

Anemia and undernutrition among children aged 6–23 months in two agroecological zones of rural Ethiopia

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Background: Child malnutrition during the first 1,000 days, commencing at conception, can have lifetime consequences. This study assesses the prevalence of anemia and undernutrition among children aged 6–23 months in midland and lowland agroecological zones of rural Ethiopia.

Methods: Cross-sectional data examining sociodemographic, anthropometry, hemoglobin levels, and meal frequency indicators were collected from 216 children aged 6–23 months and their mothers randomly selected from eight rural kebele (villages).

Results: Of 216 children, 53.7% were anemic, and 39.8%, 26.9%, and 11.6% were stunted, underweight, and wasted, respectively. The prevalence of anemia was higher in the lowland agroecological zone (59.5%) than the midland (47.6%). Among those children who were stunted, underweight, and wasted, 63.5%, 66.7%, and 68.0% were anemic, respectively. Child anemia was significantly associated with the child not achieving minimum meal frequency, sickness during the last 2 weeks before the survey, stunting and low body mass index, and with maternal hemoglobin and handwashing behavior. The prevalence of stunting was higher in the lowland agroecological zone (42.3%) than the midland (36.2%). The predictors of stunting were age and sex of the child, not achieving MMF, maternal body mass index, and age. As maternal height increases, the length for age of the children increases ($P=0.003$).

Conclusion: The overall prevalence of anemia and undernutrition among children aged 6–23 months in these study areas is very high. The prevalence was higher in the lowland agroecological zone. Health information strategies focusing on both maternal and children nutrition could be sensible approaches to minimize stunting and anemia.

Keywords: child anemia, child stunting, lowland, midland, agroecological zone, rural Ethiopia

Introduction

It has long been recognized that child malnutrition and anemia have both acute and long-term adverse effects on human development.¹ The term “malnutrition” is used to refer to undernutrition in this paper.² One of the most critical periods in the growth of the infant is between 6 and 23 months of age, and this is when malnutrition can have significant consequences. It is also reported that the incidence of stunting is at a peak in this age group, because children in this age group have great demands for nutrients, but there are limitations in the quantity and quality of available foods, particularly after exclusive breastfeeding.^{2,3} In addition, due to poor hygiene and sanitation, frequent episodes of diarrhea are major contributors to malnutrition.

It is estimated that approximately 19.4% of children aged under 5 years are underweight, and 29.9% of children are stunted in developing countries.⁴ More than

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3.4 million children aged under 5 years are dying, and approximately 40% of children are stunted in sub-Saharan Africa alone.⁵ A study conducted in the Wag-Himra zone of northern Ethiopia indicated that 23.6% of children <2 years were stunted and 66.6% of children were anemic.⁶ Similarly, a study in the northern part of Ethiopia indicated that 33% of children aged 12–23 months were stunted.⁷ The prevalence of stunting among infants aged 6–8 months and children aged 9–23 months was 43% and 39%, respectively, in the southern part of Ethiopia.⁸ A study among school children in the northwest part of Ethiopia also indicated that 15.1%, 25.2%, and 8.9% of children were underweight, stunted, and wasted, respectively.⁹ Approximately, 25.6% of children aged 7–14 years were stunted, with 10.3% of them severely stunted, and 19% of them were underweight.¹⁰ In Ethiopia, it has been demonstrated that more than one-third of child deaths are associated with malnutrition.¹¹ It is estimated that the annual costs related to child malnutrition is 55.5 billion Ethiopian birr, which is equivalent to 16.5% of gross domestic product.¹² Ethiopian Demographic and Health Survey (EDHS) (2011) reported that 44%, 44%, 10%, and 29% of children under 5 years of age were anemic, stunted, wasted, and underweight, respectively.¹³

Thus, evidence indicates that malnutrition starts early in a child's life in Ethiopia and becomes progressively worse during the first 2 years of age. It also appears that the rates of malnutrition in children vary across different regions of Ethiopia. A recent study indicated that there was significant variation in the nutritional status of lactating mothers between midland and lowland agroecological zones of rural Ethiopia.¹⁴ Therefore, given the present importance and high priority given to the health of children around the globe in general, and in Ethiopia in particular, this study attempts to build on the current limited database on malnutrition in young children and to 1) explore the levels of anemia and malnutrition among children aged 6–23 months; 2) determine agroecological variations in nutritional status and anemia; and 3) identify predictors of anemia and stunting in the children in midland and lowland agroecological zones of rural Ethiopia.

Materials and methods

This study was conducted in two study areas in Ethiopia: Eastern Oromia (Babile District) and South-Central Tigray (Enderta and Hintalo Wajirat Districts). Data were collected in two seasons: January to February 2014 (postharvest) and July to August 2014 (lean season). Babile District is 560 km away from Addis Ababa in the eastern part of Ethiopia and represents a lowland agroecological area. The major agri-

cultural products consumed in this lowland agroecological zone are sorghum, maize, and oil seeds; whereas groundnuts and Khat (*Catha edulis*) are used as major cash crop in this area. The midland agroecological zones were represented by Hintalo Wajirat and Enderta Districts, which are 683 and 773 km away from Addis Ababa in the northern part of Ethiopia, respectively. Detailed study area and methods have been published earlier.¹⁴

This study involved a nutritional subsample drawn from a larger Agridiet household survey comprising of 800 households (400 household each from both agroecological zones) where the sample sizes were calculated by single population proportion. Biological mothers were randomly identified using a kebele (a small administrative unit in Ethiopia) health extension registration logbook based on proportion to population size in each kebele. All data were collected from apparently healthy children and their biological mothers at their home.

Dietary data

Dietary intake data were collected and computed based on tools developed by food and nutrition technical assistance.^{15,16} Twenty-four hours dietary data were collected from the mothers of the children about all types of food consumed. Each mother who participated in the study was asked to recall all the dishes she had eaten and given to her child in the household in the previous 24 hours. Data collected on infant dietary intake were used to calculate the infant dietary diversity score using a seven food group classification.¹⁶ The dietary data were collected randomly on weekend days or on weekdays, as these days do not have any special difference with respect to dietary intake in this study group. We took care of not to include Ethiopian fasting days or local feasts or celebrations in the recall.

Anthropometric measurements

Data for both mothers and children were collected and computed using World Health Organization (WHO)-recommended guidelines.^{17–19} Both the mothers and their children were weighed to the nearest 0.1 kg on electronic scales (SECA, Hamburg, Germany) with minimal (light weight) clothing and without shoes. The weight of the children was taken together with the mother, and the child's weight was then obtained by subtracting the respective mother's weight from the combined weight by two different recorders and compared and confirmed later by supervisors. All anthropometric data were collected by two separate enumerators, and if any variation existed between the two enumerators,

then the first author was called to validate the measurements. Recumbent length was taken for the 6–23 months old children. Their length was measured to the nearest 0.1 cm using a portable device (SECA 2006 sliding board), consisting of a board with an upright wooden base and a movable head-piece, on a flat surface. The body mass index (BMI) of the mothers was computed by dividing weight by height/length in meters squared (weight/height² [kg/m²]). The mid-upper arm circumferences (MUAC) of both mothers and their children were taken from the left arm and measured to the nearest millimeter.

Hemoglobin data

Hemoglobin levels of both mothers and children were tested by collecting a blood sample from the tip of the middle finger after cleaning with a disinfectant. A sample of the third drop was added to the cuvettes for measuring hemoglobin level after the first two drops were wiped. Hemoglobin values were read for all children immediately in the field by using a portable HemoCue analyser (HemoCue[®] Hb 301, Ängelholm, Sweden). The precision of this procedure for the assessment of hemoglobin in the field in a resource-poor setting has been established previously.²⁰ The hemoglobin concentrations were adjusted for altitude using the WHO recommendation during analysis.²¹ The cutoff point for anemia was based on WHO (2001) recommendations for the mother: anemia is defined as hemoglobin <11 g/dL for children and <12 g/dL for mothers.

Data collectors and quality control

Data were collected by experienced nurses who were qualified to a diploma level or above. These nurses were recruited and trained intensively for 5 days on the methods of data collection and the context of each item included in the questionnaire. In addition, anthropometric data collectors were given special training and demonstrations about the procedures. For hemoglobin analysis, the blood sample was collected and tested by trained laboratory technologists who have a BSc degree or above. The data collection tool was prepared in English, translated to local languages, such as Tigrigna and Afan Oromo, by native speakers, and then translated back to English for validation and consistency check. Data were collected in the local language. Intensive training was given for data collectors, and the data collections were supervised by locally recruited supervisors and also by the principal investigator.

A pretest survey was conducted in another similar rural setting on 5% of the total sample size, and identified problems during the survey were corrected before the actual survey. Two separate measurements were taken for length/height,

weight, and MUAC in every study participant by different data collectors separately. The principal investigator oversaw the data collection process. All randomly selected children were apparently healthy during data collection, and children with signs and symptoms of diarrhea, fever, or any acute illness were excluded from the study.

The dependent variables of this study were undernutrition and anemia status of the children, while sociodemographic/economic status, health status of mothers and their children, feeding style, hygiene and sanitation conditions of households, child illness, health-seeking behaviors and health services utilization, and infant and maternal dietary diversity were independent variables of this study.

Data processing and analysis

The data were entered into EpiData version 3.1 by separate data clerks and validated for consistency. Data were cleaned and edited after transfer to SPSS statistical packages (version 16.0; SPSS Inc., Chicago, IL, USA) for data analysis. Normality of the data was checked graphically and visually using different plots. Meal frequency as well as anthropometric and hemoglobin mean and standard deviation values was considered. The WHO Anthro 2005 software (World Health Organization Geneva, Switzerland) was used to calculate the Z-scores. Weight-for-age WAZ (underweight), weight-for-length WLZ (wasting), length-for-age LAZ (stunting), BMI for age Z-score (BAZ), and MUACZ, and cutoff points of negative two (−2) were used to define undernutrition.

Independent *t*-test was used to determine mean differences in nutritional status between midland and lowland agroecological zones. The Levine's test of equality of variance was checked. When *P*-values of Levine's test of equality of variance were >0.05 (not significant), equal variances were assumed, while equal variances were not assumed if *P*<0.05. Finally, mean difference between *t*-values and *P*-values was reported.

Multivariable linear regression model was used to determine predictors of LAZ after checking for the assumptions of normality, homoscedasticity, and linearity. Variables that had significance (*P*<0.05) were retained for the final multivariable model. Similarly, children's hemoglobin failed to fulfill criteria of linearity and homoscedasticity before and after log transformation and was categorized into two groups, ie, anemic and nonanemic. Variables that did not have significant (*P*≥0.05) relationships in binary logistic regression were removed from the model. During both linear and binary logistic regression, biological plausibility of the variables was considered before including into models.

Ethical standards disclosure

This study procedure was approved by Research Ethics Review Committees of Haramaya University College of Health and Medical Sciences, Ethiopia, and University College Cork, Ireland. Subsequently, the final approval of the protocol was approved by the Ethiopian National Ministry of Science and Technology Ethical Review Committee. Caregivers of the children consented verbally, and this was formally recorded before commencing data collection. They were informed that they had the right to refuse or exit from the study at any time and that declining to participate in the study would not have any negative impacts for them. Mothers and children who were found to be anemic during assessment were given detailed information about the situation and referred to the nearest health institution.

Results

Sociodemographic and economic characteristics and anthropometric status

Among the 223 children aged between 6 and 23 months recruited, 216 (98.2%) were analyzed. Reasons for nonparticipation were fear of providing a blood sample for hemoglobin tests, one mother missing her appointment at the health center and another mother refusing to give a blood sample. In addition, one child was excluded from analysis during data cleaning because his age was <6 months.

The majority (68.5%) of the mothers were illiterate, 87.0% of the mothers were married, and 53.2% of the households used safe water, while approximately 45.0% of the households did not use toilet and 67.8% of the mothers gave birth at home. It was also found that approximately 41.7% of the mothers were wasted (BMI <18.5) (Table 1).

The mean and standard deviations of LAZ, WAZ, and WLZ for the children were -1.76 (0.1), -1.3 (0.08), and -0.5 (0.09), respectively, and the mean and standard deviation for hemoglobin was 11.4 (0.12) g/dL. The mean difference between lowland and midland agroecological zones for LAZ score was significant ($P=0.05$) (Table 1).

Prevalence of malnutrition

This study found that 11.6%, 26.9%, and 39.8% of children were wasted, underweight, and stunted, respectively (Table 2). The magnitude of malnutrition peaked at 12–17 months of age (Table 3).

Prevalence of anemia

Among the 216 children included for analysis, 116 (53.7%) had anemia, of whom 7.9%, 23.1%, and 22.7% had severe,

Table 1 Descriptive measures of children and their mothers in rural Ethiopia (n=216, mother–child pairs)

Variables	Mean (SD)	Mean difference between lowland and midland zones*	
		Mean difference	t (P-value)
Child age (months)	13.35 (4.8)	-0.3	-0.5 (0.6)
Child weight (kg)	8.21 (0.1)	0.02	0.1 (0.9)
Child length (cm)	71.38 (0.38)	-0.67	-0.9 (0.4)
Child hemoglobin (g/dL)	11.41 (0.12)	-0.02	-1.9 (0.059)
MUACZ	-1.61 (0.07)	0.05	0.32 (0.7)
LAZ	-1.76 (0.1)	0.43	2.0 (0.05)
WAZ	-1.30 (0.08)	0.03	0.16 (0.9)
WLZ	-0.51 (0.09)	0.15	0.84 (0.4)
BAZ of children	-0.33 (0.09)	0.24	1.3 (0.2)
Maternal age (years)	28.52 (0.42)	-0.8	-0.9 (0.4)
Maternal weight (kg)	48.85 (0.43)	1.3	1.4 (0.1)
Maternal height (cm)	159.47 (0.37)	0.4	0.6 (0.6)
Maternal BMI (kg/m ²)	19.21 (0.15)	0.4	1.2 (0.3)
Maternal MUAC (cm)	22.21 (0.24)	0.7	1.5 (0.1)
Maternal hemoglobin (g/dL)	13.96 (0.1)	-0.4	-2.1 (0.04)

Notes: *Lowland agroecological zone is represented by Babile District (Woreda), which is 560 km away from Addis Ababa in the eastern part of Ethiopia, while midland agroecological zone is represented by Hintalo Wajirat and Endreta Districts, which are 683 and 773 km away from Addis Ababa in the northern part of Ethiopia. Lowland and midland zones were compared by unpaired t-test, and P-values are shown.

Abbreviations: MUACZ, mid-upper arm circumference-for-age Z-score; LAZ, length-for-age Z-score; WAZ, weight-for-age Z-score; WLZ, weight-for-length Z-score; BAZ, body mass index for age Z-score; SD, standard deviation.

moderate, and mild anemia, respectively (Table 2). The proportion of anemia was higher but not significant among male children (58.3%) compared to female (50.0%) (Table 4). The proportion of anemia was higher among lowland children (59.5%) compared to midland children (47.6%) even though this significance was lost after controlling for confounding (Table 2). With regard to the classification of anemia and malnutrition by age, the incidence of both anemia and stunting was higher among the 12–17 months age group (Table 3).

Agroecological variations in the prevalence of malnutrition and anemia

Of the 53.7% anemic children, 59.6% were from lowland agroecological zone and 47.6% were from midland zone. The prevalence of all forms of anemia (severe, moderate, and mild anemia) was higher in lowland agroecological zone. Similarly, 39.8% of children in the study were stunted, with a stunting prevalence of 43.2% in the lowland agroecological zone and 36.2% in the midland. The wasting prevalence was also higher in the lowland agroecological zone (ie, 12.6% in lowland vs 10.5% in midland). The prevalence of being

Table 2 Prevalence of stunting and anemia among children aged 6–23 months by agroecological zones of rural Ethiopia (n=111, children in lowland; n=105 children in midland)

Variables	Category	Overall prevalence	Lowland ^a	Midland ^b
WLZ	≤2	25 (11.6)	14 (12.6)	11 (10.5)
	>2	191 (88.4)	97 (87.4)	94 (89.5)
WAZ	≤2	58 (26.9)	32 (28.8)	26 (24.8)
	>2	158 (73.1)	79 (71.2)	79 (75.2)
LAZ	≤2	86 (39.8)	48 (43.2)	38 (36.2)
	>2	130 (60.2)	63 (56.8)	67 (63.8)
Level of anemia				
Severe (Hgb <7 g/dL)		17 (7.9)	12 (10.8)	5 (4.8)
Moderate (Hgb 7.0–9.9 g/dL)		50 (23.1)	27 (24.3)	23 (21.9)
Mild (Hgb 10.0–10.9 g/dL)		49 (22.7)	27 (24.3)	22 (21.0)
Overall anemic (Hgb <11 g/dL)		116 (53.7)	66 (59.5)	50 (47.6)
Non-anemic (Hgb ≥11 g/dL)		100 (46.3)	45 (40.5)	55 (52.4)
MUACZ	≤2	78 (36.1)	44 (39.6)	34 (32.4)
	>2	138 (63.9)	67 (60.4)	71 (67.6)
Children received minimum meal Frequency	Yes	109 (50.5)	38 (34.2)	71 (67.6)**
	No	107 (49.5)	73 (65.8)	34 (32.4)
Child dietary diversity score	<4	168 (77.8)	80 (72.1)	88 (83.8)*
	≥4	48 (22.2)	31 (27.9)	17 (16.2)
Child drank milk in the last 24 hours	Yes	102 (47.2)	78 (70.3)	24 (22.9)
	No	114 (52.8)	33 (29.7)	81 (77.1)

Notes: Minimum meal frequency: proportion of breastfed and nonbreastfed children aged 6–23 months who received solid, semisolid, or soft foods the minimum number of times or more (minimum is defined as: two times for breastfed infants 6–8 months; three times for breastfed children 9–23 months; and four times for nonbreastfed children 6–23 months) in the previous day; ^aBabile District (Woreda), which is 560 km away from Addis Ababa in the eastern part of Ethiopia, is representative of a lowland agroecological zone; ^bHintalo Wajirat and Endreta Districts are 683 and 773 km away from Addis Ababa in the northern part of Ethiopia, respectively, and represent midland agroecological zones. The *P*-values for χ^2 test, ***P*<0.001, **P*<0.05.

Abbreviations: WLZ, weight-for-length Z-score; WAZ, weight-for-age Z-score; LAZ, length-for-age Z-score; Hgb, hemoglobin; MUACZ, mid-upper arm circumference-for-age Z-score.

Table 3 Prevalence of malnutrition and anemia among children aged 6–23 months by age categories in rural Ethiopia (n=216, children)

Variables	Classification	Age categories in months, n (%)		
		6–11	12–17	18–23
WAZ	WAZ ≤−3	1 (1.3)	12 (11.3)	4 (13.3)
	WAZ ≤−2	11 (13.8)	39 (36.8)	8 (26.7)
	Normal	69 (86.3)	67 (63.2)	22 (73.3)
LAZ	HAZ ≤−3	8 (10)	29 (27.4)	7 (23.4)
	HAZ ≤−2	19 (23.7)	56 (52.8)	11 (36.7)
	Normal	61 (76.2)	50 (47.2)	19 (63.3)
WLZ	WHZ ≤−3	1 (1.2)	6 (5.6)	0
	WHZ ≤−2	2 (2.5)	20 (18.9)	3 (10)
	Normal	78 (97.5)	86 (81.1)	27 (90)
Hgb	Severe anemia (<7)	3 (3.75)	5 (4.8)	1 (3.3)
	Moderate anemia (7–9.9)	14 (17.5)	36 (34.3)	8 (26.7)
	Mild anemia (10–10.9)	25 (31.2)	19 (17.1)	5 (16.7)
	No anemia (≥11)	38 (47.5)	46 (43.8)	16 (53.3)
	Overall anemia	42 (52.5)	60 (56.6)	14 (46.7)
MUACZ	MUACZ ≤−3	7 (8.7)	13 (12.3)	2 (6.7)
	MUACZ ≤−2	21 (26.2)	50 (47.2)	7 (23.3)
	Normal	59 (73.7)	56 (52.8)	23 (76.7)

Abbreviations: WAZ, weight-for-age Z-score; LAZ, length-for-age Z-score; WLZ, weight-for-length Z-score; Hgb, hemoglobin (g/dL); MUACZ, mid-upper arm circumference-for-age Z-score.

underweight was 28.8% for lowland children and 24.8% for children from the midland agroecological zone.

Predictors of stunting

Maternal and infant dietary diversity, minimum acceptable diet, presence of latrine in the house, child having taken a deworming tablet in the past 3 months, child falling sick within 15 days before the survey, and maternal and paternal education and occupation do not show association in the bivariate models and were removed from the models. Among variables included in final models, children who achieved minimum meal frequency (MMF), male sex, age of the child, and BMI, height, and age of the mothers were significantly related to LAZ of the children. Children who achieved MMF had a higher Z-score compared to those who did not consume adequate meals (*P*=0.043) (Table 5). The proportion of child stunting increased as the age of the child increased (β =−0.039, *P*=0.009), but female children had a lower rate of stunting than males (*P*<0.015). Similarly, as the height of the mother increased, the LAZ of the children also increased significantly (*P*=0.003). As the height and BMI of the mother increased, the length-for-age Z-score (LAZ) of children increased significantly (*P*<0.005). Those children

Table 4 Predictors of anemia among children aged 6–23 months in two agroecological zones of rural Ethiopia (n=216, children)

Variables	Anemic		COR (95% CI)	AOR (95% CI)
	Yes (n)	No (n)		
Child was sick in the last 15 days				
Yes	72	24	5.3 (2.8, 10.1) ^a	5.6 (2.6, 12.17) ^b
No	43	76		
Child received minimum meal frequency				
Yes	42	74	0.27 (0.15, 0.5)	0.32 (0.15, 0.68) ^b
No	67	33		
Hand washing after toilet (mothers)				
Yes	70	46	0.22 (0.10, 0.47) ^a	0.3 (0.12, 0.72) ^b
No	87	13		
ANC follow-up (N=179)				
>4 times	25	38	0.48 (0.24, 0.94) ^a	0.38 (0.17, 0.84) ^b
<4 times	67	49		
Continuous variables included in the model				
Hemoglobin level of the mothers			−0.21 (−0.41, −0.07) ^a	0.71 (0.53, 0.96) ^b
BMI of the mothers			−0.13 (−0.25, −0.003) ^a	0.87 (0.7, 1.03) ^b
LAZ of the child			−0.28 (−0.47, −0.08) ^a	0.75 (0.56, 0.99) ^b

Notes: Minimum meal frequency, proportion of breastfed and nonbreastfed children aged 6–23 months who received solid, semisolid, or soft foods the minimum number of times or more (minimum is defined as: two times for breastfed infants 6–8 months; three times for breastfed children 9–23 months; and four times for nonbreastfed children 6–23 months) in the previous day; ^asignificant by bivariate analysis; ^bsignificant by multiple variable analysis after adjusting for confounding.

Abbreviations: COR, crude odds ratio; AOR, adjusted odds ratio; ANC, antenatal care; BMI, body mass index; LAZ, length-for-age Z-score.

Table 5 Predictors of length-for-age Z-score (stunting) among children aged 6–23 months in rural Ethiopia (n=216, children)

Model I	P		
Predictors of LAZ (adjusted R ² =0.5199) n=216	β	Standard error	<0.001
F(12, 203) =20.40, root MSE =0.99175			
MUACZ score of the children	−0.029	0.08	0.73
Mothers BMI	0.08	0.033	0.017
Hemoglobin level of the children	−0.025	0.4	0.56
Hemoglobin level of the mother	0.009	0.05	0.86
Sex of the child	0.34	0.14	0.015
Age of the child in months	−0.039	0.015	0.009
Age of the mother in years	0.024	0.011	0.038
Maternal height	0.036	0.012	0.003
Child received minimum meal frequency	0.31	0.115	0.043
Place of delivery	−0.11	0.19	0.45
Agroecological zones	0.19	0.17	0.22
WAZ	0.76	0.73	0.000

Notes: Minimum meal frequency: proportion of breastfed and nonbreastfed children aged 6–23 months who received solid, semisolid, or soft foods the minimum number of times or more (minimum is defined as: two times for breastfed infants 6–8 months; three times for breastfed children 9–23 months; and four times for nonbreastfed children 6–23 months) in the previous day.

Abbreviations: β, coefficient for the predictor value; LAZ, length-for-age Z-score; MUACZ, mid-upper arm circumference-for-age Z-score; BMI, body mass index; WAZ, weight-for-age Z-score; MSE, mean square error.

born in the lowland area and those who had low hemoglobin level were at risk of stunting compared to children in midland area even though significance was lost after controlling for confounding.

Predictors of anemia

Child age, sex, source of drinking water for household, presence of latrine in the house, contraceptive utilization, mothers having received deworming tablets in the past 3 months, maternal and infant dietary diversity, minimum acceptable diet, child having taken deworming tablet in the past 3 months, and maternal and paternal education and occupation did not show association in the bivariate models and were removed from the models. Multiple variable analyses revealed that the predictors of child anemia were child illness in the last 2 weeks, child not having MMF, mothers not washing their hands after toilet, and mothers' antenatal care (ANC) follow-up. It was found that children who achieved MMF per day were less likely to be anemic compared to those who do not achieve MMF (adjusted odds ratio [AOR] 0.32, 95% confidence interval [CI] =0.15, 0.68) (Table 4). Mothers who received four focused ANC visits were less likely to have children with anemia compared to those mothers who received less than four ANC visits (AOR 0.38, 95% CI 0.17, 0.84). Similarly, this study revealed that those children who were sick in the 15 days before the survey were more likely to be anemic compared to those who were healthy (AOR 5.6, 95% CI 2.6, 12.17). Among continuous variables included in the same model, maternal hemoglobin level, LAZ of child, and mother's BMI were significantly associated with child anemia (Table 4). As the LAZ score of the child increased, the risk of the children being anemic decreased (AOR 0.75, 95% CI 0.56, 0.99). Likewise, the risk of the child being

Table 6 Association of stunting with anemia among children aged 6–23 months in rural Ethiopia

Variables	Anemic, n (%)	Non-anemic, n (%)	Total, n (%)	OR (95% CI)	P-value
Underweight					
Yes	38 (66.7)	19 (33.3)	57 (100)	0.47 (0.25, 0.9)	0.021
No	77 (48.7)	81 (51.3)	158 (100)	1	1
Stunting					
Yes	54 (63.5)	31 (36.5)	85 (100)	0.51 (0.29, 0.9)	0.018
No	61 (46.9)	69 (53.1)	130 (100)	1	1
Wasting					
Yes	17 (68)	8 (32)	25 (100)	0.5 (0.2, 1.2)	0.125
No	98 (51.6)	92 (48.4)	190 (100)	1	1

Abbreviations: OR, odds ratio; CI, confidence interval.

anemic decreased significantly as the hemoglobin level of the mothers increased ($\beta=0.036$, $P=0.003$) (Table 4).

Associations between anemia and malnutrition

This study indicated that among stunted, wasted, and underweight children, 63.5%, 68.0%, and 66.7% were anemic, respectively. The proportions of stunting, wasting, and being underweight were relatively higher among anemic children compared to their counterparts without anemia. It was also found that anemia among this age group was significantly related with stunting and being underweight (Table 6).

Discussion

This study revealed that 53.7% of children aged 6–23 months were anemic, with a prevalence of 59.5% in the lowland and 47.6% in the midland agroecological zone. Similarly, 39.8%, 26.9%, and 11.6% of children were stunted, underweight, and wasted, respectively. The incidence of stunting, being underweight, and wasting were higher in lowland (43.2%, 28.8%, and 12.6%) than midland zones (36.2%, 26.9%, and 10.5%), respectively. The predictors of LAZ were maternal BMI and height, age, sex, and meal frequency of the child. The predictors of child anemia were child sickness, child meal frequency, LAZ, and maternal handwashing behavior after toilet, and maternal hemoglobin, BMI, and ANC.

This study found that anemia was prevalent among the study groups, with a higher rate in lowland agroecological rural Ethiopia. The prevalence in the lowland zone was very similar to the EDHS (60.9%).¹³ The findings of this study were lower than the prevalence reported in a study among the same age (6–23 months) in the Wag-Himra zone of northern Ethiopia (66.6% anemia),⁶ but similar to a study in Brazil (51%).²⁰ The reasons for variation across agroecology need further investigations.

In this study, higher rates of anemia were found among children aged 12–17 months, followed by the 6–11 months age group. A study conducted in northern Ethiopia, Kilde Awulaelo Woreda reported that children aged 6–11 months were the most affected age group.²² Published data indicate a decreasing trend in anemia prevalence with age particularly in children >23 months.^{22–25} The risk of anemia is greatest in the first 2 years of age when growth velocity is highest.²⁶ Higher rate of anemia in children <2 years of age is influenced by increased iron requirements in this age group due to rapid growth, inadequate intake of iron rich foods, and poor diet diversity.

Children from the lowland agroecological zone had a higher prevalence of anemia compared to the midland zone even though the difference was not significant after adjustments for confounding. We have previously reported a significant difference between the two agroecological zones in children's MMF, with a higher rate of MMF in the midland agroecological zone.²⁷ An undiversified diet (cereal-based monotonous diet) and low meal frequency have been known to contribute to micronutrient deficiency, including anemia.^{28,29} A higher percentage of children (70.3%) from the lowland agroecological zone drank milk in the last 24 hours compared to the midland zone (22.9%), which may be a contributing factor to anemia as milk reduces absorption of iron from food. However, factors associated with anemia among children are multidimensional and multifaceted. In addition to nutritional problems, these may be associated with cultural, socioeconomic, environmental, and biological factors. We have previously reported on the seasonal variations in nutritional status and anemia among the lactating mothers of these children in the same agroecological zones.¹⁴ The mothers from the lowland agroecological zone had higher prevalence of anemia. Details on diets plus other factors such as traditions, cultures, and lifestyles in these two agroecological zones have been provided in the earlier publication.¹⁴

This study showed that anemic children were 5.6 times as likely to have had recent infections (15 days preceding the interview). The presence of infections can result in loss of appetite and malabsorption of nutrients, which increases the risk for anemia. This finding is similar to that conducted in the northeast part of Ethiopia.⁶ Similarly, a study conducted in the northern part of Ethiopia showed that those children with diarrhea, acute febrile illness, or who were stunted were more likely to develop anemia than their counterparts. This higher rate of anemia may also be related to poor hygiene as the handwashing habit of the mother after toilet also had a significant association with child anemia.

This study showed that as maternal BMI and hemoglobin increased, the risk of the child being anemic decreased by 29%. This study provides strong evidence that there is an association between child anemia and maternal nutritional status. A similar finding was also reported by a study conducted in Brazil.²⁰ According to another study conducted by Habte et al,³⁰ childhood anemia showed an increasing trend as maternal anemia level increased. This may be associated with nutritional status of the mothers before pregnancy as most mothers in developing countries enter into pregnancy while they are malnourished.

The prevalence of stunting among children <5 years has significantly declined during the past two decades, but this is still significantly high in South Asia and sub-Saharan Africa than elsewhere.² It was reported that approximately 165 million children were stunted globally in 2011.² This revealed that the prevalence of stunting in this study was slightly greater than few other studies conducted in Ethiopia,^{6,10,31} and relatively lower than the EDHS.¹³ A higher percentage of children from the lowland agroecological zone were stunted compared to the midland agroecological zone. The close relationship between dietary diversity, micronutrient deficiencies, and stunting in developing countries has been well documented in previous studies.^{28,29,32,33} But no study, to our knowledge, has documented the association between stunting and agroecological zones. The variation in prevalence may be associated with feeding behaviors and sociodemographic characteristics of the children.

This study indicated that low LAZ score was positively related with anemia in the multivariable model. As the LAZ score of the child increased, the risk of the children being anemic decreased by 25%. The relationship between stunting and anemia has also been reported in several other studies.^{20,30,31,34–36} The causal relationships between stunting and anemia are uncertain. Low hemoglobin levels may have a negative impact on the linear growth. Additionally, it is

possible that deficiencies of other micronutrients and stunting may synergistically increase the risk for anemia.

This study also indicated that male children were more stunted than female children. This finding has also been reported by other studies.^{37,38} Similarly, mothers with low BMI, short stature, and younger age are more likely to have stunted children. These relationships in our study strengthen the suggestions of intergenerational associations of malnutrition from mother to child reported in another study.³⁷ In contrast to other studies,^{20,31} in our study, maternal contraceptive utilization, education status, and household characteristics such as access to and utilization of latrine and safe drinking water had no association with child malnutrition.

Strengths and limitations

The strengths of this study include its use of both linear and binary logistic regression models to assess children nutritional status with their mothers (infant–mother pairing) and focusing on limited age of the vulnerable population segments. We were able to measure the magnitude of malnutrition in this transition period from breastfeeding to complementary food. A further strength of this study is that anthropometric data were collected by two separate recorders and, if there were variations in data between the two recorders, the measurement was taken on the field by principal investigators for validation. Any error is likely to be random. Even though there was no evidence of variation in the hemoglobin level between the morning and the afternoon, the tests were conducted in the morning for all participants, and the HemoCue machines were checked every morning to control reading errors.

There are identified limitations in our study that might have affected our findings. Most of the risk factors were collected from verbal reports of the biological mothers as there were no other mechanisms of obtaining such information for the children, and so this may introduce social desirability and recall bias. However, great care was taken to minimize such bias by reducing the duration of the recall period and by including some double-checking in the questionnaire for validation of results. Therefore, bias in this study was unlikely to have affected the findings. In this study, the associations between dependent and independent variables did not necessarily imply temporal causal–effect relationships. Thus, any association should be interpreted with caution. Another limitation of this study was that the sample size of this study was small, and so this may have reduced the power to detect true differences.

Conclusion

In conclusion, this study revealed that anemia and malnutrition among children aged between 6 and 23 months are a

major public health concern in rural Ethiopia. Our findings strongly suggest that stunted mothers have stunted offspring compared to their normal counterparts. Also, children born to anemic mothers are more likely to be anemic compared to children born to nonanemic mothers. Interventions focusing on improving nutritional status of the mother and children, attaining at least MMF for children at an early age, and hygienic conditions and antenatal care of the mothers should be targeted to reduce the impact of child malnutrition. Additionally, the prevalence of anemia and stunting was higher in lowland agroecological zones compared to midland counterparts. These data suggest the requirement for further agroecological-based studies in different parts of the country to determine appropriate interventions.

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Author contributions

KTR, NMOB, and TPOC conceived and designed the study, coordinated data collection and interpretation of data. KTR analyzed the data and drafted the manuscript. NMOB and TPOC helped in literature searches, provided critical review and comments on the manuscript, TB critically reviewed the final manuscript. All authors contributed toward data analysis, drafting and critically revising the paper and agree to be accountable for all aspects of the work. Finally, all authors approved the final version for publication.

Disclosure

The authors report no conflicts of interest in this work.

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