BMC Public Health

RESEARCH

Open Access

# Spatial distribution and predictors of stunting, wasting, and underweight among under-five children in Bangladesh

Mamunur Rashid[1], Mosiur Rahman[2*], Nure Alam Siddiqi[1], Reazul Islam[3], Sharif Miah[1], Tapan Kumar Roy[2] and Mostafizur Rahman[2]

## Abstract

**Background** Childhood undernutrition remains a significant public health challenge in Bangladesh, affecting both the physical and cognitive development of children and the country's economic growth. The study examined the spatial distribution and multilevel determinants of stunting, wasting, and underweight among children under five years of age in Bangladesh.

**Methods** Data were obtained from the nationally representative Bangladesh Demographic and Health Survey (BDHS) 2022. Spatial patterns were analyzed using Moran's I to assess spatial autocorrelation and the Getis-Ord Gi* statistic to identify hot and cold spots. Three-level Bayesian multilevel logistic regression models were applied to determine the predictors of stunting, wasting, and underweight at the individual, household, and community levels.

**Results** Overall, 22.5% of children were stunted, 9.7% wasted, and 19.5% underweight. Although spatial clustering was not statistically significant, distinct hotspot areas observed- stunting were concentrated in Sylhet and Mymensingh, while wasting had higher prevalence in Rajshahi, Rangpur, and Barishal. Poverty in the community was found constantly associated with the three types of undernutrition, with children from communities with high poverty having higher odds of stunting (OR = 1.60; 95% CI: 1.40–1.83), wasting (OR = 1.31; 95% CI: 1.06–1.59), and being underweight (OR = 1.57; 95% CI: 1.31–1.88). Some of the risk factors for wasting and being underweight were undernourished mothers and mothers who are aged ≥ 35 years, while stunting and underweight were associated with older child age, higher birth order, and unsatisfactory sanitation. Lower rates of stunting were found for children whose fathers had some education, employed mothers, and mothers who had at least partial autonomy in making healthcare decisions.

**Conclusion** Child undernutrition in Bangladesh is characterized by a concentration of multiple deprivations at different levels: individual, household and community as well as by the distinct regional hotspot patterns. Integrating national BDHS 2022 with geospatial hotspot mapping and three-level Bayesian multilevel models that account for maternal healthcare decision-making autonomy and contextual neighborhood measures of community poverty

*Correspondence:
Mosiur Rahman
mosiur@ru.ac.bd

Full list of author information is available at the end of the article

© The Author(s) 2026. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

and maternal illiteracy, this study provides actionable evidence to prioritize high-burden areas for targeted nutrition, WASH, and poverty-reduction interventions.

**Keywords** Stunting, wasting, underweight, malnutrition, Bayesian multilevel logistic regression model

## Introduction

Undernutrition refers to the inadequate and uncontrolled intake of nutrients, impaired nutrient utilization, and an imbalance of essential nutrients [1]. Globally, child undernutrition remains a major public health problem and is identified as a prime cause of child mortality in low- and middle-income countries (LMICs) [2]. It causes both short- and long-term complications, impeding children's mental and physical development. Undernutrition is linked to low birth weight, diarrhea, and poor development of children [3]. Furthermore, it is responsible for non-communicable diseases and lower economic development, which perpetuates poverty [4, 5]. Every year, a large number of under-five children (4.9 million) die globally, with undernutrition accounting for nearly half of these deaths [1, 6]. The prevalence of childhood undernutrition is more common in developing countries [7], where almost 45% of all deaths are attributable to undernutrition. This is an urgent issue that needs to be addressed from a health equity perspective [8].

Undernutrition in children has several forms: stunting (low height-for-age), wasting (low weight-for-height), and underweight (low weight-for-age). Globally, both stunting and wasting were recorded at 22.3% and 6.8%, respectively in 2022 [9]. However, it is much higher in LMICs where stunting affects 29.1% of children, wasting 6.3%, and underweight 13.7% of them [10]. This gap shows that undernutrition remains a serious problem in places with limited resources, despite global progress. World Health Organization [WHO] Global Nutrition Targets for 2025 include a 40% reduction in stunting among children and bringing the prevalence of wasting to under 5% [11].

Bangladesh made significant advances in many aspects: life expectancy has increased; literacy rates have risen, and both maternal and infant mortality rate have declines. However, child undernutrition continues to be a persistent issue, with improvements in this area still lacking [12–16]. This accounts for about 60% of nutrition-associated deaths among children [17]. According to the recent Bangladesh Demographic and Health Survey (BDHS) 2022 report, stunting in children stood at 24.0%, wasting was at 11.0%, and underweight at 22.0% [18]. Addressing undernutrition among children is also critical to achieving Sustainable Development Goal (SDG) 2 for Bangladesh that anticipates full eradication of undernutrition in all its forms by 2030. Therefore, understanding the determinants of this undernutrition remains paramount for the reduction of child morbidity and mortality.

In recent times, the Double Burden of Malnutrition (DBM) has become a glaring manifestation in LMICs, reflecting the coexistence of undernutrition and overnutrition at individual, household, or population levels [8, 19]. DBM emphasizes the nutrition transition, where persistent undernutrition coexists with increasing prevalence of overweight and obesity. The current study, however, focuses solely on undernutrition which refers to stunting, wasting, and underweight- the most important nutritional challenges among children under five in Bangladesh. DBM being a public health concern, indicators of overnutrition are less relevant for this age category in Bangladesh. Hence, our study differs from the DBM approach by concentrating on the spatial distribution and socioeconomic determinants of undernutrition.

Several studies [20–29] have examined maternal health factors such as body mass index (BMI), antenatal care (ANC), cesarean section (C-section) delivery, and high-risk fertility behaviors like mother's age at birth, birth interval, and birth order, as well as sociodemographic and socioeconomic determinants influencing stunting, wasting, and underweight among under-five children in Bangladesh and other LMICs. However, critical determinants remain underexplored, particularly maternal autonomy in healthcare utilization, community-level poverty and community-level maternal illiteracy. These factors may significantly influence child nutritional outcomes through women's decision-making power, poverty and educational environment within communities.

This paper aims to fill these gaps by demonstrating the spatial distribution and multilevel predictors of stunting, wasting, and underweight among under-five children in Bangladesh using the most recent nationally representative data BDHS 2022. Novel aspects of the study include the combination to spatial hotspot analysis with a three-level Bayesian multilevel Bayesian model framework (child–household–community); and the inclusion of relatively less studied yet policy-relevant factors such as maternal autonomy in healthcare decision-making, community level poverty and community level maternal literacy/illiteracy. What is useful about this combined approach is that it tells us not only where to target policies for undernutrition, but which are the high-level drivers at multilevel that should be targeted to shape geographically geo-targeted inequity sensitive interventions. The utility of this integrated approach is that it indicates where undernutrition is concentrated and which multilevel drivers need to be addressed as priority for the

design of geographically targeted and equity-focused interventions.

## Materials and methods

### Dataset and study design

We used the nationally representative BDHS 2022 data. A two-stage stratified random sampling procedure was employed in this survey. In the first stage, the survey used 675 enumeration areas (EAs), including 237 in urban areas and 438 in rural areas that were selected with a probability proportional to the size of the enumeration area. In the second stage, 45 households were selected per enumeration area by using a systematic sampling technique. A total of 30,358 ever-married women aged 15–49 was eligible for interviews, and 30,078 women were interviewed, with a response rate of 99%. After removing missing values, 2,092 respondents for stunting, 2,094 for wasting and 2,126 for underweight were selected for final analysis.

### Measures

#### *Outcome variables*

Stunting, wasting, and underweight were defined according to the WHO child growth standards as height-for-age Z-score (HAZ) ≤ − 2, weight-for-height Z-score (WHZ) ≤ − 2, and weight-for-age Z-score (WAZ) ≤ − 2, respectively [30].

#### *Explanatory variables*

Sociodemographic, maternal health-related, and high-risk fertility behavior variables were considered explanatory variables. These were identified as significant risk factors in previous studies conducted in LMICs [20, 31, 32]. The explanatory variables were divided into individual, household, and community-level factors. Individual-level factors included children's age in months (0–11, 12–23, 24–33), birth order (1–3, 4 or more), and delivery by C-section (no, yes). Household-level factors were mother's age at birth in years (< 35 and 35 and above), mother's occupation (unemployed, employed), father's education (no, primary, secondary, and higher), father's occupation (agriculture, manual labor, business, services, and others), ANC visits (0–3, 4 and more), institutional delivery (no, yes), mother's underweight (no, yes), mother's autonomy in healthcare utilization (no, yes), and toilet facilities (hygienic, unhygienic), and religion (Muslim, Non-Muslim). Maternal underweight was derived from BMI, defined as BMI < 18.5.

Factors that were at the community level included place of residence (urban, rural), region of residence (Barishal, Chattogram, Dhaka, Khulna, Mymensingh, Rajshahi, Rangpur, Sylhet), community maternal illiteracy, and community-level poverty. Fathers are usually the key decision-makers and income earners in households within the context of Bangladesh. Their education also influences household socioeconomic status, resource allocation, and healthcare-seeking behavior, which directly or indirectly influence the child's nutritional outcome. Thus, a father's education reflects household-level socioeconomic capacity rather than representing individual biological characteristics, of the child or the mother. On the contrary, community-level maternal illiteracy was determined by aggregating the proportions of women having no formal education within an enumeration area (cluster). This variable thus indicates the educational environment and normative context (the attitudes towards female education) within which families live concerning awareness of nutrition and overall empowerment at the community level. Therefore, they reflect contextual or environmental influences independent of individual or household attributes. This classification approach is consistent with prior multilevel analyses using DHS data in similar settings [33, 34].

The community-level maternal illiteracy was defined the proportion of women who had no education in the community (categorized as < 50%=low, 50%-100%= high). To measure community-level poverty, the proportion of people within a community who belong to the two lowest wealth quintiles (the 1st and 2nd) is calculated. Based on this proportion, the community is then categorized into one of three poverty levels. If less than 25% of the community belongs to these two lowest quintiles, it is categorized as low poverty. If 25% to 50% of the community belongs to these two quintiles, it is categorized as moderate poverty. Communities where more than 50% of the population falls into the two lowest wealth quintiles are considered to have high poverty. This methodology was followed in prior studies [33, 34].

### Statistical analysis

The background characteristics of the study population were described using descriptive statistics, which included percentages and confidence intervals for each categorical variable. Moran's I statistic was utilized to assess the spatial autocorrelation of child malnutrition. Getis-Ord Gi* statistic was used to identify the hotspot and cold spot areas of stunting, wasting and underweight. Three-level multilevel logistic regression using the Bayesian approach was conducted in this study to assess the determinants of child stunting, wasting, and underweight. This hierarchical structure of children (Level 1) nests them in households (Level 2), which in turn are nested in communities or enumeration areas (Level 3). Individual-level and household-level covariates were entered in the first and second levels, respectively, to represent the third level community-level factors. Random intercepts were specified for both households and communities to capture between-household and

between-community variability in the outcomes. The model was estimated using Markov Chain Monte Carlo (MCMC) procedures under the Bayesian framework.

Observations with missing values in the outcome or explanatory variables were not included the analysis. Since the proportion of missing data was < 0.5% and appeared to be randomly distributed, a complete-case analysis was considered appropriate. Multiple imputation was not performed because the low rate of missingness was unlikely to bias the estimates, and most variables were categorical, making single imputation less reliable. The significant risk factors were determined based on the $p$-value ($p < 0.05$). Odds ratios (OR) were computed to measure the strength of the association between explanatory variables and outcome variables, and 95% confidence interval was used to examine the significance of testing. Prior to conducting the multivariate regression analyses, multicollinearity diagnostics were performed. Maternal education showed a high correlation with father's education and was consequently omitted from the models. ArcGIS 10.4.1 software was utilized to explore the spatial distribution of stunting, wasting, and underweight. All analyses were conducted using Stata 17.0.

## Results

### Distribution of the prevalence of stunting, wasting, and underweight

Distribution of childhood stunting, wasting, and underweight is shown in Table 1. Overall, 22.45% of the children were stunted, 9.67% were wasted, and 19.49% were underweight. Wasting and underweight prevalence were higher for children aged 24–59 months (10.67% and 24.58%, respectively). The stunting (28.27%), wasting (10.92%), and underweight (27.55%) rates were higher among children whose fathers had no formal education. Higher birth orders (≥ 4) also had increased rates for stunting (35.56%), wasting (13.86%), and underweight (30.57%). High prevalence of undernutrition was noted among children whose mothers age at birth were 35 years and above at birth—stunting (26.0%), wasting (17.53%), and underweight (30.7%)—and those from rural backgrounds (22.85%, 9.96%, and 19.85%, respectively).

In contrast, children whose mothers had four or more ANC visits generally had lower prevalences of stunting (18.72%), wasting (6.78%), and underweight (14.48%). Likewise, C-section and institutional delivery were associated with lower levels of undernutrition: stunting (17.34% and 19.2%), wasting (7.91% and 8.32%), and underweight (15.34% and 16.64%), respectively. Additionally, children whose mothers had autonomy in health care utilization had lower stunting (21.49%), wasting (9.75%), and underweight (19.55%) than those whose mothers were nonautonomous. In communities with high maternal illiteracy, the prevalence of stunting (24.96%), wasting (10.52%), and underweight (23.6%) was higher compared to communities with low maternal illiteracy (stunting: 20.87%, wasting: 9.14%, underweight: 16.9%). The prevalence of stunting (25.73%), wasting (11.68%), and underweight (22.84%) was significantly higher in communities with high level of poverty compared to communities with low poverty (stunting: 17.65%, wasting: 8.11%, underweight: 12.72%).

### Spatial distribution of stunting, wasting, and underweight in Bangladesh

For stunting, Moran's Index showed an insignificant spatial autocorrelation (I = 0.010, $p = 0.466$) (Fig. 1a). Stunting hotspots were delineated in Sylhet and Mymensingh divisions, while cold spots were found in Khulna, Rajshahi, and Rangpur divisions. The spatial distribution for wasting also revealed an insignificant autocorrelation (I = 0.017, $p = 0.247$) (Fig. 1b). Hotspot areas for wasting were seen in Rajshahi, Rangpur, and Barishal divisions, while Dhaka, Chattogram, and parts of Khulna division looked like cold spots. The Moran's index value indicated an insignificant autocorrelation for underweight (I = 0.024, $p = 0.117$) (Fig. 1c). The hotspots for underweight were mainly concentrated in the Sylhet, Rangpur, and Barishal divisions while the cold spot pattern was seen in the Khulna, Dhaka, and Rajshahi divisions.

### Predictors of stunting

The findings of Bayesian multilevel logistic regression model for predictors of stunting were displayed in Table 2. The age grouping of 12–29 months (OR = 2.22; 95% CI: 1.85–2.66). or 24–59 months are more susceptible to stunting than the age grouping of 0–11 months (OR = 2.28; 95% CI: 1.96–2.60). Birth order is influential in the stunting status since it was revealed that children from a birth order class of ≥ 4 had greater odds of getting stunted than those in classes from 1 to 3 (OR = 2.15; 95% CI: 1.80–2.55). Children living in communities with moderate levels of poverty are more likely to be stunted (OR = 1.17; 95% CI: 1.01–1.35). and the likelihood increases further in communities with high poverty level (OR = 1.60; 95% CI: 1.40–1.83). The likelihood of stunting was higher among children from households using unhygienic toilet facilities compared to those with access to hygienic facilities (OR = 1.41; 95% CI: 1.20–1.65). There were lower odds observed for children whose fathers had higher education compared to no education (OR = 0.61; 95% CI: 0.51–0.72), and those whose mothers had autonomy in healthcare utilization compared to no autonomy (OR = 0.81; 95% CI: 0.70–0.95). Children of employed mothers, births delivered in health facilities, residence in the Rangpur division, and fathers employed in the service sector were associated with a lower likelihood of stunting.

**Table 1** Prevalence of childhood stunting, wasting, and underweight by individual, household, and community-level factors

| Characteristics | Stunting (*n* = 2,092) | | Wasting (*n* = 2,094) | | Underweight (*n* = 2,126) | |
|---|---|---|---|---|---|---|
| | Prevalence | 95% CI | Prevalence | 95% CI | Prevalence | 95% CI |
| Overall | 22.45 | 20.38, 24.65 | 9.67 | 8.42, 11.09 | 19.49 | 17.58, 21.55 |
| Children's age (in months) | | | | | | |
| 0–11 | 14.19 | 11.6, 17.26 | 9.41 | 7.36, 11.95 | 14.88 | 12.26, 17.95 |
| 12–23 | 27.4 | 23.76, 31.37 | 9.04 | 6.97, 11.66 | 19.83 | 16.83, 23.22 |
| 24–59 | 26.71 | 23.03, 30.74 | 10.67 | 8.33, 13.56 | 24.58 | 21.06, 28.48 |
| Birth order | | | | | | |
| 1–3 | 20.94 | 18.82, 23.23 | 9.19 | 7.89, 10.68 | 18.22 | 16.31, 20.31 |
| 4 or more | 35.56 | 29.24, 42.41 | 13.86 | 9.34, 20.09 | 30.57 | 24.77, 37.07 |
| Delivery by C-section | | | | | | |
| No | 26.35 | 23.4, 29.52 | 11.07 | 9.33, 13.09 | 22.71 | 19.98, 25.69 |
| Yes | 17.34 | 14.72, 20.3 | 7.91 | 6.3, 9.89 | 15.34 | 12.98, 18.05 |
| Mother's age at birth (in years) | | | | | | |
| < 35 | 22.27 | 20.14, 24.56 | 9.28 | 8.02, 10.72 | 18.93 | 16.99, 21.04 |
| 35 and over | 26.0 | 18.11, 35.82 | 17.53 | 10.87, 27.04 | 30.7 | 22.32, 40.58 |
| Mother's education | | | | | | |
| No education | 38.69 | 28.8, 49.62 | 20.66 | 13.77, 29.8 | 43.96 | 34.43, 53.97 |
| Primary | 26.85 | 22.83, 31.3 | 10.25 | 7.66, 13.58 | 23.12 | 19.51, 27.19 |
| Secondary | 22.02 | 19.26, 25.04 | 8.51 | 6.9, 10.44 | 17.72 | 15.26, 20.48 |
| Higher | 12.87 | 9.49, 17.23 | 8.9 | 6.2, 12.61 | 12.32 | 9.2, 16.31 |
| Mother's occupation | | | | | | |
| Unemployed | 22.26 | 19.86, 24.85 | 9.85 | 8.35, 11.57 | 19.25 | 17.17, 21.52 |
| Employed | 22.95 | 19.27, 27.1 | 9.2 | 6.96, 12.09 | 20.12 | 16.7, 24.03 |
| Father's education | | | | | | |
| No education | 28.27 | 22.94, 34.29 | 10.92 | 7.66, 15.34 | 27.55 | 22.53, 33.2 |
| Primary | 24.14 | 20.6, 28.06 | 10.38 | 8.16, 13.12 | 21.67 | 18.38, 25.36 |
| Secondary | 23.14 | 19.83, 26.82 | 8.02 | 6.14, 10.41 | 17.53 | 14.64, 20.86 |
| Higher | 13.49 | 10.01, 17.93 | 10.64 | 7.54, 14.81 | 13.0 | 9.72, 17.17 |
| Father's occupation | | | | | | |
| Agriculture | 27.26 | 23.14, 31.81 | 11.43 | 8.61, 15.02 | 24.69 | 20.68, 29.2 |
| Manual labor | 24.55 | 20.9, 28.6 | 9.18 | 7.09, 11.81 | 21.98 | 18.54, 25.87 |
| Business | 21.65 | 16.97, 27.2 | 10.58 | 7.32, 15.04 | 18.52 | 13.91, 24.24 |
| Services | 18.63 | 15.1, 22.77 | 7.83 | 5.51, 11.01 | 15.44 | 12.21, 19.35 |
| Others | 15.23 | 9.81, 22.89 | 10.24 | 6.63, 15.49 | 11.09 | 7.32, 16.46 |
| ANC visits | | | | | | |
| 0–3 | 24.87 | 22.16, 27.8 | 11.55 | 9.77, 13.59 | 22.76 | 20.14, 25.62 |
| 4 and more | 18.72 | 15.86, 21.96 | 6.78 | 5.22, 8.76 | 14.48 | 12.12, 17.2 |
| Institutional delivery | | | | | | |
| No | 28.1 | 24.55, 31.94 | 12.03 | 9.75, 14.75 | 24.47 | 21.25, 28.01 |
| Yes | 19.2 | 16.91, 21.71 | 8.32 | 6.88,10.02 | 16.64 | 14.56, 18.95 |
| Mother's Underweight | | | | | | |
| No | 21.47 | 19.32, 23.78 | 8.63 | 7.33, 10.12 | 18.11 | 16.15, 20.26 |
| Yes | 28.1 | 22.96, 33.89 | 15.69 | 11.93, 20.36 | 27.42 | 22.72, 32.69 |
| Mother's autonomy in healthcare utilization | | | | | | |
| No | 24.93 | 21.23, 29.05 | 9.46 | 7.18, 12.38 | 19.32 | 16.01, 23.12 |
| Yes | 21.49 | 19.19, 23.98 | 9.75 | 8.3, 11.42 | 19.55 | 17.41, 21.89 |
| Toilet facilities | | | | | | |
| Hygienic | 20.88 | 18.64, 23.31 | 9.53 | 8.11, 11.17 | 17.72 | 15.73, 19.91 |
| Unhygienic | 29.26 | 24.17, 34.92 | 10.28 | 7.49, 13.94 | 27.16 | 22.31, 32.62 |
| Religion | | | | | | |
| Muslim | 22.57 | 20.41, 24.89 | 9.55 | 8.27, 11.01 | 19.73 | 17.72, 21.91 |
| Non-Muslim | 20.96 | 15.66, 27.46 | 11.06 | 6.84, 17.4 | 16.61 | 11.67, 23.09 |
| Community-level maternal illiteracy | | | | | | |

**Table 1** (continued)

| Characteristics | Stunting (*n* = 2,092) | | Wasting (*n* = 2,094) | | Underweight (*n* = 2,126) | |
|---|---|---|---|---|---|---|
| | Prevalence | 95% CI | Prevalence | 95% CI | Prevalence | 95% CI |
| Low | 20.87 | 18.25, 23.75 | 9.14 | 7.59, 10.96 | 16.9 | 14.62, 19.46 |
| High | 24.96 | 21.74, 28.48 | 10.52 | 8.52, 12.92 | 23.6 | 20.46, 27.07 |
| Community-level poverty | | | | | | |
| Low | 17.65 | 13.81, 22.29 | 8.11 | 5.84, 11.15 | 12.72 | 9.93, 16.17 |
| Moderate | 20.65 | 17.07, 24.76 | 7.25 | 5.22, 9.98 | 19.5 | 15.95, 23.63 |
| High | 25.73 | 22.7, 29.01 | 11.68 | 9.87, 13.77 | 22.84 | 20.0, 25.96 |
| Place of residence | | | | | | |
| Urban | 21.34 | 17.67, 25.53 | 8.89 | 6.67, 11.75 | 18.49 | 15.1, 22.44 |
| Rural | 22.85 | 20.41, 25.49 | 9.96 | 8.5, 11.64 | 19.85 | 17.61, 22.31 |
| Region of residence | | | | | | |
| Barishal | 23.81 | 18.36, 30.27 | 12.19 | 8.26, 17.63 | 21.02 | 15.17, 28.37 |
| Chattogram | 22.89 | 17.97, 28.67 | 9.74 | 7.22, 13.02 | 19.11 | 14.69, 24.48 |
| Dhaka | 20.98 | 16.62, 26.12 | 7.58 | 5.22, 10.87 | 16.98 | 13.02, 21.84 |
| Khulna | 17.91 | 13.5, 23.38 | 9.71 | 6.44, 14.38 | 17.33 | 12.88, 22.91 |
| Mymensingh | 28.31 | 23.55, 33.6 | 12.26 | 8.63, 17.15 | 24.03 | 19.48, 29.26 |
| Rajshahi | 19.65 | 14.06, 26.76 | 11.03 | 7.05, 16.85 | 17.47 | 12.44, 23.98 |
| Rangpur | 21.29 | 15.74, 28.14 | 8.49 | 5.47, 12.94 | 20.99 | 15.88, 27.21 |
| Sylhet | 30.81 | 24.04, 38.53 | 11.55 | 7.81, 16.76 | 27.06 | 21.4, 33.57 |

*ANC* Antenatal care, *BMI* Body mass index, *CI* Confidence interval, *N* Number of children, *%* Percentage

### Predictors of wasting

Children of mothers age at birth at ≥ 35 years had higher odds of wasting than those < 35 years (OR = 2.23; 95% CI: 1.69–2.85). Risk was also higher for children of underweight vs. normal-weight mothers (OR = 1.99; 95% CI: 1.69–2.37) and for non-Muslims vs. Muslims (OR = 1.33; 95% CI: 1.16–1.51). The likelihood of wasting was higher among children from communities with high poverty levels compared to those from low-poverty communities (OR = 1.31; 95% CI: 1.06–1.59). Increased odds of wasting were also observed among children whose fathers had higher education compared to no education (OR = 1.30; 95% CI: 1.02–1.62), and among those whose fathers were engaged in other types of occupation compared to agricultural work (OR = 1.44; 95% CI: 1.08–1.85). In contrast, children whose mothers had ≥ 4 ANC visits vs. < 4 (OR = 0.68; 95% CI: 0.54–0.85) and those from rural vs. urban areas (OR = 0.84; 95% CI: 0.74–0.95) were less likely to be wasted. There were lower odds observed for children who resided in Dhaka and Rangpur division (Table 2).

### Predictors of underweight

Children aged 12–23 months (OR = 1.42; 95% CI: 1.22–1.62) or 24–59 months vs. 0–11 months (OR = 1.89; 95% CI: 1.60–2.19) and with birth order ≥ 4 vs. 1–3 (OR = 1.67; 95% CI: 1.40–2.01) were more likely to be underweight. Higher odds were also observed among children of underweight vs. normal-weight mothers (OR = 1.65; 95% CI: 1.37–1.96), in households with unhygienic vs. hygienic toilets (OR = 1.39; 95% CI: 1.16–1.63), and in communities with moderate (OR = 1.50; 95% CI: 1.32–1.70) or high vs. low poverty (OR = 1.57; 95% CI: 1.31–1.88). Children of mothers age at birth at ≥ 35 years had higher odds of underweight than those < 35 years (OR = 1.90; 95% CI: 1.65–2.16). Underweight risk was higher among children in households where the fathers were manual laborers than in agricultural jobs (OR = 1.20; 95% CI: 1.04–1.38); among those living in communities where maternal literacy was lower than in those where maternal literacy was high (OR = 1.16; 95% CI: 1.05–1.28). Lower odds of underweight were found for children whose mothers had ≥ 4 ANC visits (OR = 0.79; 95% CI: 0.69–0.90), and for those residing in rural versus urban areas (OR = 0.77; 95% CI: 0.62–0.94). Children whose fathers worked in business, services, or other occupations, and who resided in the Rajshahi division were less likely to be underweight compared to the reference category.

## Discussion

In this study, we examined the spatial distribution and multilevel determinants of stunting, wasting, and underweight among children under five in Bangladesh, using the latest BDHS 2022 data. While no statistically significant spatial autocorrelation was found, clear hotspot areas were defined for each undernutrition type. Concentration hot spots for stunting and underweight cases were mainly found in Sylhet and Mymensingh divisions, while Rajshahi, Rangpur, and Barishal were the major hotspots for wasting cases. Clearly, these patterns narrate a specific geography of child undernutrition across

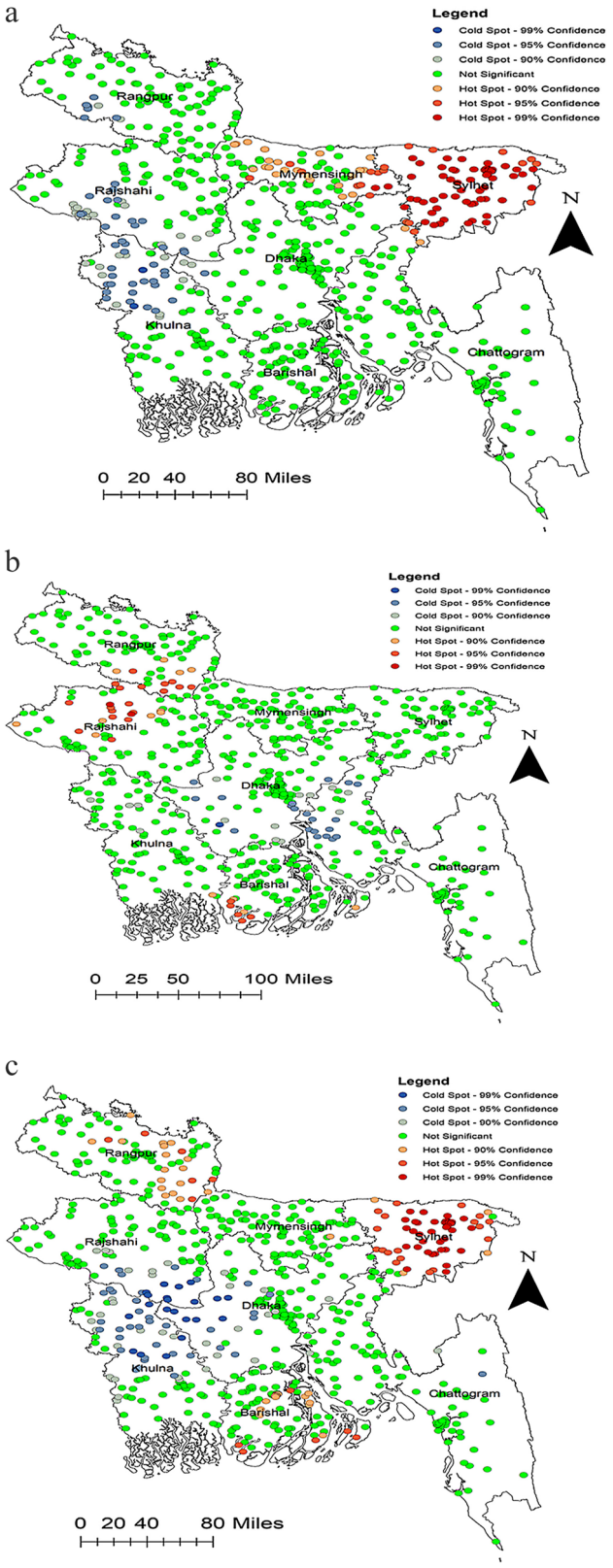



**Fig. 1** **a**. Spatial hotspot and coldspot distribution of stunting among under-five children in Bangladesh (BDHS 2022). **b** Spatial hotspot and coldspot distribution of wasting among under-five children in Bangladesh (BDHS 2022). **c**. Spatial hotspot and coldspot distribution of underweight among under-five children in Bangladesh (BDHS 2022)

the country, probably indicating different local socio-economic conditions, maternal health, or access to resources within the community. Chronic undernutrition in Sylhet and Mymensingh requires long-term maternal and child health programs, while the acute undernutrition in Rajshahi, Rangpur, and Barishal demands targeted interventions in terms of food and health. This study is unique in its application of combining spatial hotspot analysis into a three-level Bayesian multilevel model (child–household–community) and for integrating relatively unexplored, yet policy-relevant predictors like maternal autonomy over health-related decision-making, community-level poverty and literacy/illiteracy status of mothers at the community level.

Community-based poverty was the only factor that had a consistent association with all three forms of child undernutrition: stunting, wasting, and underweight. Children living with a community of moderate or high poverty status had substantially higher odds of all forms of undernutrition when compared to those living in low-poverty areas; these findings agree with previous studies done in Bangladesh and many other LMICs, whereby community poverty aggravates household food insecurity, restricts access to quality healthcare, and limits sanitation and clean water provisions [8, 21, 35]. Poverty also increases exposure to infectious diseases and decreases dietary diversity, causing chronic and acute undernutrition in the cycle as a result. The findings thus reinforce that child undernutrition is not just a household-level problem but an expression of higher structural deprivation [5]. It is therefore seen that a lack of equity should be addressed through community-based interventions combining poverty alleviation, livelihood support, and health systems strengthening.

Several determinants were significantly related to more than one nutritional outcome, underscoring shared pathways underlying child undernutrition. Older children (12–59 months) with higher birth orders (≥ 4) had higher odds of being stunted and under-weight. Earlier evidence suggests that as children get older, chronic growth faltering may be the result of cumulative dietary deficits, recurring infections, and competition in resource allocation among siblings [36, 37]. Unhygienic sanitary facilities were also associated with underweight and stunting, consistent with previous studies that have identified poor sanitation and exposure to enteric pathogens as important determinants of child growth failure in South Asia [38–40].

On the other hand, maternal underweight found to be one the most significant predictors of both wasting and underweight reflecting intergenerational transmission of nutritional disadvantage, a pattern well documented in the context of LMICs [41]. By contrast, the presence of four or more ANC visits had a significant reduction in

**Table 2** Bayesian multilevel models for childhood stunting, wasting, and underweight with individual, household, and community level factors

| Characteristics | Stunting OR (95% CI) | Wasting OR (95% CI) | Underweight OR (95% CI) |
|---|---|---|---|
| Children's age (in months) | | | |
| 0–11 [ref] | 1 | 1 | 1 |
| 12–23 | **2.22 (1.85–2.66)** | 0.95 (0.79–1.13) | **1.42 (1.22–1.62)** |
| 24–59 | **2.28 (1.96–2.60)** | 1.10 (0.95–1.29) | **1.89 (1.60–2.19)** |
| Birth order | | | |
| 1–3 [ref] | 1 | 1 | 1 |
| 4 or more | **2.15 (1.80–2.55)** | 1.14 (0.93–1.39) | **1.67 (1.40–2.01)** |
| Delivery by C-section | | | |
| No [ref] | 1 | 1 | 1 |
| Yes | 0.92 (0.83–1.02) | 0.95 (0.74–1.19) | 1.0 (0.82–1.22) |
| Mother's age at birth (in years) | | | |
| < 35 [ref] | 1 | 1 | 1 |
| 35 and over | 0.93 (0.71–1.21) | **2.23 (1.69–2.85)** | **1.90 (1.65–2.16)** |
| Mother's occupation | | | |
| Unemployed [ref] | 1 | 1 | 1 |
| Employed | **0.76 (0.65–0.87)** | 0.82 (0.64–1.02) | 0.93 (0.82–1.06) |
| Father's education | | | |
| No education [ref] | 1 | 1 | 1 |
| Primary | 0.93 (0.76–1.13) | 1.12 (0.87–1.42) | 0.95 (0.80–1.12) |
| Secondary | 0.90 (0.76–1.07) | 1.01 (0.82–1.22) | 0.87 (0.72–1.07) |
| Higher | **0.61 (0.51–0.72)** | **1.30 (1.02–1.62)** | 0.92 (0.74–1.12) |
| Father's occupation | | | |
| Agriculture [ref] | 1 | 1 | 1 |
| Manual labor | 1.12 (0.96–1.28) | 1.13 (0.96–1.32) | **1.20 (1.04–1.38)** |
| Business | 0.89 (0.74–1.05) | 1.09 (0.82–1.39) | **0.82 (0.66–0.99)** |
| Services | **0.86 (0.75–0.98)** | 1.04 (0.86–1.25) | **0.78 (0.65–0.92)** |
| Others | **0.78 (0.66–0.92)** | **1.44 (1.08–1.85)** | **0.67 (0.53–0.82)** |
| ANC visits | | | |
| 0–3 [ref] | 1 | 1 | 1 |
| 4 and more | 0.98 (0.85–1.12) | **0.68 (0.54–0.85)** | **0.79 (0.69–0.90)** |
| Institutional delivery | | | |
| No [ref] | 1 | 1 | 1 |
| Yes | **0.90 (0.83–0.98)** | 0.93 (0.74–1.15) | 0.90 (0.79–1.01) |
| Mother's Underweight | | | |
| No [ref] | 1 | 1 | 1 |
| Yes | 1.13 (0.99–1.26) | **1.99 (1.69–2.37)** | **1.65 (1.37–1.96)** |
| Mother's autonomy in healthcare utilization | | | |
| No [ref] | 1 | 1 | 1 |
| Yes | **0.81 (0.70–0.95)** | 1.09 (0.90–1.30) | 1.05 (0.96–1.15) |
| Toilet facilities | | | |
| Hygienic [ref] | 1 | 1 | 1 |
| Unhygienic | **1.41 (1.20–1.65)** | 0.92 (0.74–1.14) | **1.39 (1.16–1.63)** |
| Religion | | | |
| Muslim [ref] | 1 | 1 | 1 |
| Non-Muslim | 1.05 (0.87–1.27) | **1.33 (1.16–1.51)** | 1.01 (0.85–1.23) |
| Community-level maternal illiteracy | | | |
| Low [ref] | 1 | 1 | 1 |
| High | 0.92 (0.81–1.07) | 0.96 (0.78–1.16) | **1.16 (1.05–1.28)** |
| Community-level poverty | | | |
| Low [ref] | 1 | 1 | 1 |
| Moderate | **1.17 (1.01–1.35)** | 0.83 (0.69-1.0) | **1.50 (1.32–1.70)** |
| High | **1.60 (1.40–1.83)** | **1.31 (1.06–1.59)** | **1.57 (1.31–1.88)** |

**Table 2** (continued)

| Characteristics | Stunting OR (95% CI) | Wasting OR (95% CI) | Underweight OR (95% CI) |
|---|---|---|---|
| Place of residence | | | |
| Urban [ref] | 1 | 1 | 1 |
| Rural | 0.87 (0.71–1.04) | **0.84 (0.74–0.95)** | **0.77 (0.62–0.94)** |
| Region of residence | | | |
| Barisal [ref] | 1 | 1 | 1 |
| Chittagong | 0.92 (0.76–1.10) | 0.98 (0.83–1.18) | 0.87 (0.70–1.04) |
| Dhaka | 1.15 (0.99–1.30) | **0.67 (0.54–0.82)** | 0.93 (0.76–1.13) |
| Khulna | 0.89 (0.75–1.05) | 1.07 (0.88–1.31) | 0.94 (0.77–1.11) |
| Mymensingh | 1.05 (0.90–1.20) | 1.02 (0.85–1.21) | 0.93 (0.75–1.14) |
| Rajshahi | 0.97 (0.79–1.19) | 1.18 (0.99–1.39) | **0.77 (0.67–0.88)** |
| Rangpur | **0.76 (0.59–0.95)** | **0.66 (0.55–0.78)** | 0.89 (0.77–1.01) |
| Sylhet | **1.25 (1.04–1.47)** | 0.97 (0.74–1.25) | 1.11 (0.93–1.30) |
| Constant | 0.20 (0.16–0.25) | 0.10 (0.08–0.13) | 0.16 (0.14–0.17) |
| Community level variations | 0.060 (0.022–0.124) | 0.082 (0.014–0.235) | 0.011 (0.003–0.052) |
| DIC | 2114.143 | 1352.878 | 2015.733 |

*ANC* Antenatal care, *BMI* Body mass index, *CrI* Credible interval, *DIC* Deviance information criteria, *OR* Odds ratio, *ref* reference category

Bold values indicate 'statistically significant' results

the odds of wasting and being underweight, consistent with the results of other studies showing that regular attendance to ANC helps improve maternal nutrition, early detection of complications, and better infant feeding practices [42]. Regional patterns also persisted: children from Rangpur division were found less likely to be stunted or wasted, likely to reflect regional improvement in maternal healthcare coverage and food availability. Interestingly, fathers engaged in "other" non-agricultural occupations had mixed effects-lower odds for being underweight but higher odds for being wasting-maybe reflecting instability of work or migration that affects the quality of caregiving. Collectively, these findings indicate that both maternal health and environmental sanitation are vital for preventing multiple forms of undernutrition.

Stunting was decreased by protective forces such as maternal employment, ability of mothers to make their own healthcare choices, higher education of fathers, and fathers' jobs in the service sector. The results conform to findings of earlier studies [43–46] whereby women's empowerment, income earning, and parental education heightened child feeding, healthcare utilization, and household-level decision-making power. For wasting, maternal age at birth ≥ 35 years and being of non-Muslim religion constituted substantial risk factors, in agreement with studies [43, 47] that older mothers are under social obstetric and physiological constraints, while their culture or dietary habits may influence some aspects of their feeding practices.

For underweight, community maternal illiteracy was a significant contextual determinant. Underweight children generally resided in communities where the proportion of illiterate mothers was high, and again, dependent on earlier findings that collective maternal education increases health-seeking behavior, knowledge dissemination, and community norms around childcare and nutrition [48, 49]. Regional variations also remained evident: children in Sylhet were more likely to be stunted and those in Rajshahi had lower odds of being underweight. The spatial disparities conform to the literature indicating the geographic inequality of poverty, service coverage, and infrastructure throughout Bangladesh [34, 50–52].

Overall, the study reveals that community poverty continues being the most far-reaching cause for nearly all forms of undernutrition in children. Besides maternal nutritional status, sanitation, and parent education have demonstrated the likelihood of affecting a number of outcomes simultaneously, while other contextual and sociodemographic variabilities give rise to variations in specific forms of undernutrition. All these results are consistent with the larger body of evidence suggesting that both structural and behavioral factors must be dealt with simultaneously to have any worthwhile change in child nutrition status. Therefore, multisectoral policies targeting maternal health, education, sanitation, and community poverty are required to hasten nutritional improvements in Bangladesh.

The spatial variations observed in this study in undernutrition within Bangladesh may be partly explained by the unequal distributions of individual-, household-, and community-level determinants. The regions identified as hot spots of stunting and underweight- such as Sylhet and Mymensingh- feature high community poverty, low maternal literacy, and lack of access to improved sanitation. These are suggestive of the clustering of chronic undernutrition because of deprivation at the community level and weak health infrastructure. In contrast, wasting

hot spots in Rajshahi and Barishal appear to have more connections to households and maternal factors such as inferior maternal BMI and poor attendance of ANC, which reflect short-term nutritional stress and poor mother care practices. The combination of spatial and multilevel analysis shows that while generally community disadvantages drive chronic undernutrition (stunting and underweight), household and mother conditions are found to impact more heavily on acute undernutrition (wasting). Consequently, community-level interventions are required targeting the zones characterized by chronic undernutrition, whereas mothers and household-level nutrition behaviors may be improved to reduce waste more effectively.

### Limitations

This analysis also has several limitations that should be borne in mind when interpreting the results. The first is that BDHS 2022 data are cross-sectional so the observed relationships cannot be considered as causal. Second, some of the variables (e.g., maternal decision-making autonomy and characteristic of the household) are self-reported and may be influenced by recall or social desirability bias. Third, anthropometric measures may be prone to measurement error despite standardized DHS protocols. Fourth, the spatial analysis was performed at the cluster/division level, and displacement of cluster GPS coordinates by DHS for confidentiality might lower accuracy in hotspot detection. Fifth, several essential factors such as dietary intake, micronutrient status, detailed household food security indicators, infection history and seasonality were not collected in BDHS 2020 which could not be captured. Finally, even if the Bayesian multilevel model adjusts for clustering, residual confounding by unmeasured factors may still be present. Additional longitudinal research and more granular geographic data would increase the strength of causal inferences at the local level.

Despite these limitations, the results offer valuable evidence for geographically focused and equity-driven interventions.

Strengths.

This study has several strengths. First, it estimates the prevalence of stunting, wasting and underweight among under-five children in Bangladesh using data from the latest nationally representative BDHS 2022. Secondly, it combines the spatial hotspot analysis with a three-level Bayesian multilevel model (child–household–community) that models geographic variation while adjusting for hierarchical clustering. Third, the study includes relatively less-studied but policy-relevant contextual and empowerment predictors including maternal autonomy in healthcare decision-making, community level poverty, and community mother related literacy/illiteracy, hence enhancing policy relevance of findings.

## Conclusion

This study examined the spatial distribution and multilevel determinants of stunting, wasting, and underweight among children under five in Bangladesh using BDHS 2022 data. Statistically, the overall clustering of undernutrition was not significant, but some regions showed distinct densities for specific forms of undernutrition: stunting and underweight are higher in Sylhet and Mymensingh, while wasting concentrates in Rajshahi, Rangpur, and Barishal. These regional variations across locations show unequal social and health conditions across the country. Community-level poverty was the only factor consistently associated with all three types of undernutrition. Maternal undernutrition and older maternal age increased the risk of wasting and being underweight; however, higher birth order, child age, and poor sanitation were associated with stunting and underweight. Stunting was less in children whose fathers were educated, whose mothers were employed, and whose mothers enjoyed decision-making autonomy. These findings illustrates that child undernutrition in Bangladesh results from overlapping individual, household, and community disadvantages. Policies should focus on region-specific and multisectoral in addressing maternal nutrition, sanitation, educating and empowering women, and alleviating poverty in communities. Such spatio-temporal results can help policymakers appreciate high-risk regions and improve resource allocation to address undernutrition issues in all its diversity. Future research should incorporate indicators of overnutrition to assess the double burden of malnutrition and employ longitudinal data to better establish causal relationships over time.

#### Abbreviations

| | |
|---|---|
| BDHS | Bangladesh Demographic and Health Survey |
| ANC | Antenatal care |
| BMI | Body mass index |
| CrI | Credible interval |
| DIC | Deviance information criteria |
| OR | Odds ratio |
| CI | Confidence interval |
| SDGs | Sustainable Development Goals |

#### Acknowledgements

The authors express thankful to DHS authority for allowing data access.

#### Authors' contributions

MMR, MR, and MSM conceptualized the study and performed data management. MMR and MSM drafted the manuscript. MR, MNAS, MRI, TKR and MMR critically reviewed the manuscript. The final manuscript was approved by all authors.

#### Funding

Not applicable.

**Data availability**
Data is available from the DHS program website (www.dhsprogram.com/data/available-datasets.cfm).

## Declarations

**Ethics approval and consent to participate**
Ethical approval was obtained by the ICF Institutional Review Board and the Bangladesh Medical Research Council, Dhaka, Bangladesh and informed consent was obtained from all participants. All the study procedures were conducted in accordance with the principles of the Declaration of Helsinki as revised in 2013.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

**Author details**
[1]Department of Population Science, Jatiya Kabi Kazi Nazrul Islam University, Mymensingh, Bangladesh
[2]Department of Population Science and Human Resource Development, University of Rajshahi, Rajshahi, Bangladesh
[3]Department of Sociology, Jatiya Kabi Kazi Nazrul Islam University, Mymensingh, Bangladesh

Received: 18 March 2025 / Accepted: 20 February 2026
Published online: 29 March 2026

**References**

1. WHO. 2024. Available from: https://www.who.int/news-room/fact-sheets/detail/malnutrition. Cited 14 Nov 2024.
2. Victora CG, Christian P, Vidaletti LP, Gatica-Domínguez G, Menon P, Black RE. Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda. Lancet. 2021;397(10282):1388–99.
3. Tette EM, Sifah EK, Nartey ET. Factors affecting malnutrition in children and the uptake of interventions to prevent the condition. BMC Pediatr. 2015;15:189.
4. Grey K, Gonzales GB, Abera M, Lelijveld N, Thompson D, Berhane M, et al. Severe malnutrition or famine exposure in childhood and cardiometabolic non-communicable disease later in life: a systematic review. BMJ global health. 2021;6(3):e003161.
5. Siddiqui F, Salam RA, Lassi ZS, Das JK. The intertwined relationship between malnutrition and poverty. Front Public Health. 2020;8:453.
6. UNICEF. Levels and trends in child mortality 2024. Available from: https://data.unicef.org/resources/levels-and-trends-in-child-mortality-2024/. Cited 2 January 2025.
7. Kramer CV, Allen S. Malnutrition in developing countries. Paediatrics child health. 2015;25(9):422–7.
8. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. lancet. 2013;382(9890):427–51.
9. WHO. World health statistics 2023: monitoring health for the SDGs, sustainable development goals 2023. Available from: https://www.who.int/publications/i/item/9789240074323. Cited 03 Jan 2025.
10. Ssentongo P, Ssentongo AE, Ba DM, Ericson JE, Na M, Gao X, et al. Global, regional and national epidemiology and prevalence of child stunting, wasting and underweight in low-and middle-income countries, 2006–2018. Sci Rep. 2021;11(1):5204.
11. WHO. Global nutrition targets 2025: policy brief series 2014. Available from: https://www.who.int/publications/i/item/WHO-NMH-NHD-14.2. Cited 03 Jan 2025
12. Hossain AT, Siddique AB, Jabeen S, Khan S, Haider MM, Ameen S et al. Maternal mortality in Bangladesh: Who, when, why, and where? A national survey-based analysis. J Global Health. 2023;13:07002. https://doi.org/10.7189/jogh.13.07002.
13. Hossain MM, Mani KK, Islam MR. Prevalence and determinants of the gender differentials risk factors of child deaths in Bangladesh: evidence from the Bangladesh demographic and health survey, 2011. PLoS Negl Trop Dis. 2015;9(3):e0003616.
14. Hossain MM, Abdulla F, Rahman A. Prevalence and risk factors of underweight among under-5 children in Bangladesh: Evidence from a countrywide cross-sectional study. PLoS ONE. 2023;18(4):e0284797.
15. Abdulla F, Rahman A, Hossain MM. Prevalence and risk predictors of childhood stunting in Bangladesh. PLoS ONE. 2023;18(1):e0279901.
16. Hossain S, Chowdhury PB, Biswas RK, Hossain MA. Malnutrition status of children under 5 years in Bangladesh: A sociodemographic assessment. Child Youth Serv Rev. 2020;117:105291.
17. Faruque ASG, Ahmed AS, Ahmed T, Islam MM, Hossain MI, Roy S, et al. Nutrition: basis for healthy children and mothers in Bangladesh. J Health Popul Nutr. 2008;26(3):325.
18. National Institute of Population Research and Training (NIPORT) and ICF. Bangladesh Demographic and Health Survey 2022: Final Report. Dhaka, Bangladesh, and Rockville. Maryland, USA: NIPORT and ICF; 2024.
19. Obasohan PE. The Composite Index of Malnutrition: An emerging occurrence in low and middle-income countries. Food Microb Saf Hyg. 2025;10:344.
20. Talukder A. Factors associated with malnutrition among under-five children: illustration using Bangladesh demographic and health survey, 2014 data. Children. 2017;4(10):88.
21. Khanam M, Shimul SN, Sarker AR. Individual-, household-, and community-level determinants of childhood undernutrition in Bangladesh. Health Serv Res managerial Epidemiol. 2019;6:2333392819876555.
22. Woldeamanuel BT, Tesfaye TT. Risk factors associated with under-five stunting, wasting, and underweight based on Ethiopian demographic health survey datasets in Tigray region, Ethiopia. Journal of nutrition and metabolism. 2019;2019:6967170. https://doi.org/10.1155/2019/6967170.
23. Carlson GJ, Kordas K. Murrayraysk factors associated with under-five stunmy and child nutritional status: a review of the literature. Matern Child Nutr. 2015;11(4):452–82.
24. Kumeh OW, Fallah MP, Desai IK, Gilbert HN, Silverstein JB, Beste S, et al. Literacy is power: structural drivers of child malnutrition in rural Liberia. BMJ Nutr Prev Health. 2020;3(2):295.
25. Tariq I, Khan JI, Malik MA. Decomposing acute malnutrition by educational inequality of mother's among under five children in Jammu and Kashmir. Sci Rep. 2023;13(1):10493.
26. Chowdhury MRK, Rahman MS, Khan MMH, Mondal MNI, Rahman MM, Billah B. Risk factors for child malnutrition in Bangladesh: a multilevel analysis of a nationwide population-based survey. J Pediatr. 2016;172:194–201. e1.
27. Das S, Gulshan J. Different forms of malnutrition among under five children in Bangladesh: a cross sectional study on prevalence and determinants. Bmc Nutr. 2017;3:1–12.
28. Das S, Rahman RM. Application of ordinal logistic regression analysis in determining risk factors of child malnutrition in Bangladesh. Nutr J. 2011;10:1–11.
29. Rahman MA, Rahman MS, Shakur SM, Howlader MH, Ashikuzzaman M, Husna AU et al. Risk factors of chronic childhood malnutrition: an analysis of the Bangladesh demographic and health survey 2014 data. J Public Health. 2022:30:309–21. https://doi.org/10.1007/s10389-020-01281-4.
30. WHO. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development 2006. Available from: https://www.who.int/publications/i/item/924154693X. Cited 14 Nov 2024.
31. Rahman SJ, Ahmed NF, Abedin MM, Ahammed B, Ali M, Rahman MJ, et al. Investigate the risk factors of stunting, wasting, and underweight among under-five Bangladeshi children and its prediction based on machine learning approach. PLoS ONE. 2021;16(6):e0253172.
32. Kandala N-B, Madungu TP, Emina JB, Nzita KP, Cappuccio FP. Malnutrition among children under the age of five in the Democratic Republic of Congo (DRC): does geographic location matter? BMC Public Health. 2011;11:1–15.
33. Mezmur M, Navaneetham K, Letamo G, Bariagaber H. Individual, household and contextual factors associated with skilled delivery care in Ethiopia: evidence from Ethiopian demographic and health surveys. PLoS ONE. 2017;12(9):e0184688.
34. Das S, Baffour B, Richardson A. Prevalence of child undernutrition measures and their spatio-demographic inequalities in Bangladesh: an application of multilevel Bayesian modelling. BMC Public Health. 2022;22(1):1008.
35. Krishna A, Oh J, Lee J-k, Lee H-Y, Perkins JM, Heo J, et al. Short-term and long-term associations between household wealth and physical growth: a

cross-comparative analysis of children from four low-and middle-income countries. Global Health Action. 2015;8(1):26523.
36. Tariq J, Sajjad A, Zakar R, Zakar MZ, Fischer F. Factors associated with undernutrition in children under the age of two years: secondary data analysis based on the Pakistan demographic and health survey 2012–2013. Nutrients. 2018;10(6):676.
37. Tiwari I, Acharya K, Paudel YR, Sapkota BP, Kafle RB. Planning of births and childhood undernutrition in Nepal: evidence from a 2016 national survey. BMC Public Health. 2020;20:1–13.
38. Spears D, Ghosh A. Open Defecation and Childhood Stunting in India: An Ecological Analysis. PLoS ONE. 2015;10(9):e0136160.
39. Hasan MM, Chowdhury AA, Barua A, et al. Association of access to water, sanitation and hand-washing facilities with undernutrition of children below 5 years of age in Bangladesh. BMJ Open. 2023;13:e065330.
40. Nadeem M, Anwar M, Adil S, Syed W, Al-Rawi MBA, Iqbal A. The Association between Water, Sanitation, Hygiene, and Child Underweight in Punjab, Pakistan: An Application of Population Attributable Fraction. J Multidisciplinary Healthc. 2024;17:2475–87.
41. Victora CG, Barros AJD, França GVA, da Silva ICM, Restrepo-Méndez MC. The intergenerational consequences of maternal undernutrition in low- and middle-income countries. Lancet Glob Health. 2021;9(9):e1231–41.
42. Yaya S, Ghose B, Uthman OA. Antenatal care utilization and its association with child nutrition outcomes in low- and middle-income countries: a systematic review. BMC Pregnancy Childbirth. 2020;20:561.
43. Wemakor A, Garti H, Azongo T, Garti H, Atosona A. Young maternal age is a risk factor for child undernutrition in Tamale Metropolis, Ghana. BMC Res Notes. 2018;11:1–5.
44. Akter S, Nishu NA. Malnutrition among under-5 children and its determinants in the southwestern coastal region of Bangladesh: A community-based study. BMJ open. 2025;15(1):e090174.
45. Balogun TB, Yakubu AM. Recent illness, feeding practices and father's education as determinants of nutritional status among preschool children in a rural Nigerian community. J Trop Pediatr. 2015;61(2):92–9.
46. Tamanna T, Mahmud S, Salma N, Hossain MM, Karim MR. Identifying determinants of malnutrition in under-five children in Bangladesh: insights from the BDHS-2022 cross-sectional study. Sci Rep. 2025;15(1):14336.
47. Ahmed T, Rahman AE, Alam A, Bhuiyan M, Khanam R, Haque MA, et al. Maternal socio-demographic factors and child undernutrition in low- and middle-income countries: a multi-country analysis. Nutrients. 2022;14(3):421.
48. Tamir TT, Techane MA, Dessie MT, Atalell KA. Applied nutritional investigation spatial variation and determinants of stunting among children aged less than 5 y in Ethiopia: A spatial and multilevel analysis of Ethiopian Demographic and Health Survey 2019. Nutrition. 2022;103:111786.
49. Kabir A, Rahman A, Khan MMH. The association between maternal education and child nutritional status in low- and middle-income countries: a systematic review. J Public Health (Oxf). 2019;41(2):e226–35.
50. 36, Saha U, van Wesenbeeck C. Changes in the determinants and spatial distribution of under-five stunting in Bangladesh: Evidence from Bangladesh Demographic Health Surveys (BDHS) 1996–97, 2014 and 2017/18. PLoS ONE. 2022;17(12):e0278094.
51. Amusa LB, Yahya WB, Bengesai AV. Spatial variations and determinants of malnutrition among under-five children in Nigeria: A population-based cross-sectional study. PLoS ONE. 2023;18(4):e0284270. PLOS + 1.
52. Hailu BA, Daba C, Tsega Y, Asaminew A, Miheretu BA, Endawkie A. Geospatial distribution and multilevel determinants of inadequate minimum dietary diversity and its consequences for children aged 6–23 months in Sub-Saharan Africa. PLoS ONE. 2025;20(5):e0321254.

## Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.