 1     | 1     | 1     | 1     |
| Low            | 0.97 (0.82–1.14) | 0.97 (0.82–1.14) | 0.97 (0.82–1.14) | 0.97 (0.82–1.14) |
| Medium         | 1.05 (0.82–1.33) | 1.05 (0.82–1.33) | 1.05 (0.82–1.33) | 1.05 (0.82–1.33) |
| High           | 1.01 (0.62–1.61) | 1.01 (0.62–1.61) | 1.01 (0.62–1.61) | 1.01 (0.62–1.61) |
| Marital status |     |       |       |       |
| Never in union | 1     | 1     | 1     | 1     |
| Currently in union | 0.65 (0.42–0.99) | 0.65 (0.42–0.99) | 0.65 (0.42–0.99) | 0.65 (0.42–0.99) |
| Formerly in union | 1.01 (0.59–1.71) | 1.01 (0.59–1.71) | 1.01 (0.59–1.71) | 1.01 (0.59–1.71) |

HR hazard ratio, CI confidence interval of hazard ratio
*Significant at 0.1%; **Significant at 1.0%; ***Significant at 5.0%
Findings from our study show that the risk of dying before the age of 5 years was higher among children who lived in houses built with inadequate housing materials than those in moderate and adequate housing materials. This results gave credence to other studies that established an association between ill health and poor housing conditions [46–49]. The quality of the materials with which a building is built is mostly linked with the durability of the building and the health of its occupants [9]. Existing literature indicates general health improvements with improved housing conditions [50–52]. Izugbara [53], in his study, reported that households with floors made of mud or sand are more likely to experience under-5 mortality than households with cement residence floors.

Also, recent epidemiological studies revealed that living in houses built with inferior materials could result in chronic diseases [54, 55]. Researchers assert that houses built with mud or sand are usually not durable and are prone to damp conditions which encourage the growth of moulds in an indoor environment [35]. Exposure to damp and mouldy housing could lead to the occurrence of moulds in an indoor environment [35]. Exposure to damp and mouldy housing could lead to the occurrence of moulds in an indoor environment [35].
of asthma and other chronic respiratory infections in children [54, 55]. Asthma is the most common non-communicable disease among children, affecting 235 million people globally [56].

Moreover, damp buildings produce cracks on walls which provide a fostering environment for cockroaches, moulds, mites and respiratory viruses, all of which promote respiratory disease pathogenesis [35, 57]. Cockroaches can effect allergic sensitisation and have been seen to trigger asthma occurrence in urban areas. Children presenting with asthma who are sensitised and exposed to cockroaches are at higher risk of hospitalisation [58]. Also, exposure to pollutants such as formaldehyde and volcanic organic compounds, which are emitted from building materials have been associated with asthma, and bronchial obstruction in the first 24 months of life [59, 60]. Our study revealed that women who used biomass, water from unimproved sources and unimproved toilet facilities had experienced higher under-five deaths than those using clean fuel, improved water sources and improved toilet facilities respectively. Indeed, the use of solid fuels in homes have been reported to be the leading single environmental cause of ill health [61–63]. Previous studies have indicated that children living in homes using solid fuels for cooking are at a greater risk of dying from acute respiratory illnesses [64–66]. According to the WHO [25], about half of all deaths among under-five children in the year 2014 was

![Fig. 2](image1.png) Childhood probability of dying at age x according to housing materials. It provides the pattern of the probability of dying at ages 1, 2, 3 and 5. There was a consistent increasing pattern in the probability of dying from ages 1 to 5 years and maternal housing materials type

![Fig. 3](image2.png) Infant and Under-five mortality rates according to housing materials type. The data show that infant mortality rate reduces from 82.3 per 1000 live birth among women who live in houses built with inadequate housing materials to 52.6 per 1000 live birth among those live in houses built with adequate housing materials. This pattern was also observed for under-five mortality across the housing materials categories.
caused by acute lower respiratory infections triggered by the use of solid fuels.

Sourcing water from unimproved sources and poor sanitation practices have been implicated in the death of a child every 15 s from diarrhea disease [67]. According to the WHO, diarrhea, annually accounts for 1.7 million morbidities and 760,000 under-five children's deaths globally [68]. It remains the second leading cause of death among children under-five globally [69].

This study further revealed that child and maternal characteristics such as sex the child, the size of the child at birth, preceding birth interval, prenatal care provider, place of residence and education, play a significant role in under-five mortality. This corroborated earlier findings from Nigeria and other places in the direction of these associations between under-five deaths and child and maternal characteristics [53, 64, 65, 70–77].

Policy implication
Globally, scientific evidence on the associations between housing and health has grown considerably in recent years. This information has been used as preventive measures that are linked to better housing condition and human health. From a policy point of view, there is a need for formulation of guidelines on healthy housing by the government and other relevant stakeholders to assist in averting a wide range of preventable illnesses that are often associated with poor housing conditions. This position has earlier been echoed at the international consultation of 40 specialists drafted from 18 countries by the WHO on 13–15 October 2010 in Geneva [78]. In this regard, a national standard on “healthy housing would enable action that is scientifically based, and protects and advances the health of under-five children in households” [78]. The existing national housing policy that sees housing as a determinant of health and social stability should be strengthened in Nigeria. However, the most healthy and safest house will not support the health of its inhabitants if not maintained and used in a manner that promotes sound health. Therefore, individuals should be advised to use good housing materials while building their houses. Even the poor can get good housing materials from the little resources they have if properly managed.

Limitation
The major shortcoming of this study is the cross-sectional nature of the data where information on housing materials was based on verbal reporting instead of the use of check listing approach which could have revealed the true state of housing condition in the study area. Although this limitation was minimized since data were collected at the individual homes, the data collectors were able to assess the structures and match their observations with the report from the respondents. Also, the reporting of under-five children's death by women may include omission of few dead children. Culturally, in sub-Saharan Africa, people dislike talking about their dead children as they see this as a bad event they don't want to remember. However, in this study, we used an indirect method that accounts for such limitation for the estimation of childhood mortality across the classes of housing materials.

Conclusion
The death of under-five children in the face of various factors remains a problem in Nigeria as the estimated infant and under-five mortality rates in this study are high. Living in houses built with inadequate housing materials promoted under-five mortality in Nigeria. Also, housing materials, environmental factors in addition to maternal and childhood characteristics were associated with childhood mortality. Housing materials remain a predictor of under-five mortality when environmental, child's characteristics and health-related factors were used as covariates. However, amidst all factors, housing materials may not be so important, instead maternal education, place of residence, sex, the size of the child at birth, prenatal care provider, birth order and preceding birth interval are the key predictors of deaths among under-five children in Nigeria. The existence of under-five mortality inequalities across different areas, regions and socio-economic groups is also well documented. Various reforms and policies have been instituted by the government and relevant stakeholders to address the high rate of under-five mortality in Nigeria but these are yet to yield the expected results. Improvements in housing conditions and in the continuum of maternal and child health will play a significant role in reducing the burden of under-five mortality in Nigeria.

Abbreviations
ARIs: Acute respiratory infections; CI: Confidence interval; CloHR: Confidence interval of hazard; DHS: Demographic and health surveys; HR: Hazard ratio; MDGs: Millennium development goals; SDGs: Sustainable development goals; USM: Under-five mortality; UNDESA: United Nations Department of Economic and Social Affairs; UNICEF: United Nations Children's Fund; VPD: Vaccines preventable diseases; WHO: World Health Organisation

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Availability of data and materials
The data that support the findings of this study are available from the MEASURE DHS but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available upon reasonable request and with permission of the MEASURE DHS through http://www.dhsprogram.com.
Authors’ contributions
ASA, OMM and AGR conceived the study, developed the research questions and designed the study. ASA analysed the data, wrote the methodology and the result sections. OMM wrote the introduction, discussion and part of the result sections. AGR took part in the writing of the introduction, discussion and critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Consent for publication
Not applicable.

Ethics approval and consent to participate
Ethical approval for this study was obtained by the data originators from the Nigeria National Ethics Committee (NHREC/2008/07), functioning under the Ministry of Health. An informed consent was obtained from all the study participants after describing to them all the issues related to the study in details at the point of data collection. Each consented participants was made to sign an appropriate agreement form before the interview.

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