Journal of Tropical Pediatrics, 2018, 64, 267–278
doi: 10.1093/tropej/fmx059
Advance Access Publication Date: 27 July 2017
Original paper

OXFORD

Multilevel Analysis of the Effects of Individual- and Community-Level Factors on Childhood Anemia, Severe Anemia, and Hemoglobin Concentration in Malawi

by Peter Austin Morton Ntenda, Kun-Yang Chuang, Fentanesh Nibret Tiruneh and Ying-Chih Chuang

School of Public Health, Taipei Medical University, No. 250, Wu-Hsing St, Taipei City, Taiwan 110
Correspondence: Ying-Chih Chuang, School of Public Health, Taipei Medical University, No. 250, Wu-Hsing St, Taipei City, Taiwan 110.
E-mail <yingchih@tmu.edu.tw>.

ABSTRACT

Background: The purpose of this article was to examine individual- and community-level factors associated with childhood anemia, severe anemia, and hemoglobin (Hb) concentration in Malawi.
Methods: Using data from the 2010 Malawi demographic and health survey (MDHS), the multilevel regression models were constructed to analyze 2597 children aged 6–59 months living in 849 communities.
Results: The results showed that both childhood anemia and severe anemia were negatively associated with child's age, no fever in the previous 2 weeks and height-for-age, and positively associated with residing in poor household. Childhood anemia was negatively associated with community female education. Child's age, no fever in the previous 2 weeks and maternal Hb levels were positively associated with child Hb concentration, while residing in poorest households was negatively associated with children's Hb concentration.
Conclusion: Comprehensive public health strategies aimed at reducing childhood anemia need to focus more on the significant characteristics addressed in this study.

KEYWORDS: childhood anemia, multilevel study, Malawi

BACKGROUND

Anemia is defined as a condition in which the number of red blood cells, hemoglobin (Hb) concentration or packed-cell volume, is insufficient to meet the body's physiologic needs [1–4]. A global estimate of childhood anemia indicated that 293.1 million children under the age of 5 years are anemic, and 28.5% of these children reside in sub-Saharan Africa (SSA) [5, 6]. Malawi has one of the highest prevalence rates of anemia across nations [7]. Studies have reported that 63% of children aged 6∼59 months in Malawi are anemic and 3% are severe anemic [8].

The World Health Organization (WHO) statement on anemia underlines its multifactorial etiology [9]. Approximately 50% cases of anemia are considered to be due to an iron deficiency [5, 6, 10], although other factors such as nutritional deficiencies [6, 11, 12], acute and chronic inflammation [12–14], and inherited or acquired disorders that affect Hb

© The Author [2017]. Published by Oxford University Press. All rights reserved. For Permissions, please email: journals.permissions@oup.com

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

synthesis [12, 15], can all be etiologies of anemia. Previous studies also had demonstrated that factors such as a child's biological characteristics [5, 16–19], maternal characteristics [16–19], household economic status [17, 19], and community characteristics [19] have impacts on childhood anemia.

Despite the individual risk factors of childhood anemia have been well explored in prior studies [3, 20–23], few studies have simultaneously considered the influence of contextual- and individual-level factors on childhood anemia, particularly in Malawi. Previously, it was reported that the community constitutes a key component of socioeconomic challenges to good health [24–27]. Therefore, this study aimed to examine whether individual-level and community-level factors both can influence childhood anemia, severe anemia, and Hb concentration.

MATERIALS AND METHODS

Study design

Data came from the 2010 Malawi Demographic and Health Survey (MDHS). Methods used in this study have been described in details elsewhere [8]. Using a stratified two-stage cluster design, the 2010 MDHS produced a nationally representative sample. The first stage selected 849 communities (clusters) and the second stage selected 27 345 households. Analyses were limited to the children whose households were selected for hemoglobin estimation. A random procedure was conducted to select one child per household to avoid the clustering effects, which generated a final sample size of 2597.

Data collection

Using face-to-face interviews, data were collected from women aged 15–49 with children below the age of 5 years prior to the survey. Anemia test from children aged 6–59 months was done through finger prick blood testing using the HemoCue blood hemoglobin (Hb) system. The HemoCue system is based on the conversion of Hb to cyanmethemoglobin and its detection by measuring absorption in a spectrophotometer [28].

Measures

Outcome variables

Childhood anemia, severe anemia, and hemoglobin concentration were the outcomes. Using WHO recommendations, childhood anemia was defined as children aged 6–59 months with an Hb level of <11 g/dL, while severe anemia was defined as children aged 6–59 months with an Hb level of <7.0 g/dL [1]. Hb concentration was a continuous variable measured in g/dL.

Independent variables

Individual/maternal/household-level factors. Child-specific factors included child's sex, child's age (in months), birth order, history of fever and diarrhea in the past 2 weeks, stunting, underweight, and vitamin A supplements and deworming in the past 6 months. Maternal and household characteristics include age (in years), educational attainment, maternal anemic status, and household wealth status (Table 1). We defined stunting and underweight as children with height-for-age and weight-for-age Z-score < -2 relative to WHO standards [29, 30]. Vitamin A Supplement was defined as whether the child had received a high dose of vitamin A supplement in the past 6 months [31]. Fever diagnosis was based on the self-reports by mothers about symptoms that had occurred within 2 weeks prior to the survey date [8, 32]. Diarrheal disease was defined as the passage of three or more loose or liquid stools during a 24-h period [33]. Mothers with hemoglobin level of <12 g/dL were regarded to be anemic [1]. The wealth index was constructed using data on a household's ownership of selected assets, such as televisions, materials used for constructing the house etc., through the principal component analysis [34, 35].

Community-level factors. We included six variables. Two variables indicate an area of residence, i.e., place of residence and geographical region. Four continuous variables assessed community wealth, community female education, community water supply and community sanitation services. We defined a community based on the primary sample unit in the DHS data. All continuous community-level factors were

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

Table 1. Description of study variables

Characteristics	Measure
Outcome variables	
Childhood anemia	1 = if the child has a hemoglobin level of < 11.0 g/dL, and 0 = otherwise
Severe anemia	1 = if the child has a hemoglobin level of < 7.0 g/dL, and 0 = otherwise
Hemoglobin concentration	Continuous variable measured in grams per deciliter (g/dL)
Individual-level variables	
Sex of the child (Ref: female)	1 = female, and 0 = male
Age of the child	Continuous variable measured in months
Birth order of child	Continuous variable
Diarrhea in the past 2 weeks (Ref: yes)	1 = if the child had diarrhea, and 0 = otherwise
Fever in the past 2 weeks (Ref: yes)	1 = if the child had a fever, and 0 = otherwise
History of stunting (Ref: stunted)[a]	1 = if the child is stunted, and 0 = otherwise
History of wasting (Ref: wasted)[b]	1 = if the child is wasted, and 0 = otherwise
Vitamin A Supplements in previous 6 months (Ref: yes)	1 = if the child received vitamin supplements A in the past 6 months, and 0 = otherwise
Deworming in previous 6 months (Ref: yes)	1 = if the child received deworming medicine in the past 6 months, and 0 = otherwise
Mother's age group (Ref: 35∼49)	Continuous variable
Mother's educational level (Ref: Secondary and above)	0 = none, 1 = primary, 2 = secondary and above
Maternal anemia status (Ref: anemic)	Continuous variable
Household wealth index (Ref: Richest)	0 = poorest, 1 = poor, 2 = middle, 3 = rich, 4 = richest
Community-level variables	
Place of residence (Ref: urban)	1 = rural area; 0 = urban
Geographical region (Ref: southern)	0 = northern, 1 = central and 2 = southern
Community wealth	Mean percentage of richest (rich, richest) households in the community—upper 40% of household wealth index
Community female education	Mean percentage of women in the community with primary education and above
Community water supply[c]	Mean percentage of households in the community with access to improved drinking water sources
Community sanitation services[d]	Mean percentage of households in the community with access to improved sanitation

Note: g/dL = grams per deciliter; WHO = World Health Organization.
[a]Height-for-age < −2 standard deviation of the WHO reference group [29, 30].
[b]Weight-for-age < −2 standard deviation of the WHO reference group [29, 30].
[c]Improved drinking water (piped water into dwelling, piped water to yard/plot, public tap or standpipe, tubewell or borehole, protected dug well, protected spring and rainwater) [36].
[d]Improved sanitation (flush toilet, piped sewer system, septic tank, flush/pour flush to pit latrine, ventilated improved pit latrine, pit latrine with slab, and composting toilet) [36].

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

constructed by aggregating individual-level data to the community level (Table 1). The WHO and UNICEF Joint Monitoring Programme (JMP) for water supply and sanitation guidelines were used to define safe drinking water and improved sanitation [36].

Statistical analyses

Two-level multilevel multivariate regression models were constructed for the analyses. Generalized linear mixed models were constructed for the anemia and the severe anemia outcomes, while the linear mixed-effect models were constructed for the Hb concentration outcomes [37]. Because children living in the same community may be more similar to each other than individuals from different communities, the multilevel models were used to adjust the correlated individual responses nested under the same community. Intraclass correlations (ICC) and percentage change in variation (PCV) were reported to assess the extent of which community variances were explained in each model. Model fits were assessed using deviation information criterion, while variance inflation factor was used to examine for multicollinearity.

Ethics statement

The protocol for blood sample collection and the questionnaires was reviewed and approved by the Malawi National Health Sciences Research Committee, the Institutional Review Board of ICF Macro, and the Centers for Disease Control in Atlanta. Informed consent was obtained at the beginning of each interview, and the authors sought permission from the DHS program for the use of the data.

RESULTS

Sample characteristics

The mean Hb concentration was 10.47 g/dL. Figure 1 shows the distribution of children's Hb level. The prevalence of anemia and severe anemia were estimated at 63% and 3%, respectively. Table 2 shows the descriptive statistics. The prevalence of anemia was observed to be highest among younger, chronically undernourished, lower socioeconomic children and children with a history of diarrhea and fever and without proper parental care practices.

Figure 2 shows the scatter plots of the relationship between children's Hb levels and a selected subset of variables. Apart from the community safe

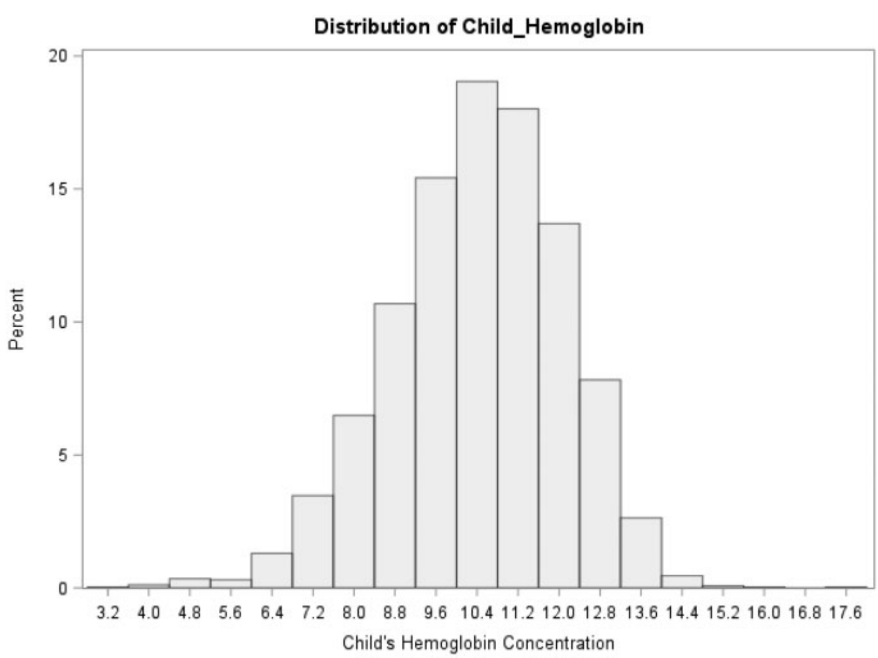

Fig. 1. Distribution of hemoglobin concentration in children (6–59 months; $n = 2597$).

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

Table 2. Characteristics of children aged 6–59 months with anemia and severe anemia in Malawi, n = 2597

Characteristics	Total	Anemia[a]			Severe anemia[b]		
		No	Yes	*p*-value	No	Yes	*p*-value
Individual-level factors							
Child age, months, *Mean±SD**	31.51±14.91	36.42±13.69	28.62±14.85	<.0001	31.77±14.91	22.68±12.09	<.0001
Sex of the child, *n (%)***							
Male	1293 (49.79)	471 (36.43)	822 (63.57)	0.4668	1254 (96.98)	39 (3.02)	0.6109
Female	1304 (50.21)	493 (37.81)	811 (62.19)		1269 (97.32)	35 (2.68)	
Birth order, *Mean ±SD**	3.67±2.32	3.62±2.25	3.70±2.35	0.7407	3.67±2.31	3.78±2.46	0.4648
Height-for-Age, *Mean ± SD**	−1.84±1.51	−1.75±1.40	−1.89±1.57	<.0001	−1.83±1.50	−1.99±1.07	0.8754
Weight-for-Age *Mean ± SD**	−0.84±1.08	−0.76±1.04	−0.88±1.10	0.0043	−0.83±1.25	1.05±1.20	0.4251
Vitamin A in the past 6 months, *n (%)***							
No	323 (12.44)	101 (31.27)	222 (68.73)	0.0200	315 (97.52)	8 (2.48)	0.6671
Yes	2274 (87.57)	863 (37.95)	1411 (62.05)		2208 (97.10)	66 (2.90)	
Deworming in previous 6 months, *n (%)***							
No	698 (26.88)	219 (31.38)	479 (68.62)	0.0002	671 (96.13)	27 (3.87)	0.0585
Yes	1899 (73.12)	745 (39.23)	1154 (60.77)		1852 (97.53)	47 (2.47)	
Diarrhea, *n (%)***							
No	2166 (83.40)	852 (39.34)	1314 (60.66)	<.0001	2110 (97.41)	56 (2.59)	0.0698
Yes	431 (16.60)	112 (25.99)	319 (74.01)		413 (95.82)	18 (4.18)	
Fever, *n (%)***							
No	1662 (64.00)	709 (42.60)	954 (57.40)	<.0001	1627 (97.89)	35 (2.11)	0.0024
Yes	935 (36.00)	256 (27.38)	679 (72.62)		896 (95.83)	39 (4.17)	
Mother's age, (years) *Mean ± SD**	28.85±6.92	29.26±6.65	28.61±7.07	0.0161	28.84±6.87	29.14±8.31	0.9135
Mother's education, *n* (%)**							
No formal education	422 (16.25)	129 (30.57)	293 (69.43)	0.0005	409 (96.92)	13 (3.08)	0.8923
Primary	1817 (69.97)	677 (37.26)	1140 (62.74)		1765 (97.14)	52 (2.86)	
Secondary and above	358 (13.79)	158 (44.13)	200 (55.87)		349 (97.49)	9 (2.51)	

(Continued)

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

Table 2. (Continued)

Characteristics	Total	Anemia[a]			Severe anemia[b]		
		No	Yes	*p*-value	No	Yes	*p*-value
Maternal hemoglobin level, *Mean ± SD**	12.78±1.75	13.10±1.75	12.59±1.72	<.0001	12.78±1.75	12.65±1.54	0.0200
Household wealth, *n (%)***							
Poorest	482 (18.56)	141 (29.25)	341 (70.75)	<.0001	462 (95.85)	20 (4.15)	0.0581
Poor	603 (23.22)	205 (34.00)	398 (66.00)		583 (96.68)	20 (3.32)	
Middle	590 (22.72)	209 (35.42)	381 (64.58)		571 (96.78)	19 (3.32)	
Rich	513 (19.75)	211 (41.13)	302 (58.87)		503 (98.05)	10 (1.95)	
Richest	409 (15.75)	198 (48.41)	211 (51.59)		404 (98.78)	5 (1.22)	
Community-level factors							
Place of residence *n (%)***							
Urban	285 (10.97)	136 (47.72)	149 (52.28)	<.0001	280 (98.25)	5 (1.75)	0.2390
Rural	2312 (89.03)	828 (35.81)	1484 (64.19)		2243 (97.02)	69 (2.98)	
Geographical region *n (%)***							
Northern	427 (16.44)	186 (43.56)	241 (56.44)	0.0082	418 (97.89)	9 (2.11)	0.1440
Central	984 (37.89)	361 (36.69)	623 (63.31)		948 (96.34)	36 (3.66)	
Southern	1186 (45.67)	417 (35.16)	769 (64.84)		1157 (97.55)	29 (2.45)	
Community wealth[c] *Mean ± SD**	37.85±29.32	37.83±28.32	30.35±29.16	<.0001	33.25±26.38	28.87±22.65	0.2174
Community female education[d] *Mean ± SD**	84.48±14.77	85.89±13.46	82.11±15.15	<.0001	83.60±14.64	80.75±15.21	0.1382
Community water supply[e] *Mean ± SD**	79.11±25.22	80.48±25.09	78.30±25.27	0.0347	79.04±25.35	81.60±20.49	0.4992
Community sanitation services[f] *Mean ± SD**	10.01±16.03	11.06±17.11	9.40±15.33	0.0040	9.96±16.03	11.85±16.31	0.1929

[a]Hb < 11g/dL.
[b]Hb < 7 g/dL; Hb = hemoglobin; SD = standard deviation.
[c]Percentage of households in the community categorized as rich (upper 40% of quintiles).
[d]Percentage of female in the community with primary and above education.
[e]Percentage of household in the community with access to improved water sources.
[f]Percentage of household in the community with access to improved sanitation facilities.
*Groups were significantly different by univariate logistic regression, $p < 0.05$.
**Groups were significantly different by chi-square test, $p < 0.05$.

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

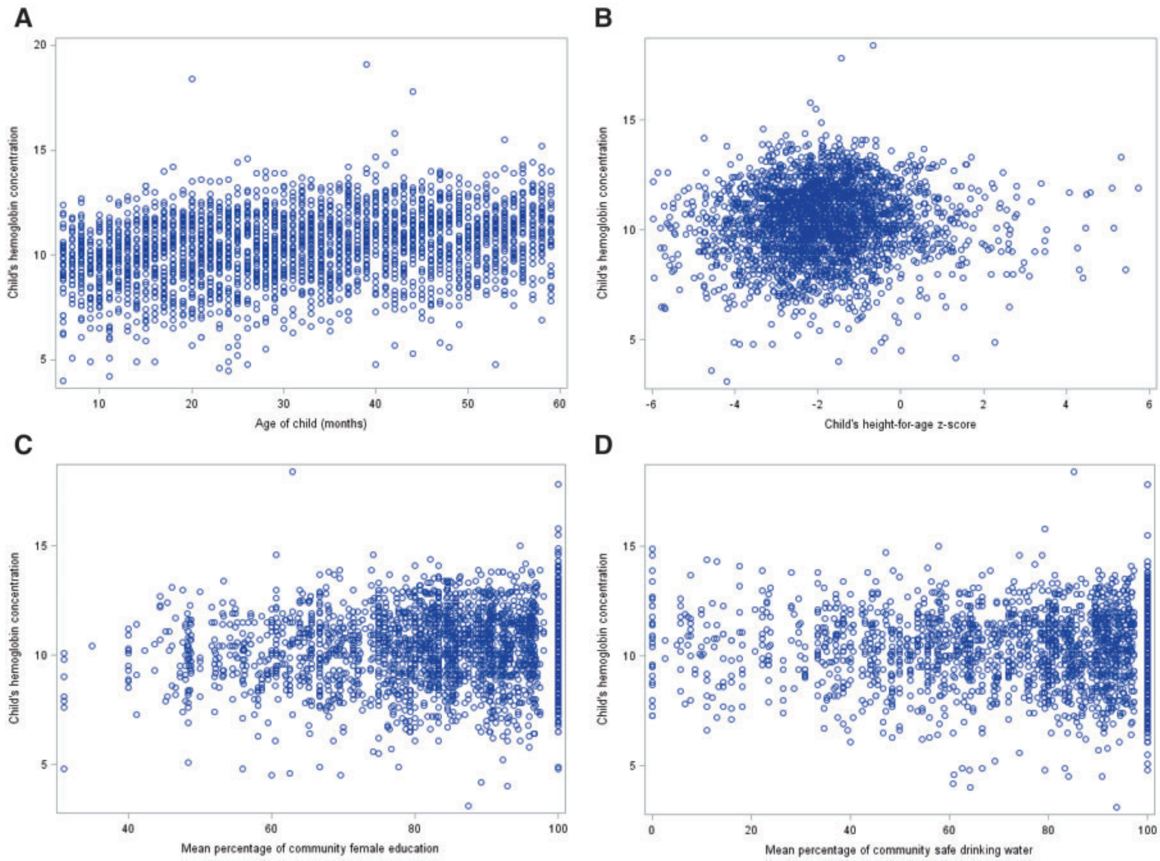

Fig. 2. Scatter plots of children's hemoglobin concentration against (**A**) age of child, (**B**) child's height-for-age z-score, (**C**) mean percentage of community female education, and (**D**) mean percentage of community safe drinking water ($n = 2597$).

drinking water, child's age, height-for-age, and community female education were positively associated with increased children's Hb levels.

Effects of individual-level and community-level factors on childhood anemia

Table 3 showed the results of the multilevel analyses (Model 4). For Hb concentration, the results showed that age of the child ($\beta = 0.2680$), having no history of fever ($\beta = 3.2172$) and mothers' Hb level ($\beta = 0.0118$) were positively associated with child Hb concentration, while residing in the poor households ($\beta = -4.8415$) and residing in communities with lower percentage of household with access to safe drinking water ($\beta = -0.05863$) were negatively associated with child Hb concentration.

For childhood anemia, the results showed that child's age ($\beta = -0.03816$), having no history of fever ($\beta = -0.4892$), height-for-age ($\beta = -0.00090$), maternal Hb level ($\beta = -0.4397$) and residing in communities with higher percentage of women with primary and above education ($\beta = -0.0099$) were negatively associated with childhood anemia, whereas residing in the poorest households ($\beta = 0.3813$) and having no vitamin A supplements ($\beta = 0.3062$) were positively associated with childhood anemia.

For severe anemia, the results showed that child's age ($\beta = -0.07556$), having no history of fever ($\beta = -0.7595$) and height-for-age ($\beta = -0.00357$) were negatively associated with childhood anemia, while maternal age ($\beta = 0.09761$) and residing in poor households were positively associated with severe anemia.

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

Table 3. Multilevel analysis of determinants of Hb concentration, anemia, and severe anemia in children aged 6–59 months in Malawi, n = 2597

Characteristics	Hb concentration (g/dL)		Anemia <11.0 g/dL		Severe anemia <7.0 g/dL	
	Coeff (SE)		Coeff (SE)		Coeff (SE)	
Individual-level factors						
Sex of the child						
Male/female	0.4025 (1.1756)	0.7321	0.03709 (0.09055	0.6822	0.2284 (0.3338)	0.4940
Child's age (months)	**0.2680 (0.04411)**	**<.0001**	**−0.03816 (0.00352)**	**<.0001**	**−0.07556 (0.01482)**	**<.0001**
Birth order	−0.3100 (0.4937)	0.5302	0.03827 (0.03800)	0.3141	−0.2121 (0.1359)	0.1186
Diarrhea						
No/yes	2.2290 (1.6806)	0.1849	−0.09258 (0.1356)	0.4950	0.3975 (0.4353)	0.3613
Fever						
No/yes	**3.2172 (1.2764)**	**0.0118**	**−0.5333 (0.1004)**	**<.0001**	**−0.7595 (0.3525)**	**0.0313**
Height-for-Age	0.003629 (0.00406)	0.3713	**−0.00090 (0.00034)**	**0.0045**	**−0.00357 (0.00120)**	**0.0028**
Weight-for-Age	0.002160 (0.00485)	0.6561	−0.00028 (0.00038)	0.4608	−0.00040 (0.00132)	0.7611
Vitamin A supplements						
No/yes	−2.3325 (1.8849)	0.2161	**0.3062 (0.1520)**	**0.0442**	−0.8281 (0.5742)	0.1494
Deworming past 6 months						
No/yes	0.2403 (1.4736)	0.8705	−0.1470 (0.1156)	0.2037	0.05171 (0.3981)	0.8967
Mother's age (years)	0.06043 (0.1654)	0.7149	−0.01366 (0.01275)	0.2841	**0.09761 (0.0437)**	**0.0256**
Mother's education						
No formal education	−0.3020 (2.5229)	0.9047	0.2593 (0.1945)	0.1826	−0.04845 (0.7058)	0.9453
Primary	1.7588 (1.9060)	0.3562	0.07648 (0.1431)	0.5932	−0.01523 (0.5739)	0.9788
Maternal Hb level g/dL	**0.0118 (0.9988)**	**<.0001**	**−0.4397 (0.08304)**	**<.0001**	0.03039 (0.2682)	0.9098
Household wealth						
Poorest	**−4.8415 (2.4753)**	**0.0497**	**0.3813 (0.1888)**	**0.0436**	**2.2544 (0.8753)**	**0.0101**
Poor	−2.8902 (2.3313)	0.2152	0.2362 (0.1756)	0.1787	**1.7866 (0.8496)**	**0.0356**
Middle	−2.8914 (2.2707)	0.2031	0.2465 (0.1706)	0.1487	**1.9761 (0.8362)**	**0.0182**
Rich	−1.5191 (2.1490)	0.4797	0.1595 (0.1603)	0.3201	1.3131 (0.8526)	0.1237
Community-level factors						
Place of residence						
Urban/Rural	−0.3966 (2.7322)	0.8846	0.04310 (0.2026)	0.8316	−0.1990 (1.0815)	0.8540
Geographical region						
Northern	−1.2210 (1.9894)	0.5394	−0.05089 (0.1481)	0.7312	0.09739 (0.8002)	0.9031
Central	0.2794 (1.4080)	0.8427	−0.08515 (0.1070)	0.4263	0.5541 (0.5236)	0.2901

(Continued)

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

Table 3. (Continued)

Characteristics	Hb concentration (g/dL)		Anemia <11.0 g/dL		Severe anemia <7.0 g/dL	
	Coeff (SE)		Coeff (SE)		Coeff (SE)	
Community wealth[a]	0.07503 (0.04151)	0.0709	−0.0058 (0.00312)	0.0614	−0.00294 (0.01561)	0.8507
Community education[b]	0.07394 (0.05281)	0.1617	**−0.0099 (0.00411)**	**0.0159**	0.004458 (0.01973)	0.8213
Community water supply[c]	**−0.05863 (0.02680)**	**0.0288**	−0.0003 (0.00205)	0.8813	0.01865 (0.01184)	0.1155
Community sanitation services[d]	−0.08770 (0.04745)	0.0647	0.0033 (0.00353)	0.3517	0.02176 (0.01720)	0.2061
Measures of variation						
Community-level variance						
Area variance [τ(SE)]	**38.5825 (17.6723)**	**0.0080**	**0.1696 (0.08952)**	**0.0113**	**16.3708 (5.2432)**	**0.0009**
ICC (%)	2.28		4.90		83.2	
PCV (%)	36.38		33.23		39.58	
Model fit statistics						
DIC (-2log likelihood)	24986.4		3096.15		570.10	

Note: Hb, hemoglobin; Coeff, beta coefficient; [τ (SE)], community-level variance; SE, standard error; ICC, intraclass correlations; PCV, proportional change in variance; DIC, deviation information criterion. The Bold texts indicate a statistically significant association at a *p*-value less than 0.05.
[a]Percentage of households in the community categorized as rich (upper 40% of quintiles).
[b]Percentage of female in the community with primary and above education.
[c]Percentage of household in the community with access to safe water supply.
[d]Percentage of household in the community with access to improved sanitation facilities.

The ICCs show that about 2%, 5% and 83% of community-level variance were unexplained for Hb concentration, childhood anemia and severe anemia, respectively, which shows the community-level characteristics included in this study cannot explain most of the community-level variance especially in severe anemia. The PCVs show that 36%, 33% and 40% of the variance in Hb concentration, anemia and severe anemia across communities were respectively explained by individual-level and community-level factors.

DISCUSSION

This is the first national and multilevel study that has ever been conducted to assess risk factors for childhood anemia in Malawi. We have found out that the likelihood of anemia increased in younger children. This result is consistent with previous findings [3, 4, 38–40]. Anemia is common among children around the time of the growth spurt, particularly between 6 and 23 months. If exogenous iron supplement is inadequate during this time, infant anemia occurs easily [38, 41–43]. Infants are known to be susceptible to infections via contaminated water and food, which can also affect their ability to absorb iron.

We also found that fever and stunting were positively associated with our outcomes. Similar findings were reported in previous studies [3, 18, 19, 38, 44]. Fever in under 5 children in Malawi is a common symptom of acute and chronical inflammatory diseases especially malaria [12, 18]. Previous studies have reported that malaria increases extravascular hemolysis of red blood cells with a concomitant failure of the bone marrow to increase red cell production to compensate for these losses [45, 46, 47]. On

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

the other hand, stunting indicates chronic food shortage and long-term effects of micronutrient deficiencies, which are associated with low concentrations of Hb [48]. In our study, we have shown that supplement of the high dose of vitamin A can be a solution to childhood anemia [49–52].

Our findings suggested that infants born to anemic mothers from economically poor households are more likely to develop anemia, which is in line with previous studies [18, 19, 38, 42]. Poor family wealth is an indicator of conditions of extreme social deprivation; hence, caregivers might face difficulties in providing nutritious food to their children [4, 18, 42]. Additionally, maternal anemia status may lead to poor stores of iron, zinc, vitamin A and B12 and folate in breast milk, which further impact child anemia status [53].

Our study showed an important result that community-level woman's education was significantly associated with childhood anemia. Possible explanations may be that higher community education provides a context where women are more likely to obtain knowledge and material resources that can benefit a child's health [54]. Thus, our findings provide important evidence that contextual factors sometimes can have significant impacts on a child's health above and beyond individual-level factors. Surprisingly communities with safe drinking water were negatively associated with Hb concentration. Future studies need to explore more about the relationship between water sources and Hb concentration.

Regarding the ICCs in our study, 7%, 89% and 5% of the total variance of childhood anemia, severe anemia and children's hemoglobin could be attributed to community-level factors, respectively. Previous research on multilevel analyses have reported similar small ICCs; however, researchers also indicated that an ICC at or above 2% is suggestive of significant group-level variance that required a multilevel study design [55, 56].

The use of a national representative sample is a main strength of this study. However, our study has some limitations. First, the use of a cross-sectional study design did not allow us to establish cause-and-effect relationships. Second, our study relied on Hb as the measure of anemia; further studies should consider other red blood cell indices [57]. Third, there might be recall bias, as the occurrences of diarrhea and fever were obtained by self-reports. Our results, like other survey studies, are prone to the interviewer bias (i.e., social desirability effect). Last, we are unable to adjust all confounding factors because this study is based on a secondary data analysis.

CONCLUSIONS

Our study results indicated that individual-level factors have stronger effects than community-level factors on childhood anemia, severe anemia and Hb concentration in Malawi. However, community-level female education still plays an important role in childhood anemia. Public health interventions targeting childhood anemia should focus on food insecurity, malaria infection, iron and other micronutrient deficiencies, household living standards, as well as community female education.

ACKNOWLEDGEMENT

The authors are sincerely grateful to National Statistical Office (NSO) and the Community Health Sciences Unit (CHSU) of Malawi for data collection. We give thanks to the MEASURE DHS for providing us with the population-based dataset through their archives which can be downloaded from http://dhsprogram.com/data/available-datasets.cfm.

FUNDING

The Ministry of Science and Technology, Taiwan [grant number: Most 103-2410-H-038-002].

REFERENCES

1. WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Vitamin and mineral nutrition information system. Geneva: World Health Organization, 2011 (WHO/NMH/NHD/MNM/11.1). http://www.who.int/vmnis/indicators/haemoglobin.pdf (7 February 2016, date last accessed).
2. Gutema B, Adissu W, Asress Y, *et al.* Anemia and associated factors among school-age children in Filtu Town, Somali region, Southeast Ethiopia. BMC Hematol 2014; 14:13.
3. Iannotti LL, Delnatus JR, Odom AR, *et al.* Determinants of anemia and hemoglobin concentration in Haitian school-aged children. Am J Trop Med Hyg 2015;93:1092–8.
4. Gao W, Yan H, Duolao W, *et al.* Severity of anemia among children under 36 months old in Rural Western China. PLoS One 2013;8:2–7.

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

5. Simbauranga RH, Kamugisha E, Hokororo A, *et al.* Prevalence and factors associated with severe anaemia amongst under-five children hospitalized at Bugando Medical Centre, Mwanza, Tanzania. BMC Hematol 2015;15:13.
6. Magalhães RJS, Clements ACA. Mapping the risk of anaemia in preschool-age children: the contribution of malnutrition, malaria, and helminth infections in West Africa. PLoS Med 2011;8:e1000438.
7. WHO. The Global Prevalence of Anaemia in 2011. Geneva: World Health Organization, 2015. http://apps.who.int/iris/bitstream/10665/177094/1/9789241564960_eng.pdf (5 February 2016, date last accessed).
8. National Statistical Office (NSO), ICF Macro. Malawi demographic and health survey 2010. Zomba, Malawi: NSO and Calverton, MD: ICF Macro, 2011. http://www.dhsprogram.com/pubs/pdf/FR247/FR247.pdf (11 August 2016, date last accessed).
9. WHO/UNICEF. Joint statement by the World Health Organization and the United Nations Children's Fund. Focusing on anaemia, towards an integrated approach for effective anaemia control. http://www.who.int/nutrition/publications/micronutrients/WHOandUNICEF_statement_anaemia_en.pdf?ua=1 (7 February 2016, date last accessed).
10. Shill KB, Karmakar P, Kibria MG, *et al.* Prevalence of iron-deficiency anaemia among university students in Noakhali Region, Bangladesh. J Heal Popul Nutr 2014;32:103–10.
11. Semba RD, Bloem MW. The anemia of vitamin A deficiency: epidemiology and pathogenesis. Eur J Clin Nutr 2002;56:271–81.
12. Calis JCJ, Phiri KS, Faragher EB, *et al.* Severe anemia in Malawian children. N Engl J Med 2008;358:888–99.
13. Williams TN, Uyoga S, Macharia A, *et al.* Bacteraemia in Kenyan children with sickle-cell anaemia: a retrospective cohort and case-control study. Lancet 2009;374:1364–70.
14. Crawley J. Reducing the burden of anemia in infants and young children in malaria-endemic countries of Africa: from evidence to action. Am J Trop Med Hyg 2004;71:25–34.
15. Morris CR, Singer ST, Walters MC. Clinical hemoglobinopathies: iron, lungs and new blood. Curr Opin Hematol 2006;13:407–18.
16. Zuffo CRK, Osorio MM, Taconeli CA, *et al.* Prevalence and risk factors of anemia in children. J Pediatr 2016;92:353–60. http://dx.doi.org/10.1016/j.jped.2015.09.007.
17. Cardoso MA, Scopel KKG, Muniz PT, *et al.* Underlying factors associated with anemia in amazonian children: a population-based, cross-sectional study. PLoS One 2012;7:e36341.
18. Ngwira A, Kazembe LN. Bayesian random effects modelling with application to childhood anaemia in Malawi. BMC Public Health 2015;15:161.
19. Ngnie-Teta I, Receveur O, Kuate-Defo B. Risk factors for moderate to severe anemia among children in Benin and Mali: insights from a multilevel analysis. Food Nutr Bull 2007;28:76–89.
20. Siekmans K, Receveur O, Haddad S. Can an integrated approach reduce child vulnerability to anaemia? Evidence from three African countries. PLoS One 2014;9:e90108.
21. Oladeinde BH, Omoregie R, Olley M, *et al.* Malaria and anemia among children in a low resource setting in Nigeria. Iran J Parasitol 2012;7:31–7.
22. Yang W, Li X, Li Y, *et al.* Anemia, malnutrition and their correlations with socio-demographic characteristics and feeding practices among infants aged 0-18 months in rural areas of Shaanxi province in northwestern China: a cross-sectional study. BMC Public Health 2012;12:1127.
23. Foote EM, Sullivan KM, Ruth LJ, *et al.* Determinants of anemia among preschool children in Rural, Western Kenya. Am J Trop Med Hyg 2013;88:757–64.
24. Uthman OA. A multilevel analysis of individual and community effect on chronic childhood malnutrition in rural Nigeria. J Trop Pediatr 2009;55:109–15.
25. Merlo J, Yang M, Chaix B, *et al.* A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. J Epidemiol Community Health 2005;59:729–36.
26. Roux AVD. A glossary for multilevel analysis. J Epidemiol Community Health 2002;56:588–94.
27. Ntenda PAM, Chuang KY, Tiruneh FN, *et al.* Analysis of the effects of individual and community level factors on childhood immunization in Malawi. Vaccine 2017;35:1907–17.
28. Wk B, He K, Lh B. Hemocue–a new haemoglobinometer in the clinic. Eur J Anaesthesiol 1991;8:55–8.
29. WHO, Multicentre Growth Reference Study Group. 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. Geneva: World Health Organization, 2006. http://www.who.int/childgrowth/standards/technical_report/en/ (7 February 2016, date last accessed).
30. Onis M. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-forheight and body mass index-for-age: methods and development: methods and development. Geneva, Switzerland. Acta Pædiatrica 2006;95:76–85.
31. WHO. Guideline: vitamin A supplementation in infants and children 6 – 59 months of age. 2011. http://apps.who.int/iris/bitstream/10665/44664/1/9789241501767_eng.pdf.
32. NHS. Choices, your health, your choices, fever in children. 2015. http://www.nhs.uk/conditions/feverchildren/Pages/Introduction.aspx (8 May 2017, date last accessed).
33. World Health Organization (WHO), United Nations Children's Fund (UNICEF). Diarrhoea: why children are still dying and what can be done. 2009. http://apps.who.int/iris/bitstream/10665/44174/1/9789241598415_eng.pdf (8 May 2017, date last accessed).

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022

34. Rutstein SO and Johnson K. The DHS wealth index. DHS Comparative Reports No. 6. Calverton, MD: ORC Macro, 2004.
35. The DHS Program. Demographic and health survey, wealth index. ICF, 530 Gaither Road, Suite 500, Rockville, MD 20850. http://www.dhsprogram.com/topics/wealth-index/Index.cfm.
36. World Health Organization (WHO), United Nations Children's Fund (UNICEF). WHO and UNICEF Joint Monitoring Programme (JMP) for water supply and sanitation: types of drinking-water sources and sanitation. Geneva, Switzerland. http://www.wssinfo.org/definitions-methods/watsan-categories/ (28 December 2015, date last accessed).
37. SAS Institute Inc. Base SAS® 9.4 Procedures Guide: Statistical Procedures. 2nd edn. Cary, NC: SAS Institute Inc. USA, 2013, 535.
38. Zhao A, Zhang Y, Peng Y, *et al*. Prevalence of anemia and its risk factors among children 6–36 months old in Burma. Am J Trop Med Hyg 2012;87:306–11.
39. Austin AM, Fawzi W, Hill AG. Anaemia among Egyptian children between 2000 and 2005: trends and predictors. Matern Child Nutr 2012;8:522–32.
40. Semedo RM, Santos MM, Baião MR, *et al*. Prevalence of anaemia and associated factors among children below five years of age in Cape Verde, West Africa. J Health Popul Nutr 2014;32:646–57.
41. Kamal MM, Hasan MM, Davey R. Determinants of childhood morbidity in Bangladesh: evidence from the Demographic and Health Survey 2011. BMJ Open 2015;5:e007538.
42. Woldie H, Kebede Y, Tariku A. Factors associated with anemia among children aged 6-23 months attending growth monitoring at Tsitsika Health Center, Wag-Himra Zone, Northeast Ethiopia. J Nutr Metab 2015;2015:e928632.
43. Osório MM, Lira PI, Batista-Filho M, *et al*. Prevalence of anemia in children 6-59 months old in the state of Pernambuco, Brazil. Rev Panam Salud Publica 2001;10:101–7.
44. Konstantyner T, Roma Oliveira TC, de Aguiar Carrazedo Taddei JA. Risk factors for anemia among Brazilian infants from the 2006 National Demographic Health Survey. Anemia 2012;2012:e850681.
45. Kai OK, Roberts DJ. The pathophysiology of malarial anaemia: where have all the red cells gone? 2008;4:4–7.
46. Phillips RE, Pasvol G. Anaemia of *Plasmodium falciparum* malaria. Baillieres Clin Haematol 1992;5:315–30.
47. Weiss G, Goodnough LT. Anemia of chronic disease. N Engl J Med 2005;352:1011–23.
48. Khan JR, Awan N, Misu F. Determinants of anemia among 6–59 months aged children in Bangladesh: evidence from nationally representative data. BMC Pediatr 2016;16:3.
49. Mwanri L, Worsley A, Ryan P, *et al*. Supplemental vitamin A improves anemia and growth in anemic school children in Tanzania. J Nutr 2000;130:2691–6.
50. Garg A, Abrol P, Tewari AD, *et al*. Effect of vitamin A supplementation on hematopoisis in children with anemia. Indian J Clin Biochem 2005;20:85–6.
51. Gebremedhin S. Effect of a single high dose vitamin A supplementation on the hemoglobin status of children aged 6 – 59 months: propensity score matched retrospective cohort study based on the data of Ethiopian Demographic and Health Survey 2011. BMC Pediatr 2014;14:79.
52. Zimmermann MB, Biebinger R, Rohner F, *et al*. Vitamin A supplementation in children with poor vitamin A and iron status increases erythropoietin and hemoglobin concentrations without changing total body iron. Am J Clin Nutr 2006;84:580–6.
53. Wang J, Wang H, Chang S, *et al*. The influence of malnutrition and micronutrient status on anemic risk in children under 3 years old in poor areas in China. PLoS One 2015;10:e0140840.
54. National Research Council and Institute of Medicine. Children's Health, the Nation's Wealth: Assessing and Improving Child Health. Committee on Evaluation of Children's Health. Board on Children, Youth, and Families, Division of Behavioral and Social Sciences and Education. Washington, DC. The National Academies Press, 2004, 28–44.
55. 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.
56. Theall KP, Scribner R, Broyles S, *et al*. Impact of small group size on neighbourhood influences in multilevel models. J Epidemiol Community Health 2011;65:688–95.
57. Coyer SM. Anemia: diagnosis and management. J Pediatr Heal Care 2005;19:380–5.

Downloaded from https://academic.oup.com/tropej/article/64/4/267/4049586 by guest on 20 August 2022