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Spatial distributions and determinants of anaemia among adolescent girls in Ethiopia: a secondary analysis of EDHS 2016 – a cross-sectional study

Kendalem Asmare Atalell [ID] , Tadesse Tarik Tamir [ID] ,
Tewodros Getaneh Alemu [ID] , Masresha Asmare Techane

Department of Pediatrics and Child Health Nursing, School of Nursing, College of Medicine and Health Sciences, University of Gondar, Gondar, Ethiopia

Correspondence to
Kendalem Asmare Atalell;
kedasmar@gmail.com

ABSTRACT

Objective This study aimed to investigate the spatial distributions and determinants of anaemia among adolescent girls in Ethiopia. Exploring the spatial epidemiology of anaemia and identifying the risk factors would inform policymakers to come up with evidence-based prevention strategies for anaemia, especially in adolescent girls, who are the most affected segment of the population.

Methods Secondary analysis of the Ethiopian Demographic and Health Survey 2016 was conducted. A total of 3172 adolescents were included in the analysis. The Bernoulli model was fitted using SaTScan V.9.6 to identify hotspot areas and the geospatial pattern and prediction of anaemia were mapped using ArcGIS V.10.8. A multilevel logistic regression model was fitted to identify factors associated with anaemia among adolescent girls. Adjusted OR with 95% CI was calculated and variables having a p value less than 0.05 were statistically significant factors of anaemia.

Result The overall prevalence of anaemia among adolescent girls in Ethiopia was 23.8 (22.4 to 25.3), with significant spatial variations across the country. The SaTScan analysis identified a primary cluster in the eastern, northeastern and southeastern parts of Ethiopia (loglikelihood ratio=39, p<0.001). High anaemia prevalence was observed in eastern parts of the country. In the multivariable multilevel logistic regression analysis, no formal education (adjusted OR (AOR)=1.49, 95% CI 1.05 to 2.12), Afar (AOR=3.36, 95% CI 1.87 to 6.05), Somali (AOR=4.63, 95% CI 2.61 to 8.23), Harari (AOR=1.90, 95% CI 1.32 to 4.10), Dire Dawa (AOR=2.32, 95% CI 1.32 to 4.10) and high cluster altitude (AOR=1.37, 95% CI 1.03 to 1.82) were significantly associated with anaemia.

Conclusion The national distributions of anaemia varied substantially across Ethiopia. Educational status, region and cluster altitude were significantly associated with anaemia in the multivariable logistic regression model. Thus, targeted public health interventions for adolescent girls should be implemented in the hotspot areas.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study was done using the nationally representative data, which uses to obtain a reliable estimate.
⇒ Due to the cross-sectional nature of the data, we were unable to show a temporal relationship.
⇒ Another limitation of this study is geographic estimates and mapping were not based on the posterior estimates or Bayesian approaches, which are mainly used to estimate and map these small areas.

1.2 billion adolescents, making up, 16% of the world's population globally.[2 3] Adolescent girls are exposed to several forms of macronutrient and micronutrient malnutrition such as anaemia[2 4] as a result of sociocultural norms, menstruation bleeding and dietary habits.

Anaemia is a condition in which the number of red blood cells (and consequently their oxygen-carrying capacity) is insufficient to meet the body's physiological needs.[5 6] It is a major global health threat, predominantly affecting low-income countries such as Ethiopia.[6] Women particularly in the adolescent age groups are largely affected because of menstruation blood loss, proinflammatory processes in menstrual cycles, the gender norms for females in the feeding practices, and increased iron requirements for their fast growth and development.[7–12] Globally, anaemia affects more than 1.62 billion people,[13] ranging from 9% in developed and 43% in low-income and middle-income countries.[9] The prevalence of anaemia in reproductive age women was 29.9% in 2019 worldwide,[14] whereas, the prevalence was 41% in sub-Saharan Africa[15] and 35% in eastern Africa.[16] Studies are scarce in determining anaemia among adolescent girls globally. A piece of pocket studies conducted in Ethiopia showed that the prevalence

BACKGROUND

According to the WHO, the term adolescent is used to describe the age group between 10 and 19 years old.[1 2] There are an estimated

of anaemia in adolescent girls were ranged from 23% to 38%.[8 17 18] However, the previous studies were not exploring the spatial patterns of anaemia in adolescent girls. Hence, understanding the geographical variations of anaemia in adolescent girls is essential to design geographically targeted interventions.

Anaemia increases the risk of birth complications such as low birth weight and preterm births, it also impedes them to reach their full potential by reducing educational achievement, labour productivity and cognitive capacity.[19–24]

Educational status, marital status, wealth status, nutritional status, inadequate dietary intake, infections and health access were identified as factors associated with anaemia in adolescent girls in different studies.[8 10 12 17] Despite the Ethiopian government aggressively expanding healthcare coverage, and agriculture, anaemia among adolescent girls is continued to be the major public health threat.[25 26] Thus, this study aimed to investigate the spatial distributions and determinants of anaemia among adolescent girls.

METHODS
Study design, setting and periods
A cross-sectional study was conducted using Ethiopian Demographic and Health Survey (EDHS) 2016, which is the fourth survey in Ethiopia. The country is located in the horn of Africa and bordered by Sudan and South Sudan in the west, Djibouti, and Somalia in the east, Kenya in the south, and Eritrea in the North. Ethiopia is one of the oldest countries in the world and the second-most populous country in Africa next to Nigeria. Administratively Ethiopia is divided into ten regions (Afar, Amhara, Benshangul, Gambela, Harari, Oromia, Somali, Southern, Nations, Nationalities and People's region, Sidama (a recently added) and Tigray) and two city administrations (Addis Ababa and Dire Dawa). More than 84% of the population in Ethiopia resides in rural areas, mainly dependent on traditional farming. Ethiopia uses three-tier health systems: (1) primary care consists of health posts, health centres and primary hospitals; (2) secondary care consists of zonal hospitals; (3) tertiary care consists of Comprehensive Specialized Hospitals.

Sample and populations
All adolescent girls aged 15–19 years during the survey in Ethiopia were the source populations for this study, whereas all adolescent girls in the selected enumeration areas (EAs) were the study populations. A two-stage stratified cluster sampling technique was employed. Stratifications were done by separating each region into urban and rural areas. In stage one, 645 EAs (202 in urban) were selected using probability sampling. In the second stage, 28 households were selected systematically in each EA.

Study variables
Outcome variable
We used individual women data sets (IR) files, EDHS 2016, to extract the anaemia status of adolescent girls. Anaemia is defined as haemoglobin levels less than 12 g/dL for non-pregnant and 11 g/dL for pregnant adolescent girls.[15]

Independent variables
Due to the hierarchical nature of the DHS data, two levels of independent variables were considered. Level 1: contained individual sociodemographic and economic factors (age, marital status, religion, educational status, wealth index) and level 2: variables were the community-level factors such as region, altitude of the cluster, residence, community poverty, community media exposure and community literacy level. Community-level factors were aggregated from the individual-level factors.

Data collection procedures
This study was done based on the 2016 EDHS, which was accessed from the official database of the DHS programme (https://dhsprogram.com/). Online registration and applications were done to grant permission for the use of these data sets. Geographic coordinate (longitude and latitude) data were taken at EAs/cluster level.

Data management and analysis
Spatial analysis
For the spatial analysis, data management was done by using STATA V.16 software and Microsoft Excel V.19. Whereas mapping was done using ArcGIS V.10.8 software and SaTScan V.9.6 software.

Spatial autocorrelations
Spatial autocorrelation (Global Moran's I) was done to test whether there is spatial clustering of anaemia among adolescent girls in Ethiopia or not. Moran's I statistics is used to measure whether anaemia among adolescent girls was distributed randomly, clustered or dispersed in Ethiopia, by taking the entire dataset and producing a single output value, which ranges from −1 to 1. Moran's, I value close to −1 indicates the anaemia is dispersed in the area. On the other hand, Moran's I value closer to 1 indicates anaemia is clustered in the area. Whereas 0 Moran's I value means the data are randomly distributed. A statistically significant Moran's I ($p < 0.05$) leads to the rejection of the null hypothesis (anaemia is randomly distributed) and accepting the alternative hypothesis that indicates there is spatial dependence of anaemia in Ethiopia.

Hotspot analysis of anaemia
Hotspot analysis (Getis-Ord Gi*) was used to identify the spatial clustering of anaemia among adolescent girls in Ethiopia. Spatial scan statistical analysis (SaTScan) using the Bernoulli model was employed to test for the presence of statistically significant clusters of anaemia. The spatial statistics uses a circular scanning window that moves across the study area. Cases, controls and geographic

coordinate data were fitted to the Bernoulli model. Likelihood ratio test statistics and p values were used to determine whether the number of observed cases within the potential cluster was significantly higher than expected.

Spatial interpolation
Spatial kriging interpolation was used to estimate the distribution of anaemia in the unobserved areas using the observed data.

Associated factors of anaemia
In the EDHS data, adolescent girls are nested within a cluster, and adolescents within the same cluster were more similar to each other than adolescents within different clusters. Hence, this violates the standard regression model assumptions, which are independence of observation and equal variance across the cluster assumptions. This implies the need to take into account between-cluster variables by using an advanced model. Therefore, a multilevel random intercept logistic regression model was fitted to estimate the association between individual-level and community-level factors and the likelihood of having anaemia. Model comparison was done based on deviance (−2log likelihood) since the models were nested. Loglikelihood and intraclass correlation coefficient (ICC) was computed to measure the variation between clusters. The ICC indicates the degree of heterogeneity of anaemia between clusters.

Patient and public involvement
There was no patient and public involvement in this study since we conducted a secondary data analysis based on already available DHS data, which were collected to provide estimates of common health and health-related indicators.

RESULTS
Sociodemographic and economic characteristics of the respondents
A total of 3172 adolescent girls were included in the analysis, with a mean age of 16.9±1.36 years. Five hundred and four (16%) of adolescent girls had no formal education. Nearly two-thirds (65.2%) of the study participants reside in rural. Two thousand four hundred and forty-five (77.1%) of the adolescent girls had never married (table 1).

Prevalence of anaemia among adolescent girls
The overall prevalence of anaemia among adolescent girls in Ethiopia was 23.8 (22.4 to 25.3), with the highest prevalence observed in Somali and Afar regions (figure 1).

Spatial analysis
Spatial autocorrelation
The spatial autocorrelation analysis result showed that the spatial distribution of anaemia significantly varied across Ethiopia, with a Global Moran's I value of 0.6 (p value <0.0001) and a z-score of 8.6. This indicates anaemia among adolescent girls has spatial dependence in Ethiopia (figure 2).

Hotspot analysis anaemia among adolescent girls
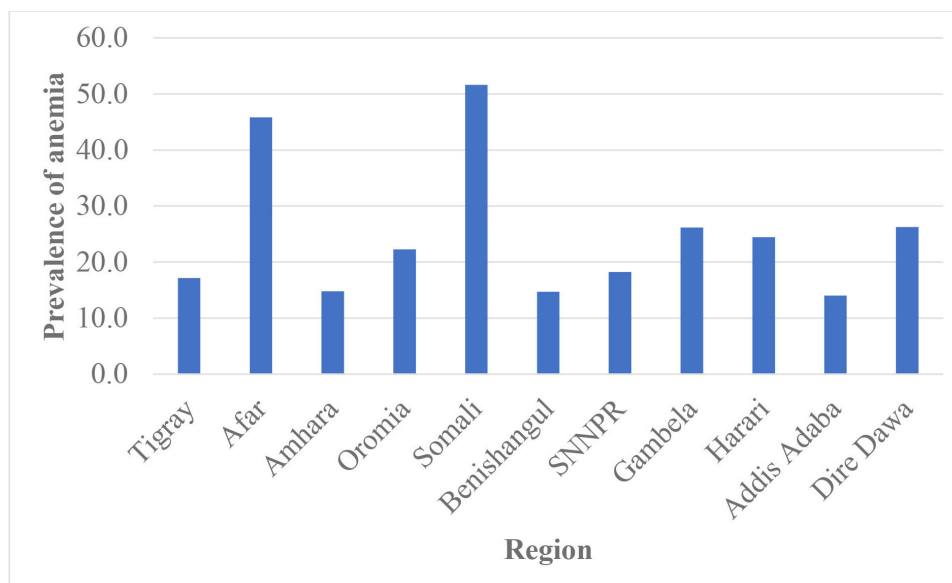In the mapping of anaemia, significant spatial clusters were observed in northeastern, eastern and southern

Table 1 Sociodemographic characteristics of late adolescents' girls in Ethiopia, Ethiopian Demographic and Health Survey 2016

Variables	Category	Frequency	Per cent
Age	15	651	20.5
	16	686	21.6
	17	554	17.5
	18	839	26.5
	19	442	13.9
Educational status	No education	504	16.0
	Primary	1859	58.6
	Secondary	717	22.6
	Higher	92	2.9
Wealth index	Poorest	715	22.5
	Poorer	379	11.9
	Middle	435	13.7
	Richer	457	14.4
	Richest	1186	37.4
Religion	Orthodox	1310	41.3
	Catholic	21	0.7
	Protestant	568	17.9
	Muslim	1255	39.6
	Traditional	9	0.3
	Others	9	0.3
Marital status	Never married	2445	77.1
	Married	590	18.6
	Living with partner	23	0.7
	Widowed	3	0.1
	Divorced	91	2.9
	Separated	20	0.6
Region	Tigray	397	12.5
	Afar	240	7.6
	Amhara	345	10.9
	Oromia	391	12.3
	Somali	279	8.8
	Benshangul	211	6.7
	SNNPR	362	11.4
	Gambela	195	6.2
	Harari	139	4.4
	Addis Ababa	392	12.4
	Dire Dawa	221	7.0
Residence	Urban	1105	34.8
	Rural	2067	65.2

SNNPR, Southern Nations, Nationalities and Peoples region.

Figure 1 Prevalence of anaemia among adolescent girls in Ethiopia by administrative regions, Ethiopian Demographic and Health Survey 2016. SNNPR, Southern, Nations, Nationalities and Peoples region.

parts of Ethiopia. Whereas, spatial dispersion of anaemia was observed in northern, central, northwestern and western parts of the country (figure 3).

In the spatial scan statistical analysis, a total of 183 significant clusters of anaemia were identified, of which 179 and 4 were primary (most likely clusters) and secondary

clusters, respectively. The primary cluster was found in the eastern, northeastern and southeastern parts of the country at 6.559519 N, 46.154797 E geospatial locations, with a relative risk of 1.8 and loglikelihood ratio (LLR of 39 at p value <0.0001). This shows adolescent girls who lived in this spatial window is 1.8 time at higher risk
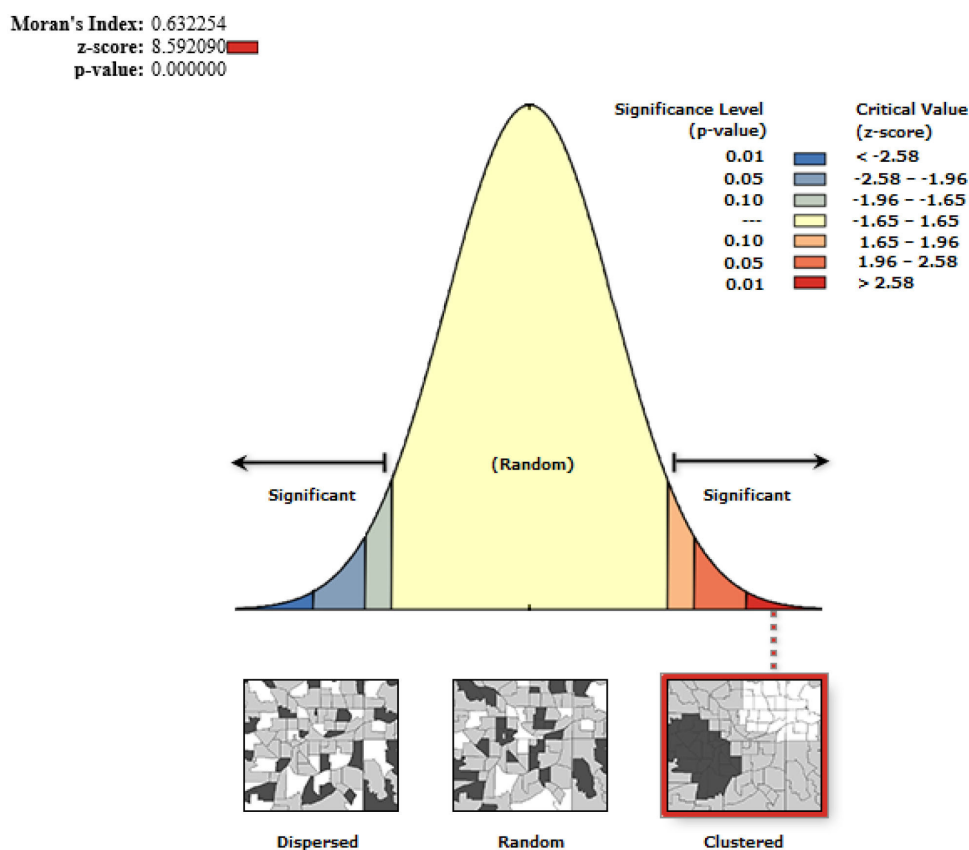

Figure 2 Autocorrelation result of anaemia among adolescent girls in Ethiopia, Ethiopian Demographic and Health Survey 2016.
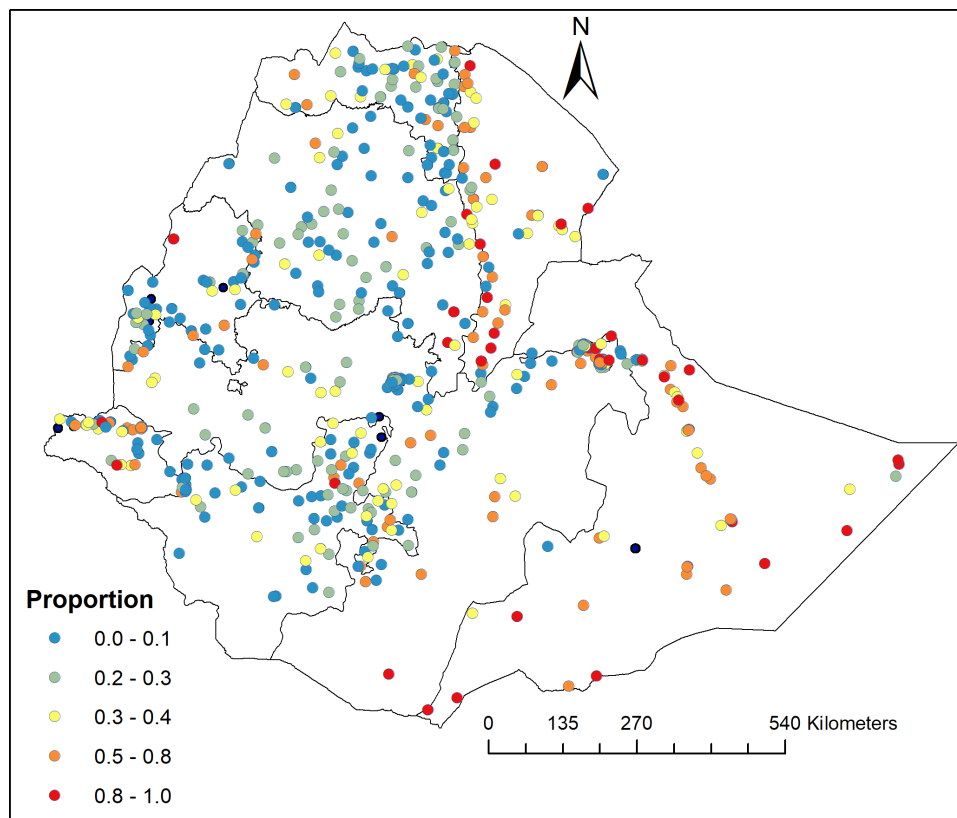
Figure 3 Cluster and outlier analysis of anaemia among adolescent girls in Ethiopia, Ethiopian Demographic and Health Survey 2016.

to develop anaemia than adolescent girls outside the window. Whereas the secondary clusters were observed in the northern borders of the country at 14.034142 N, and 39.898487 E geospatial locations, with relative risk and LLR of 3.29 and 12, respectively (table 2 and figure 4).

Interpolation of anaemia among adolescent girls
Ordinary kriging interpolation was used to map the predicted prevalence of anaemia in unobserved areas. The highest predicted prevalence of anaemia among adolescent girls was observed in the eastern, southern and northeastern parts of Ethiopia. Whereas, the lowest anaemia prediction was observed in the southwestern, western and northern parts of the country (figure 5).

Factors associated with anaemia among adolescent girls
The LR and ICC tests were checked, and the multilevel model was the best-fitted model for our data. Thus, the two-level logistic regression model was fitted to obtain an unbiased result and make a valid inference. In this study, deviance was used for model comparison and the final model was the best-fitted model with the lowest deviance value (table 3). The ICC value was 0.19 in the null model, which indicates that 19% of the total variability in amenia prevalence was attributable to between-cluster/EA variability (table 3). A two-level logistic regression model was fitted to identify factors associated with anaemia among adolescent girls in Ethiopia. Educational status, wealth index, religion and media exposure were significantly

associated with anaemia in model II. Whereas, region, place of residence and community level illiteracy were variables associated with anaemia in model III. However, educational status, region and cluster altitude remain significant in the multivariable multilevel logistic regression model. At the individual level educational status was associated with anaemia; the odds of having anaemia were 1.5 times higher among adolescent girls with no education as compared with adolescents who have secondary and above educational status (AOR=1.5, 95% CI 1.1 to 2.1). At the community level (level 2), two variables were significantly associated with anaemia. The odds of having anaemia among adolescent girls were 3.4 (AOR=3.4, 95% CI 1.9 to 6.1), 4.6 (AOR=4.6, 95% CI 2.6 to 8.2), 1.9 (AOR=1.9, 95% CI 1.3 to 4.1) and 2.3 (AOR=2.3, 95% CI 1.3 to 4.1) times higher among adolescent girls resides in Afar, Somali, Harari and Dire Dawa, respectively as compared with adolescent girls resides in Addis Ababa. The odds of having anaemia among adolescent girls who lived in high altitudes (ie, altitudes greater than 2000 m above sea level) were 1.4 times higher as compared with their counterparts (AOR=1.4, 95% CI 1.0 to 1.8) (table 3).
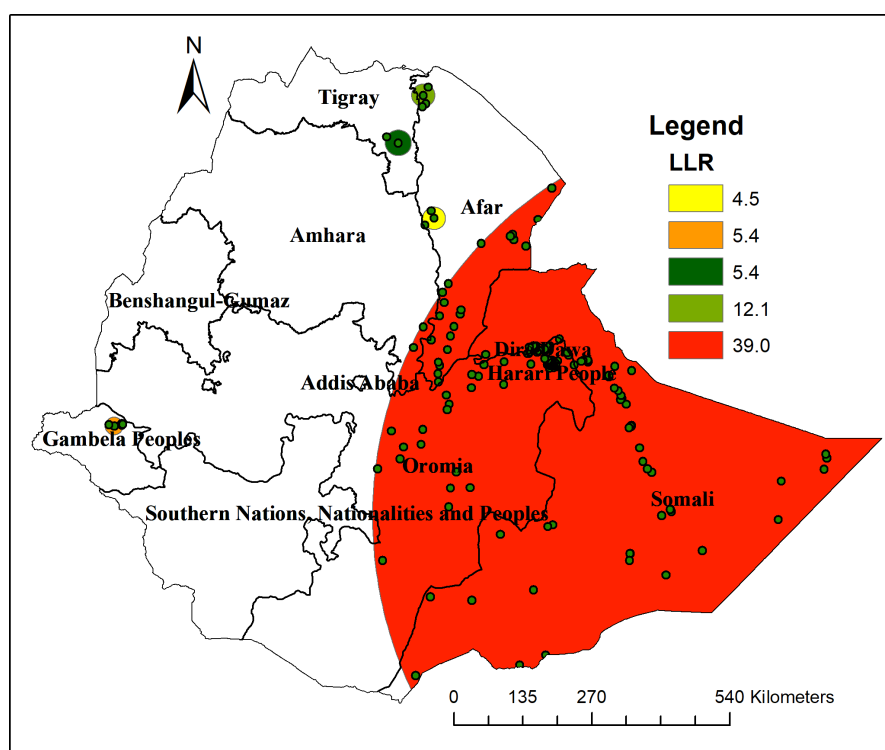
DISCUSSION
Anaemia is a major public health problem globally, especially in low-income and middle-income countries like Ethiopia. Adolescent girls are the most affected by

Table 2 SaTScan analysis results of anaemia among adolescent girls in Ethiopia, Ethiopian Demographic and Health Survey 2016

Cluster	Enumeration area (cluster) identified	Coordinate/radius	Populations	Cases	RR	LLR	P value
1	77, 629, 269, 378, 630, 146, 92, 490, 543, 492, 138, 171, 198, 95, 85, 358, 164, 497, 458, 588, 553, 521, 214, 573, 251, 239, 116, 33, 22, 568, 277, 527, 318, 187, 64, 439, 57, 210, 8, 556, 186, 566, 1, 520, 622, 212, 454, 501, 68, 513, 483, 194, 580, 321, 587, 240, 44, 357, 419, 534, 133, 418, 58, 500, 387, 29, 257, 157, 56, 179, 115, 288, 396, 228, 28, 381, 60, 614, 495, 393, 238, 607, 329, 480, 173, 383, 610, 473, 307, 642, 242, 523, 281, 453, 311, 166, 202, 352, 613, 208, 519, 30, 471, 535, 273, 74, 514, 5, 444, 631, 185, 27, 493, 380, 390, 385, 224, 606, 111, 282, 467, 363, 644, 594, 43, 190, 557, 546, 101, 140, 441, 25, 372, 286, 93, 394, 452, 472, 289, 412, 333, 476, 491, 506, 245, 529, 122, 377, 123, 319, 71, 49, 564, 51, 75, 230, 39, 336, 135, 37, 213, 562, 4, 596, 632, 440, 484, 102, 7, 524, 283, 422, 366, 624, 295, 619, 276, 620, 334	(6.5595 N, 46.1548 E)/789.35 km	765	269	1.84	39.0	<0.0001
2	263, 362, 134, 127	14.034 N, 39.8985 E/22.1 km	20	15	3.29	12.1	0.0035
3	160, 424	13.19727 N, 39.4579 E/25.01 km	14	9	2.8	5.4	0.729
4	106, 105, 221, 231, 549, 291, 469, 47, 114	8.2119 N, 34.45102 E/17.27 km	50	22	1.9	5.4	0.735
5	389, 241, 189	11.8684 N, 40.0882 E/21.90 km	15	9	2.6	4.7	0.919

LLR, loglikelihood ratio; RR, relative risk.

Figure 4 SaTScan analysis map of anaemia among adolescent girls in Ethiopia, Ethiopian Demographic and Health Survey 2016. LLR, loglikelihood ratio.
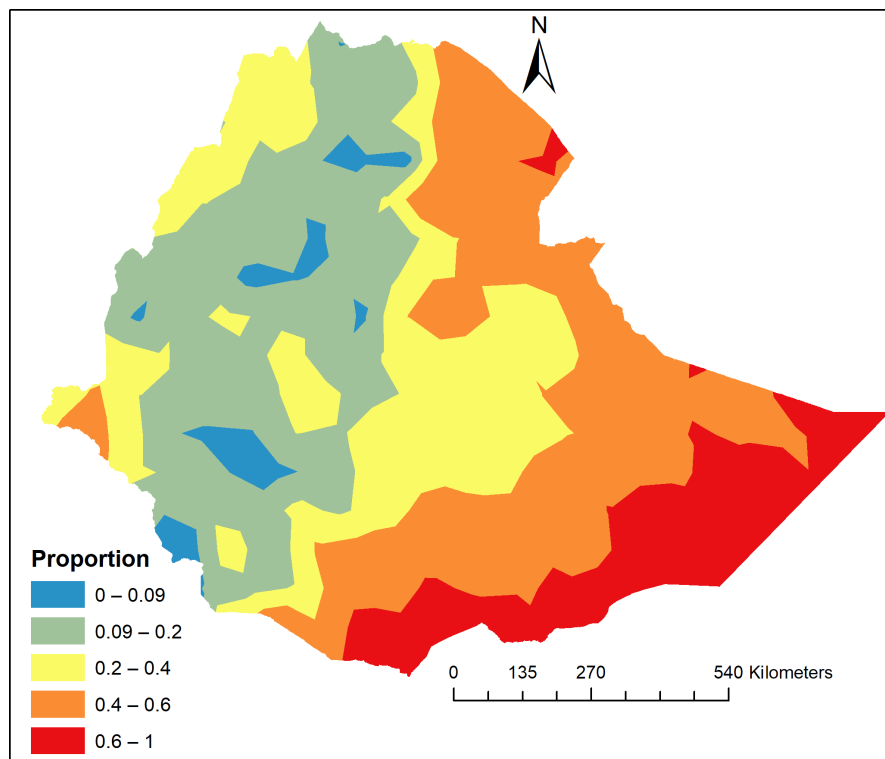
Figure 5 Kriging interpolation map of anaemia among adolescent girls in Ethiopia, Ethiopian Demographic and Health Survey 2016.

anaemia. This study aimed to investigate the spatial distribution and identify factors associated with anaemia among adolescent girls.

The prevalence of anaemia among adolescent girls in Ethiopia was 23.8%, which was lower than previous studies conducted in India (56%),[27] Nepal (51.3%),[28] (26.3%), sub-Saharan Africa (36%),[29] Jimma, Ethiopia (51.3%)[30] and West Ethiopia (27%).[31] This might be because in recent years the Ethiopian government implements different strategies to prevent anaemia: (1) through increasing income and reducing poverty, production of biofortified iron-rich crops, small livestock/poultry and dietary diversity in agricultural sectors.[32] (2) Iron supplementation, deworming, family planning, malaria prevention and treatment. (3) Increase female literacy through health education about hygiene family planning and nutrition education.[33 34] (4) Improved latrines, hand washing, access to clean water, livestock management and infectious disease prevention in water and sanitation programmes.[35]

However, the finding of this study was higher than the studies conducted in western China (14.4%)[36] and Bahir-Dar, Ethiopia (11.1%). The possible explanation might be related to the economic status of the population, education access, youth-friendly services, and water and sanitation services were good in China.[37] Furthermore, improved health access and nutrition education in China might have positive effects on anaemia prevention in China. The highest prevalence of our study with regards to the Bahir Dar study might be explained by; Bahir Dar

is a regional province capital city, where healthcare access and education services are relatively improved.

Consistent with the studies conducted in Indonesia[38] and sub-Saharan Africa,[29] significant spatial autocorrelation of anaemia was detected among adolescent girls. The spatial clustering of anaemia among adolescent girls was observed in the northeastern, eastern and southern parts of Ethiopia. The possible explanation might be, that in these parts of the country pastoralists were residing, which moves from place to place, which makes it difficult for accessing healthcare and educational services. In addition, adequate nutrition, sanitation and access to schools and healthcare facilities were poor, which might increase the prevalence of anaemia among adolescent girls in these parts of the country. Moreover, malaria and other infectious diseases are very common in this area, which can predispose to anaemia.[39]

According to the multilevel regression analysis, adolescents with no education are at higher risk to develop anaemia than adolescents with the educational status of grade 12 or above. This result was supported by a study conducted in Pakistan.[40] This might be due to educated adolescent girls can use adequate medical care and having appropriate knowledge about nutritional diet and personal hygiene, which can reduce the risk of anaemia among adolescent girls.[41]

Among the community-level variables, the odds of having anaemia among adolescent girls who reside in the regions of Afar, Somali, Harare and Dire-Dawa were higher as compared with adolescents who reside in Addis

Table 3 Multivariable multilevel logistic regression analysis results of both individual-level and community-level factors associated with anaemia among adolescent girls in Ethiopia, Ethiopian Demographic and Health Survey 2016

Individual and community-level characteristics		Null model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
Age	15		1		1
	16		0.9 (0.8 to 1.3)		1.0 (0.8 to 1.4)
	17		0.9 (0.7 to 1.3)		1.0 (0.7 to 1.4)
	18		1.1 (0.8 to 1.4)		1.1 (0.8 to 1.5)
	19		0.9 (0.7 to 1.4)		1.1 (0.8 to 1.5)
Educational status	No education		**1.7 (1.2 to 2.4)**		**1.5 (1.1 to 2.1)**
	Primary		1.2 (0.9 to 1.5)		1.2 (0.9 to 1.5)
	Secondary and higher		1		1
Ever use internet	No		1		1
	Yes		1.0 (0.7 to 1.5)		0.9 (0.7 to 1.4)
Wealth index	Poorest		**1.6 (1.2 to 2.1)**		1.1 (0.7 to 1.7)
	Poorer		0.9 (0.7 to 1.4)		1.1 (0.7 to 1.7)
	Middle		1.0 (0.7 to 1.4)		1.1 (07 to 1.7)
	Richer		0.9 (0.6 to 1.2)		0.9 (0.6 to 1.4)
	Richest		1		1
Currently pregnant	No		1		1
	Yes		1.3 (0.8 to 2.1)		1.3 (0.8 to 2.1)
Religion	Orthodox		1		1
	Muslim		**2.0 (1.6 to 2.6)**		1.2 (0.9 to 1.6)
	Protestant and others		**1.4 (1.1 to 1.9)**		1.4 (0.9 to 1.9)
Marital status	Married		1		1
	Not married		0.8 (0.6 to 1.0)		0.9 (0.7 to 1.1
Current contraceptive use	No		1		1
	Yes		0.7 (0.5 to 1.1)		0.8 (0.5 to 1.3)
Media exposure	No		**1.3 (1.0 to 1.6)**		1.2 (0.9 to 1.5)
	Yes		1		1
Region	Tigray			0.9 (0.6 to 1.6)	1.1 (0.7 to 1.9)
	Afar			**4.4 (2.5 to 7.6)**	**3.4 (1.9 to 6.1)**
	Amhara			0.8 (0.5 to 1.3)	0.9 (0.5 to 1.5)
	Oromia			1.3 (0.8 to 2.2)	1.3 (0.7 to 2.1)
	Somali			**5.7 (3.3 to 9.9)**	**4.6 (2.6 to 8.2)**
	Benshangul			0.8 (0.5 to 1.6)	0.8 (0.4 to 1.6)
	SNNPR			0.9 (0.6 to 1.6)	0.9 (0.5 to 1.8)
	Gambela			**1.9 (1.1 to 3.5)**	1.8 (0.9 to 3.4)
	Harari			**2.0 (1.1 to 3.6)**	**1.9 (1.3 to 4.1)**
	Addis Ababa			1	1
	Dire Dawa			**2.4 (1.4 to 4.2)**	**2.3 (1.3 to 4.1)**
Residence	Urban			1	1
	Rural			**1.6 (1.2 to 2.1)**	1.2 (0.8 to 1.8)
Community poverty level	Low			1	1
	High			1.1 (0.6 to 2.0)	1.2 (0.7 to 2.3)
Community illiteracy level	Low			1	1
	High			**1.4 (1.1 to 1.8)**	1.2 (0.9 to 1.5)

Table 3 Continued

Individual and community-level characteristics		Null model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
The altitude of the cluster	Low			1	1
	High			1.3 (0.9 to 1.7)	**1.4 (1.0 to 1.8**)
ICC		0.19 (0.14 to 0.25)	0.30 (0.16 to 0.57)	0.20 (0.09 to 0.48)	0.18 (0.07 to 0.46)
Log likelihood		−1707.73	−1633.13	−1610.19	−1597.2688
Deviance		3415.46	3266.26	3220.38	3194.5376

The bold value in the table indicates statstical significance.
AOR, Adjusted Odds Ratio; SNNPR, Southern, Nations, Nationalities and Peoples region.

Ababa. This might be because in these regions agricultural productivity, access to education, sanitation and infection prevention strategies were poor.[39]

Furthermore, the altitude of the clusters was significantly associated with anaemia among adolescent girls. The odds of having anaemia among adolescent girls who lived in high-altitude areas (ie, altitudes greater than 2000 m above sea level) were higher than their counterparts. This result is in agreement with previous studies done in India,[42] sub-Saharan Africa,[43] China[36] and Ethiopia.[31 39 44] This is because in areas with high altitudes agricultural products were relatively low, which could increase the risk of being anaemic. On the other hand, the risk of getting anaemia could be linked to higher population density and lower dietary habits, especially in adolescent girls due to sociocultural norms.[15]

Wealth index, religion and media exposure were variables significantly associated with anaemia among adolescent girls in model II. In agreement with previous studies, the poorest wealth status is positively associated with anaemia.[15 16] In most cases, the economic status of a community is linked with poor feeding habits, which results in anaemia and other forms of malnutrition. Religion was also significantly associated with anaemia; this could be also linked with religious habits of feeding.[45] Adolescents exposed to the media have a lower chance to develop anaemia as compared with their counterparts. This could be because of the ability of media to remove physical barriers that traditionally impede access to healthcare support, nutrition and resources. Furthermore, media would create a better understanding of the causes, early signs and prevention mechanisms of anaemia.[46] Whereas, place of residence was statistically significant in model III. The finding was supported by previous studies done in different parts of the world.[27–31 36 38 40 42 43 47 48] The reason behind this might be explained by low economic status, cultural barriers, knowledge and low access to information.

This study would have valuable policy implications to design public health intervention programmes essential to reducing anaemia among adolescent girls. High-risk areas for anaemia could be identified easily to design effective local interventions. This study has some limitations, in the first place, we fail to show the temporal relationship due to the cross-sectional nature of the data. Second, geographic estimates and mapping were not based on the posterior estimates or Bayesian approaches, which are mainly used to estimate and map this small area of data. The other limitation of the study was we did not incorporate clinically confirmed data, which might affect the outcome of the study.

Conclusion

The national distribution of anaemia varied substantially across Ethiopia. Spatial clustering of anaemia among adolescent girls was observed in eastern, southern and northeastern parts of Ethiopia. Educational status, region and cluster altitude were significantly associated with anaemia in the multivariable multilevel binary logistic regression model. Thus, interventions to increase the educational status of adolescent girls should be strengthened. Public health interventions to prevent anaemia should be implemented in the most affected areas.

ORCID iDs
Kendalem Asmare Atalell http://orcid.org/0000-0003-1127-3592
Tadesse Tarik Tamir http://orcid.org/0000-0003-0760-1100
Tewodros Getaneh Alemu http://orcid.org/0000-0002-7829-0648

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