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Original Article

Analysis of individual-level and community-level effects on childhood undernutrition in Malawi

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Key Words
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stunting;
underweight;
wasting

Background: Undernutrition is a major global public health problem among children under the age of 5 years. We aimed to untangle the effects of a wide range of individual- and community-level socioeconomic factors on the risks of childhood undernutrition in Malawi.
Methods: We analyzed 6384 women-infant pairs from the 2004 and 2010 Malawi Demographic and Health Surveys (MDHSs). The undernutrition status was assessed by three domains of stunted (height-for-age), wasted (weight-for-height), and underweight (weight-for-age). We constructed generalized estimating equation logistic models to analyze associations of individual- and community-level characteristics with childhood undernutrition.
Results: About 48.4% of the children were stunted, 4.5% were wasted, and 14.4% were underweight. At the individual level, the risk of childhood undernutrition was significantly higher in males, children with a small birth size, children with a diarrheal episode in the last 2 weeks, children that were a product of multiple births, children born to mothers with either a low socioeconomic status, or a poor education, or who were underweight, and children born in the year 2004. At community level, children born in communities with low and medium wealth, and in communities with low and medium female educational attainment were more likely to be undernourished. Unexpectedly, the maternal HIV status was not associated with childhood undernutrition at either the individual or community level.
Conclusion: This study provides evidence of the importance of both individual- and community-level factors in determining childhood undernutrition. Interventions against childhood undernutrition should consider the various predictors discussed in this study in order to reduce undernutrition in children and contribute to their well-being.
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1. Introduction

Childhood undernutrition, including being stunted, wasted, and underweight, is a major global cause of morbidity and mortality among children under the age of 5 years.[1,2] Considering all causes of mortality in under-5-year-old children, about one-third of mortalities are linked to undernutrition.[3] Globally, approximately 165 million children under the age of 5 years are stunted, 99 million are underweight, and 51 million are wasted.[4,5] Undernutrition can compromise a child's immune system, retard growth, and affect brain development by delaying motor and cognitive development and further lead to different types of diseases later in life.[3,6] The burden of undernutrition is more pervasive in low- and medium-income countries, particularly in southern Asia and sub-Saharan Africa.[2,4] Despite national nutrition guidelines, a national nutrition policy and strategic plan, and joint scaling-up nutrition movement that were implemented at the end of the 2000s, the prevalence's of stunted, underweight, and wasted children in Malawi were persistently high and reached 42.4%, 16.7%, and 3.8% respectively in 2014.[7]

The framework proposed by the United Nations Children's Fund (UNICEF) grouped the causes of child undernutrition as (a) immediate causes, which refer to inadequate dietary intake and illnesses such as pneumonia, malaria, diarrhea, and measles; (b) underlying causes, encompassing insufficient access to food in the household, inadequate health services and an unhealthy environment, and inadequate care for children and women at the household level; and (c) basic causes, which are regarded as insufficient current and potential resources at the societal level.[3,8] Responding to the above framework, a large number of previous studies emphasized the importance of socioeconomic factors,[5,9,10] demographic factors,[11–14] household factors,[9,10,12,15] environmental factors,[10,12] parental characteristics,[5,9,10,12–15] child health and feeding practice factors,[5,11,14–16] and geographical location and place of residence[5,10,13,14] on the childhood nutrition status.

Although a great number of studies have examined risk factors for childhood undernutrition in low-income countries, a majority of them focused on individual-level factors,[11–14,16] and few investigated the influence of community-level factors on childhood undernutrition.[5,9,10,15] Studies from high-income countries already proved that community-level (neighborhood-level) characteristics have independent effects on individual health outcomes after considering the individual-level socioeconomic status.[17] The underlining premise of community-level effects on individual health implies that two otherwise identical individuals have different probabilities of a health condition because they live in different types of communities.[18] However, these hypotheses have not been comprehensively examined in low-income countries, especially in sub-Saharan Africa. Thus, the aim of this study was to examine both individual- and community-level risk factors for childhood undernutrition in Malawi.

2. Methods

2.1. Study design, sampling and procedures

We analyzed 6384 women-infant pairs from the 2004 and 2010 Malawi Demographic and Health Surveys (MDHSs) joint data set. The detailed methodology of the survey design, sample selection, survey tools, and data collection was described elsewhere.[19,20] Briefly, the MDHSs were designed to produce representative samples at the national, regional, and rural levels using a two-stage sampling procedure. Stratified two-stage cluster sampling was used to select households for the survey. A proportional-to-size sampling method was used to select clusters (communities) in the first stage (522 clusters in 2004 and 849 clusters in 2010), households in the second stage, and household members in the final stage. Both the 2004 and 2010 MDHSs defined a cluster as a census enumeration area containing a systematic sample of 15,091 households in 2004 and 27,345 households in 2010. Data were collected using face-to-face interviews of women of reproductive age (15–49 years). The information was collected on measures of population health, socioeconomics, demographics, the environment, anthropometrics, human immunodeficiency virus (HIV)/acquired immunodeficiency syndrome (AIDS), immunization, and infant and young child healthcare indicators. We included only mothers who had a child younger than 5 years prior to the survey. Because the number of non-respondents was relatively small, we excluded them from the analyses.

2.2. Outcome variables

A child's undernutrition status was assessed by three nutrition indices of being stunted, wasted, and underweight. Children with a Z-score of <-2 relative to WHO standards were defined as being undernourished with the height-for-age defining stunted, weight-for-age defining underweight, and weight-for-height defining wasted.[21] Children with a Z-score of <-2 standard deviations indicated that they were moderately or severely undernourished. Moreover, each of these indicators measures a different aspect of the nutritional status of children. Stunting indicates chronic undernutrition, wasting indicates acute undernutrition, and being underweight indicates general undernutrition.

2.3. Independent variables

Independent variables in this study were classed into three levels: individual level, maternal/household level, and community level. Selection of these variables was based on the previous literature.[5,22,23]

2.3.1. Individual-level factors

Individual-level variables were the sex of the child (male or female), age of the child (0–11, 12–23, 24–35, 36–47, and 48–59 months), size of the child at birth (smaller than average, average, and larger than average), child morbidity

status (presence of diarrhea, fever and acute respiratory infection 2 weeks before the survey or not), type of birth (single or multiple). The size at birth was used as a proxy for the birth weight. Fever diagnosis was based on self-reporting by mothers about symptoms that had occurred within two weeks prior to the survey date. Diarrheal disease was defined as the passage of three or more loose or liquid stools during a 24-h period while ARI prevalence was estimated by asking mothers whether their children under age 5 had been ill with a cough accompanied by short, rapid breathing in the two weeks preceding the survey.[19,20]

2.3.2. Maternal/household-level factors

Maternal factors included the mother's HIV status (seropositive or seronegative), age (15—24, 25—34, and ≥35 years), educational level (no formal education, primary education, and secondary and higher education), the body-mass index (<18.5 kg/m^2 = underweight, 18.5—24.9 kg/m^2 = normal and ≥25 5 kg/m^2 = overweight/obese),[24] year of the survey (2004 or 2010), number of children under the age of 5 years (household with one child or none, two, three, or more), and the household wealth index (poorest, poor, middle, rich and richest). The household wealth index is a composite measure of a household's cumulative living standard and was calculated using easy-to-collect data on a household's ownership of selected assets, such as televisions and bicycles, materials used for constructing the house, access to safe water, sanitation facilities, and other characteristics of a household.[19,20] Household asset scores were generated through a principal component analysis. The resulting asset scores were standardized and categorized into quintiles.[19,20]

2.3.3. Community-level factors

Community-level factors were constructed by aggregating individual- and maternal-level data to the cluster level. Communities were defined based on sharing a common primary sample unit (PSU). We included seven continuous community-level variables in our study, i.e., community wealth, community-level mother's education, community HIV status, community prenatal visits, community skilled delivery and community distance to health facility as well as two variables indicating area of residence. Community wealth was defined as the percentage of households in the community in the upper 40% wealth quintile, whereas community-level female education was defined as the percentage of women aged 15—49 years in the community with secondary or higher education. Community skilled delivery was defined as the percentage of mothers aged 15—49 years in the community whose delivery was attended by a physician, obstetrician, midwife, nurse, or other healthcare professional, while community prenatal attendance was defined as the percentage of mothers aged 15—49 years in the community who had received prenatal care services from a doctor, clinical officer, medical assistant, nurse or midwife. The community HIV status was defined as the percentage of adults in the community who tested seropositive for HIV. Community distance to the health facility was defined as the proportion of women aged 15—49 in the community who perceived distance to the nearest health facility as a big problem. All community-level factors were categorized as "low", "medium" and "high" depending upon each variable's tertiles.

2.4. Statistical analyses

All analyses were performed using SAS software version 9.4 (SAS Institute, Cary, NC, USA).[25] Chi-squared tests were performed to describe the bivariate relationship between explanatory factors and childhood undernutrition. Multivariate analyses were conducted using a series of three-level logistic models (e.g., children, mother, and community) with generalized estimating equations (GEEs) for estimating the effects of predictors on the risk of childhood undernutrition after controlling for other confounding factors. Because children living in the same community and belonging to the same mother may be more similar to each other than individuals from different communities and different mothers, GEE models were used to adjust the correlated individual responses because the same mother was nested under a single community. Results of the multivariate analysis were reported as adjusted odds ratios (aORs) with *p* values and 95% confidence intervals (CIs). The variance inflation factor (VIF) was used to assess multicollinearity in the model. The significance level of alpha was set to 5%.

2.5. Ethics statements

The 2004 and the 2010 MDHSs were implemented by the National Statistics Office (NSO) and the Community Health Sciences Unit (CHSU), Malawi. The protocol for blood sample collection and the questionnaires was reviewed and approved by the Malawi Health Sciences Research Committee, the Institutional Review Board of ICF Macro, and the Centers for Disease Control (CDC) in Atlanta, GA, USA. Informed consent was obtained at the beginning of each interview, and the authors sought permission from the MDHS program for the use of the data.

3. Results

3.1. Sample characteristics and prevalence of childhood undernutrition

In total, 6384 children in 849 communities were analyzed in this study. About 48.4% of the children were stunted, 4.5% were wasted, and about 14.4% were underweight. The descriptive and bivariate statistics are presented in Table 1. The prevalence of undernutrition was higher among male children, children in the 24—35-month age group, children with a smaller birth size, children who had had a diarrheal episode, fever and ARI in the last 2 weeks, children of multiple births, children of an uneducated mother, children of an underweight mother, children from the socioeconomically poorest households, children born 5 years prior to the 2004 survey, children from rural areas, children from the central region, children of poor communities, children of communities with low female education, children of communities with a low HIV prevalence, and children of communities with a low percentage of skilled delivery.

Table 1 Univariate and bivariate analysis of childhood undernutrition in Malawi.

Variable	Total sample	Stunted	Wasted	Underweight
	N (%)	*n (%)*	*n (%)*	*n (%)*
Outcome variables				
Childhood undernutrition	6384 (100)	3090 (48.4)	288 (4.5)	918 (14.4)
Individual-level factors				
Sex of the child				
Male	3171 (49.7)	1645 (51.9)[a]	148 (4.6)	485 (15.3)[c]
Female	3213 (50.3)	1445 (45.0)	140 (4.4)	433 (13.5)
Age of child (months)				
0—11	1243 (19.5)	337 (27.1)[a]	96 (7.7)[a]	152 (12.2)[b]
12—23	1482 (23.2)	785 (53.0)	94 (6.3)	231 (15.6)
24—35	1231 (19.3)	704 (57.2)	41 (3.3)	202 (16.4)
36—47	1252 (19.6)	670 (53.5)	34 (2.7)	159 (12.7)
48—59	1176 (18.4)	594 (50.5)	23 (2.0)	174 (14.8)
Size of the child at birth				
Smaller than average	904 (14.2)	553 (61.2)[a]	64 (7.1)[b]	225 (24.9)[a]
Average	2908 (45.6)	1423 (48.9)	129 (4.4)	412 (14.2)
Larger than average	2572 (40.2)	1114 (43.3)	95 (3.7)	281 (11.0)
Fever in the last weeks				
No	4140 (64.9)	1980 (47.8)	168 (4.1)[c]	557 (13.5)[b]
Yes	2244 (35.2)	1110 (49.5)	120 (5.4)	371 (16.1)
Recent diarrheal disease				
No	5239 (82.0)	2491 (47.6)[b]	214 (4.1)[a]	689 (13.2)[a]
Yes	1153 (18.0)	599 (52.0)	74 (6.4)	229 (19.9)
Acute respiratory infection				
No	4381 (68.6)	2123 (48.5)	193 (4.4)	626 (14.3)
Yes	2003 (31.4)	967 (52.04)	95 (4.7)	292 (14.6)
Type of birth				
Single birth	6195 (97.0)	2946 (47.6)[a]	279 (4.5)	861 (13.9)[a]
Multiple births	189 (3.0)	144 (76.2)	9 (4.8)	57 (30.12)
Maternal-level factors				
Maternal HIV status				
Negative	5868 (91.9)	2836 (48.3)	258 (4.4)	835 (14.3)
Positive	516 (8.1)	254 (49.2)	30 (5.8)	83 (16.1)
Mother's age (years)				
15—24	2179 (34.1)	1040 (47.7)	115 (5.3)	318 (14.6)[b]
25—34	2950 (46.2)	1436 (48.7)	121 (4.1)	382 (13.0)
35—49	1255 (19.7)	614 (48.9)	52 (4.1)	218 (17.4)
Mother's educational level				
No formal education	1266 (19.8)	693 (54.7)[a]	71 (5.6)[c]	226 (17.9)[a]
Primary	4328 (67.8)	2101 (48.6)	191 (4.4)	622 (14.4)
Secondary or higher	790 (12.4)	296 (37.5)	26 (3.3)	70 (8.7)
Mother's BMI				
Underweight	395 (6.2)	222 (56.2)[a]	34 (8.6)[a]	98 (24.8)[a]
Normal	5065 (79.3)	2496 (49.3)	229 (4.5)	746 (14.7)
Overweight	924 (14.6)	372 (40.3)	25 (2.7)	74 (8.0)
Number of under 5 in the HH				
One	20735 (32.5)	991 (47.8)	101 (4.9)	283 (13.7)
Two	3290 (51.5)	1592 (48.4)	137 (4.2)	473 (14.4)
Three and above	1021 (16.0)	507 (49.7)	50 (4.9)	162 (15.9)
Household wealth				
Poorest	1243 (19.5)	689 (55.4)[a]	66 (5.3)[b]	223 (18.7)[a]
Poor	1478 (23.2)	767 (51.9)	72 (4.9)	226 (15.3)
Middle	1496 (23.4)	733 (49.0)	76 (5.1)	222 (14.8)
Richer	1292 (20.2)	592 (45.8)	54 (4.2)	177 (13.7)
Richest	875 (13.7)	309 (35.3)	20 (2.3)	60 (6.7)
Year of survey				
2004	2080 (32.6)	1102 (53.0)[a]	113 (5.4)[c]	358 (17.2)[a]
2010	4304 (67.4)	1988 (46.2)	175 (4.1)	560 (13.0)

(*continued on next page*)

Table 1 (*continued*)

Variable	Total sample	Stunted	Wasted	Underweight
	N (%)	*n (%)*	*n (%)*	*n (%)*
Community-level factors				
Place of residence				
Urban	611 (9.6)	240 (39.3)[a]	23 (3.8)	62 (10.2)[b]
Rural	5773 (90.4)	2850 (49.4)	265 (4.6)	856 (14.8)
Geographical region				
Northern	1037 (16.2)	456 (44.0)[b]	30 (2.9)[c]	114 (11.0)[b]
Central	2353 (36.9)	1181 (50.2)	107 (4.5)	348 (14.8)
Southern	2994 (46.9)	1453 (48.5)	151 (5.0)	456 (15.2)
Community wealth[†]				
Low[ψ]	2319 (36.3)	1242 (53.6)[a]	104 (4.5)	375 (16.2)[b]
Middle	2261 (35.4)	1110 (49.1)	111 (4.9)	332 (14.7)
High	1804 (28.3)	738 (40.9)	73 (4.1)	211 (11.7)
Community female education[††]				
Low[ψ]	2365 (37.1)	1243 (52.6)[a]	113 (4.8)[c]	405 (17.1)[a]
Middle	2313 (36.2)	1117 (48.3)	116 (5.0)	327 (14.1)
High	1706 (26.7)	730 (42.8)	59 (3.5)	186 (10.9)
Community HIV status[†††]				
Low[ψ]	2198 (34.4)	1093 (49.7)[c]	89 (4.1)	298 (13.6)
Middle	2298 (36.0)	1138 (49.5)	101 (4.4)	355 (15.6)
High	1888 (29.6)	859 (45.5)	98 (5.2)	265 (14.0)
Community prenatal care[‡]				
Low[ψ]	2472 (38.8)	1236 (50.0)	112 (4.5)	347 (14.0)
Middle	2140 (33.5)	1005 (47.0)	107 (5.0)	322 (15.1)
High	1772 (27.8)	849 (47.9)	69 (3.9)	249 (14.1)
Community skilled delivery[‡‡]				
Low[ψ]	2527 (39.6)	1294 (51.2)[b]	132 (5.2)	386 (15.3)
Middle	2130 (33.4)	976 (45.8)	89 (4.2)	292 (13.7)
High	1727 (27.1)	820 (47.5)	67 (3.9)	240 (13.9)
Distance to health facility[§]				
Low[ψ]	2527 (39.6)	1208 (47.8)	114 (4.5)	362 (14.3)
Middle	1939 (30.4)	979 (50.5)	87 (4.5)	299 (15.4)
High	1918 (30.0)	903 (47.1)	87 (4.5)	257 (13.4)

Note: [a]$P < 0.0001$; [b]$P < 0.001$; [c]$P < 0.05$; **BMI** ~ Body Mass Index; **HIV** ~ Human Immunodeficiency Virus; **HH** ~ Household; ψ categorized based on tertiles; † percentage of households in the community categorized as rich (upper 40% of quintiles); †† percentage of female in the community with secondary and above education; ††† prevalence of HIV in adults in the community; ‡ percentage of women in the community had prenatal care services; ‡‡ percentage of women in the community who had skilled delivery; § proportion of women aged 15–49 in the community who perceived distance to the nearest health facility as a big problem.

3.2. Influences of individual and community factors on childhood undernutrition

Table 2 presents the results of the multivariate analyses of associations of individual- and community-level characteristics with child nutrition outcomes after controlling for all other factors. Boys had odds ratios of being stunted (aOR = 1.38) and underweight (aOR = 1.19), respectively, compared to girls. Compared to children in the 48–59-month age group, those aged <12 months were 68% and 28% less likely to be stunted and underweight, while those aged 24–35 months had an increased odds of being stunted (aOR = 1.34). Furthermore, the odds of being wasted was highest in children of the age groups of <12 (aOR = 4.05) and 12–23 months (aOR = 3.06). The risk of undernutrition was highest among children with a smaller size than average compared to children with a birth size larger than average aOR = 1.96 for being stunted; aOR = 1.85 for being wasted; and aOR = 2.44 for being underweight. Reduced odds of being stunted and underweight were observed in children with no history of diarrhea in the previous 2 weeks prior to data collection, and those of single births. The odds of being stunted were highest in mothers with no formal compared to mothers with no education (aOR = 1.48). The odds of childhood undernutrition were also highest in underweight mothers compared to overweight mothers (aOR = 1.68) for being stunted; (aOR = 2.52) for being wasted; and (aOR = 3.23) for being underweight. The risk of childhood undernutrition decreased with an increase in household wealth, and the odds were highest in children who belonged to the poorest households. Children from the northern region had 38% reduced odds of being wasted (aOR = 0.64) compared to those in the southern region. Compared to children who resided in communities with high wealth, children in communities with low and middle wealth had increased odds of

Table 2 Multilevel analysis of individual and community-level characteristics and childhood undernutrition.

Variables	Stunted	Wasted	Underweight
	aORs 95% CI	aORs 95% CI	aORs 95% CI
Individual-level factors			
Sex of the child			
Male	**1.38 (1.24–1.53)**[a]	1.08 (0.85–1.38)	**1.19 (1.03–1.38)**[c]
Female	1.00 (reference)	1.00 (reference)	1.00 (reference)
Age of child (months)			
0–11	**0.32 (0.27–0.39)**[a]	**4.05 (2.54–6.46)**[a]	**0.72 (0.56–0.92)**[b]
12–23	1.02 (0.87–1.20)	**3.06 (1.90–4.92)**[a]	0.91 (0.72–1.15)
24–35	**1.34 (1.14–1.58)**[b]	1.65 (0.97–2.80)	1.12 (0.89–1.41)
36–47	1.15 (0.98–1.36)	1.33 (0.77–2.28)	0.84 (0.66–1.07)
48–59	1.00 (reference)	1.00 (reference)	1.00 (reference)
Size of the child at birth			
Smaller than average	**1.96 (1.65–2.32)**[a]	**1.85 (1.33–2.58)**[b]	**2.44 (1.98–3.00)**[a]
Average	**1.18 (1.05–1.32)**[b]	1.16 (0.89–1.52)	**1.26 (1.06–1.49)**[c]
Larger than average	1.00 (reference)	1.00 (reference)	1.00 (reference)
Fever in the last weeks			
No	0.98 (0.86–1.10)	0.89 (0.68–1.15)	0.88 (0.75–1.04)
Yes	1.00 (reference)	1.00 (reference)	1.00 (reference)
Recent diarrheal disease			
No	**0.82 (0.71–0.95)**[b]	0.86 (0.65–1.16)	**0.65 (0.54–0.78)**[a]
Yes	1.00 (reference)	1.00 (reference)	1.00 (reference)
Acute respiratory infection			
No	1.03 (0.91–1.16)	1.14 (0.87–1.49)	1.12 (0.95–1.33)
Yes	1.00 (reference)	1.00 (reference)	1.00 (reference)
Type of birth			
Single birth	**0.26 (0.17–0.36)**[a]	1.06 (0.48–2.35)	**0.40 (0.27–0.59)**[a]
Multiple birth	1.00 (reference)	1.00 (reference)	1.00 (reference)
Maternal-level factors			
Maternal HIV status			
Negative	0.86 (0.70–1.07)	0.78 (0.51–1.19)	0.86 (0.65–1.14)
Positive	1.00 (reference)	1.00 (reference)	1.00 (reference)
Mother's age (years)			
15–24	1.15 (0.97–1.35)	1.08 (0.74–1.57)	0.82 (0.66–1.02)
25–34	1.12 (0.96–1.30)	1.03 (0.72–1.46)	**0.76 (0.62–0.92)**[c]
35–49	1.00 (reference)	1.00 (reference)	1.00 (reference)
Mother's educational level			
No formal education	**1.48 (1.17–1.86)**[b]	1.35 (0.79–2.31)	1.27 (0.90–1.79)
Primary	**1.28 (1.06–1.54)**[c]	1.12 (0.71–1.77)	1.20 (0.89–1.62)
Secondary or higher	1.00 (reference)	1.00 (reference)	1.00 (reference)
Mother's BMI			
Underweight	**1.68 (1.28–2.21)**[b]	**2.52 (1.42–2.46)**[b]	**3.23 (2.28–4.57)**[a]
Normal	**1.31 (1.11–1.55)**[b]	1.40 (0.89–2.19)	**1.78 (1.37–2.32)**[a]
Overweight	1.00 (reference)	1.00 (reference)	1.00 (reference)
Number of under 5 in the HH			
One	0.99 (0.83–1.17)	1.01 (0.68–1.50)	0.92 (0.72–1.16)
Two	0.96 (0.81–1.13)	0.86 (0.59–1.25)	0.93 (0.75–1.16)
Three and above	1.00 (reference)	1.00 (reference)	1.00 (reference)
Household wealth			
Poorest	**1.69 (1.35–2.13)**[a]	**2.18 (1.14–4.19)**[c]	**2.36 (1.64–3.41)**[a]
Poor	**1.48 (1.19–1.84)**[b]	**2.03 (1.08–3.86)**[c]	**1.88 (1.31–2.70)**[b]
Middle	**1.40 (1.13–1.73)**[b]	**2.30 (1.23–4.33)**[c]	**1.96 (1.37–2.81)**[b]
Richer	**1.29 (1.05–1.58)**[c]	**1.86 (1.00–3.48)**[c]	**1.84 (1.29–2.63)**[b]
Richest	1.00 (reference)	1.00 (reference)	1.00 (reference)
Year of survey			
2004	**1.30 (1.14–1.49)**[a]	1.21 (0.91–1.59)	**1.32 (1.11–1.57)**[b]
2010	1.00 (reference)	1.00 (reference)	1.00 (reference)

(*continued on next page*)

Table 2 (*continued*)

Variables	Stunted	Wasted	Underweight
	aORs 95% CI	aORs 95% CI	aORs 95% CI
Community-level factors			
Place of residence			
Urban	1.11 (0.89–1.37)	1.21 (0.72–2.03)	1.22 (0.87–1.81)
Rural	1.00 (reference)	1.00 (reference)	1.00 (reference)
Geographical region			
Northern	1.02 (0.86–1.21)	**0.64 (0.42–0.98)**[c]	0.86 (0.67–1.09)
Central	1.08 (0.95–1.22)	0.90 (0.69–1.18)	0.98 (0.83–1.15)
Southern	1.00 (reference)	1.00 (reference)	1.00 (reference)
Community wealth†			
Low[ψ]	**1.43 (1.18–1.73)**[b]	0.71 (0.47–1.07)	0.95 (0.74–1.22)
Middle	**1.26 (1.06–1.48)**[c]	0.84 (0.59–1.19)	0.98 (0.77–1.22)
High	1.00 (reference)	1.00 (reference)	1.00 (reference)
Community female education††			
Low[ψ]	0.99 (0.82–1.19)	1.40 (0.93–2.09)	**1.37 (1.06–1.78)**[c]
Middle	0.95 (0.81–1.12)	**1.50 (1.03–2.15)**[c]	1.17 (0.93–1.47)
High	1.00 (reference)	1.00 (reference)	1.00 (reference)
Community HIV status†††			
Low[ψ]	1.11 (0.96–1.30)	0.81 (0.59–1.12)	0.89 (0.72–1.10)
Middle	1.13 (0.98–1.30)	0.84 (0.61–1.15)	1.05 (0.86–1.27)
High	1.00 (reference)	1.00 (reference)	1.00 (reference)
Community prenatal care‡			
Low[ψ]	1.07 (0.84–1.36)	0.86 (0.52–1.44)	0.85 (0.62–1.16)
Middle	0.98 (0.81–1.18)	1.21 (0.81–1.82)	1.02 (0.79–1.33)
High	1.00 (reference)	1.00 (reference)	1.00 (reference)
Community skilled delivery‡‡			
Low[ψ]	0.98 (0.77–1.24)	1.63 (0.99–2.71)	1.06 (0.77–1.45)
Middle	0.91 (0.76–1.11)	1.11 (0.73–1.69)	0.95 (0.73–1.24)
High	1.00 (reference)	1.00 (reference)	1.00 (reference)
Distance to health facility§			
Low[ψ]	0.99 (0.83–1.17)	**0.67 (0.47–0.90)**[c]	0.97 (0.77–1.23)
Middle	1.05 (0.88–1.25)	**0.62 (0.42–0.94)**[c]	0.96 (0.75–1.23)
High	1.00 (reference)	1.00 (reference)	1.00 (reference)

Note: [a]$P < 0.0001$; [b]$P < 0.001$; [c]$P < 0.05$ **BMI** ~ Body Mass Index; **aORs** ~ adjusted Odds Ratios; **HIV** ~ Human Immunodeficiency Virus; **CI** ~ Confidence Intervals; **HH** ~ Household; ψ categorized based on tertiles; † percentage of households in the community categorized as rich (upper 40% of quintiles); †† percentage of female in the community with secondary and above education; ††† prevalence of HIV in adults in the community; ‡ percentage of women in the community had prenatal care services; ‡‡ percentage of women in the community who had skilled delivery; § proportion of women aged 15–49 in the community who perceived distance to the nearest health facility as a big problem.

being stunted (aOR = 1.43) and (aOR = 1.26), respectively. Children in communities with medium (aOR = 1.50) and low female education (aOR = 1.37) had increased odds of being wasted and underweight, respectively. Children from communities with low and medium percentage of women perceiving distance to health facility as big problem were less likely to be wasted than those from communities with high percentage of women perceiving distance to health facility as a big problem.

4. Discussion

In this study, the prevalence's of being stunted, wasted, and underweight were 48.5%, 4.5%, and 14.4%, respectively, which indicates that childhood undernutrition in Malawi truly requires urgent attention. The study found that a child's age, sex, birth size, diarrhea in the last 2 weeks, type of birth, the mother's age, education, and BMI, household wealth, and the year of survey were important risk factors for childhood undernutrition. Furthermore, this study also revealed that community-level variables, notably the geographical region, community wealth, and community female education, had independent effects on childhood undernutrition over and above the effects of individual- and maternal/household-level variables.

We found that male children were more likely to be stunted and underweight compared to their female counterparts of a similar socioeconomic background and our findings are consistent with previous studies.[26,9] It is believed that boys are more likely to be influenced by environmental stress than girls. Thus, the impact of chronic undernutrition could be more fully expressed in boys. Studies reported that gender inequality in childhood undernutrition was more likely to be found in environments where stresses like recurrent infections and exposure to

toxins and air pollutants were at play.[27] The observed sex differences may also reflect caregiver behavioral patterns such as responsive feeding styles or breastfeeding frequency on the basis of gender-based cultural perceptions.[28]

In this present study, infants in the age group of 0—11 months had a reduced odds of being stunted and underweight, while those in the age group of 24—35 months had an increased odds of being stunted. Furthermore, children aged 0—23 months were more likely to be wasted. Wasting with age before 2 years was previously reported.[23] It was suggested that this could be the result of a deficit in proper complementary food and the presence of progressive childhood diseases.[22,23] The reduced odds of being stunted and underweight in the 0—11-month age group might signify the protective effects of exclusive and continued breastfeeding for up to 1 year, as specified by the WHO.[29]

Increased odds of undernutrition found among children of a smaller size than average at birth are consistent with previous studies.[9,23] Children with small birth sizes are often born from mothers with a poor socioeconomic status and poor health conditions.[30—32] Previous studies suggested that children born with an extremely low birth weight are at high risk for neurological abnormalities and delayed growth and development in the first years of life.[33] In addition, our results confirmed that multiple births increased the odds of being stunted and underweight.[9,22] Multiple births are well-known to be associated with birth defects such as premature births, low birth weight, and cerebral palsy,[22,23,34] and all of these conditions can inhibit child growth.

In this study, the presence of diarrheal morbidity in the last 2 weeks prior to data collection was a contributing risk factor for being stunted and underweight. Similar findings were also reported in Ethiopia, Malawi, and Ghana.[11,16,23] Infections play a major role in the etiology of undernutrition because they can lead to lower appetite, nutrient losses due to vomiting, diarrhea, poor digestion, malabsorption, and disruption of metabolic equilibrium.[11,23]

The present study revealed that children born to mothers who never received a formal education, had a primary education, or resided in low- or middle-wealth households were more likely to be stunted. Poverty affects a child's nutritional status through insufficient food intake, exposure to infections, and a lack of basic health care such as vaccinations.[15] In previous studies, children born to women with a high education and in high-wealth households were observed to be less malnourished[13,35] because highly educated mothers were more likely to have economic advantages associated with educational attainment (e.g., access to nutritional content, clean water, and household resources). Higher levels of maternal education can also lower childhood malnutrition through other pathways, such as increased knowledge of healthy behaviors and sanitation practices.[36]

In addition, the mother's BMI is negatively associated with childhood undernutrition, suggesting that children born in a household where a mother has low BMI have an increased odds of being undernourished. Several possible explanations could be that, children born to underweight mothers are at increased risk of low birth weight and low birth weight leads to undernutrition in children.[4,33,37] Furthermore, underweight mothers' lactation capacity may be limited as a result of their poor nutrition.[37] Also a higher proportion of underweight mothers may live in poor socioeconomic conditions and their children may be deprived of proper weaning foods and essential primary health care facilities, both of which contribute to poor nutrition.[37,38]

This study found that children from the northern region were less likely to be wasted compared to those from the southern region. Similar results were reported in Bangladesh.[5] Undernutrition may reveal intra-regional and intra-ethnic differences because of economic, political, and climatic factors and diverse sociocultural norms that might affect childcare practices.[39] In Malawi, the northern region has the most favorable health characteristics (e.g., a large percentage of men and women had completed primary and secondary education, exposure to mass media, and a better wealth status).[19]

This study provides a good example showing that childhood undernutrition cannot be entirely explained by individual-level factors. Children from communities with low and medium levels of female education were more likely to be wasted and underweight compared to those from communities with a high female education level. In addition, those from low- and middle-wealth communities were more likely to be stunted compared to those from high-wealth communities. The importance of community wealth and female education was also found in other studies,[5,22] showing that communities with a poor status and low female education might expose children to undernutrition through collective social norms regarding inadequate nutritious food intake and possibly a lack of basic healthcare facilities. In contrast, communities with a higher percentage of women who have completed their education can encourage women to increase their autonomy and control over community resources, which in turn can enhance healthcare-seeking behaviors and utilization, and the ability to respond to new knowledge.[40]

4.1. Strengths and limitations

The present study was able to identify a wide range of determinants of childhood undernutrition in Malawi and it provides important insights by which the most appropriate interventions can be designed. Our study, however, is not without limitations. First, due to the cross-sectional nature of the data, we could not draw causal inferences in relationships of individual-, maternal-, and community-level factors with childhood undernutrition. Second, measures concerning child's health outcomes and other behaviors were based on women's self-reporting and not clinical examinations; hence, our findings are possibly subject to a recall bias. Third, the use of secondary data limited our ability to include other variables that are related to child undernutrition such as other healthcare indicators.

5. Conclusions

This paper shows that not only individual-level factors but also community-level factors contribute to the high prevalence of childhood undernutrition in Malawi. Policies and public health intervention strategies by policymakers that

target childhood nutrition and health should address the risk factors identified in this study. In particular, efforts should be focused on developing relatively poor communities and improving community- and individual-level female education in order to reduce the prevalence and burden of undernutrition. There is also a need to improve environments in socioeconomically poor households so that maternal nutritional status, episodes of diarrhoea and other infectious diseases can be prevented.

Conflicts of interest

There is no potential conflict of interest, real or perceived, for all authors.

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References

1. Crowe S, Seal A, Grijalva-Eternod C, Kerac M. Effect of nutrition survey "cleaning criteria" on estimates of malnutrition prevalence and disease burden: secondary data analysis. *PeerJ* 2014;**2**:e380.
2. Schott WB, Crookston BT, Lundeen EA, Stein AD, Behrman JR, Young Lives Determinants and Consequences of Child Growth Project Team. Periods of child growth up to age 8 years in Ethiopia, India, Peru and Vietnam: key distal household and community factors. *Soc Sci Med* 2013;**97**:278—87.
3. Herrador Z, Sordo L, Gadisa E, Moreno J, Nieto J, Benito A, et al. Cross-sectional study of malnutrition and associated factors among school aged children in rural and urban settings of Fogera and Libo Kemkem Districts, Ethiopia. *PLoS One* 2014;**9**:e105880.
4. 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**:427—51.
5. Chowdhury MR, Rahman MS, Khan MM, Mondal MN, 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.
6. Martins VJ, Toledo Florêncio TM, Grillo LP, Do Carmo P, Franco M, Martins PA, et al. Long-lasting effects of undernutrition. *Int J Environ Res Public Health* 2011;**8**:1817—46.
7. National Statistical Office. *Malawi MDG Endline Survey 2014, Key Findings*. Zomba, Malawi: National Statistical Office; 2014. Available at: http://www.nsomalawi.mw/latest-publications/mdg-endline-survey-2014.html. Accessed May 5, 2016.
8. United Nations Children's Fund (UNICEF). *UNICEF Conceptual Framework; Immediate Causes of Undernutrition*. 2008. Available at: http://www.unicef.org/nutrition/training/2.5/5.html. Accessed April 26, 2016.
9. Magadi MA. Household and community HIV/AIDS status and child malnutrition in sub-Saharan Africa: evidence from the demographic and health surveys. *Soc Sci Med* 2011;**73**:436—46.
10. Pongou R, Ezzati M, Salomon JA. Household and community socioeconomic and environmental determinants of child nutritional status in Cameroon. *BMC Public Health* 2006;**6**:98.
11. Asfaw M, Wondaferash M, Taha M, Dube L. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. *BMC Public Health* 2015;**15**:41.
12. Degarege D, Degarege A, Animut A. Undernutrition and associated risk factors among school age children in Addis Ababa, Ethiopia. *BMC Public Health* 2015;**15**:375.
13. Kimani-Murage EW, Muthuri SK, Oti SO, Mutua MK, van de Vijver S, Kyobutungi C. Evidence of a double burden of malnutrition in urban poor settings in Nairobi, Kenya. *PLoS One* 2015;**10**:e0129943.
14. Yisak H, Gobena T, Mesfin F. Prevalence and risk factors for under nutrition among children under five at Haramaya district, Eastern Ethiopia. *BMC Pediatr* 2015;**15**:212.
15. Uthman OA. A multilevel analysis of individual and community effect on chronic childhood malnutrition in rural Nigeria. *J Trop Pediatr* 2009;**55**:109—15.
16. Chikhungu LC, Madise NJ. Seasonal variation of child under nutrition in Malawi: is seasonal food availability an important factor? Findings from a national level cross-sectional study. *BMC Public Health* 2014;**14**:1146.
17. Kalff AC, Kroes M, Vles JS, Hendriksen JG, Feron FJ, Steyaert J, et al. Neighbourhood level and individual level SES effects on child problem behaviour: a multilevel analysis. *J Epidemiol Community Health* 2001;**55**:246—50.
18. Chuang YC, Cubbin C, Ahn D, Winkleby MA. Effects of neighbourhood socioeconomic status and convenience store concentration on individual level smoking. *J Epidemiol Community Health* 2005;**59**:568—73.
19. National Statistical Office (NSO), ICF Macro. *Malawi Demographic and Health Survey 2010*. Zomba, Malawi, and Calverton, Maryland, USA: NSO and ICF Macro; 2011. Available at: http://www.dhsprogram.com/pubs/pdf/FR247/FR247.pdf. Accessed August 11, 2016.
20. National Statistical Office (NSO) [Malawi], ORC Macro. *Malawi Demographic and Health Survey 2004*. Calverton, Maryland: NSO and ORC Macro; 2005. Available at: https://www.dhsprogram.com/pubs/pdf/FR175/FR-175-MW04.pdf. Accessed November 23, 2015.
21. WHO Multicentre Growth Reference Study Group. WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatr Suppl* 2006;**450**:76—85.
22. Adekanmbi VT, Kayode GA, Uthman OA. Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis. *Matern Child Nutr* 2013;**9**:244—59.
23. Aheto JM, Keegan TJ, Taylor BM, Diggle PJ. Childhood malnutrition and its determinants among under-five children in Ghana. *Paediatr Perinat Epidemiol* 2015;**29**:552—61.
24. World Health Organization (WHO). *Global Database on Body Mass Index: BMI classification*. 2004. Available at: http://apps.who.int/bmi/index.jsp?introPage=intro_3.html. Accessed July 13, 2016.
25. SAS Institute Inc. *Base SAS® 9.4 Procedures Guide: Statistical Procedures*. 2nd edition. Cary, NC: SAS Institute Inc; 2013 Available at:. In: http://support.sas.com/documentation/cdl/en/procstat/66703/PDF/default/procstat.pdf. Accessed November 22, 2015.
26. Fenske N, Burns J, Hothorn T, Rehfuess EA. Understanding child stunting in India: a comprehensive analysis of socio-economic,

nutritional and environmental determinants using additive quantile regression. *PLoS One* 2013;**8**:e78692.
27. Olack B, Burke H, Cosmas L, Bamrah S, Dooling K, Feikin DR, et al. Nutritional status of under-five children living in an informal urban settlement in Nairobi, Kenya. *J Health Popul Nutr* 2011;**29**:357—63.
28. Tumilowicz A, Habicht JP, Pelto G, Pelletier DL. Gender perceptions predict sex differences in growth patterns of indigenous Guatemalan infants and young children. *Am J Clin Nutr* 2015;**102**:1249—58.
29. World Health Organization (WHO). *Infant and young child feeding: model chapter for textbooks for medical students and allied health professionals*. Geneva, Switzerland: WHO; 2009. Available at: http://www.who.int/nutrition/publications/infantfeeding/9789241597494/en/#. Accessed May 2, 2016.
30. Yadav H, Lee N. Maternal factors in predicting low birth weight babies. *Med J Malaysia* 2013;**68**:44—7.
31. Khan N, Jamal M. Maternal risk factors associated with low birth weight. *J Coll Physicians Surg Pak* 2003;**13**:25—8.
32. Gebremedhin M, Ambaw F, Admassu E, Berhane H. Maternal associated factors of low birth weight: a hospital based cross-sectional mixed study in Tigray, Northern Ethiopia. *BMC Pregnancy Childbirth* 2015;**15**:222.
33. Correia LL, Silva AC, Campos JS, Andrade FM, Machado MM, Lindsay AC, et al. Prevalence and determinants of child undernutrition and stunting in semiarid region of Brazil. *Rev Saude Publica* 2014;**48**:19—28.
34. Olusanya BO. Perinatal outcomes of multiple births in Southwest Nigeria. *J Health Popul Nutr* 2011;**29**:639—47.
35. Frost MB, Forste R, Haas DW. Maternal education and child nutritional status in Bolivia: finding the links. *Soc Sci Med* 2005;**60**:395—407.
36. Abuya BA, Ciera J, Kimani-Murage E. Effect of mother's education on child's nutritional status in the slums of Nairobi. *BMC Pediatr* 2012;**12**:80.
37. Hasan MT, Soares Magalhães RJ, Williams GM, Mamun AA. Long-term changes in childhood malnutrition are associated with long-term changes in maternal BMI: evidence from Bangladesh, 1996—2011. *Am J Clin Nutr* 2016;**104**:1121—7.
38. Rahman M, Roy SK, Ali M, Mitra AK, Alam AN, Akbar MS. Maternal nutritional status as a determinant of child health. *J Trop Pediatr* 1993;**39**:86—8.
39. Adekanmbi VT, Kandala NB, Stranges S, Uthman OA. Contextual socioeconomic factors associated with childhood mortality in Nigeria: a multilevel analysis. *J Epidemiol Community Health* 2015;**69**:1102—8.
40. Güneş PM. The role of maternal education in child health: evidence from a compulsory schooling law. *Econ Educ Rev* 2015;**47**:1—16.