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Child undernutrition and its association with household environmental conditions in Bangladesh

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Declarations

Abbreviations: LMICs, Low- and Middle-Income Countries; SDG, Sustainable Development Goal; UNICEF, United Nations International Children's Emergency Fund; WHO, World Health Organization; HAP, Household Air Pollution; ARI, Acute Respiratory Infections; WASH, Water, Sanitation and Hygiene; HEC, Household Environmental Condition CIAF, Composite Index of Anthropometric Failure; DHS, Demographic Health Survey; BDHS, Bangladesh Demographic Health Survey; NIPORT, National Institute of Population Research and Training; MoHFW, Ministry of Health and Family Welfare; EA, Enumeration Area; PSU, Primary Sampling Unit; RR, Risk Ratio; OR, Odds Ratio; CI, Confidence Interval; GLM, Generalized Linear Model.

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Data availability: Data associated in this study is freely available in https://dhsprogram.com/

Ethics approval and consent to participate: The study data were sourced from the MEASURE DHS Archive, initially gathered by Macro in Calverton, USA. The data collection procedure received approval from the ORC Macro Institutional Review Board. Prior to enrolment, informed consent was obtained from all participants.

Availability of data and materials: The dataset can download after registering with the MEASURE DHS at: http://dhsprogram.com/data/Using-DataSets-for-Analysis.cfm.

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Abstract

Objectives: Child undernutrition among under 5 aged children is a prevalent global issue, especially in Bangladesh. This study aimed to explore relationships of household environmental conditions (HECs) with child under-nutrition in Bangladesh, with a specific focus on rural-urban differences.

Design: We analysed children's data from the 2017/18 Bangladesh Demographic Health Survey (BDHS). The outcome variable considered were measures of child under-nutrition, including stunting, wasting, and underweight. The major exposure variable considered was indicators of HECs. We used a hierarchical Poisson regression model to explore the association between outcomes and exposures adjusted for potential confounders.

Setting: Nationally representative cross-sectional survey.

Participants: 8,057 under-5 aged children.

Results: The prevalence of stunting, wasting and underweight in Bangladesh was 31%, 8% and 22%, respectively, with significant urban-rural variations. Under-5 children who lived in houses constructed with unimproved materials (aRR: 1.17), exposed to household air pollution (HAP) (aPR: 1.37), had unimproved drinking water sources (aPR: 1.28), or had poor handwashing facilities (aPR: 1.24) had a greater likelihood of stunting compared to their counterparts. Similar associations were observed for underweight. The likelihood of stunting and underweight increased with increasing scores of poor HECs, varying significantly across urban-rural areas.

Conclusion: The high prevalence of stunting and underweight in Bangladesh is linked to poor HECs. Therefore, policies and programs aimed at reducing child undernutrition need to account for household environmental conditions, with a particular focus on children in poor household environments.

Keywords: Child undernutrition; Child malnutrition; Housing condition; Household environment; Under-5 children; Bangladesh.

Introduction

Child undernutrition remains a persistent global health concern, significantly affecting millions of children worldwide. It manifests in different forms, such as stunted growth, acute wasting and underweight. The global estimate indicates 148.1 million under-5 children experienced stunted growth and 45 million suffered from acute wasting in 2022 [(1)]. A significant share of this burden falls on low- and middle-income countries (LMICs) [(2, 3)], particularly in South Asia, where the prevalence of stunting and wasting is very high; 31.4% and 14.8% among under-5 children, respectively [(1)]. The outcomes of child undernutrition are multifaceted, including severe health risks, hindered cognitive and physical growth and the perpetuation of intergenerational malnutrition cycles [(4, 5)]. Undernutrition contributes to 45% of global under-5 deaths, although this burden is not evenly distributed, with a significant portion occurring in LMICs [(6)]. In response to this ongoing challenge, the Sustainable Development Goal (SDG) 2.2 has set the ambitious target of eliminating under-5 stunting and wasting by 2030 [(1-3)].

In LMICs, child undernutrition emerges from a complex interplay of factors, including socio-economic conditions, maternal nutritional status, children's age, birth weight, birth order and family size [(7, 8)]. It is also influenced by inadequate access to nutritious food, poor breastfeeding, dietary and caregiving practices [(9, 10)], parents' inadequate knowledge about healthy rearing of children [(9, 11)] and compromised healthcare [(12)]. In light of these multifaceted determinants, reducing child undernutrition, i.e., stunting, wasting and underweight, in LMICs requires a holistic approach that not only addresses these known factors but also delves into the less explored aspects of this challenge.

The effect of poor housing and its environment on child nutrition receives inadequate focus. The household environment is defined by specific quality indicators within a dwelling, including factors such as the availability of water, sanitation, and hygiene (WASH), the construction materials of the house, and the presence of potential pollutants [(13, 14)]. An estimated 494 million people worldwide still practice open defecation [(15)] and 2 billion rely on unsafe drinking water [(16)], with these statistics being particularly pronounced in LMICs like Sub-Saharan Africa and South Asia [(15, 16)]. Besides, three in ten people globally lack proper handwashing facilities [(17)]. In South Asia, two in five people lack proper handwashing facilities [(17)]. Around 2.4 billion people, mainly in LMICs, still use solid fuels for cooking, and the percentage is much higher in rural areas (52%) compared to urban areas (14%) [(18)].

All these indicators set a benchmark of poor household environmental conditions (HEC) that amplify the risks of diseases like diarrhoea, tuberculosis, and acute respiratory infections (ARI) that may cause death and hinder the healthy growth of the children [19, 20]. These factors often intertwine, forming a complex network of influences that leads to severe child undernutrition and adverse health outcomes [7, 9, 11].

Bangladesh, similar to many other LMICs, faces a higher burden of child undernutrition. Recent statistics suggest approximately 3.9 million children experience stunted growth and 1.4 million experience acute wasting in the country in 2022 [1]. The factors contributing to this situation in Bangladesh are similar to those found in other LMICs [7, 8, 21-25]. Besides, in terms of WASH indicators, in Bangladesh, approximately 68.3 million people lack access to safe water, 103 million lack proper sanitation, and 61.7 million lack proper hygiene [26]. Furthermore, solid fuels are used for cooking in around 80% of households, causing moderate to severe household air pollution (HAP) [27]. Unfortunately, the overall impact of these crucial indicators on child undernutrition is largely unexplored in the Bangladeshi context. Although a few studies considered some of these factors sporadically [19, 20, 28], they rarely conducted comprehensive assessments of overall household environmental quality indicators and/or did not include nationally representative data in their analyses. Also, it is crucial to acknowledge that these HEC indicators and their types, along with other factors, vary significantly across urban and rural areas of Bangladesh [29]. Yet, a significant research gap remains as to how HEC indicators individually and collectively affect child undernutrition. This study aims to investigate the relationship between HEC indicators and undernutrition among under-5 children in Bangladesh and to compare the magnitude of the associations in rural and urban areas.

Methods

Data source

In this study, we analysed cross-sectional survey data from the eighth round of the Bangladesh Demographic Health Survey (BDHS), which was conducted in 2017/18. The National Institute of Population Research and Training (NIPORT), under the Ministry of Health and Family Welfare (MoHFW), conducts this nationally representative survey every three years. The survey aimed to provide information on the sociodemographic, health, and nutritional aspects of women, infants, and children [27]. The BDHS 2017/18 used a multistage random sampling technique to collect nationally representative data. In the initial stage, 675 clusters or enumeration areas (EAs) were randomly selected, consisting of 250 urban and 425 rural areas; however, after excluding three EAs due to floods, a total of 672 EAs were finally chosen. These EAs, taken from the list of 293,579 EAs listed in the 2011 National Population Census, typically represent city blocks or villages, with around 120 households on average. In the second stage, 30 households were randomly selected from each EAs, yielding a list of 20,160 households. The survey covered 19,457 households and identified 20,376 eligible respondents who met the following criteria: (i) ever-married women aged 15-49 years and (ii) staying in the selected households on the night preceding the survey. A total of 20,127 women were finally interviewed, with a response rate of 98.8%[27]. Additional sampling details can be found in the survey reports [27].

Study participants

Among the women interviewed in BDHS 2017/18, a total of 7,562 women gave birth to 8,759 children during the 5 years prior to the survey. We analysed the data of 8,057 under-5 children who were eligible for anthropometric measurements (**Fig. 1**). For this study, the following criteria were used for selecting study participants: i) Children who were under the age of 5 at the time of the survey and (ii) whose anthropometric measurements were taken.

Nutritional measurements

The BDHS collected height and weight data for under-5 children. Health technicians, both male and female, received training, including standardization exercises, to ensure measurement accuracy. Weight was measured using electronic SECA 878U scales, and height was measured using ShorrBoard® [27]. Children aged under 24 months were measured lying down (recumbent length), while older children were measured standing up using the mentioned tool [27].

Outcome variables

The primary outcome variables of this study are child stunting (low height-for-age), wasting (low weight-for-height) and underweight (low weight-for-age). Basic anthropometric measures were calculated using age, height and weight, which were then converted into Z-scores. Under-5 children were classified as stunted if their height-for-age Z-score was less than -2 standard deviations from the median of the WHO Child Growth Standards (Median - 2 SD or Median - 3 SD). Similarly, the children were classified as wasted if their determined Z-score was less than 2 standard deviations from the median of the WHO Child Growth

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Standards (Median - 2 SD or Median - 3 SD) for weight-for-height, and as underweight if their Z-score was less than 2 standard deviations from the median of the WHO Child Growth Standards (Median - 2 SD or Median - 3 SD) for weight-for-age [30].

As a secondary outcome of the study, the Composite Index of Anthropometric Failure (CIAF) was used to summarize multiple indicators of child nutritional status. It combines measures of stunting, wasting, and underweight into a single index [22, 31]. We further categorized them into seven groups, each representing a specific combination of nutritional failures, such as no failure, wasted only, stunted only, underweight only, wasted with underweight, stunted with underweight, and stunted, wasted and underweight. The details can be found in the **supplementary Table 1**.

Exposure variables

The main exposure variables in our analysis were the HEC indicators, comprising WASH indicators, use of solid fuel for cooking and materials used for building the house. WASH indicators are essential metrics used in water, sanitation, and hygiene programs and include household members' access to clean drinking water, improved sanitation facilities and proper hygiene practices [27, 32]. Respondents were classified as unexposed to HAP if they used clean fuels, such as LPG or biogas, for cooking; moderately exposed if they used solid fuels for cooking in a separate building or outdoors; and highly exposed if they used solid fuels for cooking inside their homes. This classification was based on prior research conducted in LMICs [33-36]. The term "housing material" refers to the building materials utilized in constructing the roofs, floors, and walls of houses. The rationale for such inclusion is that in the Bangladeshi context, none of the literature considered the overall HEC, and the selection of HEC indicators was based on previous literature available for LMICs [13, 14]. Their operational definitions and categorizations are detailed in **Supplementary Table 1**.

Calculation of poor HEC score

A HEC score was computed to evaluate the overall quality of the household environment, serving as another primary exposure variable in this study. This score was derived using participants' responses to questions on house-building materials (natural or rudimentary materials), HAP from cooking, water sources, safe drinking water, sanitation and handwashing facilities. Each category adds to the overall score by assigning a value of 1 for each indicator of poor HEC. These individual values were then added together to create a

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composite index, resulting in a poor household environment score ranging from 0 to 6 for each household [37]. For instance, if a household had three poor HEC characteristics, it received a score of 3. A higher score signifies that the environment of that household was worse compared to households with lower scores. The calculation of poor HEC score was based on existing literature [37] and it allowed us to measure how the effect size changes with each incremental increase in the score in terms of poor HEC indicators.

Other variables/covariates

Other variables included in this study were identified through literature searches and identified based on existing evidence from LMICs and Bangladesh [7, 8, 21, 22, 24, 25, 31]. The covariates we included were child's age (continuous), child's sex (male or female), religion (Muslim or non-Muslim), sex of the household head (male or female), education level of the child's mother (no formal education, primary, secondary or higher), education level of the child's father (no formal education, primary, secondary or higher), employment status of the child's mother (unemployed or employed), household size (1-5 members, 6-10 members or 10+ members), place of residence (urban or rural) and administrative divisions (Barishal, Chattogram, Dhaka, Mymensingh, Khulna, Rajshahi, Rangpur or Sylhet).

Statistical analysis

We used descriptive statistics to estimate the prevalence of stunting, wasting and underweight, as well as the distribution of HEC indicators for the entire study population and among rural-urban sub-groups. Subsequently, we employed bivariate analysis to observe the distribution of child undernutrition indicators across HEC indicators and other covariates. The statistical significance of the bivariate analysis was assessed using the Pearson chi-square test. Multilevel mixed-effect generalized linear models (GLM) modified with a Poisson regression approach were used to examine the association between HEC indicators and different types of undernutrition among under-5 children. The rationale for choosing multilevel regression was to account for the hierarchical structure of the BDHS data, where children are nested within households (level 1) and households are nested within clusters (level 2), and to address the high prevalence of the outcome variable (>10%). Previous studies have found that ordinary logistic regression produces less precise results under these conditions and recommend multilevel modelling [38, 39]. We therefore ran two levels of multilevel modelling (household and cluster) separately for each outcome variable. Each model was run separately, with adjustments made for covariates, and the models estimated

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prevalence ratios (PRs) to assess the strength of the associations after assessing multicollinearity. Additionally, in order to examine the impact of HEC indicators on anthropometric failure, a multilevel mixed-effect multinomial logistic regression was used. This was done after adjusting for covariates, allowing for a direct assessment of risk ratios (RRs). We excluded the wealth quintile from the adjusted variables since it was calculated using household characteristics and other assets. Its inclusion caused multicollinearity with HEC indicators in the model. All analyses took into consideration the complex survey design and sampling weights. Results were reported with a 95% confidence interval and a significance level of $p<0.05$. The data were analysed using the statistical programme STATA, version 15.1 (Release 15; College Station, TX: Stata Corp LLC).

Result

Background characteristics

The study analysed the data of 8,057 under-5 children of whom 52.2% were male, 91.9% were Muslim, and 86.6% belonged to male-headed households. Most of the mothers had a primary (28.8%) or secondary level of education (48.4%). The majority of children came from poor households (41.8%), and 40.1% were from households with 6-10 members. The sample comprised 72.5% rural residents, with the highest proportions in Dhaka (25.8%) and Chattogram division (20.8%) **(Supplementary Table 2).**

HEC indicators

Table 1 presents the results of the descriptive analysis. Most households had finished roofs (98.9%), walls (87.2%), and floors constructed with natural or rudimentary materials (63.8%). Approximately 78.0% had moderate exposure to HAP from cooking, 98.4% had improved drinking water sources, and 89.9% lacked proper water treatment facilities. Around 55.0% and 61.0% lacked proper sanitation and handwashing, respectively, and over a third (33.2%) had ≥5 poor HEC characteristics **(Table 1).**

Prevalence of child undernutrition

As presented in Table 2, the prevalence of stunting, wasting and underweight among under-5 children were 30.7%, 8.4% and 21.8%, respectively. Rural-urban differences were evident, with higher rates of stunting (32.7% in rural vs. 25.3% in urban) and underweight

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(22.8% rural vs. 19.1% urban) in rural areas **(Table 2)**. Geographically, child undernutrition indicators were most prevalent in the Sylhet division (52.0%), while the Mymensingh (49.1%) and Barishal (42.5%) divisions had the highest percentages of households with poor environmental quality **(Supplementary Table 3)**.

Distribution of child undernutrition across HEC indicators

Table 3 presents bivariate associations between HEC indicators and undernutrition among under-5 children. There was a significant association between stunting and children living in households made of unimproved materials (35.5%), exposed to HAP from cooking (45.4%), with inadequate water treatment facilities (31.6%), that lacked proper sanitation (34.8%), and handwashing facilities (35.3%). There was a similar pattern of associations for underweight children. The prevalence of stunting and underweight gradually increases with the number of poor HEC characteristics of a household **(Table 3)**.

Association between HEC indicators and child undernutrition

Table 4 presents how the HEC indicators are strongly associated with stunting and underweight in under-5 children. A higher likelihood of stunting was found among under-5 children who lived in households constructed with unimproved materials (aPR: 1.17, 95% CI: 1.04-1.32), moderate (aPR: 1.16, 95% CI: 1.00-1.35) or high HAP exposure from cooking (aPR: 1.37, 95% CI: 1.01-1.70), unimproved drinking water source (aPR: 1.28, 95% CI: 1.04-1.59), and poor hand washing facilities (aPR: 1.24, 95% CI: 1.13-1.37), compared to their counterparts. Likewise, under-5 children who lived in households constructed with unimproved materials (aPR: 1.17, 95% CI: 1.02-1.35), lacked proper facilities for drinking water treatment (aPR: 1.21, 95% CI: 1.01-1.45), with poor sanitation facilities (aPR: 1.16, 95% CI: 1.06-1.30), or poor hand washing facilities (aPR: 1.18, 95% CI: 1.05-1.33) were more likely to experience under-5 underweight compared to those who did not. **(Table 4)**.

There is an incremental relationship between HEC scores and the likelihood of children being stunted and underweight **(Table 4)**. For instance, children under 5 in households with 1 to 5 or more poor HEC characteristics were 1.83 to 2.44 times likely to be stunted. Similarly, compared to children living in houses with no poor HEC, those who were living in houses with 1, 2, 3, 4 and 5 poor HEC were 1.44, 1.54, 1.90, 1.79 and 2.12 times likely to be underweight, respectively **(Table 4)**.

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Urban-rural difference in the association between HEC indicators and child undernutrition

Table 5 presents urban-rural differences in the association of HEC indicators with under-5 stunting and underweight. In urban areas, only households lacking proper drinking water treatment (aPR: 1.36, 95% CI: 1.04-1.78) and having inadequate handwashing facilities (aPR: 1.39, 95% CI: 1.16-1.65) had higher likelihoods of stunted children. Conversely, in rural settings, households constructed with unimproved materials (aPR: 1.36, 95% CI: 1.16-1.58), exposed to high HAP from cooking (aPR: 1.52, 95% CI: 1.07-2.16), poor sanitation (aPR: 1.16, 95% CI: 1.05-1.28), and with poor handwashing facilities (aPR: 1.29, 95% CI: 1.16-1.44) demonstrated higher likelihoods compared to their counterparts. In urban areas, there were significant associations between underweight and under-5 children living in households constructed with unimproved materials (aPR: 1.22, 95% CI: 1.02-1.48), exposed to moderate (aPR: 1.27, 95% CI: 1.02-1.57) and highly exposed to HAP from cooking (aPR: 2.12, 95% CI: 1.02-4.37), lack of proper drinking water treatment facility (aPR: 1.43, 95% CI: 1.13-1.83), and inadequate handwashing facility (aPR: 1.38, 95% CI: 1.12-1.69). On the contrary, in rural areas, the likelihood of underweight significantly increased among under-5 children residing in households constructed with unimproved materials (aPR: 1.23, 95% CI: 1.04-1.46), those with poor sanitation facilities (aPR: 1.25, 95% CI: 1.10-1.41), and inadequate handwashing facilities (aPR: 1.17, 95% CI: 1.02-1.33), when compared to their counterparts.

As the number of poor HEC characteristics increases, the likelihood of stunting and underweight also increases gradually. There were substantial urban-rural differences in the effect-size of their association with child undernutrition. For instance, the effect size of stunting in urban households with 5 or more poor HEC characteristics was 1.87 (95% CI: 1.12-2.83) and in rural areas it was 8.11 (1.20-54.77). Similarly, poor HEC scores demonstrated a gradual rise in the likelihood of under-5 underweight in urban areas, whereas no significant associations were observed in rural areas. **(Table 5)**

Association between HEC scores and anthropometric failure

Table 6 presents the association between under-5 children's anthropometric failure index and HEC score, adjusted for household socio-demographic traits. Multinomial analysis indicated that the chances of Failure C (stunted only) rose gradually from 3.21 (95% CI: 1.69-6.09) to 4.10 (95% CI: 2.19-7.66) with an increase in poor HEC characteristics from 1 to

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5 compared to its counterpart. Similarly, the chance of Failure E (wasted with underweight) among under-5 children increased from 4.54 (95% CI: 1.17-17.58) to 5.78 (95% CI: 1.46-22.99) with 3 to 5 poor HEC characteristics. A similar trend was observed for Failure F (stunted with underweight). The likelihood of Failure G (stunted, wasted, and underweight) was 3.66 (95% CI: 1.04-12.93) times higher with 5 or more poor HEC characteristics compared to their counterparts. **(Table 6)**.

Discussion

This study explored the relationship between undernutrition in children under 5 and HEC indicators. In Bangladesh, approximately 30.7% of children experienced stunting, 8.4% suffered from wasting, and 21.8% were underweight. Furthermore, significant disparities between urban and rural areas were observed among stunted and underweight children. Around one-third of the total households analysed reported presence of five or more poor HECs among the eight indicators considered. We found increased likelihood of stunting among children living in houses built with unimproved materials, highly exposed to HAP from cooking, with unimproved drinking water sources, and with inadequate handwashing facilities. Similarly, children residing in houses constructed with unimproved materials, utilizing unsafe drinking water, and lacking proper sanitation and handwashing facilities were also linked to underweight conditions. The likelihood of stunting and underweight increased gradually as the HEC score increased, and the results highlighted substantial urban-rural differences in the association with child undernutrition. Compared to children in rural areas, those who were living in urban areas had higher likelihoods of being underweight with poor HEC scores.

We reported that one in every three households in Bangladesh has five or more HECs out of the eight indicators considered, which cover various domains such as household roof, walls, floor, cooking fuels, and sanitation facilities. While the score we generated aligns with previous literature on LMICs, we were unable to validate our findings with existing evidence in Bangladesh due to a lack of relevant studies. Following prior literature, we classified each indicator as either poor or good, though there may be intermediate conditions that we could not account for. Such binary classification may lead to conflicting estimates of HECs, with a risk of over- or under-estimation. Although these issues are likely random, they could affect the associations reported in this study. Addressing this limitation would require surveys with

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sufficient variables to classify HECs across more nuanced levels, which are currently lacking. Therefore, the findings of this study should be interpreted with this limitation in mind.

In the LMIC context, living in houses constructed with poor housing materials, and exposure to HAP are widely known global risks of under-5 stunting and aligns greatly with our findings [33, 40, 41]. Conversely, child underweight is associated with living in houses constructed with poor housing materials but not with HAP exposure. Poor housing conditions are characterized by low-quality roofs, walls, floors and inadequate insulation and ventilation, thereby exposing children to extreme temperatures and pollutants [33, 41, 42]. Besides, HAP, which often stems from the use of solid fuels such as wood or biomass for cooking and heating, emits harmful particulate matter and toxic gases that pollute households' indoor environments [19]. These heighten the vulnerability to infections, especially ARIs [19], subsequently contributing to severe chronic undernutrition [33, 41, 43]. Similarly, other poor HEC indicators, i.e., poor-quality drinking water, inadequate sanitation, and insufficient handwashing facilities, also play a significant role in contributing to underweight or stunted growth in under-5 children in the context of LMICs, which strongly supports our findings as well [20, 44-46]. These conditions are well-established as contributors to waterborne diseases and infections [7, 20, 45, 47], promote pathogen transmission, causing inflammation, disrupting nutrient absorption, and ultimately hindering children's growth and nutrition [7, 20, 45, 47].

We found no significant association between wasting and HECs. The underlying reasons for this, despite the significant associations of stunting and underweight with HECs, are unknown and require further exploration. However, this might be linked to the government's focus on reducing child undernutrition through several programs, with wasting often receiving priority due to its ease of detection and growing community concern. Additionally, methodological issues may have contributed to the lack of a significant association. Wasting is a measure of acute malnutrition and usually indicates recent and severe weight loss because a person has not had sufficient food intake and/or has had an infectious disease, such as diarrhea, resulting in rapid weight loss [6]. However, our results suggest that the detrimental effects of HECs primarily manifest over a long period of time, impacting the growth and development of children with little or no immediate effect on their short-term nutritional status. The lack of relevant data on the duration that the households maintained improved conditions may also explain the insignificant association we found, for

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instance, between the use of unimproved sources of drinking water and wasting. However, our results are consistent with that in the existing literature [44, 46].

The study revealed a dose-response relationship between HEC scores and the likelihood of child undernutrition such as stunting and underweight. While each HEC indicators independently contribute to child undernutrition, their combined impact is expected to be amplified. For instance, a child living in a household with poor sanitation facilities might already face an increased likelihood of stunting and underweight due to the potential exposure to diseases and inadequate nutrient absorption. If this household also lacks proper ventilation, highly exposed to HAP produced from the use of solid fuels and has substandard water sources, the combined impact of these factors is likely to be greater than the impact of individual HEC factors.

The underlying reasons for d that child undernutrition varied between rural and urban areas. There may be different underlying reasons for these differences. In urban settings, high population density often restricts the access to clean water and increases the risk of diseases that impede child growth [48, 49]. Besides, in rural areas, low-quality housing, HAP exposure, and poor water and sanitation increase waterborne diseases and respiratory issues, results in to increased prevalence of stunting [28, 47]. A range of factors, including poor socioeconomic conditions, poor maternal health and nutrition, frequent illness, and/or inappropriate feeding and inadequate care in early life, are likely to cause child undernutrition, apart from genetic factors, if there are any. In rural areas, these unfavourable social determinants of health are also prevalent. It is possible that the effect of relatively poor HEC aggravates undernutrition, especially stunting, caused by the unfavourable social determinants of health. Further research is recommended to examine this association.

The study has several strengths and limitations that should be taken into account while interpreting the results. Firstly, the use of a hierarchical model allowed us to account for potential clustering effects within urban and rural settings, enhancing the robustness of our results. The utilization of a large and diverse sample from both urban and rural areas enhanced the generalisability of our findings. The use of nationally representative data on HEC and child nutritional status increased the reliability and validity of our analysis. By focusing on urban-rural disparities, our study shed light on variations that might have important policy implications. Lastly, the HEC composite scoring helped to critically illustrate and understand the associations. However, the study also has several limitations.

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The cross-sectional nature of BDHS data hampers establishing causality, and reliance on self-reported variables may have introduced recall and social desirability biases. While constructing the HEC variables and scores, we were unable to cover all aspects of housing quality, such as ventilation, insulation, heating/cooling facilities, and tenure security. Additionally, the data allowed us to classify the indicators as either poor or good, though there may be intermediate conditions that we were unable to account for. Moreover, using equal weighting to all components in constructing HEC score is a potential limitation of our analysis. Another limitation of BDHS nutritional measurements for children is their reliance on anthropometric data, which may not capture all aspects of nutritional health, such as micronutrient deficiencies or dietary quality and can also be influenced by measurement errors. The lack of dietary data limits our ability to fully explore how household environments impact overall nutritional status. Future research should include comprehensive dietary assessments to better understand and address the multifaceted nature of undernutrition in Bangladesh.

Conclusion

The prevalence of stunting, wasting, and underweight among under-5 children is relatively high in Bangladesh, with variations observed across urban and rural areas. The study highlights the critical role of HEC indicators, exposure to HAP from cooking, access to safe potable water sources, and handwashing facilities in influencing the nutritional status of children. To address these challenges and reduce the burden of malnutrition, there is a need for improved housing infrastructure, reduced HAP, access to clean water and proper handwashing facilities across the countries and especially in rural areas. Bangladesh has made significant progress in improving its water, sanitation, and hygiene sectors in recent years. Thus, while ensuring improved housing materials may be a distant goal, augmenting the ongoing programmes of access to clean water and sanitation should be an achievable goal.

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References

1. World Health Organization (2023) Levels and trends in child malnutrition: UNICEF/WHO/World Bank Group joint child malnutrition estimates: key findings of the 2023 edition. In *Levels and trends in child malnutrition: UNICEF/WHO/World Bank Group joint child malnutrition estimates: key findings of the 2023 edition*.
2. UNICEF (2021) *Southeast Asia Regional Report on Maternal Nutrition and Complementary Feeding*. Bangkok, Thailand: UNICEF East Asia and Pacific Region.
3. UNICEF (2023) Chlid Malnutrition: Stunting has declined steadily since 2000 – but faster progress is needed to reach the 2030 target. Wasting persists at alarming rates and overweight will require a reversal in trajectory if the 2030 target is to be achieved. https://data.unicef.org/topic/nutrition/malnutrition/ (accessed 17 June 2023)
4. De Sanctis V, Soliman A, Alaaraj N *et al.* (2021) Early and Long-term Consequences of Nutritional Stunting: From Childhood to Adulthood. *Acta Biomed* 92, e2021168.
5. Swaminathan S, Hemalatha R, Pandey A *et al.* (2019) The burden of child and maternal malnutrition and trends in its indicators in the states of India: the Global Burden of Disease Study 1990–2017. *The Lancet Child & Adolescent Health* 3, 855-870.
6. World Health Organization (2021) Fact sheet: Malnutrition. https://www.who.int/news-room/fact-sheets/detail/malnutrition (accessed 17 June 2023)
7. Katoch OR (2022) Determinants of malnutrition among children: A systematic review. *Nutrition* 96, 111565.
8. Chowdhury MRK, Rahman MS, Billah B *et al.* (2023) Prevalence and factors associated with severe undernutrition among under-5 children in Bangladesh, Pakistan, and Nepal: a comparative study using multilevel analysis. *Scientific Reports* 13, 10183.
9. Clarke P, Zuma MK, Tambe AB *et al.* Caregivers' Knowledge and Food Accessibility Contributes to Childhood Malnutrition: A Case Study of Dora Nginza Hospital, South Africa. *International Journal of Environmental Research and Public Health*. doi: 10.3390/ijerph182010691.
10. Megersa B, Haile A Kitron U (2021) Effects of dietary and health factors on nutritional status of children in pastoral settings in Borana, southern Ethiopia, August–October 2015. *Archives of Public Health* 79, 169.

https://doi.org/10.1017/S1368980024002325 Published online by Cambridge University Press

11. Forh G, Apprey C Frimpomaa Agyapong NA (2022) Nutritional knowledge and practices of mothers/caregivers and its impact on the nutritional status of children 6–59 months in Sefwi Wiawso Municipality, Western-North Region, Ghana. *Heliyon* 8, e12330.
12. Elhady GW, Ibrahim Sk, Abbas ES *et al.* (2023) Barriers to adequate nutrition care for child malnutrition in a low-resource setting: Perspectives of health care providers. *Frontiers in Public Health* 11.
13. Morakinyo OM, Adebowale AS, Obembe TA Oloruntoba EO (2020) Association between household environmental conditions and nutritional status of women of childbearing age in Nigeria. *PloS one* 15, e0243356.
14. Husseini M, Darboe MK, Moore SE *et al.* (2018) Thresholds of socio-economic and environmental conditions necessary to escape from childhood malnutrition: a natural experiment in rural Gambia. *BMC Med* 16, 199.
15. World Health Organization (2021) *Progress on household drinking water, sanitation and hygiene 2000-2020: five years into the SDGs*. no. 9240030840. Geneva, Switzerland: World Health Organization.
16. World Health Organization (WHO) (2022) Key Facts: Drinking Water. https://www.who.int/news-room/fact-sheets/detail/drinking-water (accessed 25 June 2023)
17. Anowar (2021) The Financial Express Bangladesh: Drinking water and sanitation facilities in rural Bangladesh.
18. World Health Organization (WHO) (2022) Key facts: Household air pollution.
19. Raju S, Siddharthan T McCormack MC (2020) Indoor Air Pollution and Respiratory Health. *Clinics in chest medicine* 41, 825-843.
20. Shrestha A, Six J, Dahal D *et al.* (2020) Association of nutrition, water, sanitation and hygiene practices with children’s nutritional status, intestinal parasitic infections and diarrhoea in rural Nepal: a cross-sectional study. *BMC Public Health* 20, 1241.
21. Das S & Gulshan J (2017) Different forms of malnutrition among under five children in Bangladesh: A cross sectional study on prevalence and determinants. *BMC Nutrition* 3.
22. Islam MS & Biswas T (2020) Prevalence and correlates of the composite index of anthropometric failure among children under 5 years old in Bangladesh. *Maternal & Child Nutrition* 16, e12930.

https://doi.org/10.1017/S1368980024002325 Published online by Cambridge University Press

23. Chowdhury MRK, Khan HTA, Rashid M *et al.* (2021) Differences in risk factors associated with single and multiple concurrent forms of undernutrition (stunting, wasting or underweight) among children under 5 in Bangladesh: a nationally representative cross-sectional study. *BMJ Open* 11, e052814.
24. Chowdhury MRK, Khan HTA, Mondal MNI Kabir R (2021) Socio-demographic risk factors for severe malnutrition in children aged under five among various birth cohorts in Bangladesh. *Journal of biosocial science* 53, 590-605.
25. Chowdhury MRK, Rahman MS, Billah B *et al.* (2022) The prevalence and socio-demographic risk factors of coexistence of stunting, wasting, and underweight among children under five years in Bangladesh: a cross-sectional study. *BMC Nutr* 8, 84.
26. UNICEF (2023) Billions of people will lack access to safe water, sanitation and hygiene in 2030 unless progress quadruples – warn WHO, UNICEF. https://www.unicef.org/bangladesh/en/press-releases/billions-people-will-lack-access-safe-water-sanitation-and-hygiene-2030-unless (accessed 25 Oct 2023)
27. National Institute of Population Research and Training (NIPORT) (2020) *Bangladesh Demographic and Health Survey 2017-18*. Ministry of Health and Family Welfare, Dhaka, Bangladesh: NIPORT/ICF.
28. Ghosh S, Kabir M, Islam M *et al.* (2020) Association between water, sanitation, and hygiene practices (WASH) and anthropometric nutritional status among selected under-five children in rural Noakhali, Bangladesh: a cross-sectional analysis. *Journal of Water, Sanitation and Hygiene for Development* 11.
29. Srinivasan CS, Zanello G Shankar B (2013) Rural-urban disparities in child nutrition in Bangladesh and Nepal. *BMC Public Health* 13, 581.
30. World Health Organisation (2023) Malnutrition in children: Stunting, wasting, overweight and underweight. https://www.who.int/data/nutrition/nlis/info/malnutrition-in-children (accessed 19 Oct 2023)
31. Permatasari TAE & Chadirin Y (2022) Assessment of undernutrition using the composite index of anthropometric failure (CIAF) and its determinants: A cross-sectional study in the rural area of the Bogor District in Indonesia. *BMC Nutrition* 8, 133.

https://doi.org/10.1017/S1368980024002325 Published online by Cambridge University Press

32. Schwemlein S, Cronk R Bartram J (2016) Indicators for monitoring water, sanitation, and hygiene: a systematic review of indicator selection methods. *International journal of environmental research and public health* 13, 333.
33. Ranathunga N, Perera P, Nandasena S *et al.* (2021) Effects of indoor air pollution due to solid fuel combustion on physical growth of children under 5 in Sri Lanka: A descriptive cross sectional study. *PloS one* 16, e0252230.
34. Khan MN, B. Nurs CZ, Mofizul Islam M *et al.* (2017) Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: a nationwide population-based study. *Environmental Health* 16, 57.
35. Alam MB, Acharjee S, Mahmud SMA *et al.* (2022) Household air pollution from cooking fuels and its association with under-five mortality in Bangladesh. *Clinical Epidemiology and Global Health* 17.
36. Rana J, Islam RM, Khan MN *et al.* (2021) Association between household air pollution and child mortality in Myanmar using a multilevel mixed-effects Poisson regression with robust variance. *Scientific Reports* 11, 12983.
37. Brown C, Ravallion M van de Walle D (2023) Child health and the housing environment. *World Development* 168, 106265.
38. Khan MMA, Rahman MM, Islam MR *et al.* (2020) Suicidal behavior among school-going adolescents in Bangladesh: findings of the global school-based student health survey. *Social Psychiatry and Psychiatric Epidemiology* 55, 1491-1502.
39. Zou G (2004) A modified poisson regression approach to prospective studies with binary data. *American journal of epidemiology* 159, 702-706.
40. Tusting LS, Gething PW, Gibson HS *et al.* (2020) Housing and child health in sub-Saharan Africa: A cross-sectional analysis. *PLOS Medicine* 17, e1003055.
41. Sinharoy SS, Clasen T Martorell R (2020) Air pollution and stunting: a missing link? *The Lancet Global Health* 8, e472-e475.
42. Vardoulakis S, Dimitroulopoulou C, Thornes J *et al.* (2015) Impact of climate change on the domestic indoor environment and associated health risks in the UK. *Environment International* 85, 299-313.
43. Nasanen-Gilmore SPK, Saha S, Rasul I Rousham EK (2015) Household environment and behavioral determinants of respiratory tract infection in infants and young children in northern bangladesh. *American Journal of Human Biology* 27, 851-858.

https://doi.org/10.1017/S1368980024002325 Published online by Cambridge University Press

44. Bekele T, Rahman B Rawstorne P (2020) The effect of access to water, sanitation and handwashing facilities on child growth indicators: Evidence from the Ethiopia Demographic and Health Survey 2016. *PloS one* 15, e0239313.
45. Gizaw Z & Worku A (2019) Effects of single and combined water, sanitation and hygiene (WASH) interventions on nutritional status of children: a systematic review and meta-analysis. *Italian Journal of Pediatrics* 45, 77.
46. Sahiledengle B, Petrucka P, Kumie A *et al.* (2022) Association between water, sanitation and hygiene (WASH) and child undernutrition in Ethiopia: a hierarchical approach. *BMC Public Health* 22, 1943.
47. Tofail F, Fernald LC, Das KK *et al.* (2018) Effect of water quality, sanitation, hand washing, and nutritional interventions on child development in rural Bangladesh (WASH Benefits Bangladesh): a cluster-randomised controlled trial. *The Lancet Child & adolescent health* 2, 255-268.
48. Rosenberg P, Kano M, Ludford I *et al.* (2016) *Global report on urban health: equitable, healthier cities for sustainable development*: World Health Organization.
49. Neiderud CJ (2015) How urbanization affects the epidemiology of emerging infectious diseases. *Infect Ecol Epidemiol* 5, 27060.

https://doi.org/10.1017/S1368980024002325 Published online by Cambridge University Press

Table 1. Distribution of household environmental condition indicators of the study participants (n = 8759)

Indicators	**% (95% CI)**
Roof material	
Finished	99.0 (98.4-99.4)
Natural/rudimentary	1.0 (0.6-1.7)
Wall material	
Finished	87.2 (85.2-89.1)
Natural/rudimentary	12.8 (11.0-14.8)
Floor material	
Finished	36.2 (34-38.5)
Natural/rudimentary	63.8 (61.5-66.0)
Household air pollution from cooking	
Unexposed	20.5 (18.5-22.7)
Moderately exposed	78.3 (76.1-80.4)
Highly exposed	1.1 (0.8-1.6)
Drinking water source	
Improved	98.4 (97.4-99.0)
Unimproved	1.6 (1.0-2.6)
Drinking water treatment	
Appropriately treated	10.1 (8.7-11.6)
Inappropriate or no treatment	89.9 (88.4-91.3)
Sanitation facility	
Basic/standard sanitation	44.3 (42.4-46.2)
Poor sanitation or open defecation	55.7 (53.8-57.6)
Handwashing facilities [a]	
Standard	38.3 (36.2-40.5)
Poor	61.7 (59.5-63.8)
Poor HEC score [b]	
No poor HEC characteristics	4.4 (3.5-5.4)
1 poor HEC characteristics	7.9 (6.9-9.1)
2 poor HEC characteristics	12.6 (11.4-13.8)
3 poor HEC characteristics	17.9 (16.5-19.3)
4 poor HEC characteristics	24.1 (22.6-25.6)
5 or more poor HEC characteristics	33.2 (31.3-35.2)

Note: All are column percentages. [a] missing = 317. [b] Calculated using composite scoring. All values are weighted. HEC refers to household environmental condition

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Table 2. Prevalence of child undernutrition among under-5 children and their anthropometric failure index (n = 8,057)

Child undernutrition	**Overall, % (95% CI)**	**Urban, % (95% CI)**	**Rural, % (95% CI)**
Stunting	30.7 (29.3-32.2)	25.3 (22.8-28.1)	32.7 (31-34.4)
Wasting	8.4 (7.7-9.2)	9 (7.6-10.7)	8.2 (7.4-9.2)
Underweight	21.8 (20.6-23.1)	19.1 (17-21.4)	22.8 (21.3-24.3)
Anthropometric failure index			
Failure A: No anthropometric failure	61.7 (60.1-63.2)	66.5 (63.7-69.3)	59.9 (58.1-61.7)
Failure B: Wasted only	2.5 (2.1-2.9)	2.9 (2.2-3.9)	2.3 (1.9-2.9)
Failure C: Stunted only	14.1 (13.2-15.1)	11.5 (10.1-13.2)	15.0 (14-16.2)
Failure D: Underweight only	3 (2.6-3.5)	2.5 (1.9-3.3)	3.2 (2.7-3.7)
Failure E: Wasted with underweight	3.1 (2.7-3.5)	3.6 (2.8-4.5)	2.9 (2.4-3.4)
Failure F: Stunted with underweight	13.1 (12.2-14.1)	10.8 (9.2-12.6)	13.9 (12.8-15.1)
Failure G: Stunted, wasted and underweight	2.7 (2.3-3.1)	2.2 (1.7-2.9)	2.8 (2.4-3.4)

Note: All are column percentages. Survey weight was applied.

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Table 3. Bivariate analyses of under-5 children's stunting, wasting and underweight across household environment condition indicators.

Characteristics	Stunting (n = 7,849)		Wasting (n = 7,831)		Underweight (n = 8050)	
	% (95% CI)	p-value	% (95% CI)	p-value	% (95% CI)	p-value
Housing materials						
Improved	23.1 (20.9-25.5)	0.000	8.2 (7-9.7)	0.658	17.1 (15.3-19.2)	0.000
Unimproved	35.5 (33.8-37.4)		8.6 (7.7-9.5)		25.2 (23.6-26.8)	
Household air pollution from cooking						
Unexposed	21.9 (18.9-25.3)	0.000	8.7 (7-10.8)	0.851	16.1 (13.7-18.9)	0.000
Moderately exposed	32.7 (31.1-34.3)		8.4 (7.6-9.2)		23 (21.6-24.4)	
Highly exposed	45.4 (34.9-56.4)		7.3 (3.7-13.8)		32.1 (24.3-41.1)	
Drinking water source						
Improved	31 (29.5-32.5)	0.013	8.4 (7.7-9.2)	0.355	22.2 (20.9-23.6)	0.122
Unimproved	41.9 (33.3-51)		10.5 (6.7-16)		28.2 (20.9-36.8)	
Drinking water treatment						
Appropriately treated	22.6 (18.5-27.3)	0.001	8 (6.1-10.5)	0.691	15.9 (13.1-19.1)	0.000
Inappropriate or no treatment	31.6 (30.1-33)		8.5 (7.7-9.3)		22.4 (21.1-23.8)	
Sanitation facility						
Basic/standard sanitation	26.6 (24.7-28.6)	0.000	7.4 (6.5-8.6)	0.016	18.1 (16.7-19.7)	0.000

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Poor sanitation or open defecation	34.8 (33-36.8)		9.3 (8.3-10.4)		25.7 (23.9-27.6)	
Handwashing facility						
Standard	22.2 (20.5-24.1)	0.000	8 (6.7-9.4)	0.350	16.6 (15.1-18.3)	0.000
Poor	35.3 (33.5-37.1)		8.7 (7.9-9.7)		24.8 (23.2-26.4)	
Poor HEC score						
No household environment characteristics	9.6 (6.5-13.9)	0.000	5.4 (2.9-9.9)	0.050	8.8 (5.7-13.2)	0.000
1 poor HEC characteristics	21.0 (16.9-25.8)		8.6 (6.1-12)		14.1 (11-17.9)	
2 poor HEC characteristics	23.2 (19.8-26.9)		7.0 (5.3-9.2)		16.4 (13.6-19.6)	
3 poor HEC characteristics	28.4 (25.6-31.5)		10.4 (8.5-12.7)		22.0 (19.2-25.2)	
4 poor HEC characteristics	32.0 (29.3-34.8)		7.4 (6.1-8.8)		21.6 (19.4-23.9)	
5 or more poor HEC characteristics	38.6 (36.3-41)		9.0 (7.8-10.4)		28.1 (25.9-30.4)	

Note: All are row percentages. All results are weighted. HEC refers to household environmental condition

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Table 4. Generalised linear regressions modified with the Poisson regression examining associations of under-5 children's stunting, wasting and underweight with household environment condition indicators adjusted for household-level socio-demographic characteristics.

Characteristics	Stunting (n = 7,849)	Wasting (n = 7,831)	Underweight (n = 8050)
	Adj. PR (95% CI)	Adj. PR (95% CI)	Adj. PR (95% CI)
Housing materials			
Improved (ref)	1.00	1.00	1.00
Unimproved	1.17 (1.04-1.32)**	1.07 (0.86-1.33)	1.17 (1.02-1.35)*
Household air pollution from cooking			
Unexposed (ref)	1.00	1.00	1.00
Moderately exposed	1.16 (1.00-1.35)*	0.98 (0.73-1.32)	1.16 (0.97-1.39)
Highly exposed	1.37 (1.01-1.70)*	0.76 (0.36-1.63)	1.24 (0.91-1.71)
Drinking water source			
Improved (ref)	1.00	1.00	1.00
Unimproved	1.28 (1.04-1.59)*	1.23 (0.75-2.00)	1.16 (0.86-1.56)
Drinking water treatment			
Appropriately treated (ref)	1.00	1.00	1.00
Inappropriate or no treatment	1.10 (0.92-1.32)	1.09 (0.81-1.48)	1.21 (1.01-1.45)*
Sanitation facility			
Basic/standard sanitation (ref)	1.00	1.00	1.00
Poor sanitation or open defecation	1.07 (0.98-1.18)	1.19 (0.97-1.45)	1.16 (1.06-1.30)***
Handwashing facilities			
Standard (ref)	1.00	1.00	1.00
Poor	1.24 (1.13-1.37)***	1.03 (0.83-1.27)	1.18 (1.05-1.33)**
Poor HEC score			
No poor HEC characteristics	1.00	1.00	1.00

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(ref)			
1 poor HEC characteristics	1.83 (1.20-2.80)**	1.58 (0.8-3.10)	1.44 (0.90-2.32)
2 poor HEC characteristics	1.92 (1.26-2.93)**	1.32 (0.67-2.59)	1.54 (0.98-2.42)
3 poor HEC characteristics	2.13 (1.41-3.20)***	1.89 (0.97-3.70)	1.90 (1.23-2.94)**
4 poor HEC characteristics	2.21 (1.47-3.34)***	1.44 (0.74-2.81)	1.79 (1.15-2.79)**
5 or more poor HEC characteristics	2.44 (1.62-3.69)***	1.75 (0.89-3.43)	2.12 (1.36-3.30)***

Note: All the models were run separately for each type of household environment condition characteristics and was adjusted for child's age, child's sex, religion, sex of the household head, education level of child's mother, education level of child's father, employment status of the child's mother, household size, place of residence and administrative division. Values with superscript asterisks *, **, and *** indicate p<0.05, p<0.01, and p<0.001, respectively. (ref): Reference category, PR: prevalence ratio, CI: confidence interval; HEC refers to household environmental condition.

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Table 5. Generalised linear modified Poisson regression examining the association of under-5 children's stunting, wasting and underweight with household environment condition indicators, adjusted for household-level socio-demographic characteristics

Characteristics	Stunting (n = 7,849)		Wasting (n = 7,831)		Underweight (n = 8,050)	
	Adj. PR (95% CI)		Adj. PR (95% CI)		Adj. PR (95% CI)	
	Urban	Rural	Urban	Rural	Urban	Rural
Housing materials						
Improved (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Unimproved	1.10 (0.92-1.32)	1.36 (1.16-1.58)***	1.23 (0.85-1.78)	1.02 (0.78-1.32)	1.22 (1.02-1.48)*	1.23 (1.04-1.46)*
Household air pollution from cooking						
Unexposed (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Moderately exposed	1.19 (0.98-1.43)	1.31 (0.99-1.71)	1.04 (0.66-1.62)	1.05 (0.64-1.70)	1.27 (1.02-1.57)*	1.20 (0.91-1.59)
Highly exposed	0.76 (.039-1.46)	1.52 (1.07-2.16)*	1.22 (0.28-5.30)	0.73 (0.30-1.78)	2.12 (1.02-4.37)*	1.22 (0.83-1.80)
Drinking water source						
Improved (ref)	1.00	1.00	-	1.00	1.00	1.00
Unimproved	1.04 (0.76-1.41)	1.33 (1.05-1.67)*	-	1.44 (0.94-2.18)	0.85 (0.56-1.25)	1.18 (0.85-1.64)
Drinking water treatment						
Appropriately treated (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Inappropriate or no treatment (ref)	1.36 (1.04-1.78)*	0.96 (0.77-1.21)	1.24 (0.83-1.89)	0.99 (0.67-1.47)	1.43 (1.13-1.83)**	1.07 (0.83-1.39)
Sanitation facility						
Basic/standard sanitation (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Poor sanitation or open defecation	1.05 (0.63-1.27)	1.16 (1.05-1.28)**	1.29 (0.85-1.96)	1.11 (0.90-1.38)	1.09 (0.89-1.33)	1.25 (1.10-1.41)***
Handwashing						

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facilities						
Standard (ref)	1.00	1.00	1.00	1.00	1.00	1.00
Poor	1.39 (1.16-1.65)***	1.29 (1.16-1.44)**	1.13 (0.81-1.59)	0.96 (0.74-1.24)	1.38 (1.12-1.69)**	1.17 (1.02-1.33)*
Poor HEC score						
No poor HEC characteristics (ref)	1.00	1.00	1.00	1.00	1.00	1.00
1 poor HEC characteristics	1.89 (1.22-2.91)**	3.91 (0.58-26.53)	1.57 (0.75-3.27)	1.92 (0.23-15.72)	1.58 (0.94-2.64)	0.97 (0.27-3.45)
2 poor HEC characteristics	1.59 (0.99-2.54)*	6.22 (0.92-42.19)	1.32 (0.62-2.82)	1.55 (0.20-12.07)	1.34 (0.77-2.32)	1.52 (0.48-4.8)
3 poor HEC characteristics	1.76 (1.13-2.74)**	6.90 (1.02-46.45)*	2.07 (0.97-4.44)	2.09 (0.27-15.98)	1.74 (1.06-2.87)*	1.80 (0.59-5.54)
4 poor HEC characteristics	1.84 (1.15-2.94)**	7.20 (1.07-48.68)*	1.05 (0.46-2.38)	1.84 (0.25-13.78)	1.75 (1.01-2.95)*	1.68 (0.55-5.15)
5 or more poor HEC characteristics	1.87 (1.12-2.83)*	8.11 (1.20-54.77)*	1.94 (0.85-4.43)	2.09 (0.28-15.68)	2.05 (1.21-3.48)**	2.00 (0.65-6.13)

Note: All models were run separately for each type of household environment condition characteristics and was adjusted for child's age, child's sex, religion, sex of the household head, education level of child's mother, education level of child's father, employment status of the child's mother, household size, place of residence and administrative division. Values with superscript asterisks *, **, and *** indicate $p<0.05$, $p<0.01$, and $p<0.001$, respectively. (ref): Reference category, PR: prevalence ratio, CI: confidence interval; HEC refers to household environmental condition.

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Table 6. Association of under-5 children's anthropometric failure index with household environmental quality score adjusted for household level socio-demographic characteristics using multinomial logistic regression analysis, n = 8,057

Characteristics	Adj. RRR (95% CI)					
	Failure B	**Failure C**	**Failure D**	**Failure E**	**Failure F**	**Failure G**
Poor HEC score						
No poor HEC characteristics (ref)	1.00	1.00	1.00	1.00	1.00	1.00
1 poor HEC characteristics	1.23 (0.48-3.14)	3.21 (1.69-6.09)***	1.25 (0.45-3.45)	3.44 (0.79-15.05)	1.47 (0.71-3.04)	1.46 (0.39-5.51)
2 poor HEC characteristics	0.82 (0.29-2.32)	3.21 (1.70-6.05)***	1.39 (0.48-3.99)	3.35 (0.86-12.96)	1.66 (0.85-3.23)	1.56 (0.42-5.85)
3 poor HEC characteristics	1.24 (0.46-3.37)	3.31 (1.80-6.07)***	1.62 (0.55-4.77)	4.54 (1.17-17.58)*	2.12 (1.10-4.10)*	3.23 (0.93-11.21)
4 poor HEC characteristics	0.85 (0.33-2.19)	3.78 (2.04-7.00)***	1.58 (0.53-4.70)	3.54 (0.89-14.09)*	2.1 (1.08-4.08)*	2.58 (0.74-9.03)
5 or more poor HEC characteristics	0.76 (0.27-2.10)	4.10 (2.19-7.66)***	1.46 (0.48-4.44)	5.78 (1.46-22.99)**	2.71 (1.39-5.30)**	3.66 (1.04-12.93)*

Note: All models were run separately for each type of household environment condition characteristics and was adjusted for child's age, child's sex, religion, sex of the household head, education level of child's mother, education level of child's father, employment status of the child's mother, household size, place of residence and administrative division. Values with superscript asterisks *, **, and *** indicate $p<0.05$, $p<0.01$, and $p<0.001$, respectively. (ref): Reference category, RRR: relative risk ratio, CI: confidence interval; HEC refers to household environmental condition.

Failure A: No anthropometric failure (reference category); Failure B: Wasted only; Failure C: Stunted only; Failure D: Underweight only; Failure E: Wasted with underweight; Failure F: Stunted with underweight; Failure G: Stunted, wasted and underweight

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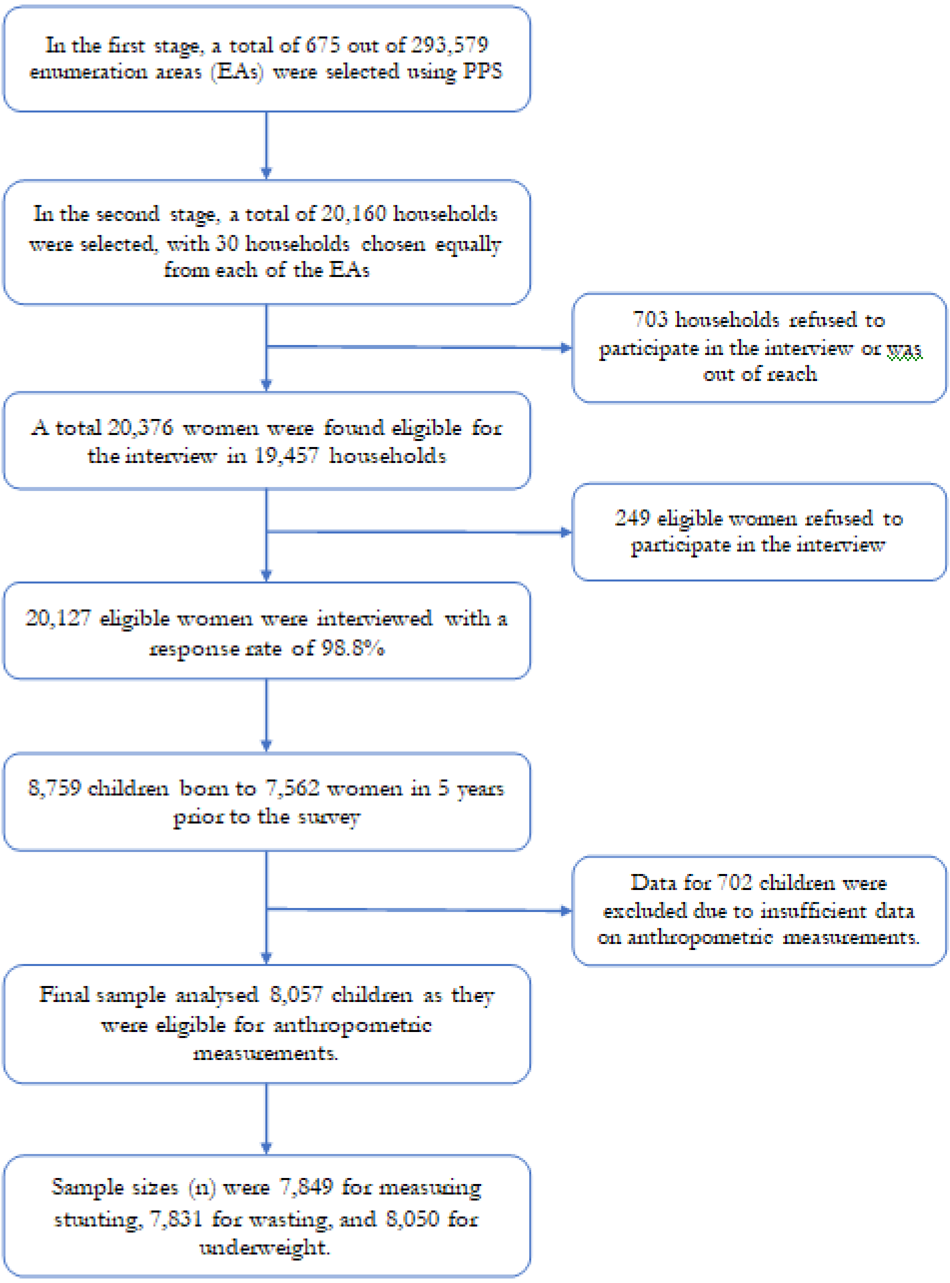

Fig 1. Sampling strategy of the BDHS 2017/18 and selection of study participants using STORBE guideline

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