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Characterization of Healthy Housing in Africa: Method, Profiles, and Determinants

Samuel Iddi · **Kanyiva Muindi** · **Hellen Gitau** · **Blessing Mberu**

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Abstract Housing is a key social determinant of health with implications for both physical and mental health. The measurement of healthy housing and studies characterizing the same in sub-Saharan Africa (SSA) are uncommon. This study described a methodological approach employed in the assessment and characterization of healthy housing in SSA using the Demographic and Health Survey (DHS) data for 15 countries and explored healthy housing determinants using a multiple survey-weighted logistic regression analysis. For all countries, we demonstrated that the healthy housing index developed using factor analysis reasonably satisfies both reliability and validity tests and can therefore be used to describe the distribution of healthy housing across different groups and in understanding the linkage with individual health outcomes. We infer from the results that unhealthy housing remains quite high in most SSA countries. Having a male head of the household was associated with decreased odds of healthy housing in Burkina Faso (OR = 0.80, CI = 0.68–0.95), Cameroon (OR = 0.65, CI = 0.57, 0.76), Malawi (OR = 0.70, CI = 0.64–0.78), and Senegal (OR = 0.62, CI = 0.51–0.74). Further, increasing household size was associated with reducing odds of healthy housing in Kenya (OR = 0.53, CI = 0.44–0.65), Namibia (OR = 0.34, CI = 0.24–0.48), Nigeria (OR = 0.57, CI = 0.46–0.71), and Uganda (OR = 0.79, CI = 0.67–0.94). Across all countries, household wealth was a strong determinant of healthy housing, with middle and rich households having higher odds of residing in healthy homes compared to poor households. Odds ratios ranged from 3.63 (CI = 2.96–4.44) for households in the middle wealth group in the DRC to 2812.2 (CI = 1634.8–4837.7) in Namibia's wealthiest households. For other factors, the analysis also showed variation across countries. Our findings provide timely insights for the implementation of housing policies across SSA countries, drawing attention to aspects of housing that would promote occupant health and wellbeing. Beyond the contribution to the measurement of healthy housing in SSA, our paper highlights key policy and program issues that need further interrogation in the search for pathways to addressing the healthy housing deficit across most SSA countries. This has become critical amid the COVID-19 pandemic, where access to healthy housing is pivotal in its control.

Keywords Housing · Healthy · Determinants · COVID-19 · Africa

S. Iddi (✉)
Department of Statistics and Actuarial Science, University of Ghana, Accra, Legon, Ghana
e-mail: siddi@ug.edu.gh

K. Muindi (✉) · H. Gitau · B. Mberu
Urbanization and Wellbeing Unit, African Population and Health Research Center, Nairobi, Kenya
e-mail: kmuindi@aphrc.org

Introduction

Housing is a key social determinant of health with implications for both physical and mental health [1–3]. The WHO's housing and health guidelines strongly recommend action on the following housing attributes: crowding, indoor cold and insulation, safety and injuries, and accessibility. There are also conditional recommendations for indoor heat and cold, especially for countries that experience high temperatures and cold seasons, respectively. [3] The WHO's definition of healthy housing places emphasis on human health and includes various attributes of the housing structure and associated amenities such as adequate space and safe fuel. In addition, neighborhood attributes that ensure social interactions are important to healthy housing while the immediate housing environment is also key in enabling access to services such as green spaces, active and public transport options [3]. Housing conditions are critical for children, their caregivers, the disabled, and the older persons who spend more than 70% of their time indoors [3, 4]. For example, improving housing conditions has been linked to a number of benefits, like reduced morbidity, increased quality of life, and reduced poverty. It also helps to mitigate climate change through improved energy efficiency, reduced greenhouse gas (GHG) emissions, and minimized penetration of ambient air pollutants as well as contribute to the achievement of a number of Sustainable Development Goals (SDG), including those addressing health (SDG 3) and sustainable cities (SDG 11) [3].

People are exposed to various toxins in the home environment including household air pollution from cooking and lighting fuels such as wood and kerosene; and mold, [5] which has been associated with poor respiratory health [6–9]. In addition, lead poisoning from paint and water contamination from supply lead pipes have impacts on children's neural and cognitive health, with further mental and economic consequences in adulthood [10–12]. Analysis of housing environment and early childhood development in sub-Saharan Africa (SSA) found that improved housing is associated with both on-track cognitive development as well as on-track social-emotional development in girls. These findings suggest that housing improvement in SSA may be associated not only with benefits for children's physical health but also with broader aspects of healthy child development [13]. Further, crowded homes expose individuals to communicable diseases, for example, a study in South Africa reported elevated levels of respiratory symptoms and fever/chills in both moderately and extremely crowded houses, as well as diarrhea in extremely overcrowded housing [14], while poorly insulated homes expose occupants to extremes of temperatures which have an effect on cardiovascular health [3]. Other health outcomes associated with housing quality include injuries, sanitation-related illnesses, vector-borne diseases, and mental health. For example, a randomized controlled trial (RCT) illustrated that screening of doors and windows, reduced anemia due to malaria by 50% among Gambian children [15]. Beyond the indoor environment, structural deficiencies are linked to vermin, mites, and mold, which are associated with allergies. Structurally weak housing is a cause of injury and death as exemplified in the recent collapse of residential blocks in Nairobi [16]. Neighborhood characteristics also have an impact on housing-related health outcomes. For example, housing units with limited access have implications for mobility into and out of homes especially for disabled and elderly occupants who remain isolated and become prone to mental health issues, while it also acts as a barrier for emergency services providers such as firefighters. In addition, houses with weak security of tenure expose the occupants to frequent evictions and demolitions, 17,18 rendering them homeless and having an impact on mental health and general wellbeing [19, 20].

In the context of the COVID-19 pandemic, self-isolation for those with symptoms and self-quarantine for 14 days after exposure and recommendations such as working from home has become the default for workers all over the world [21]. The challenge is that about one billion people estimated to live in urban slums or informal settlements are highly susceptible to COVID-19 infection due to existing housing, water, and sanitation challenges [21–23]. Further, space constraints, violence, and overcrowding in slums make physical distancing and self-quarantine impractical, and the rapid spread of infection is highly likely [21]. A study of adequate housing by the Asian Development Bank (ADB) Outlook, [24] acknowledged that perceptions as to what constitutes adequate housing vary substantially across communities and countries. However, it states that housing should satisfy four basic criteria irrespective of local context: a finished roof that protects the occupants from weather, sufficient living area so that no more than three people need to share a bedroom, access in the dwelling or plot to spring water or improved piped water, and improved sanitation in the form of a flush toilet or ventilated pit latrine not shared by more than two households. However, measuring healthy housing in Africa remains a challenge that is exacerbated by a lack of data across contexts and countries in the region. Our focus on healthy housing within the African context aims to address this knowledge gap and builds on this ADB's basic characterization of adequate housing but explores further variables based on the WHO definition and availability of data. This will contribute to the definition of short-term interventions as well as long-term strategies in the housing sector.

In theory, the demand for healthy housing is almost unlimited as the demand for better housing than what people currently have, remains, but this demand is not met in reality [25]. Urban housing demand in Africa is largely an outcome of rapid urbanization as people migrate to urban areas in search of economic opportunities. This has placed and will continue to place immense pressure on housing in primary and secondary cities [24]. Consequently, understanding both the characteristics of healthy housing in Africa remains an important evidence generation agenda. This is critical given that adequate and affordable housing is generally in short supply and will remain so for the 58.9% of the African population expected to live in urban areas by 2050, with the majority projected to live in slums or slum-like conditions with poor housing and debilitating environmental conditions [26–30]. In order to design and implement appropriate policies and programs to respond to the housing challenges worldwide, it is important to identify and quantify the proportion of the population that lives in slums within urban areas, those living in informal settlements, or those who have inadequate housing [24].

Existing studies have used individual indicators of healthy housing such as access to safe drinking water, sanitation, or structural attributes in the analysis of their impacts on health. Our paper proposes a composite index of healthy housing that is derived from a combination of structural attributes as well as access to amenities such as water, sanitation, and clean energy. This index goes above what the UN uses to classify slum households that consider a lack in one or more of (1) durable housing, (2) sufficient living areas, (3) access to improved water, (4) access to improved sanitation facilities, and (5) secure tenure [25]. While the UN definition is limited to urban areas, our index includes housing in rural areas, and in addition to the first four UN indicators, it includes measures of access to clean cooking energy and cigarette smoking but excludes tenure. Therefore, the main aim of this study was to develop a healthy housing index for Africa and to categorize the characteristics of healthy housing across sub-Saharan African countries. Specifically, we categorized healthy housing by using the area of residence, household-level, and socio-demographic factors. We also assessed the association between healthy housing and these factors.

Study Design and Data Source

This study involved a secondary data analysis using the latest Demographic and Health Survey data and information across 15 sub-Saharan African countries. The DHS was designed to collect data to facilitate the understanding of the population and health situations of participating countries. Each country utilizes similar data collection tools to ensure comparability across countries. Data are collected by trained interviewers, on a wide range of demographic and health outcomes for household members and household-level information. Particularly for the household questionnaire, source of drinking/non-drinking water, type of sanitation facilities, materials used to construct the house, ownership of various consumer goods, and other household-level information are collected through self-reports by respondents. More details on the DHS can be found on this page. The data were extracted from the IPUMS International database [31].

Methodology

We constructed and categorized a healthy housing index in Africa using the DHS data across 15 selected countries (See Table 1). The data were first prepared to permit the use of factor analysis for developing the health housing index. The processes and

Table 1 Test for Reliability

Country	Cronbach α	Standardized Cronbach α	Guttman's $\lambda 6$	Composite reliability	Number of variables used
Burkina Faso (2010)	0.72	0.72	0.73	0.74	8
Cameroon (2011)	0.78	0.82	0.81	0.82	7
Democratic Republic of Congo (2013–2014)	0.75	0.75	0.77	0.79	8
Ethiopia (2016)	0.78	0.78	0.79	0.80	8
Ghana (2014)	0.58	0.55	0.57	0.60	8
Kenya (2014)	0.78	0.80	0.80	0.81	7
Malawi (2015–2016)	0.64	0.64	0.66	0.67	8
Mali (2012–2013)	0.75	0.73	0.74	0.76	8
Namibia (2013)	0.82	0.82	0.84	0.84	8
Nigeria (2018)	0.71	0.68	0.70	0.71	8
Senegal (2017)	0.75	0.74	0.75	0.77	8
South Africa (2016)	0.66	0.66	0.67	0.68	8
Tanzania (2015–2016)	0.73	0.70	0.73	0.75	8
Uganda (2016)	0.71	0.67	0.70	0.72	8
Zambia (2013–2014)	0.80	0.80	0.82	0.83	8

steps involved are described in detail in the following sections.

Data Preparation

To construct the healthy housing index, we extracted and recoded eight variables relating to housing conditions for all countries. The variables include the main wall, roof, and floor materials, type of toilet facility, source of drinking water, type of cooking fuel, presence of electricity (yes = 2, no = 1), and frequency of smoking in the households. The inclusion of smoking in the index was guided by its impact on household air quality and subsequent health of members including non-smokers [32–34]. Source of drinking water was grouped into unimproved, un-piped improved, slightly improved, and piped improved sources. Similarly, the type of toilet facility was grouped into no/unimproved, unimproved pit latrine, improved pit/composting toilet, and flush toilet [35]. Floor, wall, and roof materials were also reclassified into natural, rudimentary, low quality, and high quality using the classifications used in the DHS data collection tools [36]. Cooking fuel was classified into five levels namely charcoal/coal/kerosene, natural gas/LPG/biogas, electricity from other sources, electricity, and no food cooked in house using a broader definition of dirty fuels to include both solid fuels and kerosene-based on evidence of kerosene as a highly polluting fuel [37]. Finally, the frequency of smoking had five levels, which include daily, weekly, less than monthly, monthly, and never. Appendix Tables 10, 11, 12, 13, 14, 15, 16, and 17 show how each of the original variables from the DHS was re-coded and prepared for analysis. Before conducting the factor analysis, all the categorical variables/items were converted into an ordinal scale (from 1 to 4 or 5) with high values corresponding to higher housing quality. Variables with no variation (standard deviation of 0) or with missing proportions above 20% were checked and eliminated before further analysis.

Development of the Healthy Housing Index (HHI)

It is standard practice to conduct validity and reliability tests for a newly constructed construct. The reliability test ensures that the items used are internally consistent. A measure of internal consistency ensures that the scale or index measures the intended construct consistently and precisely. To ensure that the healthy housing index is reliable, we assessed the reliability of the set of questions/variables for each country using three internal consistency measures, namely, Cronbach's coefficient alpha, Standardized

Cronbach's coefficient alpha, [38, 39] and the Guttman's Lambda-6 [40], and composite reliability. The Cronbach's alpha is a function of the number of items, the average inter-item covariance among the items, and the average variance of all items. It is computed using the formula, $\alpha = \frac{N\bar{c}}{\bar{v}+(N-1)\bar{c}}$ where N is the number of items, $\bar{c}$ is the average inter-item covariance among the items, and $\bar{v}$ is the average variance. When the average covariance is high, then alpha increases when the number of items is held fixed. The Cronbach's alpha is known to often underestimate the reliability of a test but is widely used due to the ease in the calculation. The standardized Cronbach alpha is based on a correlation matrix instead of the covariance matrix. It is mostly preferred when items are measured on different scales [38, 39, 41]. Guttman's lambda, which is computed based on the squared multiple correlations when each item is regressed on all the other items, is considered a better estimate of internal consistency. The formula to compute it is given by, $\lambda_6 = 1 - \frac{\sum_{i=1}^{N}\sigma_i^2}{s_t}$ where σ_i^2 represents the variance of a particular item and s_t is the variance of the sum of items or total test variance. Another good measure, the composite reliability, is based on the factor loadings of confirmatory factor analysis (CFA). It is computed by $C = \frac{(\sum_{i=1}^{p} l_i)^2}{(\sum_{i=1}^{p} l_i)^2+\sum_{i=1}^{p} r_i}$ where l_i is the standardized loading for each item, p is the number of loadings, and $r_i = 1 - l_i^2$. The loadings, which capture the correlation between each item and the construct, in a one-factor CFA, are used to generate estimates of the composite reliability. The composite reliability overcomes the weakness of the other estimates and measures the overall reliability of items that are heterogeneous but similar. Usually, a value of reliability that is 0.7 and above is acceptable [41]. Next, we determined if the factor analysis was appropriate for creating the composite score. We tested the validity of the factor analysis by testing the sampling adequacy using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and whether the correlation matrix of the data is an identity matrix using Bartlett's Test of Sphericity. The KMO test is based on correlation and partial correlation matrix of the data and measures the proportion of variance among the variables that might be caused by an underlying factor. The value is computed as, $KMO = \frac{\sum\sum_{i\neq j} r_{ij}^2}{\sum\sum_{i\neq j} r_{ij}^2+\sum\sum_{i\neq j} u_{ij}^2}$, where r_{ij}'s and u_{ij}'s are the components of the correlation and partial covariance matrix describing the relationship between two items whilst taking away the effects of other items, respectively. The measure usually ranges from 0 and 1, with a higher value indicating that factor analysis can be performed for the data. A general rule of thumb is that a value higher than 0.7 indicates sample adequacy. Bartlett's test tests the hypothesis that the correlation matrix is identity. The test statistics is given by $\chi^2 = -\left(n - 1 - \frac{2p+5}{6}\right) \times \ln|R|$, which follows a chi-square distribution with $p(p-1)/2$ degrees of freedom, with p being the number of items and R the observed correlation matrix. When the hypothesis is rejected, this means that the variables are related and therefore suitable for conducting a factor analysis. We then performed a one-factor analysis with varimax rotation, separately for rural and urban areas for each country, and extracted the first-factor score estimated using the regression method. A 1-factor model is defined as follows:

$$Z = LF + \epsilon$$

where Z is a $p \times 1$ matrix of the standardized set of housing variables, F is the 1 latent factor, L is a $p \times 1$ matrix of factor loadings which measures the correlation between observed scores and latent scores, and ϵ is a $p \times 1$ error component. The model assumes that the error term and latent factor are independent. Model parameters are estimated by using principal component methods and the factor scores, F, are extracted using the regression methods [42]. The extracted factors scores are used for developing the healthy housing index [43, 44].

We assessed the degree to which the housing index represents what it is intended to measure by conducting a validity analysis. Due to the seeming limitation of DHS to include important variables such as income and expenditure, we rely on the wealth index and child morbidity outcomes to validate the healthy housing index. Concurrent validity was assessed by examining the Pearson correlation between household wealth index (HWI) and the healthy housing index (HHI) across countries for rural and urban residency. Building on the high association between healthy housing and child health in theoretical and empirical literature, we also assessed the relationship between child morbidity outcomes in the DHS data and the newly constructed HHI using survey-weighted logistic regression.

Determinants of Health Housing Index

A weighted multiple logistic regression model was fitted to assess the association between healthy housing and socio-demographic factors. The factors that are assessed include gender and age of household head, residency (rural vs urban), household wealth status, household size, and the number of children in a household. This analysis was performed for each of the countries separately.

Ethical Consideration

This study is based on a secondary analysis of data that is publicly available on the DHS website. Therefore, no further ethical approval was required.

Results

Reliability Test

Reliability tests using different reliability measures were explored for each country. Table 1 shows the results of the reliability test and the number of variables used for each country. With the exception of Cameroon and Kenya, where the proportion of missing information was above 20%, all 8 variables were used in the analysis for the other countries. Also, except for Ghana, Malawi, and South Africa, Cronbach α, standardized Cronbach α, and Guttman's λ6 values were higher than 0.7. These indicate that for most countries the items under consideration have acceptable internal consistency with the exception of the three aforementioned countries which have questionable internal consistency.

Appropriateness of Factor Analysis

The next step was to test for the appropriateness of conducting a factor analysis for the data by checking for sampling accuracy and sufficiency of the correlation structure. The Kaiser–Meyer–Olkin (KMO) Measure of sampling adequacy and Bartlett's Test of Sphericity were performed and results are shown in Table 2. From the results, KMO values were higher than 0.70, and Bartlett's test of sphericity with approximate chi-square was < 0.001 indicating the appropriateness of conducting a factor analysis without the need for remedial action.

Table 2 Test for appropriateness of factor analysis

Country	KMO measure of sampling adequacy	Bartlett's Test of Sphericity		
KMO	**approx. chi-square**	***df***	***p* value**	
Burkina Faso (2010)	0.83	22,975.78	28	< 0.001
Cameroon (2011)	0.88	30,346.14	21	< 0.001
Democratic Republic of Congo (2013–2014)	0.86	43,988.57	28	< 0.001
Ethiopia (2016)	0.87	38,177.07	28	< 0.001
Ghana (2014)	0.77	10,603.12	28	< 0.001
Kenya (2014)	0.84	81,136.47	21	< 0.001
Malawi (2015–2016)	0.76	35,060.56	28	< 0.001
Mali (2012–2013)	0.87	17,816.38	28	< 0.001
Namibia (2013)	0.87	31,741.47	28	< 0.001
Nigeria (2018)	0.82	60,926.72	28	< 0.001
Senegal (2017)	0.85	16,235.07	28	< 0.001
South Africa (2016)	0.75	13,248.81	28	< 0.001
Tanzania (2015–2016)	0.85	24,955.66	28	< 0.001
Uganda (2016)	0.83	35,344.19	28	< 0.001
Zambia (2013–2014)	0.88	46,456.75	28	< 0.001

Healthy Housing Index

Following the DHS methodology for creating wealth index, [43] we performed a 1-factor analysis described in Sect. 3.2 for the common factors in a pulled sample and also for rural and urban areas separately using all sets of variables described in Sect. 3.1. Next, we regressed the factor scores for the whole sample with the scores from the urban and rural areas separately to obtain the intercept and slopes which are used to compute the combined score. The estimated factor loadings for each dwelling variable for the common factor model are shown in Appendix A8 per country. Most of the factor loadings were more than 0.5 indicating how closely the variables were related to the factor. Thus, the combined factor scores are referred to as the healthy housing index (HHI). The index is categorized into tertiles and merged with the original data. This is calculated per country, separately.

Validity Test

Finally, we assessed the degree to which the computed healthy housing index represents what it is intended to measure by conducting a concurrent validity analysis. This was done by examining the Pearson's correlation coefficient between HHI and Household Wealth Index (HWI) computed by the DHS. We observed, in Table 3, a high to a very high correlation between the two indexes by country and residency. We note that the DHS wealth index includes housing indicators within it which might induce circularity in the analysis. To support the validation analysis, we identified and used data on children under five for some countries where diarrhea outcomes were available in the DHS dataset. A survey-weighted logistic regression was fitted to assess the association between a child's recent diarrhea status (coded yes and no) and healthy housing (households in the 2 upper quintiles of the index are classified as healthy; otherwise, they are unhealthy). Children nested within a household was accounted for by adding the household variable as a cluster in the analysis. The results of this analysis are shown in Table 4. From the results, we observed that except for Burkina Faso, healthy housing reduces the odds of having child morbidity for all the other countries. This establishes the association of the healthy housing index to child morbidity.

Table 3 Test of validity: correlation coefficient between HHI and HWI

Country	Urban	Rural
Burkina Faso (2010)	0.75	0.71
Cameroon (2011)	0.71	0.84
Democratic Republic of Congo (2013–2014)	0.92	0.77
Ethiopia (2016)	0.78	0.60
Ghana (2014)	0.72	0.67
Kenya (2014)	0.82	0.78
Malawi (2015–2016)	0.86	0.85
Mali (2012–2013)	0.69	0.81
Namibia (2013)	0.86	0.86
Nigeria (2018)	0.75	0.82
Senegal (2017)	0.81	0.80
South Africa (2016)	0.69	0.75
Tanzania (2015–2016)	0.88	0.88
Uganda (2016)	0.84	0.79
Zambia (2013–2014)	0.87	0.85

Distribution of Healthy Housing

Descriptive analysis showed that while there was an urban advantage in almost half of the countries, there were cases where we observed more than 60% of healthy housing in rural areas, for example, in Burkina Faso, DRC, Ethiopia, and Malawi (see Tables 5 and 6). We further assessed the distribution of healthy housing by household-level factors that may determine this outcome. Across all countries, male-headed households had more than 50% of healthy housing while female-headed households had the lowest proportion of healthy housing, with the lowest observed in Mali (9%) and South Africa and Namibia having

Table 4 Association between recent diarrhea for children under 5 and healthy housing

Country	Effects (odds ratio)	
Intercept		Healthy housing
Burkina Faso (2010)	0.16 (0.15, 0.18)	1.18 (1.04, 1.33)
Cameroon (2011)	0.34 (0.31, 0.38)	0.57 (0.48, 0.66)
Ghana (2014)	0.15 (0.13, 0.18)	0.76 (0.59, 0.97)
Kenya (2014)	0.20 (0.19, 0.22)	0.75 (0.66, 0.85)
Nigeria (2018)	0.18 (0.17, 0.20)	0.57 (0.50, 0.65)
South Africa (2016)	0.16 (0.13, 0.19)	0.69 (0.53, 0.91)

Table 5 Distribution of healthy housing by background characteristics (absolute number of households and percentage)

Country (survey year)	Place of residence		Sex of household head		Age of household head			
Rural	Urban	Female	Male	0–17 years	18–35 years	36–59 years		60 + years
Burkina Faso (2010)	5780 (67%)	2804 (33%)	946 (11%)	7638 (89%)	31 (0%)	2966 (35%)	3962 (46%)	1623 (19%)
Cameroon (2011)	3420 (38%)	5636 (62%)	2409 (27%)	6646 (73%)	42 (0%)	3240 (36%)	4215 (47%)	1552 (17%)
Democratic Republic of Congo (2013–2014)	5604 (61%)	3656 (39%)	2205 (24%)	7055 (76%)	24 (0%)	3116 (34%)	4546 (49%)	1574 (17%)
Ethiopia (2016)	8498 (81%)	2000 (19%)	2575 (25%)	7922 (75%)	38 (0%)	3539 (34%)	4366 (42%)	2545 (24%)
Ghana (2014)	3774 (42%)	5226 (58%)	3124 (35%)	5876 (65%)	15 (0%)	3228 (36%)	4145 (46%)	1612 (18%)
Kenya (2014)	11,461 (48%)	12,498 (52%)	7270 (30%)	16,689 (70%)	52 (0%)	10,578 (44%)	10,040 (42%)	3282 (14%)
Malawi (2015–2016)	9205 (75%)	3059 (25%)	3368 (27%)	8895 (73%)	37 (0%)	4386 (36%)	5541 (45%)	2262 (19%)
Mali (2012–2013)	4155 (74%)	1483 (26%)	518 (9%)	5120 (91%)	8 (0%)	1671 (30%)	2698 (48%)	1240 (22%)
Namibia (2013)	2326 (40%)	3480 (60%)	2436 (42%)	3370 (58%)	14 (0%)	1843 (32%)	2871 (49%)	1074 (19%)
Nigeria (2018)	13,095 (46%)	15,332 (54%)	5636 (20%)	22,791 (80%)	50 (0%)	8989 (32%)	13,715 (48%)	5664 (20%)
Senegal (2017)	2782 (42%)	3921 (58%)	2212 (33%)	4491 (67%)	2 (0%)	985 (15%)	3542 (53%)	2169 (32%)
South Africa (2016)	2689 (29%)	6739 (71%)	3973 (42%)	5456 (58%)	31 (0%)	2439 (26%)	4567 (49%)	2330 (25%)
Tanzania (2015–2016)	4038 (57%)	3036 (43%)	1614 (23%)	5460 (77%)	9 (0%)	2299 (32%)	3529 (50%)	1238 (17%)
Uganda (2016)	7735 (67%)	3770 (33%)	3544 (31%)	7961 (69%)	59 (1%)	4850 (42%)	4856 (42%)	1700 (15%)
Zambia (2013–2014)	4751 (48%)	5058 (52%)	2381 (24%)	7428 (76%)	5 (0%)	3492 (36%)	4776 (49%)	1533 (16%)

the highest proportion at 42%. Next, we assessed the distribution of healthy housing by age of the household head. Excluding the youngest age group (17 years and below) which had 1% or less of healthy housing across all countries, we observed higher proportions of healthy housing among those headed by individuals aged 36–59 years (with the exception of Kenya) followed by those aged 18–35 years and lastly by those 60 years and older.

When household wealth is considered, the proportion of healthy housing is lowest among poor households with Malawi having 8% healthy housing among her poorest households while South Africa has 32% of healthy housing among the poorest. In the middle wealth group, we observe an almost equal distribution (about 20%) of healthy housing across all countries. Lastly, the richest households posted the highest proportions of healthy housing ranging from 45% in South Africa to 72% in Malawi. The distribution of healthy housing by household size appears counterintuitive with households having more than one member also having higher proportions of healthy housing, with the exception of a few countries. This is because larger households have been found to be poor or crowded, which impacts the quality of housing. The proportions appear to be similar across the categories of household size with the exception of Ghana, Kenya, and South Africa where households with eight or more members have the lowest proportions of healthy housing (6% and below). An assessment of the distribution of healthy housing by the number of children aged below 5 years within a household (a proxy indicator of dependency ratio) revealed that across all countries, the proportion of healthy housing was highest among those with no child within this age range. The proportion decreased as the number of

Table 6 Distribution of healthy housing by background characteristics (absolute number of households and percentage) (cont.)

Country (survey year)	Household wealth			Number of children below 5 years			Household size				
Poor	Middle	Rich	0	1 to 2	3+	1	2 to 3	4 to 5	6 to 7		8+
Burkina Faso (2010)	1504 (18%)	1788 (21%)	5291 (62%)	3146 (37%)	4487 (52%)	951 (11%)	616 (7%)	1774 (21%)	2373 (28%)	1746 (20%)	2073 (24%)
Cameroon (2011)	1677 (19%)	1679 (19%)	5699 (63%)	4525 (50%)	3714 (41%)	817 (9%)	1347 (15%)	2098 (23%)	2197 (24%)	1707 (19%)	1706 (19%)
Democratic Republic of Congo (2013–2014)	2101 (23%)	1868 (20%)	5291 (57%)	3373 (36%)	4686 (51%)	1200 (13%)	643 (7%)	1765 (19%)	2518 (27%)	2120 (23%)	2214 (24%)
Ethiopia (2016)	2439 (23%)	2390 (23%)	5668 (54%)	5276 (50%)	4780 (46%)	441 (4%)	763 (7%)	2701 (26%)	3395 (32%)	2339 (22%)	1300 (12%)
Ghana (2014)	1866 (21%)	2093 (23%)	5041 (56%)	5684 (63%)	3103 (34%)	213 (2%)	2377 (26%)	2822 (31%)	2271 (25%)	1097 (12%)	433 (5%)
Kenya (2014)	3464 (14%)	4410 (18%)	16,086 (67%)	14,508 (61%)	8957 (37%)	494 (2%)	5150 (21%)	7477 (31%)	6932 (29%)	2907 (12%)	1493 (6%)
Malawi (2015–2016)	948 (8%)	2466 (20%)	8849 (72%)	5715 (47%)	6257 (51%)	292 (2%)	725 (6%)	3045 (25%)	4362 (36%)	2894 (24%)	1238 (10%)
Mali (2012–2013)	1038 (18%)	1335 (24%)	3265 (58%)	1785 (32%)	3114 (55%)	738 (13%)	205 (4%)	991 (18%)	1695 (30%)	1424 (25%)	1323 (23%)
Namibia (2013)	652 (11%)	1078 (19%)	4076 (70%)	3607 (62%)	1964 (34%)	235 (4%)	1043 (18%)	1763 (30%)	1513 (26%)	842 (15%)	644 (11%)
Nigeria (2018)	4612 (16%)	6703 (24%)	17,112 (60%)	14,408 (51%)	11,731 (41%)	2288 (8%)	4653 (16%)	7541 (27%)	8057 (28%)	4619 (16%)	3557 (13%)
Senegal (2017)	1529 (23%)	1495 (22%)	3680 (55%)	2363 (35%)	2922 (44%)	1418 (21%)	497 (7%)	776 (12%)	990 (15%)	1120 (17%)	3320 (50%)
South Africa (2016)	2975 (32%)	2183 (23%)	4271 (45%)	6572 (70%)	2719 (29%)	138 (1%)	2076 (22%)	3494 (37%)	2414 (26%)	925 (10%)	520 (6%)
Tanzania (2015–2016)	781 (11%)	1479 (21%)	4814 (68%)	3205 (45%)	3500 (49%)	370 (5%)	665 (9%)	1768 (25%)	2128 (30%)	1428 (20%)	1086 (15%)
Uganda (2016)	1681 (15%)	2071 (18%)	7754 (67%)	5134 (45%)	5554 (48%)	818 (7%)	1654 (14%)	2962 (26%)	3172 (28%)	2091 (18%)	1626 (14%)
Zambia (2013–2014)	2144 (22%)	1867 (19%)	5797 (59%)	3863 (39%)	5300 (54%)	646 (7%)	667 (7%)	2000 (20%)	2878 (29%)	2333 (24%)	1931 (20%)

children below 5 years increased, with South Africa, Malawi, Ghana, and Kenya having the lowest proportion of healthy housing (2% and below) among households with three or more children below the age of 5 years.

Association Between Healthy Housing and Socio-demographic Factors

We fitted a survey-weighted logistic regression model to assess the association between healthy housing and socio-demographic factors. Tables 7, 8, and 9 show the estimated odds ratios and 95% confidence interval corresponding to the various factors. Across all countries, household wealth was a strong determinant of healthy housing, with middle and rich households having higher odds of residing in healthy homes compared to poor households. Odds ratios ranged from 3.63 (CI = 2.96–4.44) for households in the middle wealth group in the DRC to 2812.2 (CI = 1634.8–4837.7) in Namibia's wealthiest households. On the other hand, the age of the household head did not reach statistical significance across all countries. The rest of the factors assessed in this analysis showed variation in statistical significance across countries. Urban residence was significantly associated with decreased odds of living in healthy homes across all countries (OR ranged from 0.02 (CI = 0.01–0.04) in Namibia to 0.48 (CI = 0.38–0.60) in Malawi and Kenya) except in South Africa where this was not statistically significant. Having a male head of the household was associated with decreased odds of healthy housing in Burkina Faso (OR = 0.80, CI = 0.68–0.95), Cameroon (OR = 0.65, CI = 0.57, 0.76), Malawi (OR = 0.70, CI = 0.64–0.78), and Senegal (OR = 0.62, CI = 0.51–0.74). Further, increasing household size was associated with reducing odds of healthy housing in Kenya (OR = 0.53, CI = 0.44–0.65), Namibia (OR = 0.34, CI = 0.24–0.48), Nigeria (OR = 0.57, CI = 0.46–0.71), and Uganda (OR = 0.79, CI = 0.67–0.94) though, in the latter country, only some categories of household size were statistically significant. In Tanzania (OR = 1.54, CI = 1.14–2.06), increasing household size was associated with higher odds of healthy housing. Odds ratios and confidence intervals for household size are only presented for the largest size category (8 + members) except for Uganda where we present the significant category (4–5 members). Lastly, an increase in the number of children below 5 years old was significantly associated with reducing odds of healthy housing in Burkina Faso (OR = 0.68, CI = 0.56–0.83), Cameroon (OR = 0.77, CI = 0.61–0.97), DRC (OR = 0.75, CI = 0.61–0.93), Kenya (OR = 0.55, CI = 0.4–0.67), and South Africa (OR = 0.44, CI = 0.27–0.71). In Malawi (OR = 0.88, CI = 0.78–0.98) however, an increase in the number of children under the age of 5 years was associated with increased odds of healthy housing though the highest category was not statistically significant. For

Table 7 Estimated odds ratio and 95% confidence interval

Variable	Burkina Faso (2010)	Cameroon (2011)	DRC (2013–2014)	Ethiopia (2016)	Ghana (2014)
Intercept	0.41 (0.17, 1.00)	1.20 (0.57, 2.52)	0.47 (0.18, 1.22)	0.33 (0.09, 1.21)	4.15 (0.99, 17.39)
Residence (urban)	**0.23 (0.16, 0.34)**	**0.03 (0.01, 0.05)**	**0.14 (0.09, 0.21)**	**0.10 (0.07, 0.15)**	**0.11 (0.08, 0.15)**
Gender (male)	**0.80 (0.68, 0.95)**	**0.65 (0.57, 0.76)**	0.87 (0.76, 1.01)	0.98 (0.85, 1.13)	0.76 (0.65, 0.89)
Age (18–35 years)	1.04 (0.44, 2.50)	0.57 (0.28, 1.19)	1.06 (0.41, 2.71)	2.00 (0.58, 6.97)	0.29 (0.07, 1.18)
Age (36–59 years)	1.20 (0.50, 2.88)	0.56 (0.27, 1.16)	1.03 (0.41, 2.57)	2.40 (0.70, 8.22)	0.40 (0.10, 1.65)
Age (60 +)	1.21 (0.50, 2.93)	0.53 (0.26, 1.11)	1.13 (0.45, 2.87)	2.72 (0.78, 9.47)	0.45 (0.11, 1.87)
Wealth status (middle)	**5.52 (4.67, 6.53)**	**37.50 (18.87, 74.52)**	**3.63 (2.96, 4.44)**	**5.49 (4.42, 6.83)**	**11.74 (9.23, 14.94)**
Wealth status (rich)	**61.2 (45.3, 82.7)**	**1103.7 (527.7, 2308.4)**	**53.9 (36.2, 80.0)**	**25.75 (18.6, 35.6)**	**103.47 (74.2, 144.3)**
Household size (1 to 2)	0.91 (0.72, 1.15)	1.10 (0.93, 1.31)	0.87 (0.70, 1.09)	0.87 (0.69, 1.10)	0.97 (0.81, 1.16)
Household size (4 to 5)	1.14 (0.89, 1.46)	1.09 (0.89, 1.32)	0.98 (0.75, 1.29)	0.85 (0.65, 1.10)	1.02 (0.80, 1.31)
Household size (6 to 7)	1.09 (0.83, 1.44)	1.10 (0.89, 1.37)	0.93 (0.68, 1.26)	0.70 (0.53, 0.92)	0.98 (0.76, 1.28)
Household size (8 +)	**1.34 (1.00, 1.79)**	1.10 (0.85, 1.42)	1.10 (0.78, 1.55)	1.00 (0.69, 1.44)	0.99 (0.71, 1.37)
No. children U5 (1–2)	**0.81 (0.71, 0.92)**	0.88 (0.76, 1.03)	**0.83 (0.73, 0.95)**	0.98 (0.85, 1.12)	0.94 (0.78, 1.13)
No. children U5 (3 +)	**0.68 (0.56, 0.83)**	**0.77 (0.61, 0.97)**	**0.75 (0.61, 0.93)**	1.05 (0.75, 1.46)	0.77 (0.53, 1.11)

Table 8 Estimated odds ratio and 95% confidence interval (cont.)

Variable	Kenya (2014)	Malawi (2015–2016)	Mali (2012–2013)	Namibia (2013)	Nigeria (2018)
Intercept	0.66 (0.36, 1.23)	0.16 (0.07, 0.36)	0.79 (0.30, 2.07)	0.28 (0.09, 0.94)	1.09 (0.50, 2.36)
Residence (urban)	**0.48 (0.39, 0.58)**	**0.48 (0.38, 0.60)**	**0.12 (0.08, 0.17)**	**0.02 (0.01, 0.04)**	**0.20 (0.16, 0.24)**
Gender (male)	0.94 (0.86, 1.03)	**0.70 (0.64, 0.78)**	0.96 (0.79, 1.15)	1.05 (0.90, 1.24)	0.71 (0.63, 0.79)
Age (18–35 years)	1.44 (0.79, 2.64)	0.59 (0.27, 1.27)	0.42 (0.16, 1.08)	2.14 (0.65, 7.09)	1.01 (0.48, 2.14)
Age (36–59 years)	1.08 (0.59, 1.97)	0.77 (0.35, 1.67)	0.41 (0.16, 1.05)	2.03 (0.62, 6.68)	1.08 (0.51, 2.30)
Age (60+)	0.95 (0.52, 1.75)	0.85 (0.40, 1.83)	0.43 (0.16, 1.14)	1.57 (0.48, 5.08)	1.11 (0.52, 2.37)
Wealth status (middle)	**4.85 (4.32, 5.45)**	**10.34 (9.10, 11.75)**	**6.44 (5.39, 7.68)**	**28.97 (21.81, 38.48)**	**17.61 (15.23, 20.37)**
Wealth status (rich)	**81.0 (64.9, 101.0)**	**112.4 (95.8, 131.8)**	**61.0 (44.26, 84.0)**	**2812.2 (1634.8, 4837.7)**	**190.2 (136.1, 265.8)**
Household size (1 to 2)	**0.73 (0.65, 0.83)**	1.02 (0.83, 1.25)	0.91 (0.65, 1.26)	**0.66 (0.53, 0.83)**	**0.70 (0.61, 0.81)**
Household size (4 to 5)	**0.56 (0.49, 0.64)**	1.10 (0.89, 1.36)	1.14 (0.81, 1.60)	**0.51 (0.40, 0.66)**	**0.64 (0.55, 0.74)**
Household size (6 to 7)	**0.51 (0.44, 0.60)**	1.15 (0.91, 1.44)	1.15 (0.81, 1.63)	**0.44 (0.32, 0.61)**	**0.60 (0.50, 0.71)**
Household size (8+)	**0.53 (0.44, 0.65)**	1.06 (0.82, 1.38)	1.11 (0.77, 1.59)	**0.34 (0.24, 0.48)**	**0.57 (0.46, 0.71)**
No. children U5 (1–2)	**0.81 (0.74, 0.88)**	**0.88 (0.78, 0.98)**	0.98 (0.85, 1.12)	0.84 (0.70, 1.02)	0.97 (0.88, 1.07)
No. children U5 (3+)	**0.55 (0.45, 0.67)**	1.15 (0.85, 1.58)	0.97 (0.77, 1.23)	0.90 (0.62, 1.31)	1.01 (0.87, 1.18)

Table 9 Estimated odds ratio and 95% confidence interval (cont.)

Variable	Senegal (2017)	South Africa (2016)	Tanzania (2015–2016)	Uganda (2016)	Zambia (2013–2014)
Intercept	0.43 (0.06, 3.27)	1.81 (0.81, 4.05)	0.20 (0.03, 1.52)	0.57 (0.34, 0.95)	0.34 (0.09, 1.24)
Residence (urban)	**0.09 (0.06, 0.13)**	0.74 (0.49, 1.12)	**0.10 (0.07, 0.14)**	**0.29 (0.22, 0.38)**	**0.06 (0.05, 0.09)**
Gender (male)	**0.62 (0.51, 0.74)**	0.99 (0.84, 1.16)	1.13 (0.99, 1.28)	0.88 (0.80, 0.97)	0.99 (0.88, 1.11)
Age (18–35 years)	4.22 (0.57, 31.34)	1.57 (0.73, 3.36)	0.75 (0.10, 5.63)	0.71 (0.42, 1.18)	2.10 (0.56, 7.79)
Age (36–59 years)	4.69 (0.64, 34.23)	1.25 (0.58, 2.71)	0.81 (0.11, 6.07)	0.64 (0.38, 1.08)	1.77 (0.48, 6.59)
Age (60+)	5.05 (0.69, 37.25)	1.18 (0.53, 2.66)	0.75 (0.10, 5.64)	0.66 (0.40, 1.12)	1.68 (0.45, 6.27)
Wealth status (middle)	**49.97 (35.53, 70.27)**	**19.01 (12.65, 28.58)**	**7.82 (6.52, 9.38)**	**5.10 (4.46, 5.83)**	**9.12 (7.76, 10.71)**
Wealth status (rich)	**1854.0 (868.4, 3958.1)**	**91.33 (54.0, 154.4)**	**202.1 (139.7, 292.5)**	**87.5 (70.0, 109.4)**	**244.6 (181.7, 329.1)**
Household size (1 to 2)	0.93 (0.61, 1.41)	0.98 (0.80, 1.20)	1.21 (0.98, 1.48)	0.88 (0.75, 1.03)	0.87 (0.70, 1.08)
Household size (4 to 5)	0.71 (0.47, 1.07)	0.99 (0.76, 1.29)	**1.39 (1.10, 1.77)**	**0.79 (0.67, 0.94)**	0.86 (0.69, 1.08)
Household size (6 to 7)	0.80 (0.51, 1.25)	0.89 (0.63, 1.27)	**1.67 (1.27, 2.19)**	0.91 (0.76, 1.09)	0.79 (0.62, 1.02)
Household size (8+)	1.13 (0.73, 1.75)	0.93 (0.64, 1.35)	**1.54 (1.14, 2.06)**	0.99 (0.80, 1.24)	0.96 (0.74, 1.24)
No. children U5 (1–2)	0.82 (0.67, 1.00)	0.88 (0.72, 1.08)	0.90 (0.78, 1.04)	0.95 (0.86, 1.06)	0.91 (0.79, 1.04)
No. children U5 (3+)	0.91 (0.71, 1.16)	**0.44 (0.27, 0.71)**	0.78 (0.59, 1.03)	0.99 (0.82, 1.20)	0.96 (0.77, 1.21)

all countries with statistically significant results for the number of children aged below the age of 5 years, we present the OR and CI for the largest category (3 + children) except for Malawi where this category was not significant, so we present the lower category (1–2 children). The odds were lower for households with three or more children below the age of 5 years, in the countries where this variable reached statistical significance.

Discussion and Conclusion

This paper has developed a healthy housing index for the African context and explored the distribution as well as the determinants of healthy housing in 15 sub-Saharan African countries. The index was developed using eight variables relating to housing structure and amenities. The variables include main wall, roof, and floor materials, type of toilet facility, source of drinking water, type of cooking fuel, presence of electricity, and frequency of smoking in the households. We also used factor analysis and performed both reliability and validity tests for each country's data.

The findings from the descriptive analysis indicated that there were variations in the distribution of healthy housing by some of the socio-demographic variables considered in the analysis. The regression analysis also indicated that household wealth was associated with increased odds of healthy housing. This finding was expected as has been observed in other outcomes such as health, where poor households are disadvantaged compared with richer households. Wealth confers the household the ability to invest in better housing and amenities, have access to cleaner sources of energy, and access to safe sources of drinking water and adequate sanitation.

The burden of unhealthy housing that is borne by poor households may be worse in urban areas where homeownership is low and households have to rent homes. The cost of renting for poor households is a limiting factor, confining them to slums where housing is quite poor, 45 with consequent impacts on health [21, 46]. This may be related to the finding showing that urban residence was significantly associated with decreased odds of living in healthy homes across all countries except in South Africa where this was not statistically significant. The finding was consistent with results from a corpus of studies in the region that identified decreasing urban advantage (where urban populations enjoy better services such as health, education, etc., leading to better indicators of wellbeing compared to rural populations) relative to rural areas in key development indicators [47] and explained by the increasing urbanization of poverty and growth of slums with an attendant high prevalence of substandard housing for the majority of urban dwellers [48]. This challenge has raised intricate policy and program questions on the sustainability of urban living in the region and across many countries in the Global South [49]. Our finding contradicted that by Tusting et al. [46] that found urban areas to have higher odds of improved housing. This difference may be due to the variables used to define healthy housing in our study that included more attributes compared to Tusting's study that used fewer attributes (improved water and sanitation, sufficient living area, and durable construction).

The result for South Africa may be attributed to child welfare grants that are accessible to families across the country, [50] which could have been used to bridge the housing quality gaps. Additionally, the South African government-subsidized home building through the Reconstruction and Development Program (RDP), which also provided some direction on quality housing [51]. These targeted efforts in ensuring homeownership may have led to averting the development of poor housing in informal settlements as has been noted elsewhere on the continent. Further South Africa is one of few countries in SSA that has "Gross National Income per capita that is higher or equal to the least expensive formal dwelling" [18]. Other factors may be related to governments withdrawing from the provision of affordable and quality housing, and the un/under-employment of city residents, limiting their ability to afford the often privately owned better housing or access formal urban land markets [30, 52]. In addition, major financial institutions have excluded the majority of urban poor from accessing housing loans or mortgages [52, 53] due to lack of tenure on land and unemployment. This calls for African governments to work towards removing the barriers to homeownership especially in urban areas, where housing has been found to be quite expensive and beyond the reach of the majority of residents [18]. Addressing homeownership barriers will contribute towards SDG 11:1 that targets to ensure access for all to adequate, safe, and affordable housing and basic services and upgrade slums by 2030.

Female headship is associated with higher odds of healthy housing and this appears to contradict literature that has often associated female headship with poverty and poorer outcomes compared to male-headed households [54, 55]. The finding is supported by a World Bank study [18] that found that female-headed households in SSA had not been left behind in the region's reduction in poverty, but rather contributed to the observed trend. Other studies have found that female heads tend to allocate resources at their disposal towards improving their household's wellbeing, [56] and this is also expected to extend to housing. The extent to which the outcome in this analysis is valid may represent the perspective that people are poor and become poor not because they are male or female, but because they are subjected to socioeconomic and political processes that deprive them of access to material conditions of existence [54, 57]. This underscores the point that programs that target only female poverty may be missing the second half of the fundamentally vulnerable group: poor men [58]. While this finding is a positive development, many communities across the region still have customary laws that rob women of individual land rights especially in patrilineal communities [59]. A review of such laws to align with existing statutory laws, in conjunction with removing other barriers to accessing quality housing would go a long way in bridging gender disparities in access to healthy housing. In addition, understanding why male-headed households appear to lag behind in access to healthy housing would inform the course of action to reverse this trend and bring both genders at par.

Large household size and presence of children younger than 5 years were associated with reduced odds of healthy housing in all countries where these variables achieved statistical significance except in Tanzania where there were increased odds with larger households. The reduced odds of healthy housing in households with children younger than 5 years has implications for the health of these children but also speaks to the economic disadvantage associated with having many children in quick succession. Previous studies have identified the size of households and number of children as a good proxy for economic dependency and in a situation of significant poverty may compound household poverty by increasing both the vulnerability to chronic poverty and lesser prospects of moving out of poverty [60, 61]. This is especially intuitive for the number of under-5 children following the need for child care and related expenditures among children of that age [62].

In conclusion, beyond the contribution to the measurement of healthy housing in Africa, our paper highlights key policy and program issues that need further interrogation, policy, and program interventions in the search for pathways to addressing the healthy housing deficit that remains high across most sub-Saharan countries, especially in urban areas of the largest countries. This focus becomes critical amid the COVID-19 pandemic where access to healthy housing has become very pivotal in its control as many people are confined or compelled to work from home. Notably, the basic source of data used in this study is the DHS project (demographic and health surveys). This is an advantage because it is undoubtedly the only available, consistent set of data for several countries. At the same time, it limits the project to the DHS system limits and structure. A second limitation is the fact that the analysis is based on 1-year data only. An analysis of the healthy housing index over several years would give an indication of the definition of the present and future housing policy. Further, the inclusion of measures of cleanliness, presence/absence of pests, and thermal controls will enrich the index, a worthwhile goal, which remains hindered following the dearth of comparable data across African countries.

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Author Contributions All authors conceptualized the study. SI developed the index and conducted the data analysis, HG and KM conducted the literature review, KM and SI drafted the manuscript, and the authors reviewed and approved the final manuscript.

Appendix A: Recoding of Variables

Tables 10, 11, 12, 13, 14, 15, 16, 17

Table 10 Source of drinking/non-drinking water

Classification	Code	Levels
Unimproved source	1	Bicycle with jerrycans, cart with small tank, other, river etc., tanker truck, unprotected spring, unprotected well, river/dam/lake/ponds/stream/canal/irrigation channel
Unpiped improved source	2	Protected spring, protected well, tube well or borehole
Slightly improved source	3	Bottled water, rainwater, sachet water
Piped improved source	4	Piped from the neighbor, piped into dwelling, piped to neighbor, piped to yard/plot, public tap/standpipe

Table 11 Type of toilet facility

Classification	Code	Levels
No/unimproved facility	1	Bucket toilet, hanging toilet/latrine, no facility/bush/field, other
Unimproved pit latrine	2	Pit latrine without slab non-washable, pit latrine without slab/open pit, pit latrine without ventilation pipe
Improved pit/composting toilet	3	Chemical toilet, composting toilet, pit latrine with slab, pit latrine with ventilation pipe but no gauze/mesh, Ventilated Improved Pit latrine (VIP), ventilated improved pit latrine (vip)
Flush toilet	4	Composting toilet/ECOSAN, flush to piped sewer system, flush to pit latrine, flush to septic tank, flush to somewhere else, flush, don't know where

Table 12 Floor

Classification	Code	Levels
Natural floor	1	Dung, Earth/sand, Earth, sand, Earth/sand, Earth/sand, mud/clay, other
Rudimentary floor	2	Palm/bamboo, palm, bamboo, palm, bamboo, leeds, palm/bamboo, palm/bamboo, wood planks
Low-quality finished floor	3	Bricks, carpet, stones, woolen carpets/synthetic carpet
High-quality finished floor	4	Cement, cement screed, ceramic tiles, ceramic/marble/porcelain tiles/terrazzo, ceramic/terrazzo tiles, concrete, laminated or polished wood, linoleum/rubber carpet, parquet or polished wood, parquet, polished wood, vinyl or asphalt strips, vinyl, asphalt strips

Table 13 Wall

Classification	Code	Levels
Natural wall	1	Adobe not covered/bamboo/wood with mud, bamboo/pole with mud, bamboo with mud, bamboo with mud/clay/dung, cane/palm/trunks, cane/palm/trunks, cardboard, cane/palm/trunks/bamboo, dirt, dirt/mud, dung / mud / sod, grass, no walls, mud, thatched/straw, other, other, plastic, plywood, pole with mud, poles with mud, reused wood, sticks with mud/clay/dung, stone with mud, thatched/straw, unburnt bricks with mud, uncovered adobe, wattle and daub
Rudimentary wall	2	Sun-dried bricks/mud bricks, tin, sun-dried bricks/mud bricks
Low-quality finished wall	3	Corrugated iron/zinc, iron sheets, mud with cement mix
High-quality finished wall	4	Adobe covered, baked bricks, bricks, burnt bricks with cement, burnt bricks with mud, cement, cement block/concrete, cement blocks, cement/concrete, cement blocks/cement stones, cement/concrete, covered adobe, stone with lime/cement, stone with lime/cement, unburnt bricks with cement, unburnt bricks with plaster, wood, wood planks, wood planks / shingles, wood planks/shingles, wood, timber

Table 14 Roof

Classification	Code	Levels
Natural roof	1	Cardboard, dung/mud/sod, grass/thatch/palm leaf, lump of earth, mud, mud tiles, mud with cement mix, mud/sod, no roof, other, other, palm/bamboo, palm/bamboo, palm/bamboo, plastic, plastic/pvc, rustic mat, sod, sticks with mud and dung, straw, tarpaulin, thatch/grass/makuti, thatch/palm leaf, thatch/mud, thatch/palm leaf, thatch/palm leaf/grass, thatch/palm/leaf, thatching/grass, wattle and daub, grass/thatch/palm leaf
Rudimentary roof	2	Bricks, tin, tin cans, tins, wood planks
Low-quality finished roof	3	Corrugated iron sheet, corrugated iron/zinc, iron sheets, metal, metal/iron sheets, metal/corrugated iron, metal/zinc
High-quality finished roof	4	Asbestos, asbestos sheet, asbestos/slate roofing sheets, calamine/cement fiber, calamine/cement fiber (asbestos), calamine/cement fiber, cement, ceramic tiles, ceramic tiles/harvey tiles, ceramic/brick tiles, concrete, roofing shingles, shingles, slate, tiles, tiles/slate, wood, zinc/cement fiber

Table 15 Cooking fuel

Classification	Code	Levels
Unprocessed biomass fuel	1	Agricultural crop, animal dung, other, straw/shrubs/grass
Charcoal/coal/kerosene	2	Kerosene, kerosene/paraffin, paraffin/kerosene, wood, charcoal, coal, lignite
Natural gas/lpg/biogas	3	Biogas, bottled gas, LPG, natural gas, LPG
Electricity	4	Electricity, electricity from generator, electricity from other source, solar energy, solar power
Clean	5	No food cooked in house

Table 16 Frequency of smoking

Classification	Code
Daily	1
Weekly	2
Less than monthly	3
Monthly	4
Never	5

Table 17 Factor loadings

Country	Factor loadings for each variable							
Toilet	**Floor**	**Wall**	**Roof**	**Water source**	**Cook fuel**	**Electricity**		Frequency smoking
Burkina Faso (2010)	0.722	0.693	0.563	0.611	0.559	0.219	0.650	−0.211
Cameroon (2011)	0.697	0.785	0.601	0.598	0.598	0.322	0.789	-
Democratic Republic of Congo (2013–2014)	0.406	0.853	0.747	0.741	0.615	0.284	0.752	−0.141
Ethiopia (2016)	0.700	0.832	0.556	0.526	0.585	0.504	0.832	−0.151
Ghana (2014)	0.563	0.367	0.678	0.456	0.209	0.314	0.662	−0.203
Kenya (2014)	0.697	0.844	0.774	0.526	0.433	0.285	0.696	-
Malawi (2015–2016)	0.319	0.849	0.351	0.691	0.435	0.269	0.648	−0.117
Mali (2012–2013)	0.561	0.715	0.772	0.561	0.579	0.229	0.736	−0.120
Namibia (2013)	0.833	0.709	0.630	0.607	0.460	0.799	0.811	−0.132
Nigeria (2018)	0.532	0.678	0.788	0.595	0.365	0.221	0.638	−0.202
Senegal (2017)	0.722	0.687	0.704	0.721	0.320	0.315	0.715	−0.232
South Africa (2016)	0.507	0.413	0.487	0.386	0.385	0.701	0.708	−0.151
Tanzania (2015–2016)	0.786	0.806	0.622	0.570	0.421	0.192	0.702	−0.147
Uganda (2016)	0.636	0.838	0.786	0.595	0.311	0.101	0.612	−0.119
Zambia (2013–2014)	0.696	0.818	0.519	0.783	0.630	0.581	0.794	−0.136

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