

# BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email [info.bmjopen@bmj.com](mailto:info.bmjopen@bmj.com)

# BMJ Open

## **Spatio-temporal distribution and associated factors of anemia among children aged 6–59 months in Ethiopia: Based on the EDHS 2005- 2016: A spatial and multilevel analysis**

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-045544
Article Type:	Original research
Date Submitted by the Author:	04-Oct-2020
Complete List of Authors:	Hailgebreal, Samuel; Arba Minch University, Department of Health Informatics Nigatu, Araya Mekonnen, Zeleke; University of Gondar College of Medicine and Health Sciences, Public Health ; Endehabtu, Berhanu; Health Informatics
Keywords:	PUBLIC HEALTH, Anaemia < HAEMATOLOGY, PAEDIATRICS

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1 1 Spatio-temporal distribution and associated factors of anemia among children aged 6–59  
2  
3 2 months in Ethiopia: Based on the EDHS 2005- 2016: A spatial and multilevel analysis  
4  
5  
6 3 Samuel Hailgebreal<sup>1\*</sup>, Araya Mesfin Nigatu<sup>2</sup>, Zeleke Abebaw Mekonnen<sup>2,3</sup>, Berhanu Fikadie  
7  
8 4 Endehabtu<sup>2</sup>  
9

### 10 **Affiliation**

11  
12  
13  
14 6 <sup>1</sup>Department of Health Informatics, College of Health Science, Arbaminch University, Ethiopia

15  
16  
17 7 <sup>2</sup>Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia

18  
19  
20 8 <sup>3</sup>Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia  
21  
22  
23 9

### 24 25 26 10 **Corresponding author**

27  
28 11 Samuel Hailgebreal

29  
30  
31 12 Email: [samuastd@gmail.com](mailto:samuastd@gmail.com)  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## Abstract

**Objectives:** Anemia is a global public health problem with major health and socio-economic consequences. Though childhood anemia is a major public health problem in Ethiopia, there is limited evidence on the spatio-temporal variability of childhood anemia overtime. Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anemia using the Ethiopian Demographic and health survey (EDHS) data from 2005-2016.

**Design:** Survey-based cross-sectional study design was employed for the EDHS.

**Setting:** Data were collected in all nine regions and two city administrations of Ethiopia in 2005, 2011 and 2016.

**Participants:** The source population for this study was all 6–59 months of children in Ethiopia. A total weighted sample of 21,302 children aged 6-59 months were included in this study.

**Outcome measure:** The outcome variable was child anemia status.

**Results:** The prevalence of anemia has been declined from 53.9% in 2005 to 44.6% in 2011, but it showed increment 2016 to 57.6%. The Spatial analysis revealed that the spatial distribution of anemia varied across the country. In spatial scan statistics analysis, a total of 22 clusters (RR= 1.54, P-value < 0.001) in 2005, 180 clusters (RR = 1.14, P-value < 0.001) in 2011, and 219 clusters (RR = 1.44, P-value < 0.001) in 2016 significant primary clusters were identified. Child age, women age, maternal anemia status, wealth index, birth order, fever, stunting, wasting status, and region were significant predictors of childhood anemia.

**Conclusions:** In this study, childhood anemia remains a public health problem. The spatial distribution of childhood anemia was significantly varied across the country. Identifying the risk areas and determinants would help to design strategies in the area. Therefore, regions with a

1 43 high risk of childhood anemia, individual and community level factors should be intensified by  
2  
3 44 allocating additional resources and providing appropriate and tailored strategies.  
4  
5

6 45 **Keywords:** Anemia, children, EDHS, Spatial analysis, Ethiopia  
7  
8

9 46

### 11 47 **Strengths and limitations of this study**

- 13 48 • This study applied different methods of spatial pattern, trend and a multilevel regression  
14 49 models accounting the nested nature of EDHS data
- 16 49 • The study was based on three consecutive EDHS dataset's representing the whole  
17  
18 50 country of Ethiopia  
19  
20 51
- 22 52 • The cross-sectional nature of the data prevents causality from being inferred between  
23 53 the independent and dependent variables  
24  
25 53
- 27 54 • Respondents' data that didn't have files (longitude and latitude) were excluded from the  
28 55 spatial analysis which could affect the generalizability of the findings  
29  
30 55  
31  
32

33 56

34 57

37 58

40 59

43 60

46 61

49 62

### 52 63 **Background**

53  
54  
55  
56  
57  
58  
59  
60

1 64 Anemia is a condition characterized by a low level of hemoglobin in the blood(1). Over 273  
2  
3 65 million under-five children suffer from anemia worldwide(2). Sub-Saharan Africa is one of the  
4  
5 66 most affected regions which accounts for about 53.8%(2). World health organization had  
6  
7  
8 67 developed a classification system to facilitate international comparisons of anemia as public  
9  
10 68 health crises. The problem was considered severe if anemia prevalence is  $\geq 40\%$ , moderate  
11  
12 69 from 20% to 39.9%, and mild from 5% to 19.9%(3). The high prevalence of anemia and its  
13  
14  
15 70 consequences on children's health, especially on their growth and development, have made it  
16  
17 71 an important public health problem and it also increases the risk of mortality and morbidity  
18  
19 72 which come from other diseases(4,5).

21  
22 73 Anemia is a public health problem that affects populations in both industrialized and non-  
23  
24 74 industrialized countries. It affects all segments of the population. It is frequently observed  
25  
26  
27 75 among children and pregnant women who are the most vulnerable group because their  
28  
29 76 requirements for iron are higher than any other group. Childhood anemia is mostly caused  
30  
31 77 by dietary Iron deficiency. Folate, vitamin B12 and vitamin A deficiencies, chronic  
32  
33  
34 78 inflammation, parasitic infections, and inherited disorders can also contribute to childhood  
35  
36 79 anemia (6). For children, age 6-59month Anemia is defined as a hemoglobin level below  
37  
38 80 11.0 g/dl(6). Childhood anemia is mostly coexisting with malaria, parasitic infection,  
39  
40  
41 81 nutritional deficiencies, and hemoglobinopathies(7).

42  
43  
44 82 The prevalence of anemia in Africa, South East Asia, America, and European regions  
45  
46 83 was,62.3%,53.8%,23.3%, and,22.9%, respectively(3). Pregnant women and children in low-  
47  
48 84 income countries were at risk for anemia because they were believed to be those with the  
49  
50 85 greatest problems with inadequate nutrition, high infectious disease burden, and poor access  
51  
52  
53 86 to routine health care(8). In sub-Saharan Africa, Anemia is a major public health problem  
54  
55 87 associated with an increased risk of death and impaired cognitive development(9). In Ethiopia,  
56  
57

1 88 the three crude summaries of the country reported between,2005 and 2016, indicated the  
2  
3 89 prevalence of anemia among Ethiopian children declined from,54% to,44% from, 2005 to,2011  
4  
5 90 but increased to,57% in 2016(10–12).  
6  
7

8 91 Different studies across different countries showed that the prevalence of anemia among 6-  
9  
10 92 59-month children is high and a severe public health problem. Evidence from different studies  
11  
12 93 indicated that women age, residence, family income, maternal education(13), an introduction  
13  
14 94 of complementary foods, poor breastfeeding practice, poor utilization of folic acid by  
15  
16 95 mothers(14), maternal anemia(15), unemployment of the parent, malaria, and presence of  
17  
18 96 sickle hemoglobin(13), household wealth index, sex of the child(16), and nutritional status were  
19  
20 97 factors for childhood anemia. There are few studies done in Ethiopia on factors associated with  
21  
22 98 anemia. But at the national level, there was no yet study done on the spatio-temporal patterns  
23  
24 99 of childhood anemia and associated factors using multilevel analysis. Therefore, this study  
25  
26 100 attempts to fill the gap by investigating the spatial distribution of anemia and its associated  
27  
28 101 factors using multilevel model analysis in Ethiopia using the EDHS survey between 2005-  
29  
30 102 20016 data.  
31  
32  
33  
34  
35

## 36 103 **Methods**

### 37 104 **Study design and setting**

38  
39 105 The survey-based cross-sectional study design was employed using the Ethiopian  
40  
41 106 Demography and Health Surveys (EDHS) in 2005, 2011, and 2016. Data access, extraction,  
42  
43 107 and analysis were conducted from January to June 2020. The study was conducted in Ethiopia  
44  
45 108 located at the horn of Africa (3°-14°N and 33° – 48°E). Administratively, the country is divided  
46  
47 109 into nine regional states and two city administrations. Each region is sub-divided into zones,  
48  
49 110 districts, towns, and kebeles (the smallest administrative units).  
50  
51  
52  
53  
54  
55

### 56 111 **Source and study population**



1 112 The source population for this study was all 6–59 months of children in Ethiopia. The study  
2  
3 113 population was all children aged from 6-59 months in the selected enumeration areas within  
4  
5  
6 114 five years before the survey.  
7

### 8 115 **Sampling size and sampling technique**

9  
10  
11 116 A total of 21,302 children (3,868 children in 2005, 8,958 children in 2011, and 8476 Children  
12  
13 117 in 2016) were included in this study. Weighted values were used to restore the  
14  
15 118 representativeness of the sample data. Sample weights were calculated in each children's  
16  
17  
18 119 Record (KR) EDHS dataset. The survey covered all nine regions and the two city  
19  
20 120 administrations of Ethiopia. Participants were selected based on a stratified two-stage cluster  
21  
22 121 sampling technique in each survey year (2005, 2011, and 2016). After excluding clusters with  
23  
24 122 zero coordinates and missing information, a total of 503 clusters in 2005, 569 clusters in 2011,  
25  
26  
27 123 and 615 clusters in 2016 were included. The detailed sampling procedure was available in  
28  
29 124 each EDHS report(10–12)  
30

### 31 125 **Data collection tools and procedures**

32  
33  
34 126 The three EDHS datasets were downloaded from the measure DHS program (Demographic  
35  
36 127 and Health Survey) website ([www.measuredhsprogram.com](http://www.measuredhsprogram.com)) after obtaining the necessary  
37  
38 128 permissions for the download and further analyses. Data extraction was performed using  
39  
40 129 STATA version 14.1 similarly, location data (latitude and longitudinal) were extracted from the  
41  
42  
43 130 downloaded excel file. Then after extraction, the missing values for the significant independent  
44  
45 131 variables were excluded and the analysis was undertaken using a complete set of data.  
46  
47

### 48 132 **Key variables and Measurements**

49  
50  
51 133 **Dependent variable:** The study variables were grouped into dependent and independent  
52  
53 134 variables. The dependent variable is child anemia status, categorized as “anemic/not-anemic”  
54  
55  
56  
57  
58  
59  
60

1 135 variable. Children whose hemoglobin level was less than 11Hb were taken as anemic and not  
2  
3 136 anemic otherwise.

### 6 137 **Independent variables:**

8 138 From the EDHS dataset all sociodemographic variables, Maternal and Child-related factors  
9  
10 139 (individual and community level) were taken as independent variables in the three-consecutive  
11  
12  
13 140 survey.

### 15 141 **Data management and analysis**

17 142 The data were cleaned using STATA 14.1 software and Microsoft excel. The data were  
18  
19  
20 143 weighted using sampling weight, primary sampling unit, and strata before any statistical  
21  
22 144 analysis to restore the representativeness of the survey to take into account the sampling  
23  
24 145 design when calculating standard errors to get reliable statistical estimates.

### 27 146 **Spatial analysis**

29 147 The weighted frequency of outcome variable with cluster number was cross-tabulated in  
30  
31  
32 148 STATA software and exported to excel to get the case to the total proportion. Geographic  
33  
34 149 coordinate data were merged in STATA 14.1. Observations within clusters having longitude  
35  
36 150 and latitude 0 were dropped from the spatial analysis section. Then CSV file imported to  
37  
38  
39 151 ArcGIS 10.7 for spatial analysis.

### 41 152 **Spatial autocorrelation analysis**

43 153 The spatial autocorrelation (Global Moran's I) statistic measures whether childhood anemia  
44  
45  
46 154 patterns were dispersed, clustered or randomly distributed in the study area. Moran's, I output  
47  
48 155 value ranges from (-1 to +1). Values close to -1 indicate disease dispersed, whereas moran's  
49  
50 156 I close to +1 indicate childhood anemia clustered and distributed randomly if I value is zero.

1 157 Anselin Local Moran's I was used to investigating the local level cluster locations of anemia in  
2  
3 158 terms of positively correlated (high-high and low-low) clusters or negatively correlated (high-  
4  
5 159 low and low-high).  
6  
7

### 8 160 **Hot spot analysis (Getis-Ord $G_i^*$ statistic)**

10 161 Getis-Ord  $G_i^*$  statistics were computed to measure how spatial autocorrelation varies over the  
12  
13 162 study location by calculating  $G_i^*$  statistic for each area. Z-score is computed to determine the  
14  
15 163 statistical significance of clustering, and the p-value computed for the significance. Statistical  
16  
17 164 output with high  $G_i^*$  indicates "hotspot" whereas low  $G_i^*$  means a "cold spot". hot spot areas  
19  
20 165 indicated that there was a high proportion of anemia and the cold spot indicated that there was  
21  
22 166 a low proportion of anemia.  
23

### 24 167 **Spatial interpolation**

26 168 Spatial interpolation technique is used to predict anemia in the un-sampled areas in the country  
28  
29 169 based on sampled EAs. There are various deterministic and geostatistical interpolation  
30  
31 170 methods. Ordinary Kriging spatial interpolation method was used for this study for predictions  
32  
33 171 of childhood anemia in unobserved areas of Ethiopia since it had low mean square error and  
34  
35 172 residual as compared to the other interpolation techniques.  
36  
37  
38

### 39 173 **Spatial scan statistical analysis**

41 174 Spatial scan statistical analysis Bernoulli based model was employed to test for the presence  
42  
43 175 of statistically significant spatial clusters of anemia using Kulldorff's Sat Scan version 9.6  
44  
45 176 software. The spatial scan statistic uses a circular scanning window that moves across the  
46  
47 177 study area. Children with anemia were taken as cases and those who were not-anemic as  
48  
49 178 controls to fit the Bernoulli model. The default maximum spatial cluster size of <50% of the  
50  
51 179 population was used, as an upper limit, which allowed both small and large clusters to be  
52  
53 180 detected and ignored clusters that contained more than the maximum limit. The scanning  
54  
55  
56  
57  
58  
59

1 181 window with maximum likelihood was the most likely performing cluster, and the p-value was  
2  
3 182 assigned to each cluster using Monte Carlo hypothesis testing by comparing the rank of the  
4  
5 183 maximum likelihood from the real data with the maximum likelihood from the random datasets.  
6  
7  
8 184 The primary and secondary clusters were identified and assigned p-values and ranked based  
9  
10 185 on their likelihood ratio test, based on 999 Monte Carlo replications(17).  
11  
12

## 13 186 **Model building**

14  
15  
16 187 Four models were fitted using **melogit**, a STATA command, the null model without predictors,  
17  
18 188 the model I with only individual-level variables, model II with only community-level variables,  
19  
20 189 and model III both individual-level and community-level variables. Model comparison was  
21  
22 190 conducted by using deviance and likelihood ratio.  
23  
24  
25

26 191 ICC (Intra-class correlation), MOR (median odds ratio), and PCV (proportional change in  
27  
28 192 variance) were computed to measure the variation between clusters. The intra-class  
29  
30 193 correlation coefficient (ICC) quantifies the degree of heterogeneity of childhood anemia  
31  
32 194 between clusters (the proportion of the total observed individual variation in anemia that is  
33  
34 195 attributable between cluster variations) calculated as  $ICC = \frac{\sigma^2}{\sigma^2 + \pi^2/3}$ (18) but MOR is  
35  
36 196 quantifying the variation or heterogeneity in outcomes between clusters and is defined as the  
37  
38 197 median value of the odds ratio between the cluster at high risk of anemia and cluster at lower  
39  
40 198 risk when randomly picking out two clusters (EAs) MOR:  $\exp(\sqrt{2 \cdot Va} \cdot 0,6745) \sim MOR = \exp$   
41  
42 199  $(0,95 \cdot \sqrt{Va})$ (19). PCV measures the total variation attributed by individual-level factors and  
43  
44 200 community-level factors in the multilevel model as compared to the null model PCV. In the  
45  
46 201 multivariable multilevel logistic regression analysis variables with a p-value of <0.05 were  
47  
48 202 considered as statistically significant. Adjusted Odds Ratio (AOR) with their corresponding  
49  
50 203 95% confidence interval was determined to identify factors associated with anemia. After  
51  
52 204 comparing all models, a model with low deviance was considered as a better model.  
53  
54  
55  
56  
57  
58  
59

1 205 Multicollinearity was checked using the Variance Inflation Factor (VIF). VIF less than 10% was  
2  
3 206 taken as no multicollinearity.  
4

## 5 207 **Ethics and confidentiality**

6  
7

8 208 Ethical clearance was obtained from the ethical review board of the University Of Gondar  
9  
10 209 Institute Of Public Health, CMHS. Permission for data access was obtained from the measure  
11  
12  
13 210 demographic and health survey through an online request by a written letter of objective and  
14  
15 211 significance of the study from <http://www.dhsprogram.com>  
16  
17

## 18 212 **Patient and public involvement**

19

20  
21 213 This study did not involve patients and the public  
22  
23

## 24 214 **Results**

25

### 26 215 **Descriptive characteristics of the study population**

27  
28

29 216 A total of 21,302 children with known hemoglobin levels (3,868 in 2005, 8,958 in 2011, and  
30  
31  
32 217 8467 in 2016) were included in this study. The prevalence of anemia for the three consecutive  
33  
34 218 surveys was 53.9%, 44.6%, and 57.6% in 2005, 2011, and 2016 EDHS data respectively. The  
35  
36 219 majority of the participants were in the age group of 36-47 (23%), 36-47 (24%), and, 12-23  
37  
38 220 (22%) in EDHS 2005, 2011, and 2016 survey respectively. The mean age of children was  
39  
40  
41 221  $32.57 \pm 15.6$ -SD,  $32.6 \pm 15.4$ -SD, and  $31.7 \pm 15.6$ -SD in 2005, 2011, and 2016 respectively.  
42  
43 222 Among the eligible children, male participants were high proportion in 2011 and 2016 EDHS  
44  
45 223 as compared to 2005 survey periods. The majority of children were from rural residency in five  
46  
47  
48 224 years preceding the survey in three surveys. About 78.6%, 70%, and 67% of women were  
49  
50 225 unable to read and write in 2005, 2011, and 2016 survey respectively. Children from poor and  
51  
52 226 middle economic class families were more anemic than children from rich families across the  
53  
54  
55  
56  
57  
58  
59  
60

three EDHS survey (Table 1). During the study period the trends in the prevalence of childhood anemia in Ethiopia, were ups and down across regions (Fig.1).

Table 1: Descriptive characteristics of study participants included in the analysis for childhood anemia five years preceding the survey from EDHS 2005 - 2016 in Ethiopia

Characteristics	2005 (N, 3868) Frequency (%)	2011(N, 8958) Frequency (%)	2016(N, 8476) Frequency (%)
<b>Sex of child</b>			
Male	1,931(49.93)	4,500(51.35)	4,395(51.85)
Female	1,937(50.07)	4,358(48.65)	4,081(48.15)
<b>Age of child</b>			
6-11	418 (10.81)	1,029(11.48)	1,000(11.80)
12-23	842 (21.76)	1,804(20.14)	1,902(22.43)
24-35	825 (21.33)	1,895(21.16)	1,803(21.27)
36-47	919 (23.76)	2,184(24.37)	1,832(21.62)
48-59	864 (22.34)	2,047(22.85)	1,939(22.87)
<b>Mean ± SD</b>	<b>32.57 ±15.6</b>	<b>32.6±15.4</b>	<b>31.7±15.6</b>
<b>Residence</b>			
Urban	244 (6.31)	1,047(11.69)	857(10.12)
Rural	3,624 (93.69)	7,911(88.31)	7,619(89.88)
<b>Religion</b>			
Orthodox	1,624 (41.97)	3,416(38.13)	2,913(34.37)
Muslim	1,276 (32.99)	3,108(34.70)	3,432(40.48)
Protestant	836 (21.61)	2,151(24.01)	1,874(22.11)
Others	133 (3.43)	283(3.16)	258(3.05)
<b>Women age</b>			
15-29	1,930(49.90)	4,908(54.78)	4,356(51.40)
30-39	1,474(38.10)	3,223(35.98)	3,335(39.34)
40-49	464(12.00)	828(9.24)	785(9.26)
<b>Women education</b>			
No education	3,042 (78.63)	6,285(70.16)	5,685(67.07)
Primary	684 (17.68)	2,389(26.67)	2,275(26.84)
Secondary	136 (3.51)	168(1.88)	346(4.08)
Higher	7 (0.18)	117(1.30)	170(2.01)
<b>Marital status</b>			
Single	7(0.17)	50(0.56)	45(0.53)

1	262	Married	3,704(95.74)	8,425(94.04)	8,129(95.9)
2					
3	263	Widowed	80(2.06)	178(1.99)	93(1.10)
4					
5	264	Divorced	78(2.03)	306 (3.41)	210(2.48)
6					
7	265	<b>Husband education</b>			
8					
9	266	No-education	2,235 (58)	4,532(50.87)	4, 33(51.10)
10	267	Primary	1,233(32)	3,710(41.65)	3,273(38.62)
11					
12	268	Secondary	362(9)	412(4.63)	572(6.75)
13					
14	269	Higher education	31(0.81)	255 (2.86)	300(3.53)
15					
16	270	<b>Wealth index</b>			
17					
18	271	Poor	1,697(43.86)	4,048(45.19)	3,977(46.92)
19					
20	272	Middle	854(22.07)	1,873(20.91)	1,821(21.48)
21					
22	273	Rich	1,318(34.07)	3,038 (33.91)	2,678(31.60)
23					
24	274	<b>Women working status</b>			
25					
26	275	Not working	2,841(73.45)	5,793(64.67)	6,140(72.44)
27					
28	276	Working	1,027(26.55)	3,165(35.33)	2,336(27.56)
29					
30	277	Total	3,868(100)	8,958(100)	8,476(100)
31					

32 278

33

34

35 279

36

37

38

39

40

41

42

43

44

45 283

46

47 284

48

49 285

50

51

52 286

53

54 287

55

56

57

58

59

60

### Community-level characteristics of the study population

Findings from this study revealed that there is a regional variation of childhood anemia, with 83% in Somalia, 75%, in Afar, 72% in Dire Dawa, and 67% in Harari. However, Amhara, and Benishangul with 43% which was relatively low compared to other regions.

Childhood Anemia varies by urban-rural of residence. Children residing in communities with low poverty level had a lower percent of anemia (51.2%) as compared to with high community poverty level (62.5%%). Children from low community women education level (59.5%) were more anemic than children resided with high community women (53%) educational level (Table 2).

Table 2: Community Level Factors of under five children participated on EDHS (2016), Ethiopia. (N, 8476)

Community level factors	Child anemia status		
	Not-anemic (%)	Anemic (%)	Total (%)
<b>Residence</b>			
Urban	435(50.6)	424(49.4)	857(100)
Rural	3164(41.5)	4455(58.5)	7619(100)
<b>Region</b>			
Amhara	950(57.5)	703(42.5)	1653(100)
Oromia	1273(34.2)	2446(65.8)	3719(100)
SNNP	875(49.1)	906(50.9)	1781(100)
Somali	58(16.7)	290(83.3)	348(100)
Tigray	263(46)	309(54)	572(100)
Addis Ababa	82(50.9)	79(49.1)	161(100)
Afar	21(25.3)	62(74.7)	83(100)
Benishangul	51(56.6)	39(43.4)	90(100)
Gambelia	8(42.1)	11(57.9)	19(100)
Harari	5(31.2)	11(68.8)	16(100)
Dire Dawa	9(28.1)	23(71.9)	32(100)
<b>Community women education</b>			
Low	2281(40.5)	3358(59.5)	5639(100)
High	1315(46.4)	1520(53.6)	2837(100)
<b>Community women poverty</b>			
Low	1815(48.8)	1905(51.2)	3719(100)
High	1782(37.5)	2974(62.5)	4756(100)
<b>Total</b>			<b>8476(100)</b>

### Spatio-temporal distribution of anemia among children age 6-59 months in Ethiopia

The spatial distribution of childhood anemia in Ethiopia was non-random in all three consecutive surveys. A global spatial autocorrelation statistic was estimated using Moran's *I* statistic. The global Moran's *I* test value was 0.176 (P-value <0.001) in 2005, 0.18 (P-value < 0.001) in 2011, and 0.09(P-value < 0.005) in 2016 Ethiopian Demographic and health surveys.

### Hot spot analysis of the three surveys



1 322 The spatial distribution of childhood anemia in Ethiopia was different in the three survey  
2  
3 323 periods. In EDHS 2005, a high proportion of childhood anemia was detected in Dire Dawa,  
4  
5 324 Harari, Eastern Oromia, Benishangul in Metekel zone, Gambela, Southern and Eastern Tigray,  
6  
7  
8 325 and Somali region mainly Liben, Afdar, and Fafna zone which was hotspot area within 95%  
9  
10 326 confidence level. On the counterpart, GamoGofa, Wolayita, Hadiya, Southern Omo, and  
11  
12 327 Segen zone of SNNPR, Addis Ababa, central Oromia, Jima, North Shewa zone were cold spot  
13  
14  
15 328 area. In EDHS 2011, highly significant clustering of childhood anemia was detected in Somalia,  
16  
17 329 Dire Dawa, Harari, Afar, Gambela, Benishangul, Eastern Oromia, Bale, and Arsi zone were  
18  
19 330 the hotspot areas within 95% level of confidence. The low hotspot area of childhood anemia  
20  
21 331 was detected in central Tigray, East and West Gojam, North Gondar, a central part of Oromia,  
22  
23  
24 332 Addis Ababa and SNNPR were areas identified as the low percentage of childhood anemia in  
25  
26 333 the 2011 EDHS survey.

27  
28  
29 334 In EDHS-2016 sampled data, hot spot (high risk) regions for childhood anemia were observed  
30  
31 335 in Somalia, Dire Dawa, Harari, Gambela, Eastern, and Southern part of Oromia. However,  
32  
33  
34 336 Amhara, Benishangul, and Southern Nations Nationalities and Peoples (SNNP) were identified  
35  
36 337 as cold spot (low risk) regions for childhood anemia within a 95% confidence interval (**Fig.2**)  
37  
38

### 39 338 **Spatial interpolation**

40  
41 339 Based on EDHS-2005 sampled data, the geostatistical analysis predicts that the highest  
42  
43 340 prevalence of childhood anemia (65.75%-88.89%) was detected in East Oromia, Ilubabur, Arsi,  
44  
45  
46 341 some parts of Benishangul, Agnuak zone in Gambela, North Shewa Amhara region, South and  
47  
48 342 central Tigray Afar in zone2, some parts of Dire Dawa city and Somalia. In EDHS-2011  
49  
50 343 Geostatistical analysis, a high percent of anemia was detected in Afar, most parts of Somalia,  
51  
52  
53 344 Oromia in East Harerge and Borena, some part of Dire Dawa, and the Meketel zone in  
54  
55 345 Benishangul. In 2016 EDHS most of Somalia, some parts of Gambela, Guji and some parts of  
56  
57  
58  
59  
60

1 346 Borena, East Shewa, East Harerge and Arsi in Oromia and part of Dire Dawa were highly  
2  
3 347 prevalent areas in childhood anemia (**Fig.3**)  
4

### 5 348 **Spatial scan statistics**

6  
7  
8 349 In 2005 EDHS most likely (primary clusters) and secondary clusters of anemia were identified.  
9  
10 350 A total of 3 significant clusters were identified. One was most likely (primary) clusters and 2  
11  
12  
13 351 were secondary clusters of spatial sat scan analysis. The primary cluster's spatial window was  
14  
15 352 located in Somalia, which was centered at (9.018373 N, 43.110635 E) of geographic location  
16  
17  
18 353 with a 97.93 km radius, and Log-Likelihood ratio (LLR) of 20.03, at  $p < 0.001$  which was  
19  
20 354 detected as the most likely cluster with Maximum Likelihood. It showed that children within the  
21  
22 355 spatial window had 1.54 times more likely a higher risk of anemia than the children outside  
23  
24 356 areas of the spatial window. The secondary clusters scanning window was located in the  
25  
26  
27 357 southern part of Somali region. Which was centered at (3.998656 N, 41.240691 E) with a 92.08  
28  
29 358 km radius and LLR of 1.73 at p-value 0.0010. It showed that children within the spatial window  
30  
31 359 had a 1.73 times higher risk of anemia than children outside the window.  
32  
33

34 360 In 2011 EDHS, a total of 10 clusters were identified and five of them were significant clusters  
35  
36  
37 361 with p-value  $< 0.05$ . A total of 180 locations/spots with a total sampled population of 2478 were  
38  
39 362 found as primary cluster areas were identified using sat scan analysis with a p-value  $< 0.001$ .  
40  
41 363 The primary cluster spatial window was located mainly in Somali, Afar, Eastern Oromia, Dire  
42  
43  
44 364 Dawa, and Harari. The primary cluster spatial window was centered at (8.975207 N, 43.790264  
45  
46 365 E) / 540.29 km, with a relative risk (RR) of 1.43 and a log-likelihood ratio (LLR) of 127.79. It  
47  
48 366 showed that children within the spatial window had 1.4 times more likely a higher risk of anemia  
49  
50 367 than the children outside areas of the spatial window. The secondary cluster spatial window  
51  
52  
53 368 was located mainly in Afar regional state and 72 cases were found among the total population.  
54  
55  
56  
57  
58  
59  
60

1 369 The secondary cluster spatial window was centered at (12.758587 N, 40.175990 E) / 39.58  
2  
3 370 km, with a relative risk (RR) of 1.68 and a log-likelihood ratio (LLR) of 21.5 P-value=0.001.  
4  
5

6 371 In 2016 EDHS, a total of 7 clusters (1 most likely cluster) which were located in Somalia, Afar,  
7  
8 372 Eastern Oromia, Dire Dawa, and Harari. The cluster window was centered with a radius at  
9  
10  
11 373 (7.650693 N, 47.007920 E) / 912.19 km with a Relative Risk (RR) of 1.44. The Log-Likelihood  
12  
13 374 Ratio (LLR) for the most likely cluster was 182.86,  $p < 0.001$ . Secondary clusters were located  
14  
15 375 in Gambela which was centered at (8.195862 N, 34.289837 E) with a radius of 29.01 km, and  
16  
17  
18 376 LLR of 18.8 at  $p$ -value 0.001. It showed that children within the spatial window had a 1.5 times  
19  
20 377 higher risk of anemia than outside the window (**Fig.4**).  
21  
22

### 23 378 **Multilevel Analysis**

24  
25  
26 379 The intra-cluster correlation coefficient (ICC) in the empty model indicated that 18.8% of the  
27  
28 380 total variability for children anemia was due to differences between clusters and the remaining  
29  
30 381 unexplained 81.2% attributable to individual differences. The median odds ratio for anemia  
31  
32 382 was 2.3 in the null model which indicates that there was variation between clusters. If we  
33  
34 383 randomly select children from two different clusters children at the cluster with a higher risk of  
35  
36 384 anemia had 2.3 times higher odds of experiencing anemia as compared with children at cluster  
37  
38  
39  
40 385 with a lower risk of anemia.  
41

42  
43 386 Bi-variable multilevel logistic regression analysis was done to identify variables for  
44  
45 387 multivariable multilevel logistic analysis and Variable with a  $p$ -value less than 0.2 were  
46  
47 388 considered for multivariable analysis.  
48  
49

### 50 389 **Individual-level predictors for anemia**

51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 390 In multivariable multilevel mixed-effect logistic regression analysis individual-level factors such  
2  
3 391 as the age of the child, wealth index, mother age, maternal anemic status, birth order, fever,  
4  
5 392 stunting, and wasting status were a significant predictor of childhood anemia.  
6  
7

8 393 Children age between 12–23 months (AOR = 0.66, 95%CI = 0.53-0.81), between 24–35  
9 394 months (AOR= 0.35, 95% CI = 0.28-0.43), between 36–47 months (AOR = 0.23-95%CI =  
10  
11 395 0.19-0.29), and between 48–59 months (AOR = 0.15, 95%CI = 0.12-0.19) were less likely to  
12  
13 396 develop anemia when compared with children age between 6–11 months.  
14  
15  
16  
17

18 397 The likelihood of developing anemia for those children residing with the family wealth index of  
19 398 middle and rich was lower by 21% (AOR=0.79, 95%CI = 0.67-0.94), and 23% (AOR=0.77,  
20 399 95%CI = 0.65-0.91), respectively as compared with children with poor wealth index. Children  
21 400 whose mother's age were between 40-49 had 25% decreased odds of developing childhood  
22 401 anemia as compared to age 15-29, (AOR=0.75, 95%CI = 0.59-0.95).  
23  
24  
25  
26  
27  
28  
29

30 402 The odds of experiencing anemia for those birth orders 4-5, 6, and above six were 1.22 times  
31 403 (AOR=1.22, 95%CI = 1.01-1.47) and, 1.35 times (AOR=1.35, 95%CI = 1.08-1.67) higher as  
32 404 compared with first-order respectively. The odds of developing anemia of children born from  
33 405 who had anemia history mother was 1.39 higher than that of children born from not anemic  
34 406 history before. Children who had fever were 39% (AOR =1.39, 95% CI: 1.24-1.58) more likely  
35 407 to develop anemia as compared with their counterparts. Children with moderate and severe  
36 408 stunting status were 35% (AOR=1.35, 95% CI: 1.17-1.54) and, 96% (AOR=1.95, 95% CI: 1.68-  
37 409 2.28), more likely to develop anemia respectively as compared to no stunting status. Similarly,  
38 410 children who had to severe wasting status were 51% more (AOR =1.51, 95% CI: 1.07-2.12)  
39 411 likely to develop anemia as compared with those children who had no wasting.  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53

#### 54 412 **Community-level predictors for anemia**

55  
56  
57  
58  
59  
60

1 413 In the multivariable multilevel logistic regression model region of residence was significantly  
 2  
 3 414 associated with community-level factors for childhood anemia.  
 4  
 5 415 Odds of children live in Somalia were 5.65 times (AOR=5.65, 95% CI: 3.92-8.16), Dire Dawa  
 6  
 7 3.45 times (AOR=3.45, 95% CI: 2.27-5.26), Afar 3.01 times (AOR=3.01, 95% CI: 2.09-4.34),  
 8 416 and Oromia 2.34 times (AOR=2.34, 95% CI: 1.73-3.18) had more likely to develop childhood  
 9  
 10 417 anemia as compared to Amhara regional state. Similarly, the odds of developing anemia in  
 11  
 12 418 Addis Ababa was 2.10 times (AOR=2.10, 95% CI: 1.40-3.16), Gambella 1.94 times  
 13  
 14 (AOR=1.94, 95% CI: 1.32-2.84), and Tigray 1.46 times (AOR=1.46, 95% CI: 1.08-1.98), more  
 15 419 likely as compared to Amhara region. Benishangul and SNNPR had not significantly different  
 16  
 17 420 in the prevalence of anemia as compared to the reference region Amhara (Table 3).  
 18  
 19 421  
 20 422  
 21  
 22 423  
 23

24 423 Table 3: Multilevel logistic regression analysis result of both individual and community level  
 25 424 factors associated with anemia in Ethiopia, EDHS 2016

Individual Level	Null Model	Model II AOR (95% CI)	Model III AOR (95% CI)	Model IV AOR (95% CI)
<b>Age in month</b>				
6 – 11	--	1		1
12 – 23		0.66[0.54-0.82] **		0.66 [0.53-0.81] **
24 – 35		0.35[0.28-0.44] **		0.35 [0.28-0.43] **
36 – 47		0.23[0.18-0.28] **		0.23 [0.19-0.29] **
48 – 59	--	0.15[0.12-0.19] **	---	0.15 [0.12-0.19] **
<b>Religion</b>				
Orthodox		1		1
Muslim		2.07[1.77-2.47] **		1.21 [0.97-1.46]
Protestant		1.20 [1.002-1.48] *		1.09[0.86-1.37]
Others	--	1.55[1.07-2.32] *	---	1.44[0.96-2.13]
<b>Wealth index</b>				
Poor		1		1
Middle		0.71[0.61-0.84] **		0.79 [0.67-0.94] *
Rich	--	0.72[0.63-0.85] **	---	0.77 [0.65-0.91] *
<b>Child size at birth</b>				
Small		1		1
Average		0.96[0.84-1.09]		0.93 [0.80-1.07]
Large	--	0.94[0.81-1.08]	---	0.96 [0.84-1.10]
<b>Birth order</b>				
1st		1		1
2-3		1.09[0.94-1.28]		1.13[0.97-1.32]
4-5		1.17[0.97-1.40]		1.22 [1.01-1.47] *

1	450	6 and above	--	1.30[1.05-1.62]	---	1.35 [1.08-1.67] **
2	451	<b>No of children under 5</b>				
3	452	1-2 children		1		1
4	453	≥ 3 children	--	1.22[1.1-1.4] *	---	1.09 [0.94-1.27]
5	454	<b>Maternal anemia</b>				
6	455	Not-anemic		1		1
7	456	Anemic	--	1.51[1.34, 1.72] **	---	1.39 [1.24-1.58] **
8	457	<b>Maternal BMI</b>				
9	458	≥18.5 kg/m <sup>2</sup>		1		1
10	459	<18.5 kg/m <sup>2</sup>	--	1.12[0.97-1.26]	---	1.05 [0.92-1.19]
11	460	<b>Mather's working status</b>				
12	461	Not-working		1		1
13	462	Working	--	0.88[0.77-0.99] *	---	0.92 [0.81-1.04]
14	463	<b>Women age</b>				
15	464	15-29		1		1
16	465	30-39		0.91[0.71-1.06]		0.90 [0.78-1.04]
17	466	40-49	--	0.75[0.59-1.12] *	---	0.75 [0.59-0.95] *
18	467	<b>Breastfeeding</b>				
19	468	No		1		1
20	469	Yes	--	0.92[0.81-1.04]	---	0.98 [0.87-1.12]
21	470	<b>Vitamins in last 6 month</b>				
22	471	No		1		1
23	472	Yes	---	0.90[0.81-1.09]	---	0.93 [0.84-1.05]
24	473	<b>Diarrhea last 2 week</b>				
25	474	No		1		1
26	475	Yes	---	0.88[0.73, 1.04]	---	0.90 [0.76-1.07]
27	476	<b>Fever in last 2 weeks</b>				
28	477	No		1		1
29	478	Yes	---	1.35[1.15-1.59] **	---	1.32 [1.13-1.56] *
30	479	<b>Stunting status</b>				
31	480	No-stunting		1		1
32	481	Moderate stunting		1.27[1.10-1.46] **		1.35 [1.17-1.54] **
33	482	Severely stunting	---	1.81[1.55-2.11] **	---	1.96 [1.68-2.28] **
34	483	<b>Wasting status</b>				
35	484	No-wasting		1		1
36	485	Moderate wasting		1.27[1.11-1.45]		0.98 [0.80-1.19]
37	486	Severe wasting	---	1.68[1.55-2.10] *	---	1.51 [1.07-2.12] *
38	487	<b>Place of residence</b>				
39	488	Urban		1		1
40	489	Rural	--	--	1.40[1.12-1.78]	1.28 [0.99-1.64]
41	490	<b>Region</b>				
42	491	Amhara	--	1		1
43	492	Tigray		1.46 [1.09-1.97] **		1.46 [1.08-1.98] **
44	493	Afar		3.90 [2.84-5.35] **		3.01 [2.09-4.34] **
45	494	Oromia		2.48 [1.89-3.25] **		2.34 [1.73-3.18] **
46	495	Somali		6.34[4.65-8.63]		5.65 [3.92-8.16] **

1	496	Benishangul			0.86 [0.62-1.17]	0.81 [0.58-1.15]
2	497	SNNPR			1.33 [1.00-1.76]	1.30 [0.94-1.80]
3	498	Gambela			1.93 [1.38-2.69] **	1.94 [1.32-2.84] **
4	499	Hareri			3.08 [2.15-4.43] **	2.98 [1.99-4.46] **
5	500	Addis Ababa			1.91[1.29-2.83] **	2.10 [1.40-3.16] **
6	501	Dire Dawa	--	--	3.92 [2.67-5.77] **	3.45 [2.27-5.26] **
9	502	<b>Community education</b>				
10	503	Low education			1	1
11	504	High education	--	--	1.07[0.90-1.26]	1.13[0.94-1.34]
13	505	<b>Community poverty</b>				
14	506	Low poverty			1	1
15	507	High poverty	--	--	1.41[1.17-1.68] *	1.15[0.94-1.40]
16	508	<b>Model comparison and</b>				
17	509	<b>Random effect</b>				
18	510	<b>ICC</b>	0.187	--	--	--
19	511	<b>Log-likelihood</b>	-4981.63	-4513.17	-4836.83	-4436.60
20	512	<b>Deviance</b>	9963.26	9026.34	9673.66	8873.2
21	513	<b>PVC (%)</b>	Ref	41.22	60.11	62.59
22	514	<b>MOR</b>	2.30	1.72	1.42	1.38

\*Key: 1: reference group; p-value 0.05-0.01 \*: p-value < 0.01 \*\*

### Multicollinearity

Multicollinearity was checked for those variables included in the final model using VIF. Accordingly, the VIF for all predictor variables included in the final model was below 10 indicating the absence of multicollinearity among the predictor variables.

### Comparison of models

Deviance was used to compare the models. The model with the lowest value of deviance was considered to be the better mode.

### Discussion

This study tried to identify spatio-temporal distribution and predictors of childhood anemia across the regions in Ethiopia. 2005, 2011, and, 2016 Ethiopian Demographic and Health Survey data were used. In this study, the trend of anemia was decreased from 2005 to 2011, while the rate significantly increased from 2011 to 2016. The study revealed that 57.56% [CL:

0.56-0.59] of children were anemic in 2016 preceding the survey. This finding was in line with a study done in Gondar, Northwest Ethiopia 58.6%(20), whereas higher than the study done in cape Verde, west Africa 51.8%(21), and southern Ethiopia(22). Among children of 6–59 months, anemia is still considered to be a major public health problem in Ethiopia. Though the levels of anemia among children vary by background factors like region and lowest household wealth index and maternal related factors, more of the children in Ethiopia were suffering anemia.

The spatial pattern figures out that the geographical inequality of anemia by using sat scan and GIS spatial techniques like cluster mapping tools and interpolation techniques. The spatial analysis indicates that the distribution of childhood anemia was non- random across the country with global Moran's I index of 0.176 in 2005, 0.18 in 2011, and 0.09 in 2016 with significant p-value which indicates significant clustering areas. Findings from this study were in line with a study done in Nigeria, Malawi, Tanzania, and Uganda (23,24).

The spatial pattern of sat scan analysis showed that Eastern Somalia regions were primary (most likely) cluster and secondary cluster also located in the southern part of Somalia in 2005 sat scan analysis. In 2011 Somali, Afar, Eastern Oromia, Dire Dawa, and Harari were located in the primary window and centered at (8.975207 N, 43.790264 E/ 540.29 km with a significant p-value. Similarly, spatial sat scan analysis showed that Somalia, Afar, Eastern Oromia, Dire Dawa, Harari were hotspot areas in the 2016 EDHS spatial analysis.

This study indicated that children age 12-59 months were less affected by childhood anemia. This finding was consistent with studies conducted in Ethiopia and Togo (25–27). This could be explained by the fact that children who are getting older receive a diet that is richer and complete, with a sufficient intake of iron which could prevent the occurrence of iron deficiency



1 554 anemia. The deficiency may result from inadequate dietary intake of iron, malabsorption of iron  
2  
3 555 an increased iron demand during rapid growth might it be the possible reason (28).  
4  
5

6 556 The finding of this study indicated that children whose mother's age was between 40-49 were  
7  
8 557 less anemic as compared to age 15-29. This finding is a study done in line with other studies  
9  
10 558 conducted in sub-Saharan Africa and Ghana (15,29). This group consists of more at-risk  
11  
12 559 population segments (Adolescent) for anemia. They are vulnerable to malnutrition because  
13  
14 560 they are growing faster than at any time after their first year of life which contributes to the  
15  
16 561 intergenerational cycle of malnutrition and he most common forms of malnutrition among  
17  
18 562 Ethiopian adolescent girls is iron deficiency anaemia. Aside from, the bodies of the growing  
19  
20 563 adolescent mother and her baby may compete for nutrients, raising the infant's risk of low birth  
21  
22 564 weight, however, the lack of such nutrients might lead to anemia.  
23  
24  
25  
26

27 565 Children from households of middle and rich wealth indexes were less affected by childhood  
28  
29 566 anemia as compared to children from a poor household. This finding has also been  
30  
31 567 demonstrated in similar studies in Nigeria and northern Ethiopia (23,30). This is due to the  
32  
33 568 reason that children from poor households are less likely to get iron-rich foods like animal foods  
34  
35 569 and vitamin-rich foods especially vitamins A and C which are very important for iron absorption.  
36  
37  
38  
39

40 570 Maternal anemia was highly associated with the occurrence of childhood anemia. This finding  
41  
42 571 was in line with a study done in South Africa, Haiti, and India(31–33). Reasons may be mothers  
43  
44 572 and children share a common home environment, socioeconomic, and dietary conditions, and  
45  
46 573 maternal and child anemia may reflect the common nutritional status of the household and  
47  
48 574 poor maternal iron intake during pregnancy, reduce breast milk might be the possible reason.  
49  
50  
51

52 575 EDHS data set indicated that the incidence of fever had an impact on childhood anemia. This  
53  
54 576 is in line with studies done in Ghana and South Ethiopia Wolaita (22,34) Results showed that  
55  
56 577 children who had a fever in the last two weeks before the survey had had a higher likelihood  
57  
58  
59

1 578 of anemia than children who had not to fever. This could be attributed to the infectious cause  
2  
3 579 of childhood fever mainly malaria, tuberculosis, and Leishmaniasis which cause anemia by  
4  
5 580 destructing red blood cells or other related mechanisms.  
6  
7

8 581 The nutritional status of children had a significant association with childhood anemia. The  
9  
10 582 stunting status of children was an independent predictor in the multilevel mixed effect model  
11  
12 583 of this study. The result of this study indicated that it was in line with previous studies conducted  
13  
14 584 in South Africa(33), Bangladesh(35,36), and Ethiopia(37,38). This study revealed that there  
15  
16 585 was a greater prevalence of anemia among stunted children compared to non-stunted children.  
17  
18 586 Children suffering from nutritional deficiency were more likely to have weak immune systems  
19  
20 587 which makes them vulnerable to various illnesses and healthiness such as parasitic infections  
21  
22 588 or chronic inflammation. Many of these conditions reduce the hemoglobin level in the blood  
23  
24 589 leading to increased anemia prevalence. The statement is supported by the evidence given in  
25  
26 590 other studies(39)that nutritional deficiency causes several health hazards.  
27  
28  
29  
30  
31

32 591 Besides, severely wasting children were 1.51 times more likely to be anemic than their  
33  
34 592 counterpart. Since stunting and wasting are long-term and short-term indicators of malnutrition,  
35  
36 593 the results implied that under-nourished children experience a higher risk of developing anemia  
37  
38 594 as compared to nourished children. Odds of experiencing anemia for those birth order four up  
39  
40 595 to five and six and greater than six were higher than that of with first order. This finding was  
41  
42 596 similar to a study done in Indian(15,40). This could be due to the distribution of scarce  
43  
44 597 resources within the family and interrelated to maternal exhaustion of micronutrients feeding  
45  
46 598 practice.  
47  
48  
49  
50

51 599 In a multivariable multilevel analysis, the odds of developing childhood anemia were higher  
52  
53 600 among children who lived in Somalia, Dire Dawa, Afar, and Gambela as compared to the  
54  
55 601 Amhara region. This might be due to the unavailability and inaccessibility of health facilities as  
56  
57  
58  
59  
60

1 602 compared to the regions. Regional variation in the nutrient intake can cause significant health  
2  
3 603 disparity, and this variability may be mediated by factors such as food availability, food  
4  
5 604 customs, and culture.  
6  
7

8 605 This study was used different methods of spatial pattern, trend and a multilevel regression  
9  
10 606 model used because of nested or cluster samples to show the effect of individual predictors  
11  
12 607 and community-level variables on the dependent variable. The study was based on a large  
13  
14 608 dataset representing the whole country of Ethiopia and which was weighted to make it  
15  
16 609 nationally representative and adjusted for the design to get a reliable estimate. However, there  
17  
18 610 were some limitations to this study. The cross-sectional nature of the data prevents causality  
19  
20 611 from being inferred between the independent and dependent variables. Also, respondents'  
21  
22 612 data that didn't have files (longitude and latitude) were excluded from the spatial analysis which  
23  
24 613 could affect the overall result and the generalizability of the findings.  
25  
26  
27  
28  
29

## 30 614 **Conclusion**

31  
32 615 Findings from this study indicated that the prevalence of childhood anemia decreased between  
33  
34 616 the 2005-2011 survey while the prevalence increased from 2011-2016 EDHS. The spatial  
35  
36 617 pattern of child anemia in Ethiopia was non-random among the three consecutive surveys with  
37  
38 618 the global Moran's I value of 0.176, 0.18, and 0.09 in EDHS 2005, 2011, and 2016 respectively.  
39  
40 619 In this study, Sat Scan analysis identified the primary and secondary clusters for the three  
41  
42 620 survey periods. In 2005 EDHS the hotspot area was identified in eastern and southern parts  
43  
44 621 of Somalia, in 2011 Somali, Afar, Eastern Oromia, Dire Dawa, and Harari were among the  
45  
46 622 hotspot regions. Spatial sat scan analysis revealed that spatial clustering of childhood anemia  
47  
48 623 was identified in Somalia, Afar, Eastern Oromia, Dire Dawa, Harari hotspot area in the 2016  
49  
50 624 EDHS period.  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 625 Child age, women age, wealth index, maternal anemia, had a fever, birth order, stunting,  
2  
3 626 wasting and region were significant predictors among 6-59 months. Therefore, these results  
4  
5 627 provide further insight into identifying the true picture of childhood anemia spatio-temporal  
6  
7 628 clusters in the country and enable timely spatial targeting factors to alleviate home delivery.  
8  
9  
10 629 Therefore, policymakers and health planners should design effective intervention strategies for  
11  
12 630 the identified hot spot areas and individual and community-level factors.

### 15 631 **Abbreviations**

16  
17  
18 632 AOR-Adjusted Odds Ratio, CSA-Central Statics Agency, CI-Confidence Interval, COR-Crude  
19  
20 633 Odds Ratio, EDHS-Ethiopia Demographic and Health Survey, GPS-Global Positioning  
21  
22 634 System, ICC-Intra Class Correlation Coefficient, LLR-Log-Likelihood Ratio, MOR-Median odds  
23  
24 635 ratio, OR-Odds Ratio, RR-Relative Risk, PVC-Proportional Change in Variance, SNNPR-  
25  
26  
27 636 Southern Nations, Nationalities, and Peoples' Region.

### 33 638 **Declarations**

#### 37 639 **onsent to participate**

38  
39  
40 640 The study was approved by the institutional ethical review committee board of the University  
41  
42 641 of Gondar and ethical clearance was obtained from the board. Upon this clearance, the study  
43  
44 642 was conducted. The congeniality of the data was maintained by using the extracted data only  
45  
46 643 for the study purpose and keeping the data from a third party.

#### 49 644 **Consent for publication**

52 645 Not-applicable

#### 55 646 **Data sharing statement**

1 647 The data in which the authors used to produce this manuscript are available upon reasonable  
2  
3 648 request

#### 4 649 **Competing interests**

6 650 The authors declare that they have no competing interests.

#### 8 651 **Funding**

10 652 No funding

#### 12 653 **Contributors**

14 654 Proposal preparation, acquisition of data, analysis, and interpretation of data was done by SA.

16  
17 655 AM, ZM and BF guided the study design data collection and analysis. SA drafted the

18  
19 656 manuscript and all authors have a substantial contribution in revising and finalizing the

20  
21 657 manuscript. All authors read and approved the final manuscript.

#### 23 658 **Acknowledgments**

25  
26 659 The authors gratefully acknowledge the support received from the University of Gondar. We

27  
28  
29 660 also thank the Ethiopian Central Statistics Agency for providing us with the data and shape

30  
31 661 files for this study.

32  
33 662

#### 35 663 **References**

36 664 1. WHO. Nutritional Anaemias : Tools for Effective Prevention. World Health Organization.  
37 665 2017. 1–83 p.

38 666 2. WHO. Global estimates of the prevalence of anaemia in infants and children aged 6 –  
39 667 59 months , 2011 Global estimates of the prevalence of anaemia , all women of  
40 668 reproductive age , 15 – 49 years , 2011. Scaling Up Nutr [Internet]. 2015; Available from:  
41 669 [http://www.who.int/nutrition/publications/micronutrients/global\\_prevalence\\_anaemia\\_20](http://www.who.int/nutrition/publications/micronutrients/global_prevalence_anaemia_2011_maps.pdf?ua)  
42 670 [11\\_maps.pdf?ua](http://www.who.int/nutrition/publications/micronutrients/global_prevalence_anaemia_2011_maps.pdf?ua)

43 671 3. WHO. The global prevalence of anaemia in 2011. Who [Internet]. 2011;1–48. Available  
44 672 from: <https://apps.who.int/iris/handle/10665/177094>

45 673 4. Pollitt E. Early iron deficiency anemia and later mental retardation. Oxford University  
46 674 Press; 1999.

47 675 5. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of  
48 676 anaemia, WHO vitamin and mineral nutrition information system, 1993–2005. Public  
49 677 Health Nutr. 2009;12(4):444–54.

50 678 6. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of  
51 679 anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. Public  
52 680 Health Nutr. 2009;12(4):444–54.

53 681 7. Leal LP, Batista Filho M, de Lira PIC, Figueiroa JN, Osório MM. Temporal trends and

54  
55  
56  
57  
58 26

- 1 682 anaemia-associated factors in 6- to 59-month-old children in Northeast Brazil. *Public*  
2 683 *Health Nutr.* 2012;15(9):1645–52.
- 3 684 8. Olivares M, Walter T, Hertrampf E, Pizarro F. Anaemia and iron deficiency disease in  
4 685 children. *Br Med Bull [Internet].* 1999 Sep 1;55(3):534–43. Available from:  
5 686 <https://doi.org/10.1258/0007142991902600>
- 6 687 9. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual,  
7 688 maternal and household risk factors for anaemia among young children in sub-Saharan  
8 689 Africa: a cross-sectional study. *BMJ Open [Internet].* 2018 May 1;8(5):e019654.  
9 690 Available from: <http://bmjopen.bmj.com/content/8/5/e019654.abstract>
- 10 691 10. Central Statistical Agency, ORC Macro. Ethiopia Demographic and Health Survey 2005.  
11 692 Heal San Fr [Internet]. 2006;(September):[446]. Available from:  
12 693 [http://www.measuredhs.com/pubs/pdf/FR179/FR179\[23June2011\].pdf](http://www.measuredhs.com/pubs/pdf/FR179/FR179[23June2011].pdf)
- 13 694 11. Central Statistical Agency [Ethiopia], ICF International. Ethiopia Demographic and  
14 695 Health Survey 2011. 2012;1–452.
- 15 696 12. ECSA. Ethiopian Demographic Health Survey 2016. 2016. 161 p.
- 16 697 13. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged  
17 698 from 6 to 59 months in Togo: analysis from Togo demographic and health survey data,  
18 699 2013–2014. *BMC Public Health.* 2019;19(1):1–9.
- 19 700 14. Malako BG, Teshome MS, Belachew T. Anemia and associated factors among children  
20 701 aged 6-23 months in Damot Sore District, Wolaita Zone, South Ethiopia. *BMC Hematol.*  
21 702 2018;18(1):1–9.
- 22 703 15. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual,  
23 704 maternal and household risk factors for anaemia among young children in sub-Saharan  
24 705 Africa: A cross-sectional study. *BMJ Open.* 2018;8(5):1–14.
- 25 706 16. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns  
26 707 of anaemia among young children in nigeria: A bayesian semi-parametric modelling. *Int*  
27 708 *Health.* 2014;6(1):35–45.
- 28 709 17. Kulldorff M. *SatScan user guide 2006.* 2018;
- 29 710 18. Bartko JJ. The Intraclass Correlation Coefficient as a Measure of Reliability. *Psychol*  
30 711 *Rep.* 1966 Aug;19(1):3–11.
- 31 712 19. Assessment IS. Understanding Variability in Multilevel Models Sophia Rabe-Hesketh  
32 713 Example : PISA ( Programme for International Student Assessment ) PISA : Distribution  
33 714 of SES.
- 34 715 20. Enawgaw B, Workineh Y, Tadesse S, Mekuria E, Addisu A, Genetu M. Prevalence of  
35 716 anemia and associated factors among hospitalized children attending the University of  
36 717 Gondar Hospital, Northwest Ethiopia. *Electron J Int Fed Clin Chem Lab Med.*  
37 718 2019;30(1):35–47.
- 38 719 21. Semedo RML, Santos MMAS, Baião MR, Luiz RR, Da Veiga G V. Prevalence of  
39 720 Anaemia and Associated Factors among Children below Five Years of Age in Cape  
40 721 Verde, West Africa. *J Heal Popul Nutr.* 2014;32(4):646–57.
- 41 722 22. Tiku YS, Mekonnen TC, Workie SB, Amare E. Does Anaemia Have Major Public Health  
42 723 Importance in Children Aged 6–59 Months in the Duggina Fanigo District of Wolaita  
43 724 Zone, Southern Ethiopia? *Ann Nutr Metab [Internet].* 2018;72(1):3–11. Available from:  
44 725 <https://www.karger.com/DOI/10.1159/000484324>
- 45 726 23. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns  
46 727 of anaemia among young children in Nigeria: a Bayesian semi-parametric modelling. *Int*  
47 728 *Health [Internet].* 2014 Jan 31;6(1):35–45. Available from:  
48 729 <https://doi.org/10.1093/inthealth/iht034>
- 49 730 24. Roberts DJ, Matthews G, Snow RW, Zewotir T, Sartorius B. Investigating the spatial  
50 731  
51 732  
52 733  
53 734  
54 735  
55 736  
56 737  
57 738  
58 739  
59 740

- 1 731 variation and risk factors of childhood anaemia in four sub-Saharan African countries.  
2 732 BMC Public Health. 2020;20(1):126.
- 3 733 25. Gebreweld A, Ali N, Ali R, Fisha T. Prevalence of anemia and its associated factors  
4 734 among children under five years of age attending at Gugufu health center, South Wollo,  
5 735 Northeast Ethiopia. PLoS One [Internet]. 2019 Jul 5;14(7):e0218961. Available from:  
6 736 <https://doi.org/10.1371/journal.pone.0218961>
- 7 737 26. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged  
8 738 from 6 to 59 months in Togo: analysis from Togo demographic and health survey data,  
9 739 2013–2014. BMC Public Health [Internet]. 2019;19(1):215. Available from:  
10 740 <https://doi.org/10.1186/s12889-019-6547-1>
- 11 741 27. Mohammed SH, Habtewold TD, Esmailzadeh A. Household, maternal, and child related  
12 742 determinants of hemoglobin levels of Ethiopian children: Hierarchical regression  
13 743 analysis. BMC Pediatr. 2019;19(1):1–10.
- 14 744 28. Keikhaei B, Zandian K, Ghasemi A, Tabibi R. Iron-Deficiency Anemia among Children  
15 745 in Southwest Iran. Food Nutr Bull. 2007 Dec;28(4):406–11.
- 16 746 29. Campbell JR, Holland J. Development research. Focaal. 2007;2005(45):3–17.
- 17 747 30. Gebreegziabiher G, Etana B, Niggusie D. Determinants of Anemia among Children Aged  
18 748 6–59 Months Living in Kilte Awulaelo Woreda, Northern Ethiopia. Benz EJ, editor.  
19 749 Anemia [Internet]. 2014;2014:245870. Available from:  
20 750 <https://doi.org/10.1155/2014/245870>
- 21 751 31. Ayoya MA, Ngnie-Teta I, Séraphin MN, Mamadoultaiou A, Boldon E, Saint-Fleur JE, et  
22 752 al. Prevalence and risk factors of anemia among children 6-59 months old in Haiti.  
23 753 Anemia. 2013;2013:2–5.
- 24 754 32. Pasricha SR, Black J, Muthayya S, Shet A, Bhat V, Nagaraj S, et al. Determinants of  
25 755 anemia among young children in rural India. Pediatrics. 2010;126(1).
- 26 756 33. Ntenda PAM, Nkoka O, Bass P, Senghore T. Maternal anemia is a potential risk factor  
27 757 for anemia in children aged 6–59 months in Southern Africa: a multilevel analysis. BMC  
28 758 Public Health [Internet]. 2018;18(1):650. Available from: <https://doi.org/10.1186/s12889-018-5568-5>
- 29 759 34. Shenton LM, Jones AD, Wilson ML. Factors Associated with Anemia Status Among  
30 760 Children Aged 6–59 months in Ghana, 2003–2014. Matern Child Health J.  
31 761 2020;24(4):483–502.
- 32 762 35. Khan JR, Awan N, Misu F. Determinants of anemia among 6–59 months aged children  
33 763 in Bangladesh: evidence from nationally representative data. BMC Pediatr [Internet].  
34 764 2016;16(1):3. Available from: <https://doi.org/10.1186/s12887-015-0536-z>
- 35 765 36. Rahman MS, Mushfiquee M, Masud MS, Howlader T. Association between malnutrition  
36 766 and anemia in under-five children and women of reproductive age: Evidence from  
37 767 Bangladesh Demographic and Health Survey 2011. PLoS One. 2019  
38 768 Jul;14(7):e0219170–e0219170.
- 39 769 37. Belachew A, Tewabe T. Under-five anemia and its associated factors with dietary  
40 770 diversity, food security, stunted, and deworming in Ethiopia: systematic review and meta-  
41 771 analysis. Syst Rev. 2020 Feb;9(1):31.
- 42 772 38. Malako BG, Asamoah BO, Tadesse M, Hussen R, Gebre MT. Stunting and anemia  
43 773 among children 6–23 months old in Damot Sore district, Southern Ethiopia. BMC Nutr.  
44 774 2019;5(1):1–11.
- 45 775 39. Pelletier DL, Frongillo Jr EA, Schroeder DG, Habicht JP. The effects of malnutrition on  
46 776 child mortality in developing countries. Bull World Health Organ. 1995;73(4):443–8.
- 47 777 40. Goswami S, Das KK. Socio-economic and demographic determinants of childhood  
48 778 anemia. J Pediatr (Rio J). 2015;91(5):471–7.
- 49 779
- 50 780
- 51 781
- 52 782
- 53 783
- 54 784
- 55 785
- 56 786
- 57 787
- 58 788
- 59 789
- 60 790

1 780  
2 781  
3 782 **Figure legend/caption**

5 783 Figure 1: Trends in anemia overtime across the regions in Ethiopia, EDHS 2005 to 2016

7 784 Figure 2: Hot spot and cold spot analysis of anemia in Ethiopian, EDHS 2005 to 20016

9 785 Figure 3: Ordinary Kriging interpolation of anemia in Ethiopia, EDHS 2005 to 2016

11 786 Figure 4: SaTScan scan statistics analysis of anemia in Ethiopia, EDHS, 2005-2016

13 787  
14  
15 788  
16  
17 789  
18  
19 790  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

For peer review only



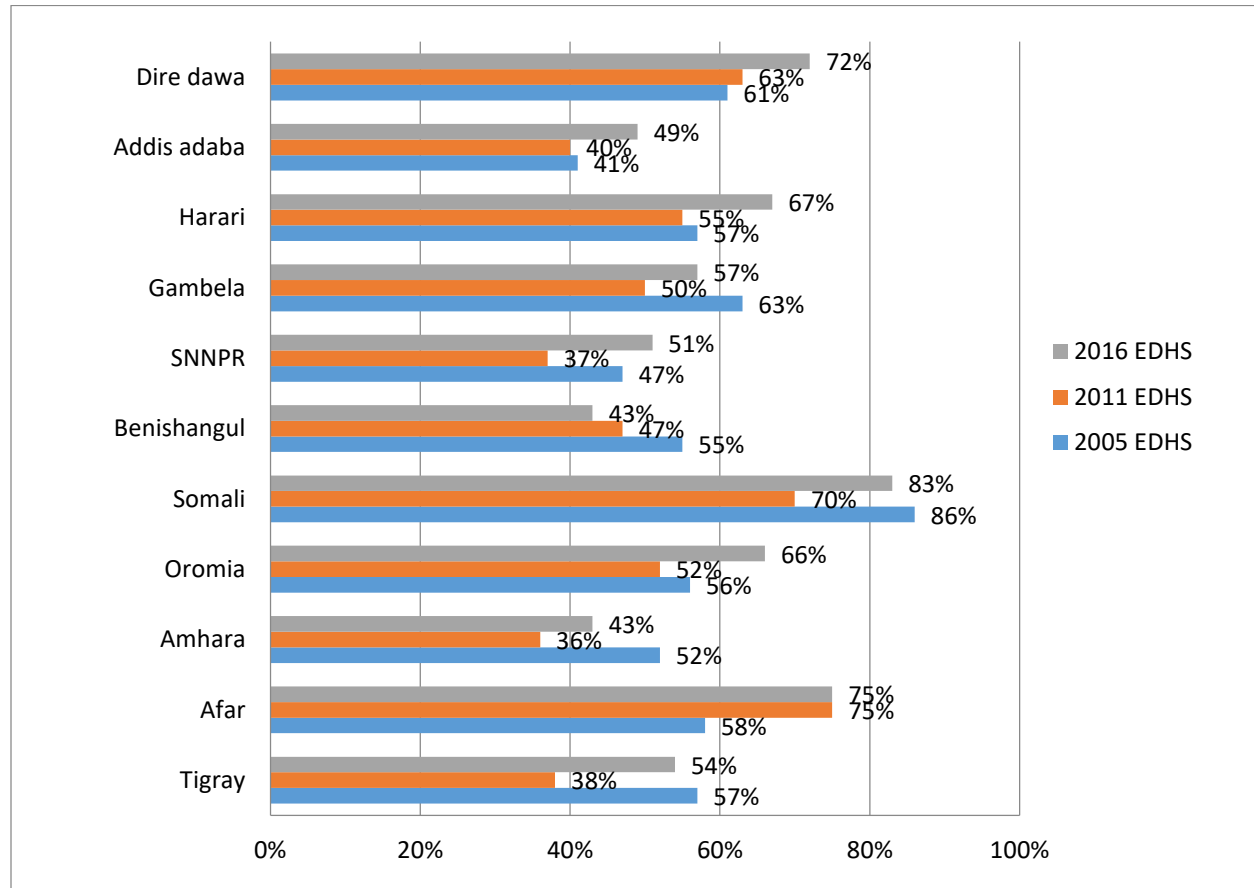


Figure 1: Trends in anemia overtime across the regions in Ethiopia, EDHS 2005 to 2016





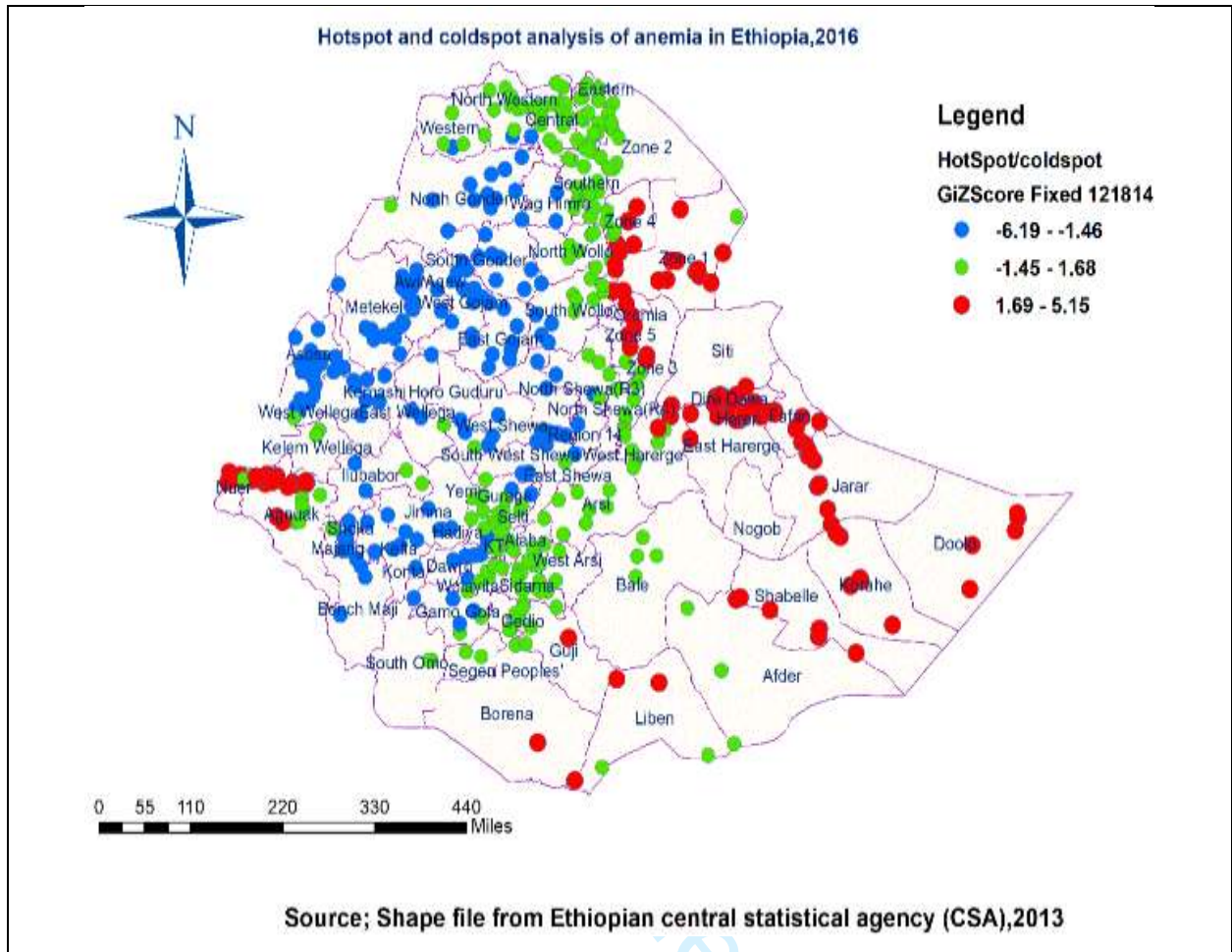
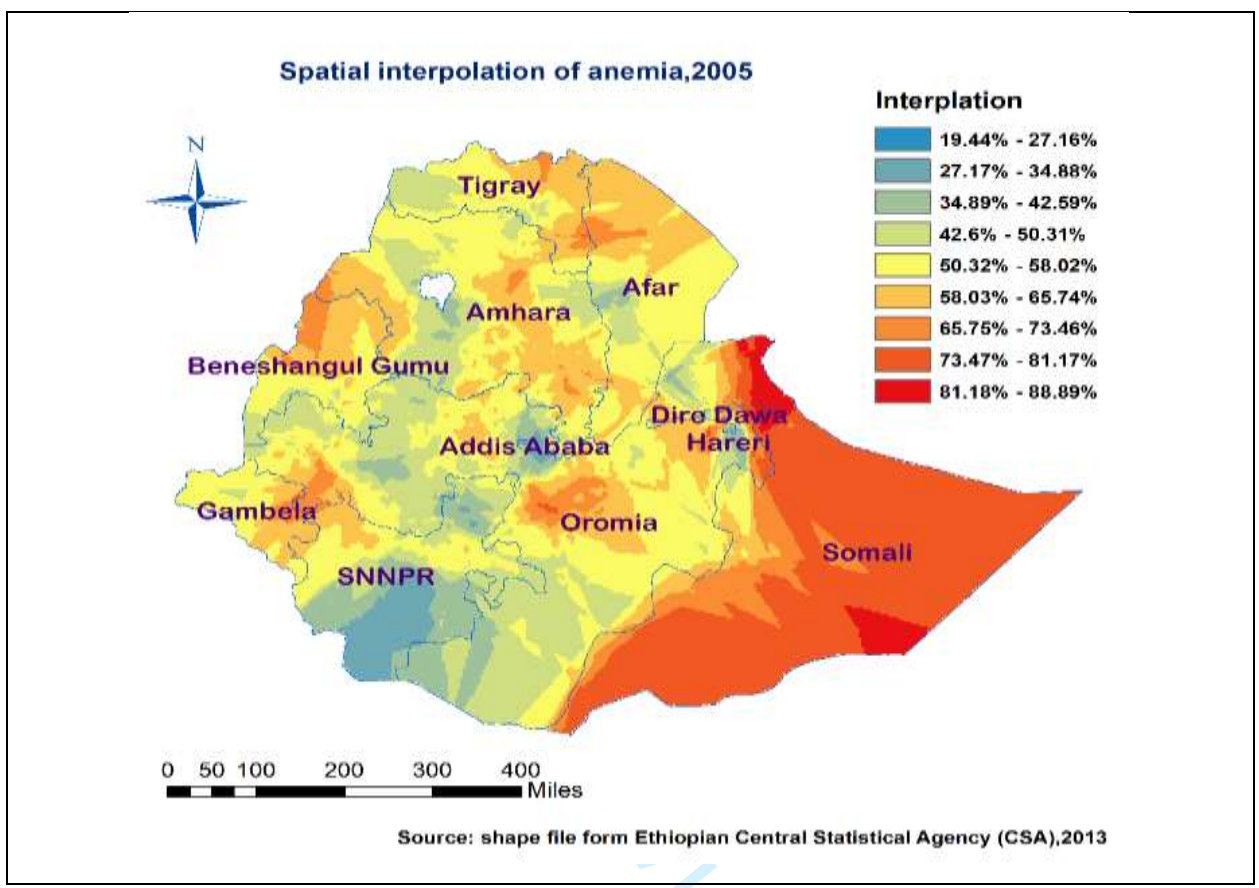
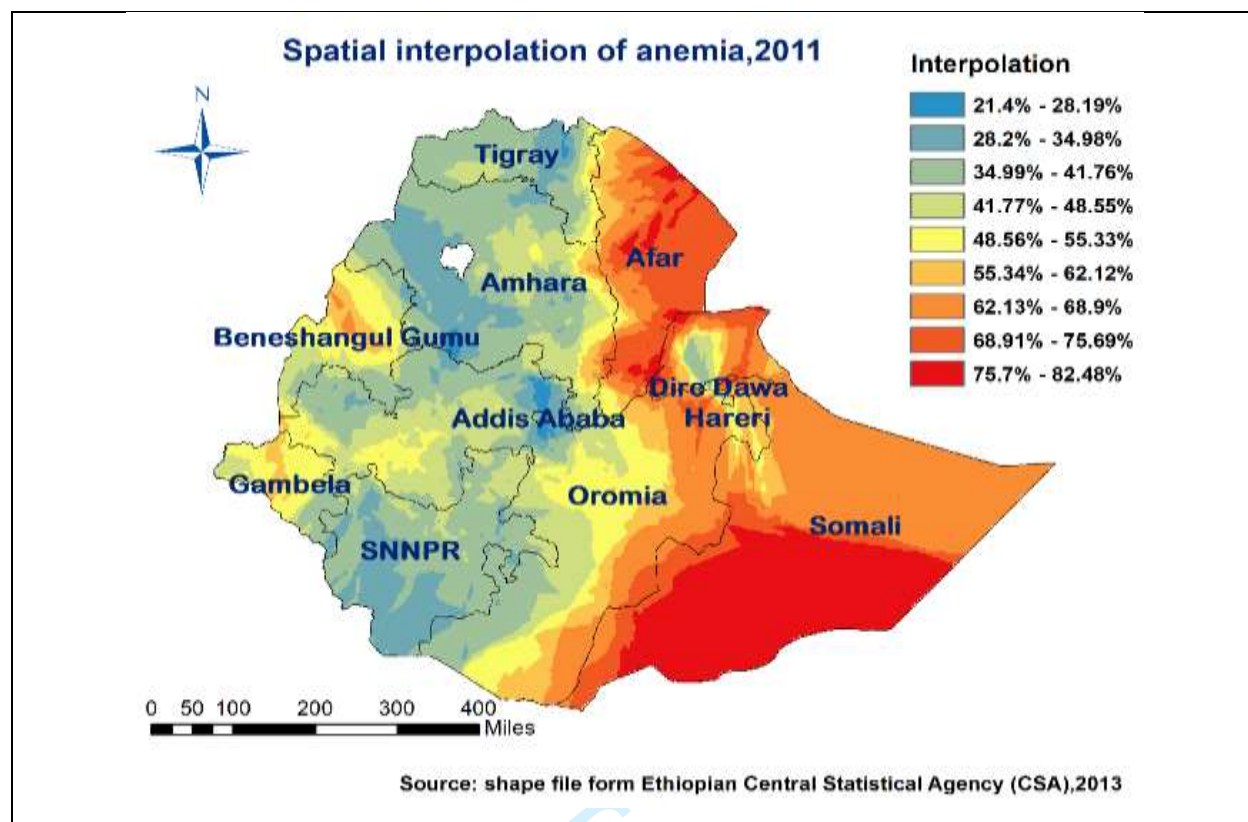


Figure 2: Hot spot and cold spot analysis of anemia in Ethiopian, EDHS 2005 to 20016

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



BMJ Open: first published as 10.1136/bmjopen-2020-045544 on 17 August 2021. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.



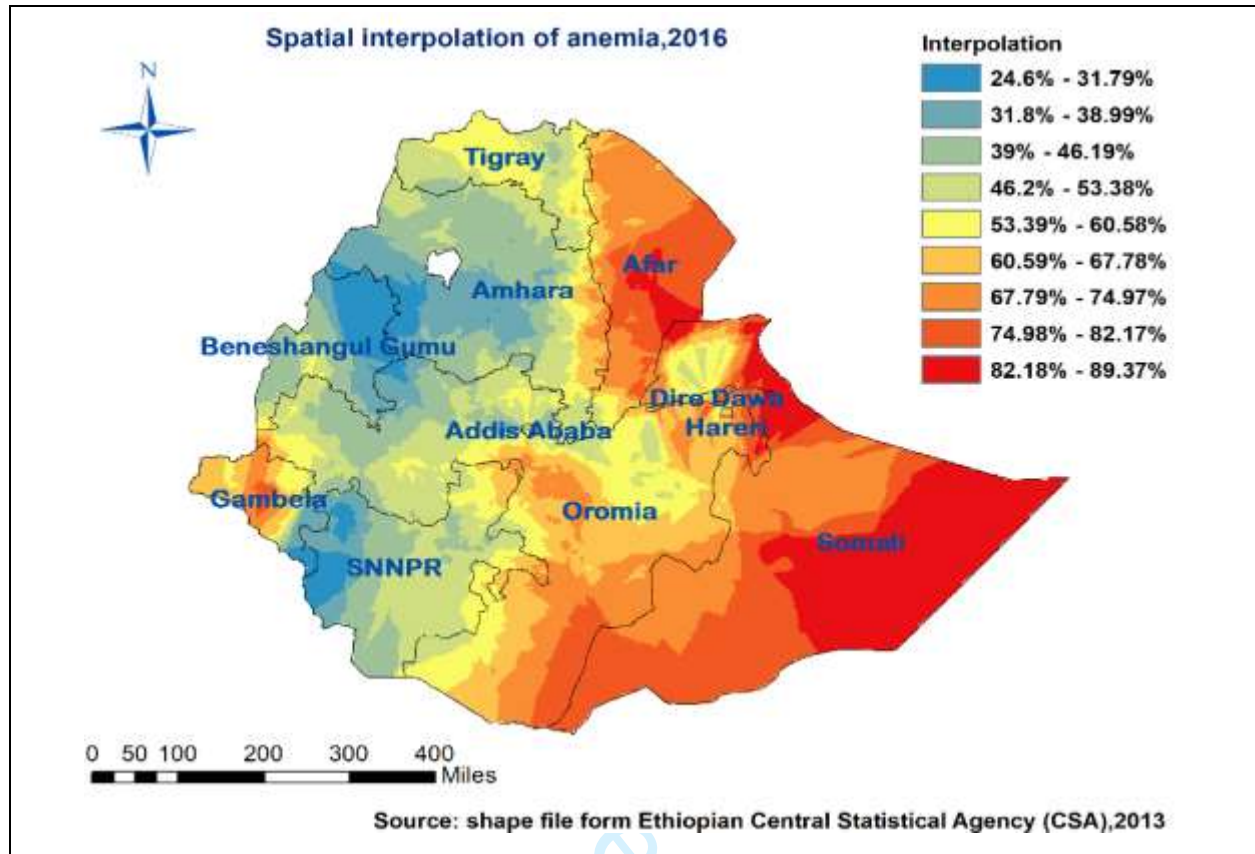
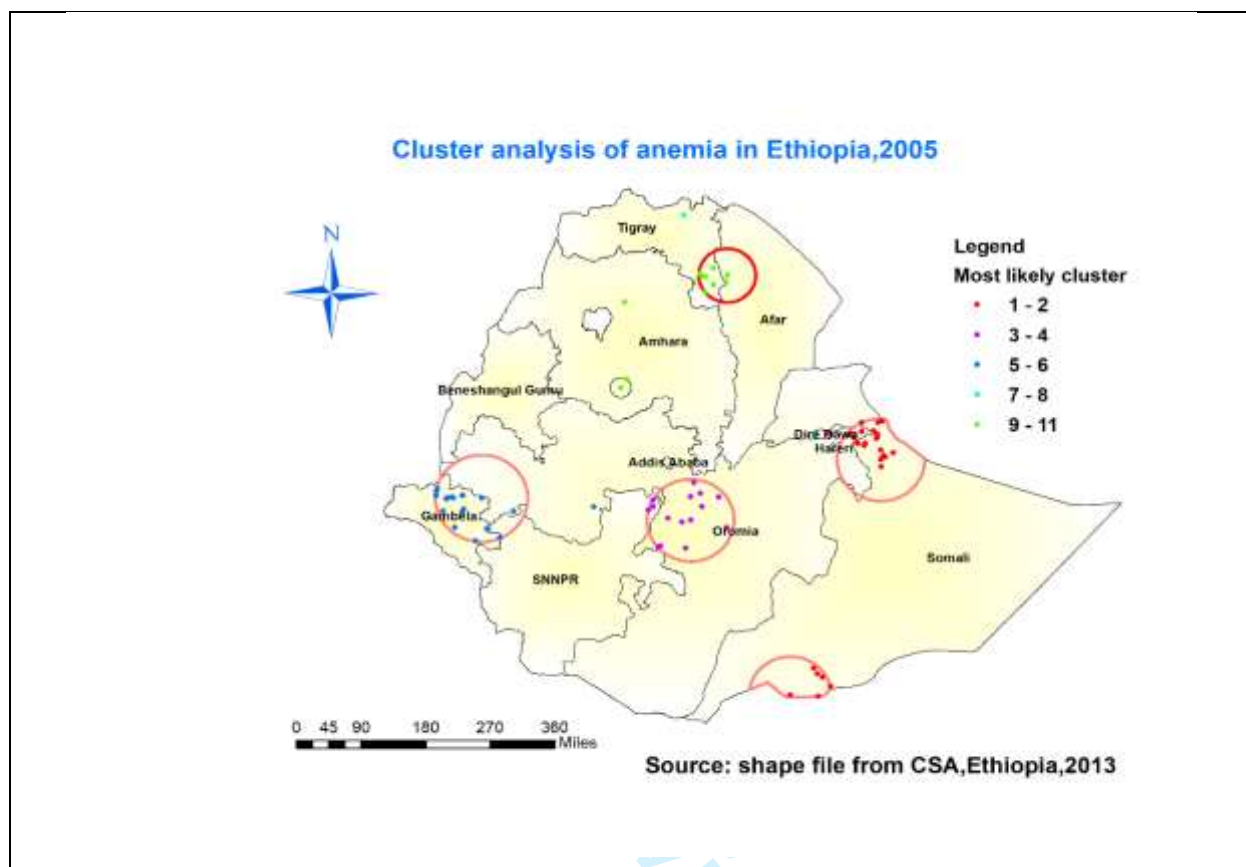
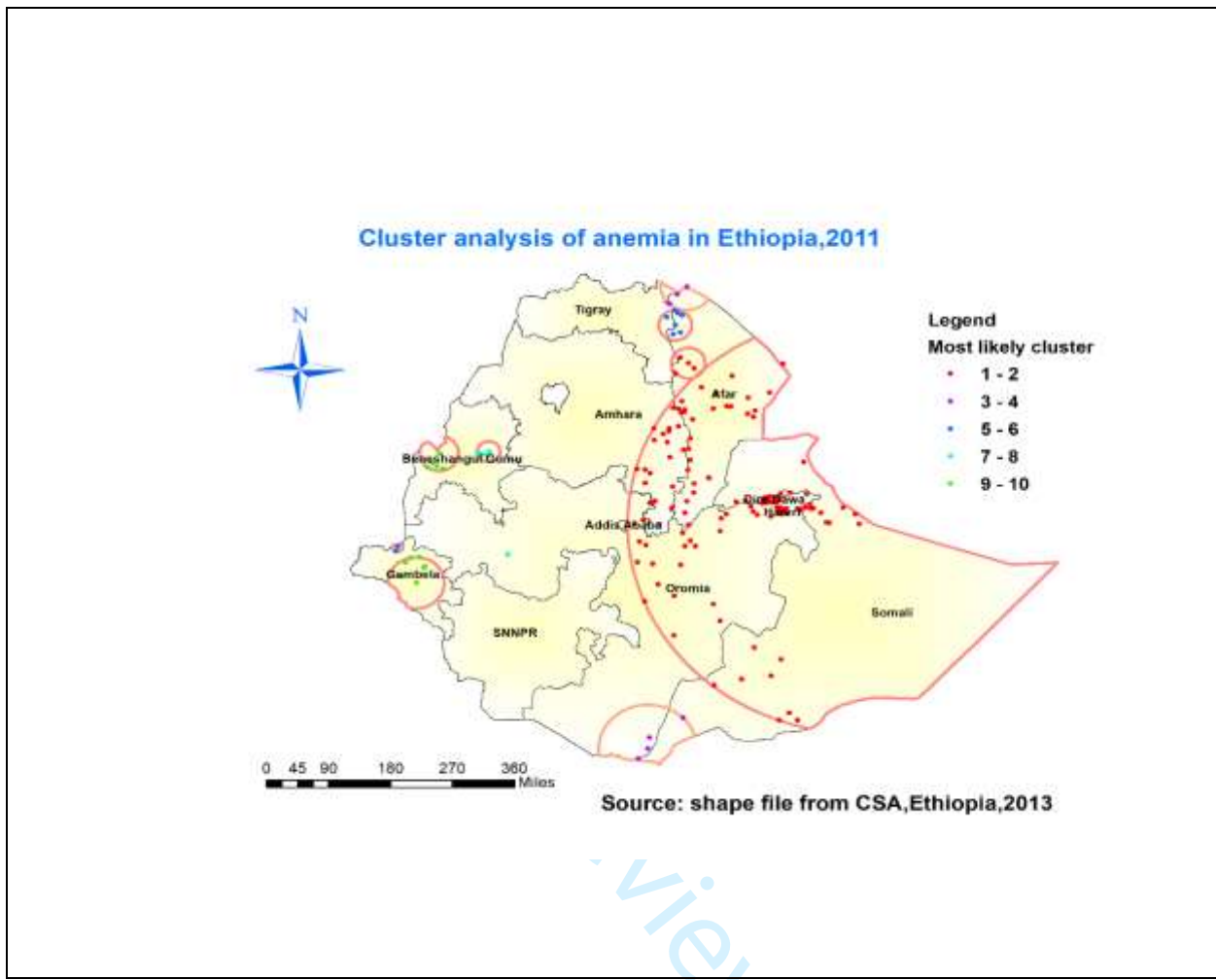


Figure 3: Ordinary Kriging interpolation of anemia in Ethiopia, EDHS 2005 to 2016

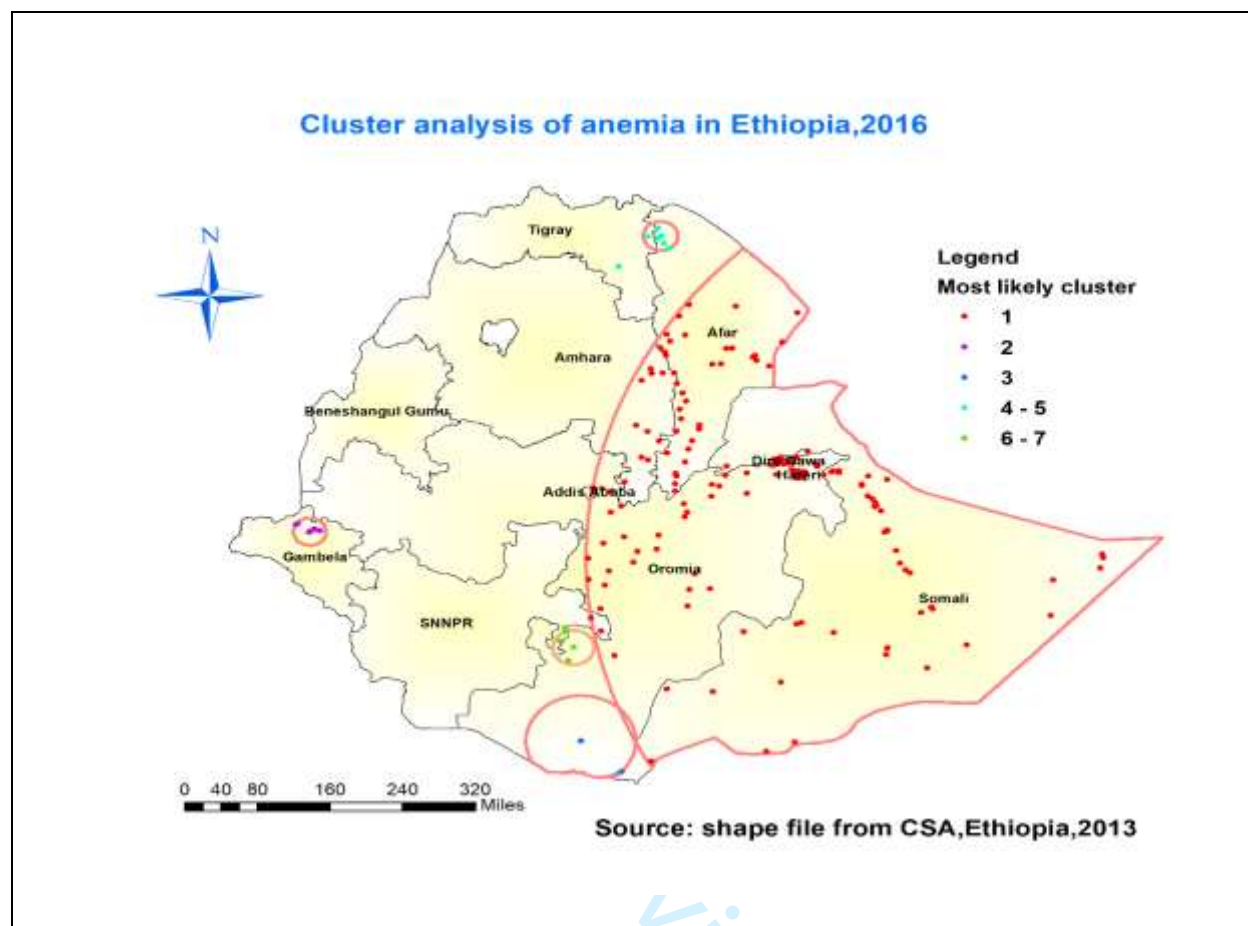




1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



BMJ Open: first published as 10.1136/bmjopen-2020-045544 on 17 August 2021. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.



34 Figure 4: SaTScan scan statistics analysis of anemia in Ethiopia, EDHS, 2005-2016

# BMJ Open

## Spatio-temporal distribution and associated factors of anaemia among children aged 6–59 months in Ethiopia: Based on the EDHS 2005– 2016: A spatial and multilevel analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-045544.R1
Article Type:	Original research
Date Submitted by the Author:	27-Feb-2021
Complete List of Authors:	Samuel, Hailegebreal; Arba Minch University, Department of Health Informatics Nigatu, Araya; University of Gondar, Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia Mekonnen, Zeleke; Ethiopia Ministry of Health, Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia; Endehabtu, Berhanu; University of Gondar, Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia
<b>Primary Subject Heading</b>:	Paediatrics
Secondary Subject Heading:	Public health
Keywords:	Anaemia < HAEMATOLOGY, PAEDIATRICS, Community child health < PAEDIATRICS

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1 Spatio-temporal distribution and associated factors of anaemia among children aged 6–59  
2 months in Ethiopia: Based on the EDHS 2005- 2016: A spatial and multilevel analysis

3 Samuel Hailegebreal<sup>1\*</sup>, Araya Mesfin Nigatu<sup>2</sup>, Zeleke Abebaw Mekonnen<sup>2,3</sup>, Berhanu Fikadie  
4 Endehabtu<sup>2</sup>

### 5 **Affiliation**

6 <sup>1</sup>Department of Health Informatics, College of Health Science, Arbaminch University,  
7 Ethiopia

8 <sup>2</sup>Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia

9 <sup>3</sup>Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia

### 11 **Corresponding author**

12 Samuel Hailegebreal

13 Email: [samuastd@gmail.com](mailto:samuastd@gmail.com)

## Abstract

**Objectives:** Anaemia is a global public health problem with major health and socio-economic consequences. Though childhood anaemia is a major public health problem in Ethiopia, there is limited evidence on the spatio-temporal variability of childhood anaemia overtime. Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anaemia using the Ethiopian Demographic and health survey (EDHS) data from 2005-2016.

**Design:** Survey-based cross-sectional study design was employed for the EDHS.

**Setting:** Data were collected in all nine regions and two city administrations of Ethiopia in 2005, 2011 and 2016.

**Participants:** The source population for this study was all 6–59 months of children in Ethiopia. A total of 21,302 children aged 6-59 months were included in this study.

**Outcome measure:** The outcome variable was child anaemia status.

**Results:** The prevalence of anaemia declined from 53.9% in 2005 to 44.6% in 2011, but it showed an increment in 2016 to 57.6%. The Spatial analysis revealed that the spatial distribution of anaemia varied across the country. In spatial scan statistics analysis, a total of 22 clusters (RR= 1.54, P-value < 0.001) in 2005, 180 clusters (RR = 1.14, P-value < 0.001) in 2011, and 219 clusters (RR = 1.44, P-value < 0.001) in 2016 significant primary clusters were identified. Child age, women age, maternal anaemia status, wealth index, birth order, fever, stunting, wasting status, and region were significant predictors of childhood anaemia.

**Conclusions:** In this study, childhood anaemia remains a public health problem. The spatial distribution of childhood anaemia was significantly varied across the country. Identifying the risk areas and determinants would help to design strategies in the area. Therefore, in regions

1 45 with a high risk of childhood anaemia, individual and community level factors should be  
2  
3 46 intensified by allocating additional resources and providing appropriate and tailored  
4  
5 47 strategies.  
6  
7

8 48 **Keywords:** Anemia, children, EDHS, Spatial analysis, Ethiopia  
9  
10

11  
12 49

### 13 14 50 **Strengths and limitations of this study**

- 15 51 • This study applied different methods of spatial pattern, trend and a multilevel  
16 52 regression models accounting for the nested nature of EDHS data
- 17  
18 53 • The study was based on three consecutive EDHS dataset's representing the whole  
19  
20 54 country of Ethiopia
- 21  
22 55 • The cross-sectional nature of the data prevents causality from being inferred between  
23 56 the independent and dependent variables
- 24  
25 57 • Respondents' without coordinate (longitude and latitude) were excluded from the  
26 58 spatial analysis, which could affect the generalizability of the findings  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## 67 **Background**

68 Anaemia is a condition characterized by a low level of haemoglobin in the blood(1). Over 273  
69 million under-five children suffer from anaemia worldwide(2). Sub-Saharan Africa is one of  
70 the most affected regions, accounting for about 53.8%(2). World health organization had  
71 developed a classification system to facilitate international comparisons of anaemia as public  
72 health crises. The problem was considered severe if anaemia prevalence is  $\geq 40\%$ , moderate  
73 from 20% to 39.9%, and mild from 5% to 19.9%(3). The high prevalence of anaemia and its  
74 consequences on children's health, especially on their growth and development, have made  
75 it important public health problem, It also increases the risk of mortality and morbidity that  
76 come from other diseases(4,5).

77 Anaemia is a public health problem that affects populations in both industrialized and non-  
78 industrialized countries. It affects all segments of the population. It is frequently observed  
79 among children and pregnant women who are the most vulnerable group because their  
80 iron requirements are higher than any other group. Childhood anaemia is mainly caused  
81 by dietary Iron deficiency. Folate, vitamin B12 and vitamin A deficiencies, chronic  
82 inflammation, parasitic infections, and inherited disorders can also contribute to childhood  
83 anaemia (6). For children age 6-59month Anaemia is defined as a haemoglobin level  
84 below 11.0 g/dl(6). Childhood anaemia is mostly coexisting with malaria, parasitic  
85 infection, nutritional deficiencies, and hemoglobinopathies(7).

86 The 2015 WHO report, from the global anaemia prevalence in 2011 showed that Africa,  
87 South East Asia, America, and European regions was,62.3%,53.8%,23.3%, and,22.9%,  
88 respectively(3). Pregnant women and children in low-income countries were at risk for  
89 anaemia because they were believed to be those with the most significant problems with  
90 inadequate nutrition, high infectious disease burden, and poor access to routine health



1 91 care(8). In sub-Saharan Africa, anaemia is a significant public health problem associated with  
2  
3 92 an increased risk of death and impaired cognitive development(9). In Ethiopia, the three  
4  
5 93 crude summaries of the country reported between 2005 and 2016 indicated the prevalence of  
6  
7  
8 94 anaemia among Ethiopian children declined from 54% to 44% from 2005 to 2011 but  
9  
10 95 increased to 57% in 2016(10–12).

13 96 Various-studies showed that the prevalence of anaemia among 6-59-month children is high  
14  
15 97 and a severe public health problem. Evidence from various studies indicated that women  
16  
17  
18 98 age, residence, family income, maternal education(13), an introduction of complementary  
19  
20 99 foods, poor breastfeeding practice, poor utilization of folic acid by mothers(14), maternal  
21  
22 100 anaemia(15), unemployment of the parent, malaria, and presence of sickle haemoglobin(13),  
23  
24  
25 101 household wealth index, sex of the child(16), and nutritional status were factors for childhood  
26  
27 102 anaemia. Few studies have been done on factors associated with anemia in Ethiopia, to  
28  
29 103 date; the risk areas (hot spot) of anaemia among children are not identified. Thus, this study  
30  
31 104 aimed to explore the spatiotemporal patterns of anaemia among children in Ethiopia over the  
32  
33  
34 105 last one and half-decades to point out whether there was either the shift or improvement in  
35  
36 106 anaemia risk areas following intervention programs in between the survey periods in  
37  
38  
39 107 Ethiopia. Geographical differences in the causes of anemia can be partially explained by  
40  
41 108 large-scale variability in environmental drivers, particularly nutritional and infectious  
42  
43 109 causes(17). The risk of malaria is known to be associated with elevation and land surface  
44  
45 110 temperature(18). Environmental drivers of anemia tend to show a high degree of spatial  
46  
47  
48 111 dependence. Therefore, detecting the geographic variation of anemia during childhood is  
49  
50 112 important to prioritize and design targeted intervention programs to reduce anemia especially  
51  
52 113 in those areas with a consistently higher risk of anemia over time. Therefore, this study  
53  
54  
55 114 attempts to fill the gap by investigating the spatio-temporal distribution of anaemia and its

1 115 associated factors using multilevel model analysis in Ethiopia using the EDHS survey  
2  
3 116 between 2005-2016 data.  
4

## 5 117 **Methods and materials**

### 8 118 **Study design, setting and period**

10 119 The survey-based cross-sectional study design was employed using the Ethiopian  
11  
12  
13 120 Demography and Health Surveys (EDHS) in 2005, 2011, and 2016. Data access, extraction,  
14  
15 121 and analysis were conducted from January to June 2020. The study was conducted in  
16  
17  
18 122 Ethiopia located at the horn of Africa (3°-14°N and 33° – 48°E). Administratively, the country  
19  
20 123 is divided into nine regional states and two city administrations. Each region is sub-divided  
21  
22 124 into zones, districts, towns, and kebeles (the smallest administrative units).  
23  
24

### 25 125 **Source and study population**

28 126 All 6–59 months children in Ethiopia were the source population for this study whereas all  
29  
30 127 children aged from 6-59 months in the selected enumeration areas within five years before  
31  
32  
33 128 the survey were the study population.  
34  
35

### 36 129 **Sample size and sampling technique**

38 130 A total of 21,302 children (3,868 in 2005, 8,958 - in 2011, and 8476 in 2016) were included in  
39  
40 131 this study. children's Record (KR) EDHS dataset was used for analysis. The survey covered  
41  
42  
43 132 all nine regions and the two city administrations of Ethiopia. Participants were selected based  
44  
45 133 on a stratified two-stage cluster sampling technique in each survey year. After excluding  
46  
47 134 clusters with zero coordinates and missing information, a total of 503 clusters in 2005, 569  
48  
49 135 clusters in 2011, and 615 clusters in 2016 were used for analysis. The detailed sampling  
50  
51  
52 136 procedure was available in each EDHS report(10–12)  
53

### 54 137 **Data collection tools and procedures**

56  
57  
58  
59

1 138 The three EDHS datasets were downloaded from the measure DHS program (Demographic  
2  
3 139 and Health Survey) website ([www.measuredhsprogram.com](http://www.measuredhsprogram.com)) after obtaining the necessary  
4  
5 140 permissions for the download and further analyses. Similarly, location data (latitude and  
6  
7  
8 141 longitudinal) were extracted from the downloaded excel file. After extraction, the missing  
9  
10 142 values for the significant independent variables were excluded and the analysis was  
11  
12 143 undertaken using a complete set of data. In all survey years for all children age 6-59 month  
13  
14  
15 144 from whom consent was obtained from their parents. Blood samples were drawn from the  
16  
17 145 drop of blood taken from a finger prick or a heel prick in the case of 6-11 month, and  
18  
19 146 collected in a microcuvette. Haemoglobin analysis was carried out on-site using a battery-  
20  
21  
22 147 operated portable HemoCue analyzer.

## 25 148 **Key variables and Measurements**

27 149 **Dependent variable:** The study variables were grouped into dependent and independent  
28  
29 150 variables. The dependent variable is child anaemia status, categorized as “anaemic/not-  
30  
31 151 anaemic” variable. Children whose haemoglobin level was less than 11g/dl were considered  
32  
33  
34 152 anaemic and not anaemic otherwise.

## 36 153 **Independent variables:**

39 154 sociodemographic (religion, mother age, marital status, educational status, husband  
40  
41 155 education, wealth index, mothers working status, numbers of under five children) Maternal  
42  
43 156 and Child- related (child sex, age, birth size, birth order, maternal BMI, maternal anaemia,  
44  
45  
46 157 breastfeeding, fever, diarrhoea, vitamin supplement, stunting and wasting). Community-level  
47  
48 158 (residence, region, community women education and community women poverty).

50 159 We created community education and community poverty variables by aggregating the  
51  
52  
53 160 individual characteristics within their clusters. The aggregates were computed using the  
54  
55 161 median values of the proportions of women in each category of a given variable. We

1 162 categorized the aggregate values of a cluster into groups based on national median values,  
2  
3 163 since all aggregates were not normally distributed.  
4  
5

6 164 **Community women's education:** was defined as the proportion of women who attended  
7  
8 165 primary, secondary and higher education within the cluster. The aggregate of individual  
9  
10  
11 166 primary, secondary and higher educational attainment can show the overall educational and  
12  
13 167 academic status of women within the cluster. They were categorized into two categories a  
14  
15 168 higher proportion of women's education within the cluster and a lower proportion of women  
16  
17  
18 169 education based on the national median value.  
19

20 170 **Community poverty status:** defined as the proportion of poor and poorest mothers within  
21  
22 171 the cluster. For each cluster, the proportion of poor and poorest as-was aggregated and  
23  
24  
25 172 show overall poverty status within the cluster. It was categorized into two categories based  
26  
27 173 on national median value as higher proportion of poor/poorest mother's and lower proportion  
28  
29 174 of mothers within a cluster.  
30

### 31 175 **Data management and analysis**

32  
33  
34 176 The data were cleaned using STATA 14.1 software and Microsoft excel. The data were  
35  
36 177 weighted using sampling weight, primary sampling unit, and strata before any statistical  
37  
38  
39 178 analysis to restore the representativeness of the survey to take into account the sampling  
40  
41 179 design when calculating standard errors to get reliable statistical estimates.  
42  
43

### 44 180 **Spatial analysis**

45  
46 181 For the spatial analysis, ArcGIS V.10.7 software was used to evaluate whether the pattern  
47  
48 182 was clustered, dispersed or random across the study area, and SaTScan V.9.6 software was  
49  
50  
51 183 used for the local cluster detection analysis. It uses a circular window that moves  
52  
53 184 systematically throughout the study area to identify a significant SaTScan clustering of  
54  
55 185 childhood anaemia.  
56  
57  
58  
59  
60

## 186 **Spatial autocorrelation analysis**

187 The spatial autocorrelation (Global Moran's I) statistic measures whether childhood anaemia  
188 patterns were dispersed, clustered or randomly distributed in the study area. Moran's I output  
189 value ranges from (-1 to +1). Values close to -1 indicate disease dispersed, whereas  
190 Moran's I close to +1 indicate childhood anaemia clustered and distributed randomly if I value  
191 zero. Anselin Local Moran's I was used to indicate the local level cluster locations of anaemia  
192 positively correlated (high-high and low-low) clusters or negatively correlated (high-low and  
193 low-high).

## 194 **Hot spot analysis (Getis-Ord $G_i^*$ statistic)**

195 Local Moran's I, Gettis-Ord $G_i^*$  statistics was computed to measure how spatial  
196 autocorrelation of anemia among under-five children varies across different locations in  
197 Ethiopia. Hotspot analysis computes Z-score and p-value to determine the statistical  
198 significance of the clustering of anaemia over the study area at different significance levels  
199 simultaneously. Statistical output with high  $G_i^*$  indicates "hotspot" whereas low  $G_i^*$  means a  
200 "cold spot". hot spot areas showed that there was a high proportion of anaemia and the cold  
201 spot indicated a low proportion of anaemia.

## 202 **Spatial interpolation**

203 There are various deterministic and geostatistical interpolation methods. Among all of the  
204 methods, ordinary Kriging and empirical Bayesian Kriging are considered the best methods  
205 since they incorporate spatial autocorrelation and statistically optimize the weight. Ordinary  
206 Kriging spatial interpolation method was used for this study for predictions of childhood  
207 anaemia in unobserved areas of Ethiopia since it had low mean square error and residual as  
208 compared to the other interpolation techniques.

## 209 **Spatial scan statistical analysis**

1 210 Spatial scan statistical analysis used to Identifying most likely clusters was done using the  
2  
3 211 spatial Scan statistical method. This method is widely recommended as it is very important in  
4  
5 212 detecting local clusters and has higher power than other available spatial statistical methods.  
6  
7  
8 213 Bernoulli based model was employed to test for statistically significant spatial clusters of  
9  
10 214 anaemia using Kulldorff's Sat Scan version 9.6 software. Children with anaemia were taken  
11  
12 215 as cases, and were not-anaemic as controls to fit the Bernoulli model. The default maximum  
13  
14 216 spatial cluster size of <50% of the population was used. The scanning window with maximum  
15  
16 217 likelihood was the most likely cluster, and the p-value was assigned to each cluster using  
17  
18 218 Monte Carlo hypothesis testing. The primary and secondary clusters were identified and  
19  
20 219 assigned p-values and ranked based on their likelihood ratio test, based on 999 Monte Carlo  
21  
22  
23  
24 220 replications(19).

### 27 221 **Associated factors of anaemia**

30 222 Four models were fitted using **melogit**, a STATA command, the null model without  
31  
32 223 predictors, model I with only individual-level variables, model II with only community-level  
33  
34 224 variables, and Model III both individual-level and community-level variables. Model  
35  
36  
37 225 comparison was conducted by using deviance and likelihood ratio.

40 226 Intra-class correlation (ICC), median odds ratio (MOR), and proportional change in variance  
41  
42 227 (PCV) were computed to measure the variation between clusters. The intra-class correlation  
43  
44 228 coefficient (ICC) quantifies the degree of heterogeneity of childhood anaemia between  
45  
46  
47 229 clusters (the proportion of the total observed individual variation in anaemia that is  
48  
49 230 attributable between cluster variations) calculated as

$$52 \text{ 231 } ICC = \frac{\sigma^2}{(\sigma^2 + \pi^2/3)} \text{ (20)}$$

but MOR is quantifies the variation or heterogeneity in outcomes between clusters and is defined as the median value of the odds ratio between the cluster at high risk of anaemia and cluster at lower risk when randomly picking out two clusters (EAs).

$$MOR = e^{(0.95 * \text{sqrt}(Va))_{(21)}}.$$

PCV measures the total variation attributed by individual-level factors and community-level factors in the multilevel model compared to the null model PCV. In the multivariable multilevel logistic regression analysis variables with a p-value of <0.05 were considered as statistically significant. Adjusted Odds Ratio (AOR) with their corresponding 95% confidence interval was determined to identify factors associated with anaemia. After comparing all models, a model with low deviance was considered a better model. Multicollinearity was checked using the Variance Inflation Factor (VIF). VIF less than 10% was taken as no multicollinearity.

## Ethics and confidentiality

Ethical clearance was obtained from the ethical review board of the University of Gondar Institute of Public Health, CMHS. Permission for data access was obtained from the measure demographic and health survey through an online request by a written letter of objective and significance of the study from <http://www.dhsprogram.com>

## Patient and public involvement

This study did not involve patients and the public

## Results

### Descriptive characteristics of the study population

A total of 21,302 children with known haemoglobin levels (3,868 in 2005, 8,958 in 2011, and 8467 in 2016) were included in this study. The prevalence of anaemia for the three consecutive surveys was 53.9%, 44.6%, and 57.6% in 2005, 2011, and 2016 EDHS data

respectively. The majority of the participants were in the age group of 36-47 (23%), 36-47 (24%), and, 12-23 (22%) in EDHS 2005, 2011, and 2016 survey respectively. The mean age of children was  $32.57 \pm 15.6$ -SD,  $32.6 \pm 15.4$ -SD, and  $31.7 \pm 15.6$ -SD in 2005, 2011, and 2016 respectively. Among children involved in the analysis, male participants were high proportion in 2011 and 2016 EDHS compared to 2005 survey periods. The majority of children were from rural residency in five years preceding the survey in three surveys. About 78.6%, 70%, and 67% of women were unable to read and write in 2005, 2011, and 2016 survey respectively. Children from poor and middle-class families were more anaemic than children from rich families across the three EDHS survey (Table 1). During the study period, the trends in the prevalence of childhood anaemia in Ethiopia, were fluctuates across regions (Fig.1).

Table 1: Descriptive characteristics of study participants included in the analysis for childhood anaemia in EDHS 2005,2011, and2016 in Ethiopia

Characteristics	2005 (N, 3868) Frequency (%)	2011(N, 8958) Frequency (%)	2016(N, 8476) Frequency (%)
<b>Sex of child</b>			
Male	1,931(49.93)	4,500(51.35)	4,395(51.85)
Female	1,937(50.07)	4,358(48.65)	4,081(48.15)
<b>Children age (6-59) month</b>			
6-11	418 (10.81)	1,029(11.48)	1,000(11.80)
12-23	842 (21.76)	1,804(20.14)	1,902(22.43)
24-35	825 (21.33)	1,895(21.16)	1,803(21.27)
36-47	919 (23.76)	2,184(24.37)	1,832(21.62)
48-59	864 (22.34)	2,047(22.85)	1,939(22.87)
<b>Mean <math>\pm</math> SD</b>	<b>32.57 <math>\pm</math>15.6</b>	<b>32.6<math>\pm</math>15.4</b>	<b>31.7<math>\pm</math>15.6</b>
<b>Residence</b>			
Urban	244 (6.31)	1,047(11.69)	857(10.12)
Rural	3,624 (93.69)	7,911(88.31)	7,619(89.88)
<b>Religion</b>			
Orthodox	1,624 (41.97)	3,416(38.13)	2,913(34.37)
Muslim	1,276 (32.99)	3,108(34.70)	3,432(40.48)
Protestant	836 (21.61)	2,151(24.01)	1,874(22.11)
Others	133 (3.43)	283(3.16)	258(3.05)



1	288	<b>Women age</b>			
2					
3	289	15-29	1,930(49.90)	4,908(54.78)	4,356(51.40)
4					
5	290	30-39	1,474(38.10)	3,223(35.98)	3,335(39.34)
6					
7	291	40-49	464(12.00)	828(9.24)	785(9.26)
8					
9	292	<b>Women education</b>			
10					
11	293	No education	3,042 (78.63)	6,285(70.16)	5,685(67.07)
12					
13	294	Primary	684 (17.68)	2,389(26.67)	2,275(26.84)
14					
15	295	Secondary	136 (3.51)	168(1.88)	346(4.08)
16					
17	296	Higher	7 (0.18)	117(1.30)	170(2.01)
18					
19	297	<b>Marital status</b>			
20					
21	298	Single	7(0.17)	50(0.56)	45(0.53)
22					
23	299	Married	3,704(95.74)	8,425(94.04)	8,129(95.9)
24					
25	300	Widowed	80(2.06)	178(1.99)	93(1.10)
26					
27	301	Divorced	78(2.03)	306 (3.41)	210(2.48)
28					
29	302	<b>Husband education</b>			
30					
31	303	No-education	2,235 (58)	4,532(50.87)	4,333(51.10)
32					
33	304	Primary	1,233(32)	3,710(41.65)	3,273(38.62)
34					
35	305	Secondary	362(9)	412(4.63)	572(6.75)
36					
37	306	Higher education	31(0.81)	255 (2.86)	300(3.53)
38					
39	307	<b>Wealth index</b>			
40					
41	308	Poor	1,697(43.86)	4,048(45.19)	3,977(46.92)
42					
43	309	Middle	854(22.07)	1,873(20.91)	1,821(21.48)
44					
45	310	Rich	1,318(34.07)	3,038 (33.91)	2,678(31.60)
46					
47	311	<b>Women working status</b>			
48					
49	312	Not working	2,841(73.45)	5,793(64.67)	6,140(72.44)
50					
51	313	Working	1,027(26.55)	3,165(35.33)	2,336(27.56)
52					
53	314	Total	3,868(100)	8,958(100)	8,476(100)
54					
55	315				
56					
57	316				
58					
59					
60					

## 1 317 **Community-level characteristics of the study population**

2  
3 318 Findings from this study revealed a regional variation of childhood anaemia, with 83% in  
4  
5 319 Somali, 75%, in Afar, 72% in Dire Dawa, and 67% in Harari. However, Amhara, and  
6  
7 320 Benishangul with 43%, which was relatively low compared to other regions.

8  
9  
10  
11 321 Childhood anaemia varies by urban-rural of residence. Children residing in communities with  
12  
13 322 low poverty level had a lower percent of anaemia (51.2%) than high community poverty level  
14  
15 323 (62.5%%). Children from low community women education level (59.5%) were more anaemic  
16  
17  
18 324 than children resided with high community women (53%) educational level (Table 2).

19  
20  
21 325 Table 2: Community Level Factors of under five children participated on EDHS (2016),  
22 326 Ethiopia. (N, 8476)

24 327 <b>Background characteristics</b>	25 <b>Child anaemia status</b>		
26 328 <b>Community level factors</b>	<b>Not-anaemic (%)</b>	<b>Anaemic (%)</b>	<b>Total (%)</b>
28 329 <b>Residence</b>			
29 330 Urban	435(50.6)	424(49.4)	857(100)
31 331 Rural	3164(41.5)	4455(58.5)	7619(100)
32 332 <b>Region</b>			
33 333 Amhara	950(57.5)	703(42.5)	1653(100)
35 334 Oromia	1273(34.2)	2446(65.8)	3719(100)
36 335 SNNP	875(49.1)	906(50.9)	1781(100)
37 336 Somali	58(16.7)	290(83.3)	348(100)
39 337 Tigray	263(46)	309(54)	572(100)
40 338 Addis Ababa	82(50.9)	79(49.1)	161(100)
41 339 Afar	21(25.3)	62(74.7)	83(100)
43 340 Benishangul	51(56.6)	39(43.4)	90(100)
44 341 Gambelia	8(42.1)	11(57.9)	19(100)
45 342 Harari	5(31.2)	11(68.8)	16(100)
47 343 Dire Dawa	9(28.1)	23(71.9)	32(100)
48 344 <b>Community women education</b>			
49 345 Low	2281(40.5)	3358(59.5)	5639(100)
51 346 High	1315(46.4)	1520(53.6)	2837(100)
52 347 <b>Community women poverty</b>			
54 348 Low	1815(48.8)	1905(51.2)	3719(100)
55 349 High	1782(37.5)	2974(62.5)	4756(100)

56 350

57

58

59

60

1 351 Total 8476(100)

---

## 352 353 **Spatio-temporal distribution of anaemia among children age 6-59 months in Ethiopia**

354 The spatial distribution of childhood anaemia in Ethiopia was non-random in all three  
355 consecutive surveys. . The global Moran's I test value was 0.176 (P-value <0.001) in 2005,  
356 0.18 (P-value < 0.001) in 2011, and 0.09(P-value < 0.005) in 2016 Ethiopian Demographic  
357 and health surveys.

### 358 **Hot spot analysis of the three surveys**

359 The spatial distribution of childhood anaemia in Ethiopia was different in the three survey  
360 periods. In EDHS 2005, a high proportion of childhood anaemia was detected in Dire Dawa,  
361 Harari, Eastern Oromia, Benishangul in Metekel zone, Gambela, Southern and Eastern  
362 Tigray, and Somali region mainly Liben, Afdar, and Fafna zone which was hotspot area  
363 within 95% confidence level. On the counterpart, GamoGofa, Wolayita, Hadiya, Southern  
364 Omo, and Segen zone of SNNPR, Addis Ababa, central Oromia, Jima, North Shewa zone  
365 were cold spot area. In EDHS 2011, a highly significant clustering of childhood anaemia was  
366 detected in Somalia, Dire Dawa, Harari, Afar, Gambela, Benishangul, Eastern Oromia, Bale,  
367 Arsi zone were the hotspot areas within 95% level of confidence. The low hotspot area of  
368 childhood anaemia was detected in central Tigray, East and West Gojam, North Gondar, a  
369 central part of Oromia, Addis Ababa and SNNPR were areas identified as the low percentage  
370 of childhood anaemia in the 2011 EDHS survey.

371 In EDHS-2016 sampled data, hot spot (high risk) regions for childhood anaemia were  
372 observed in Somali, Dire Dawa, Harari, Gambela, Eastern, and Southern part of Oromia.  
373 However, Amhara, Benishangul, and Southern Nations Nationalities and Peoples (SNNP)

1 374 were identified as cold spot (low risk) regions for childhood anaemia within a 95% confidence  
2  
3 375 interval (**Fig.2**)  
4  
5

### 6 376 **Spatial interpolation**

7

8 377 Based on EDHS-2005 sampled data, the geostatistical analysis predicts that the highest  
9  
10 prevalence of childhood anaemia (65.75%-88.89%) was detected in East Oromia, Ilubabur,  
11 378  
12 Arsi, some parts of Benishangul, Agnuak zone in Gambela, North Shewa Amhara region,  
13 379  
14 South and central Tigray Afar in zone2, some parts of Dire Dawa city and Somali. In EDHS-  
15 380  
16 2011 Geostatistical analysis, a high percentage of anaemia was detected in Afar, most parts  
17  
18 381  
19 of Somalia, Oromia in East Harerge and Borena, some part of Dire Dawa, and the Meketel  
20 382  
21 zone in Benishangul. In 2016 EDHS most of Somali, some parts of Gambela, Guji and some  
22 383  
23 parts of Borena, East Shewa, East Harerge and Arsi in Oromia and part of Dire Dawa were  
24 384  
25 highly prevalent areas in childhood anaemia (**Fig.3**)  
26  
27 385  
28

### 29 386 **Spatial scan statistics**

30  
31

32 387 In 2005 EDHS, a total of 3 significant clusters were identified, one most likely (primary)  
33  
34 388 cluster and 2 were secondary clusters of spatial scan analysis. The primary cluster's  
35  
36 spatial window was located in Somali, which was centered at (9.018373 N, 43.110635 E) of  
37 389  
38 geographic location with a 97.93 km radius, and Log-Likelihood ratio (LLR) of 20.03, at  $p <$   
39 390  
40 0.001 which was detected as the most likely cluster with Maximum Likelihood. It showed that  
41 391  
42 children within the spatial window had 1.54 times more likely a higher risk of anaemia than  
43 392  
44 the children outside the spatial window areas. The secondary clusters scanning window was  
45  
46 393  
47 located in the southern part of Somali region, which was centered at (3.998656 N, 41.240691  
48 394  
49 E) with a 92.08 km radius and LLR of 1.73 at  $p$ -value 0.0010. It showed that children within  
50 395  
51 the spatial window had a 1.73 times higher risk of anaemia than children outside the window.  
52  
53 396  
54  
55  
56  
57  
58  
59  
60

1 397 In 2011 EDHS, 10 clusters were identified and five of them were significant clusters with a p-  
2  
3 398 value  $<0.05$ . A total of 180 locations/spots with a total sampled population of 2478 were  
4  
5 399 found as primary cluster areas were identified using sat scan analysis with a p-value  $< 0.001$ .  
6  
7  
8 400 The primary cluster spatial window was located mainly in Somali, Afar, Eastern Oromia, Dire  
9  
10 401 Dawa, and Harari. The primary cluster spatial window was centered at (8.975207 N,  
11  
12 402 43.790264 E) / 540.29 km, with a relative risk (RR) of 1.43 and a log-likelihood ratio (LLR) of  
13  
14  
15 403 127.79. It showed that children within the spatial window had 1.4 times more likely a higher  
16  
17 404 risk of anaemia than the children outside the spatial window areas. The secondary cluster  
18  
19 405 spatial window was located mainly in Afar regional state. The secondary cluster spatial  
20  
21 406 window was centered at (12.758587 N, 40.175990 E) / 39.58 km, with a relative risk (RR) of  
22  
23  
24 407 1.68 and a log-likelihood ratio (LLR) of 21.5 P-value=0.001.  
25  
26

27 408 In 2016 EDHS, 7 clusters (1 most likely cluster) were located in Somali, Afar, Eastern  
28  
29 409 Oromia, Dire Dawa, and Harari. The cluster window was centered with a radius at (7.650693  
30  
31 410 N, 47.007920 E) / 912.19 km with a Relative Risk (RR) of 1.44. The Log-Likelihood Ratio  
32  
33  
34 411 (LLR) for the most likely cluster was 182.86,  $p < 0.001$ . Secondary clusters were located in  
35  
36 412 Gambela which was centered at (8.195862 N, 34.289837 E) with a radius of 29.01 km, and  
37  
38 413 LLR of 18.8 at p-value 0.001. It showed that children within the spatial window had a 1.5  
39  
40  
41 414 times higher risk of anaemia than outside the window (**Fig.4**).  
42  
43

### 44 415 **Multilevel Analysis**

45

46 416 The intra-cluster correlation coefficient (ICC) in the empty model indicated that 18.8% of the  
47  
48  
49 417 total variability for children anaemia was due to differences between clusters. The remaining  
50  
51 418 unexplained 81.2% were attributable to individual differences. The median odds ratio for  
52  
53  
54 419 anaemia was 2.3 in the null model, indicating variation between clusters. If we randomly  
55  
56 420 select children from two different clusters children at the cluster with a higher risk of anaemia  
57  
58  
59  
60

1 421 had 2.3 times higher odds of experiencing anaemia than children at the cluster with a lower  
2  
3 422 risk of anaemia.  
4  
5

6 423 Bi-variable multilevel logistic regression analysis was done to identify variables for  
7  
8 424 multivariable multilevel logistic analysis, and variable with a p-value less than 0.2 were  
9  
10  
11 425 considered for multivariable analysis.  
12  
13

#### 14 426 **Individual-level predictors for anaemia**

  
15

16  
17 427 In multivariable multilevel mixed-effect logistic regression analysis, individual-level factors  
18  
19 428 such as the age of the child, wealth index, mother age, maternal anaemic status, birth order,  
20  
21 429 fever, stunting, and wasting status were significant predictor of childhood anaemia.  
22  
23

24 430 Children age between 12–23 months (AOR = 0.66, 95%CI = 0.53-0.81), between 24–35  
25  
26 431 months (AOR= 0.35, 95% CI = 0.28-0.43), between 36–47 months (AOR = 0.23-95%CI =  
27  
28 0.19-0.29), and between 48–59 months (AOR = 0.15, 95%CI = 0.12-0.19) were less likely to  
29 432 develop anaemia when compared with children age between 6–11 months.  
30  
31 433  
32  
33

34 434 The likelihood of developing anaemia for those children residing with the family wealth index  
35  
36 435 of middle and rich was lower by 21% (AOR=0.79, 95%CI = 0.67-0.94), and 23% (AOR=0.77,  
37  
38 95%CI = 0.65-0.91), respectively as compared with children with low wealth index. Children  
39 436 whose mother's age were between 40-49 had 25% decreased odds of developing childhood  
40  
41 437 anaemia compared to age 15-29, (AOR=0.75, 95%CI = 0.59-0.95).  
42  
43 438  
44  
45

46 439 The odds of experiencing anaemia for those birth orders 4-5, 6, and above six were 1.22  
47  
48 440 times (AOR=1.22, 95%CI = 1.01-1.47) and, 1.35 times (AOR=1.35, 95%CI = 1.08-1.67)  
49  
50  
51 441 higher as compared with first-order respectively. The odds of developing anaemia of children  
52  
53 442 born from anaemia history mother were 1.39 higher more elevated than those born from not  
54  
55 443 anaemic history before. Children who had fever were 39% (AOR =1.39, 95% CI: 1.24-1.58)  
56  
57  
58  
59  
60

more likely to develop anaemia than their counterparts. Children with moderate and severe stunting status were 35% (AOR=1.35, 95% CI: 1.17-1.54) and, 96% (AOR=1.95, 95% CI: 1.68-2.28), more likely to develop anaemia respectively as compared to no stunting status. Similarly, children who had to sever wasting status were 51% more (AOR =1.51, 95% CI: 1.07-2.12) likely to develop anaemia compared with those children who had no wasting.

### Community-level predictors for anaemia

The multivariable multilevel logistic regression analysis region was significantly associated with community-level factors for childhood anaemia.

Odds of children live in Somali were 5.65 times (AOR=5.65, 95% CI: 3.92-8.16), Dire Dawa 3.45 times (AOR=3.45, 95% CI: 2.27-5.26), Afar 3.01 times (AOR=3.01, 95% CI: 2.09-4.34), and Oromia 2.34 times (AOR=2.34, 95% CI: 1.73-3.18) had more likely to develop childhood anaemia as compared to Amhara regional state. Similarly, the odds of developing anaemia in Addis Ababa were 2.10 times (AOR=2.10, 95% CI: 1.40-3.16), Gambella 1.94 times (AOR=1.94, 95% CI: 1.32-2.84), and Tigray 1.46 times (AOR=1.46, 95% CI: 1.08-1.98), more likely as compared to Amhara region. Benishangul and SNNPR had not significantly different in the prevalence of anaemia than the reference region Amhara (Table 3).

Table 3: Multilevel logistic regression analysis result of both individual and community level factors associated with anaemia in Ethiopia, EDHS 2016

Individual Level	Null Model	Model I AOR (95% CI)	Model II AOR (95% CI)	Model III AOR (95% CI)
<b>Children age (6-59) month</b>				
6 – 11	--	1		1
12 – 23		0.66[0.54-0.82] **		0.66 [0.53-0.81] **
24 – 35		0.35[0.28-0.44] **		0.35 [0.28-0.43] **
36 – 47		0.23[0.18-0.28] **		0.23 [0.19-0.29] **
48 – 59	--	0.15[0.12-0.19] **	---	0.15 [0.12-0.19] **
<b>Religion</b>				
Orthodox		1		1
Muslim		2.07[1.77-2.47] **		1.21 [0.97-1.46]
Protestant		1.20 [1.002-1.48] *		1.09[0.86-1.37]

1	474	Others	--	1.55[1.07-2.32] *	---	1.44[0.96-2.13]
2	475	<b>Wealth index</b>				
3	476	Poor		1		1
4	477	Middle		0.71[0.61-0.84] **		0.79 [0.67-0.94] *
5	478	Rich	--	0.72[0.63-0.85] **	---	0.77 [0.65-0.91] *
6	479	<b>Child size at birth</b>				
7	480	Small		1		1
8	481	Average		0.96[0.84-1.09]		0.93 [0.80-1.07]
9	482	Large	--	0.94[0.81-1.08]	---	0.96 [0.84-1.10]
10	483	<b>Birth order</b>				
11	484	1st		1		1
12	485	2-3		1.09[0.94-1.28]		1.13[0.97-1.32]
13	486	4-5		1.17[0.97-1.40]		1.22 [1.01-1.47] *
14	487	6 and above	--	1.30[1.05-1.62]	---	1.35 [1.08-1.67] **
15	488	<b>No of children under 5</b>				
16	489	1-2 children		1		1
17	490	≥ 3 children	--	1.22[1.1-1.4] *	---	1.09 [0.94-1.27]
18	491	<b>Maternal anemia</b>				
19	492	Not-anemic		1		1
20	493	Anemic	--	1.51[1.34, 1.72] **	---	1.39 [1.24-1.58] **
21	494	<b>Maternal BMI</b>				
22	495	≥18.5 kg/m2		1		1
23	496	<18.5 kg/m2	--	1.12[0.97-1.26]	---	1.05 [0.92-1.19]
24	497	<b>Mother's working status</b>				
25	498	Not-working		1		1
26	499	Working	--	0.88[0.77-0.99] *	---	0.92 [0.81-1.04]
27	500	<b>Women age</b>				
28	501	15-29		1		1
29	502	30-39		0.91[0.71-1.06]		0.90 [0.78-1.04]
30	503	40-49	--	0.75[0.59-1.12] *	---	0.75 [0.59-0.95] *
31	504	<b>Breastfeeding</b>				
32	505	No		1		1
33	506	Yes	--	0.92[0.81-1.04]	---	0.98 [0.87-1.12]
34	507	<b>Vitamins in last 6 month</b>				
35	508	No		1		1
36	509	Yes	---	0.90[0.81-1.09]	---	0.93 [0.84-1.05]
37	510	<b>Diarrhea last 2 week</b>				
38	511	No		1		1
39	512	Yes	---	0.88[0.73, 1.04]	---	0.90 [0.76-1.07]
40	513	<b>Fever in last 2 weeks</b>				
41	514	No		1		1
42	515	Yes	---	1.35[1.15-1.59] **	---	1.32 [1.13-1.56] *
43	516	<b>Stunting status</b>				
44	517	No-stunting		1		1
45	518	Moderate stunting		1.27[1.10-1.46] **		1.35 [1.17-1.54] **
46	519	Severely stunting	---	1.81[1.55-2.11] **	---	1.96 [1.68-2.28] **
47	520	<b>Wasting status</b>				



1	521	No-wasting		1			
2	522	Moderate wasting	1.27[1.11-1.45]			0.98 [0.80-1.19]	
3	523	Severe wasting	---	1.68[1.55-2.10] *	---	1.51 [1.07-2.12] *	
4		<b>Place of residence</b>					
5	524						
6	525	Urban		1		1	
7	526	Rural	--	--	1.40[1.12-1.78]	1.28 [0.99-1.64]	
8		<b>Region</b>					
9	527						
10	528	Amhara	--	1		1	
11	529	Tigray		1.46 [1.09-1.97] **		1.46 [1.08-1.98] **	
12	530	Afar		3.90 [2.84-5.35] **		3.01 [2.09-4.34] **	
13	531	Oromia		2.48 [1.89-3.25] **		2.34 [1.73-3.18] **	
14	532	Somali		6.34[4.65-8.63]		5.65 [3.92-8.16] **	
15	533	Benishangul		0.86 [0.62-1.17]		0.81 [0.58-1.15]	
16	534	SNNPR		1.33 [1.00-1.76]		1.30 [0.94-1.80]	
17	535	Gambela		1.93 [1.38-2.69] **		1.94 [1.32-2.84] **	
18	536	Hareri		3.08 [2.15-4.43] **		2.98 [1.99-4.46] **	
19	537	Addis Ababa		1.91[1.29-2.83] **		2.10 [1.40-3.16] **	
20	538	Dire Dawa	--	--	3.92 [2.67-5.77] **	3.45 [2.27-5.26] **	
21		<b>Community education</b>					
22	539						
23	540	Low education		1		1	
24	541	High education	--	--	1.07[0.90-1.26]	1.13[0.94-1.34]	
25		<b>Community poverty</b>					
26	542						
27	543	Low poverty		1		1	
28	544	High poverty	--	--	1.41[1.17-1.68] *	1.15[0.94-1.40]	
29		<b>Model comparison and Random effect</b>					
30	545						
31	546						
32	547	ICC	0.187	--	--	--	
33	548	Log-likelihood	-4981.63	-4513.17	-4836.83	-4436.60	
34	549	Deviance	9963.26	9026.34	9673.66	8873.2	
35	550	PVC (%)	Ref	41.22	60.11	62.59	
36	551	MOR	2.30	1.72	1.42	1.38	

\*Key: 1: reference group; p-value 0.05-0.01 \*: p-value < 0.01 \*\*

### 555 Multicollinearity

556 Multicollinearity was checked for those variables included in the final model using VIF.  
 557 Accordingly, the VIF for all predictor variables included in the final model was below 10  
 558 indicating the absence of multicollinearity among the predictor variables.

### 559 Comparison of models

1 560 Deviance was used to compare the models, and the lowest value of deviance (Model III) was  
2  
3 561 considered the better mode.  
4

## 5 562 **Discussion**

6  
7  
8 563 This study tried to identify spatio-temporal distribution and predictors of childhood anaemia  
9  
10 564 across the regions in Ethiopia. 2005, 2011, and, 2016 Ethiopian Demographic and Health  
11  
12  
13 565 Survey data were used. In this study, anaemia's trend was decreased from 2005 to 2011,  
14  
15 566 while the rate significantly increased from 2011 to 2016. The study revealed that 57.56% [CL:  
16  
17 567 0.56-0.59] of children were anaemic in 2016, preceding the survey. This finding was in line  
18  
19  
20 568 with a study done in Gondar, Northwest Ethiopia 58.6%(22), whereas higher than the study  
21  
22 569 done in cape Verde, west Africa 51.8%(23), and southern Ethiopia(24). Among children of 6–  
23  
24 570 59 months, anaemia is still considered a significant public health problem in Ethiopia. Though  
25  
26  
27 571 the levels of anaemia among children vary by background factors like region and lowest  
28  
29 572 household wealth index and maternal related factors, more of the children in Ethiopia were  
30  
31 573 suffering anaemia.  
32  
33

34 574 The spatial pattern shows the geographical inequality of anaemia by using sat scan and GIS  
35  
36 575 spatial techniques like cluster mapping tools and interpolation techniques. The spatial  
37  
38  
39 576 analysis indicates that the distribution of childhood anaemia was non-random across the  
40  
41 577 country with a global Moran's I index of 0.176 in 2005, 0.18 in 2011, and 0.09 in 2016 with a  
42  
43 578 significant p-value, which indicates substantial-considerable clustering areas. This study's  
44  
45  
46 579 findings were in line with a study done in Nigeria, Malawi, Tanzania, and Uganda (25,26).  
47

48  
49 580 The spatial pattern of sat scan analysis showed that Eastern Somali regions were primary  
50  
51 581 (most likely) cluster and secondary cluster also located in the southern part of Somali in 2005  
52  
53 582 sat scan analysis. In 2011 Somali, Afar, Eastern Oromia, Dire Dawa, and Harari were located  
54  
55  
56 583 in the primary window and centered at (8.975207 N, 43.790264 E/ 540.29 km with a  
57

1 584 significant p-value. Similarly, spatial sat scan analysis showed that Somali, Afar, Eastern  
2  
3 585 Oromia, Dire Dawa, Harari were hotspot areas in the 2016 EDHS spatial analysis. In  
4  
5 586 addition, this study revealed that eastern parts of the country had similar spatiotemporal  
6  
7  
8 587 trend over the study periods. It might be, which are less developed compared with other  
9  
10 588 Ethiopian states in terms of economy, gender, healthcare facility and food availability(27).

11  
12  
13 589 This study indicated that children age 12-59 months were less affected by childhood  
14  
15 590 anaemia. This finding was consistent with studies conducted in Ethiopia and Togo (28–30).  
16  
17  
18 591 This could be explained by the fact that children who are getting older receive a richer and  
19  
20 592 complete diet, with a sufficient intake of iron which could prevent the occurrence of iron  
21  
22 593 deficiency anaemia. The deficiency may result from inadequate dietary intake of iron,  
23  
24 594 malabsorption of iron an increased iron demand during rapid growth might it be the possible  
25  
26  
27 595 reason (31).

28  
29  
30 596 The finding of this study indicated that children whose mother's age was between 40-49 were  
31  
32 597 less anaemic as compared to age 15-29. This finding is a study done in line with other  
33  
34 598 studies conducted in sub-Saharan Africa and Ghana (15,32). This group consists of more at-  
35  
36  
37 599 risk population segments (Adolescent) for anaemia. They are vulnerable to malnutrition  
38  
39 600 because they are growing faster than at any time after their first year of life which contributes  
40  
41 601 to the intergenerational cycle of malnutrition and he most common forms of malnutrition  
42  
43  
44 602 among Ethiopian adolescent girls is iron deficiency anaemia. Aside from, growing adolescent  
45  
46 603 mother and her baby's bodies may compete for nutrients, raising the infant's risk of low birth  
47  
48 604 weight; however, the lack of such nutrients might lead to anaemia.

49  
50  
51 605 Children from households of middle and rich wealth indexes were less affected by childhood  
52  
53 606 anaemia as compared to children from a poor household. This finding has also been  
54  
55  
56 607 demonstrated in similar studies in Nigeria and northern Ethiopia (25,33). This is due to the

1 608 reason that children from poor households are less likely to get iron-rich foods like animal  
2  
3 609 foods and vitamin-rich foods especially vitamins A and C which are very important for iron  
4  
5 610 absorption.  
6  
7

8 611 Maternal anaemia was highly associated with the occurrence of childhood anaemia. This  
9  
10 612 finding was in line with a study done in South Africa, Haiti, and India(34–36). Reasons may  
11  
12 613 be mothers and children share a common home environment, socioeconomic, and dietary  
13  
14 614 conditions, and maternal and child anaemia may reflect the household's common nutritional  
15  
16 615 status, and poor maternal iron intake during pregnancy, reduce breast milk might be the  
17  
18 616 possible reason.  
19  
20  
21  
22

23 617 EDHS data set indicated that the incidence of fever had an impact on childhood anaemia.  
24  
25 618 This is in line with studies done in Ghana and South Ethiopia Wolaita (24,37) Results showed  
26  
27 619 that children who had a fever in the last two weeks before the survey had had a higher  
28  
29 620 likelihood of anaemia than children who had not to fever. This could be attributed to the  
30  
31 621 infectious cause of childhood fever mainly malaria, tuberculosis, and Leishmaniasis which  
32  
33 622 cause anaemia by destructing red blood cells or other related mechanisms.  
34  
35  
36

37 623 The nutritional status of children had a significant association with childhood anaemia. The  
38  
39 624 stunting status of children was an independent predictor in the multilevel mixed effect model  
40  
41 625 of this study. The result of this study indicated that it was in line with previous studies  
42  
43 626 conducted in South Africa(36), Bangladesh(38,39), and Ethiopia(40,41). This study revealed  
44  
45 627 that there was a greater prevalence of anaemia among stunted children compared to non-  
46  
47 628 stunted children. Children suffering from nutritional deficiency were more likely to have weak  
48  
49 629 immune systems, making them vulnerable to various illnesses and healthiness such as  
50  
51 630 parasitic infections or chronic inflammation. Many of these conditions reduce the  
52  
53 631 haemoglobin level in the blood leading to increased anaemia prevalence. The statement is  
54  
55  
56  
57  
58  
59  
60

1 632 supported by the evidence given in other studies(42)that nutritional deficiency causes several  
2  
3 633 health hazards.  
4  
5

6 634 Besides, severely wasting children were more likely to be anaemic than their counterpart.  
7  
8 635 Since stunting and wasting are long-term and short-term indicators of malnutrition, the results  
9  
10  
11 636 implied that under-nourished children experience a higher risk of developing anaemia than  
12  
13 637 nourished children. Odds of experiencing anaemia for those birth order four up to five and six  
14  
15 638 and greater than six were higher than those of the first order. This finding was similar to a  
16  
17  
18 639 study done in Indian(15,43). This could be due to the distribution of scarce resources within  
19  
20 640 the family and related to the maternal exhaustion of micronutrient feeding practices.  
21  
22

23 641 In a multivariable multilevel analysis, the odds of developing childhood anaemia were higher  
24  
25 642 among children who lived in Somali, Dire Dawa, Afar, and Gambela compared to the Amhara  
26  
27  
28 643 region. This might be due to the unavailability and inaccessibility of health facilities as  
29  
30 644 compared to the regions. Regional variation in the nutrient intake can cause significant health  
31  
32 645 disparity, and this variability may be mediated by factors such as food availability, food  
33  
34  
35 646 customs, and culture.  
36

37 647 This study, used different spatial pattern, trends, and a multilevel regression model because  
38  
39  
40 648 of nested or cluster samples to show the effect of individual predictors and community-level  
41  
42 649 variables on the dependent variable. The study was based on a large dataset representing  
43  
44  
45 650 the whole country of Ethiopia and which was weighted to make it nationally representative  
46  
47 651 and adjusted for the design to get a reliable estimate. However, there were some limitations  
48  
49 652 to this study. The cross-sectional nature of the data prevents causality from being inferred  
50  
51 653 between the independent and dependent variables. Also, respondents' data that didn't have  
52  
53  
54 654 files (longitude and latitude) were excluded from the spatial analysis which could affect the  
55  
56 655 overall result and the generalizability of the findings.  
57  
58  
59  
60

## Conclusion

This study indicated that the prevalence of childhood anaemia decreased between the 2005-2011 survey while the prevalence increased from 2011-2016 EDHS. The spatial pattern of child anaemia in Ethiopia was non-random among the three consecutive surveys with the global Moran's I value of 0.176, 0.18, and 0.09 in EDHS 2005, 2011, and 2016. In this study, Sat Scan analysis identified the primary and secondary clusters for the three survey periods. In 2005 EDHS, the hotspot area was identified in eastern and southern parts of Somalia, in 2011, Somali, Afar, Eastern Oromia, Dire Dawa, and Harari were among the hotspot regions. Spatial sat scan analysis revealed that spatial clustering of childhood anaemia was identified in Somali, Afar, Eastern Oromia, Dire Dawa, Harari hotspot area in the 2016 EDHS period. Child age, women age, wealth index, maternal anaemia, fever, birth order, stunting, wasting and region were significant predictors among 6-59 months. Therefore, these results provide further insight into identifying the true picture of childhood anaemia spatio-temporal clusters and enable timely spatial targeting factors to alleviate childhood anaemia. Therefore, policymakers and health planners should design effective intervention strategies for the identified hot spot areas and individual and community-level factors.

## Abbreviations

AOR-Adjusted Odds Ratio, CSA-Central Statics Agency, CI-Confidence Interval, COR-Crude Odds Ratio, EDHS-Ethiopia Demographic and Health Survey, GPS-Global Positioning System, ICC-Intra Class Correlation Coefficient, LLR-Log-Likelihood Ratio, MOR-Median odds ratio, OR-Odds Ratio, RR-Relative Risk, PVC-Proportional Change in Variance, SNNPR- Southern Nations, Nationalities, and Peoples' Region.

## 679 **Declarations**

### 680 **Onset to participate**

681 The institutional ethical review committee board approved the study. Ethical clearance was  
682 obtained from ethical review board of the University of Gondar. Upon this clearance, the  
683 study was conducted. The congeniality of the data was maintained by using the extracted  
684 data only for the study purpose and keeping the data from a third party.

### 685 **Consent for publication**

686 Not-applicable

### 687 **Data sharing statement**

688 The data in which the authors used to produce this manuscript are available upon reasonable  
689 request

### 690 **Competing interests**

691 The authors declare that they have no competing interests.

### 692 **Funding**

693 No funding

### 694 **Contributors**

695 Proposal preparation, acquisition of data, analysis, and interpretation of data was done by  
696 SH, AM, ZM and BF guided the study design data collection and analysis. SH drafted the  
697 manuscript and all authors have a substantial contribution in revising and finalizing the  
698 manuscript. All authors read and approved the final manuscript.

### 699 **Acknowledgments**

700 The authors gratefully acknowledge the support received from the University of Gondar. We  
701 also thank the Ethiopian Central Statistics Agency for providing us with the data and shape  
702 files for this study.

## References

1. WHO. Nutritional Anaemias : Tools for Effective Prevention. World Health Organization. 2017. 1–83 p.
2. WHO. Global estimates of the prevalence of anaemia in infants and children aged 6 – 59 months , 2011 Global estimates of the prevalence of anaemia , all women of reproductive age , 15 – 49 years , 2011. Scaling Up Nutr [Internet]. 2015; Available from: [http://www.who.int/nutrition/publications/micronutrients/global\\_prevalence\\_anaemia\\_2011\\_maps.pdf?ua=1](http://www.who.int/nutrition/publications/micronutrients/global_prevalence_anaemia_2011_maps.pdf?ua=1)
3. WHO. The global prevalence of anaemia in 2011. Who [Internet]. 2011;1–48. Available from: <https://apps.who.int/iris/handle/10665/177094>
4. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of anaemia, WHO vitamin and mineral nutrition information system, 1993–2005. *Public Health Nutr.* 2009;12(4):444–54.
5. Malkanthi RLDK, Silva KDRR, Jayasinghe-Mudalige UK. Risk Factors Associated with High Prevalence of Anemia among Children under 5 Years of Age in Paddy-Farming Households in Sri Lanka. *Food Nutr Bull.* 2010;31(4):475–82.
6. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. *Public Health Nutr.* 2009;12(4):444–54.
7. Leal LP, Batista Filho M, de Lira PIC, Figueiroa JN, Osório MM. Temporal trends and anaemia-associated factors in 6- to 59-month-old children in Northeast Brazil. *Public Health Nutr.* 2012;15(9):1645–52.
8. Olivares M, Walter T, Hertrampf E, Pizarro F. Anaemia and iron deficiency disease in children. *Br Med Bull [Internet].* 1999 Sep 1;55(3):534–43. Available from: <https://doi.org/10.1258/0007142991902600>
9. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study. *BMJ Open [Internet].* 2018 May 1;8(5):e019654. Available from: <http://bmjopen.bmj.com/content/8/5/e019654.abstract>
10. Central Statistical Agency, ORC Macro. Ethiopia Demographic and Health Survey 2005. *Heal San Fr [Internet].* 2006;(September):[446]. Available from: [http://www.measuredhs.com/pubs/pdf/FR179/FR179\[23June2011\].pdf](http://www.measuredhs.com/pubs/pdf/FR179/FR179[23June2011].pdf)
11. Central Statistical Agency [Ethiopia], ICF International. Ethiopia Demographic and Health Survey 2011. 2012;1–452.
12. ECSA. Ethiopian Demographic Health Survey 2016. 2016. 161 p.
13. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: analysis from Togo demographic and health survey data, 2013–2014. *BMC Public Health.* 2019;19(1):1–9.
14. Malako BG, Teshome MS, Belachew T. Anemia and associated factors among children aged 6-23 months in Damot Sore District, Wolaita Zone, South Ethiopia. *BMC Hematol.* 2018;18(1):1–9.
15. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: A cross-sectional study. *BMJ Open.* 2018;8(5):1–14.
16. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns of anaemia among young children in nigeria: A bayesian semi-parametric modelling. *Int Health.* 2014;6(1):35–45.
17. Desalegn A, Mossie A, Gedefaw L. Nutritional Iron Deficiency Anemia: Magnitude and



- 1 752 Its Predictors among School Age Children, Southwest Ethiopia: A Community Based  
 2 753 Cross-Sectional Study. PLoS One [Internet]. 2014 Dec 1;9(12):e114059. Available  
 3 754 from: <https://doi.org/10.1371/journal.pone.0114059>  
 4 755 18. Guerra CA, Snow RW, Hay SI. Defining the global spatial limits of malaria transmission  
 5 756 in 2005. *Adv Parasitol*. 2006;62:157–79.  
 6 757 19. Kulldorff M. *SatScan user guide 2006*. 2018;  
 7 758 20. Bartko JJ. The Intraclass Correlation Coefficient as a Measure of Reliability. *Psychol*  
 8 759 *Rep*. 1966 Aug;19(1):3–11.  
 9 760 21. Assessment IS. Understanding Variability in Multilevel Models Sophia Rabe-Hesketh  
 10 761 Example : PISA ( Programme for International Student Assessment ) PISA :  
 11 762 Distribution of SES.  
 12 763 22. Enawgaw B, Workineh Y, Tadesse S, Mekuria E, Addisu A, Genetu M. Prevalence of  
 13 764 anemia and associated factors among hospitalized children attending the University of  
 14 765 Gondar Hospital, Northwest Ethiopia. *Electron J Int Fed Clin Chem Lab Med*.  
 15 766 2019;30(1):35–47.  
 16 767 23. Semedo RML, Santos MMAS, Baião MR, Luiz RR, Da Veiga G V. Prevalence of  
 17 768 Anaemia and Associated Factors among Children below Five Years of Age in Cape  
 18 769 Verde, West Africa. *J Heal Popul Nutr*. 2014;32(4):646–57.  
 19 770 24. Tiku YS, Mekonnen TC, Workie SB, Amare E. Does Anaemia Have Major Public  
 20 771 Health Importance in Children Aged 6–59 Months in the Duggina Fanigo District of  
 21 772 Wolaita Zone, Southern Ethiopia? *Ann Nutr Metab* [Internet]. 2018;72(1):3–11.  
 22 773 Available from: <https://www.karger.com/DOI/10.1159/000484324>  
 23 774 25. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns  
 24 775 of anaemia among young children in Nigeria: a Bayesian semi-parametric modelling.  
 25 776 *Int Health* [Internet]. 2014 Jan 31;6(1):35–45. Available from:  
 26 777 <https://doi.org/10.1093/inthealth/iht034>  
 27 778 26. Roberts DJ, Matthews G, Snow RW, Zewotir T, Sartorius B. Investigating the spatial  
 28 779 variation and risk factors of childhood anaemia in four sub-Saharan African countries.  
 29 780 *BMC Public Health*. 2020;20(1):126.  
 30 781 27. Diao X, Taffesse AS, Thurlow J, Pratt AN, Yu B, Orkin K, et al. NEWSLETTER -  
 31 782 Ethiopia Strategy Support Program II ( ESSP-II ) Highlights of Presentations Summer –  
 32 783 Fall 2010 : h NEWSLETTER - Ethiopia Strategy Support Program II ( ESSP-II )  
 33 784 Capacity Building Initiatives 2010 : 2010;(December).  
 34 785 28. Gebreweld A, Ali N, Ali R, Fisha T. Prevalence of anemia and its associated factors  
 35 786 among children under five years of age attending at Guguftu health center, South  
 36 787 Wollo, Northeast Ethiopia. *PLoS One* [Internet]. 2019 Jul 5;14(7):e0218961. Available  
 37 788 from: <https://doi.org/10.1371/journal.pone.0218961>  
 38 789 29. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged  
 39 790 from 6 to 59 months in Togo: analysis from Togo demographic and health survey data,  
 40 791 2013–2014. *BMC Public Health* [Internet]. 2019;19(1):215. Available from:  
 41 792 <https://doi.org/10.1186/s12889-019-6547-1>  
 42 793 30. Mohammed SH, Habtewold TD, Esmailzadeh A. Household, maternal, and child  
 43 794 related determinants of hemoglobin levels of Ethiopian children: Hierarchical  
 44 795 regression analysis. *BMC Pediatr*. 2019;19(1):1–10.  
 45 796 31. Keikhaei B, Zandian K, Ghasemi A, Tabibi R. Iron-Deficiency Anemia among Children  
 46 797 in Southwest Iran. *Food Nutr Bull*. 2007 Dec;28(4):406–11.  
 47 798 32. Campbell JR, Holland J. *Development research. Focaal*. 2007;2005(45):3–17.  
 48 799 33. Gebreegiabiher G, Etana B, Niggusie D. Determinants of Anemia among Children  
 49 800 Aged 6–59 Months Living in Kilte Awulaelo Woreda, Northern Ethiopia. *Benz EJ*,

- 1 801 editor. Anemia [Internet]. 2014;2014:245870. Available from:  
 2 802 <https://doi.org/10.1155/2014/245870>
- 3 803 34. Ayoya MA, Ngnie-Teta I, Séraphin MN, Mamadoultai bou A, Boldon E, Saint-Fleur JE,  
 4 804 et al. Prevalence and risk factors of anemia among children 6-59 months old in Haiti.  
 5 805 Anemia. 2013;2013:2-5.
- 6 806 35. Pasricha SR, Black J, Muthayya S, Shet A, Bhat V, Nagaraj S, et al. Determinants of  
 7 807 anemia among young children in rural India. *Pediatrics*. 2010;126(1).
- 8 808 36. Ntenda PAM, Nkoka O, Bass P, Senghore T. Maternal anemia is a potential risk factor  
 9 809 for anemia in children aged 6-59 months in Southern Africa: a multilevel analysis. *BMC*  
 10 810 *Public Health* [Internet]. 2018;18(1):650. Available from:  
 11 811 <https://doi.org/10.1186/s12889-018-5568-5>
- 12 812 37. Shenton LM, Jones AD, Wilson ML. Factors Associated with Anemia Status Among  
 13 813 Children Aged 6-59 months in Ghana, 2003-2014. *Matern Child Health J*.  
 14 814 2020;24(4):483-502.
- 15 815 38. Khan JR, Awan N, Misu F. Determinants of anemia among 6-59 months aged children  
 16 816 in Bangladesh: evidence from nationally representative data. *BMC Pediatr* [Internet].  
 17 817 2016;16(1):3. Available from: <https://doi.org/10.1186/s12887-015-0536-z>
- 18 818 39. Rahman MS, Mushfiquée M, Masud MS, Howlader T. Association between malnutrition  
 19 819 and anemia in under-five children and women of reproductive age: Evidence from  
 20 820 Bangladesh Demographic and Health Survey 2011. *PLoS One*. 2019  
 21 821 Jul;14(7):e0219170-e0219170.
- 22 822 40. Belachew A, Tewabe T. Under-five anemia and its associated factors with dietary  
 23 823 diversity, food security, stunted, and deworming in Ethiopia: systematic review and  
 24 824 meta-analysis. *Syst Rev*. 2020 Feb;9(1):31.
- 25 825 41. Malako BG, Asamoah BO, Tadesse M, Hussen R, Gebre MT. Stunting and anemia  
 26 826 among children 6-23 months old in Damot Sore district, Southern Ethiopia. *BMC Nutr*.  
 27 827 2019;5(1):1-11.
- 28 828 42. Pelletier DL, Frongillo Jr EA, Schroeder DG, Habicht JP. The effects of malnutrition on  
 29 829 child mortality in developing countries. *Bull World Health Organ*. 1995;73(4):443-8.
- 30 830 43. Goswami S, Das KK. Socio-economic and demographic determinants of childhood  
 31 831 anemia. *J Pediatr (Rio J)*. 2015;91(5):471-7.

### 32 832 **Figure legend/caption**

- 33 833
- 34 834
- 35 835 **Figure 1: Trends in anemia overtime across the regions in Ethiopia, EDHS 2005 to 2016**
- 36 836
- 37 837 **Figure 2: Hot spot and cold spot analysis of anemia in Ethiopian, EDHS 2005 to 2016**
- 38 838
- 39 839 **Figure 3: Ordinary Kriging interpolation of anemia in Ethiopia, EDHS 2005 to 2016**
- 40 840
- 41 841
- 42 842
- 43 843 **Figure 4: SaTScan scan statistics analysis of anemia in Ethiopia, EDHS, 2005-2016**
- 44 844
- 45 845
- 46 846
- 47 847
- 48 848
- 49 849
- 50 850
- 51 851
- 52 852
- 53 853
- 54 854
- 55 855
- 56 856
- 57 857
- 58 858
- 59 859
- 60 860

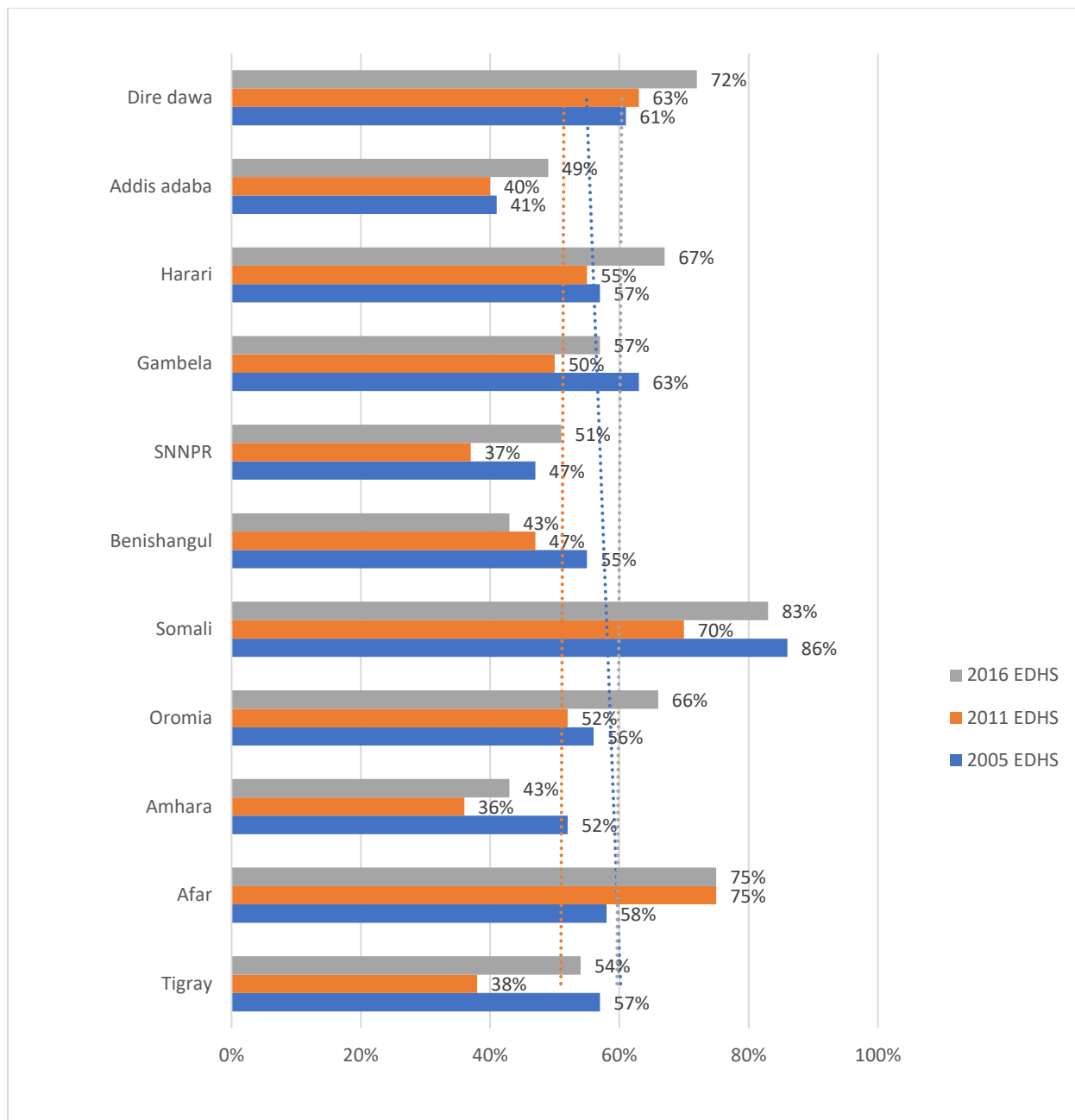
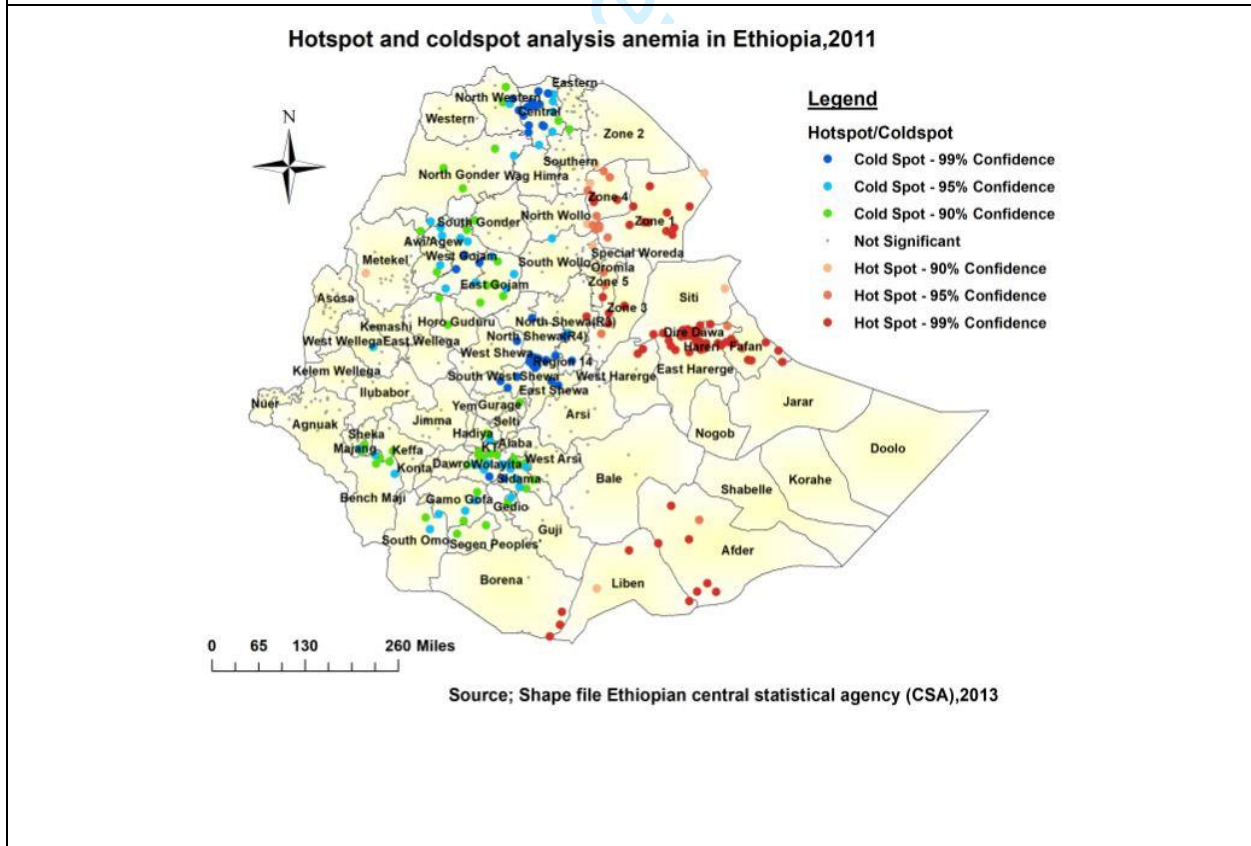
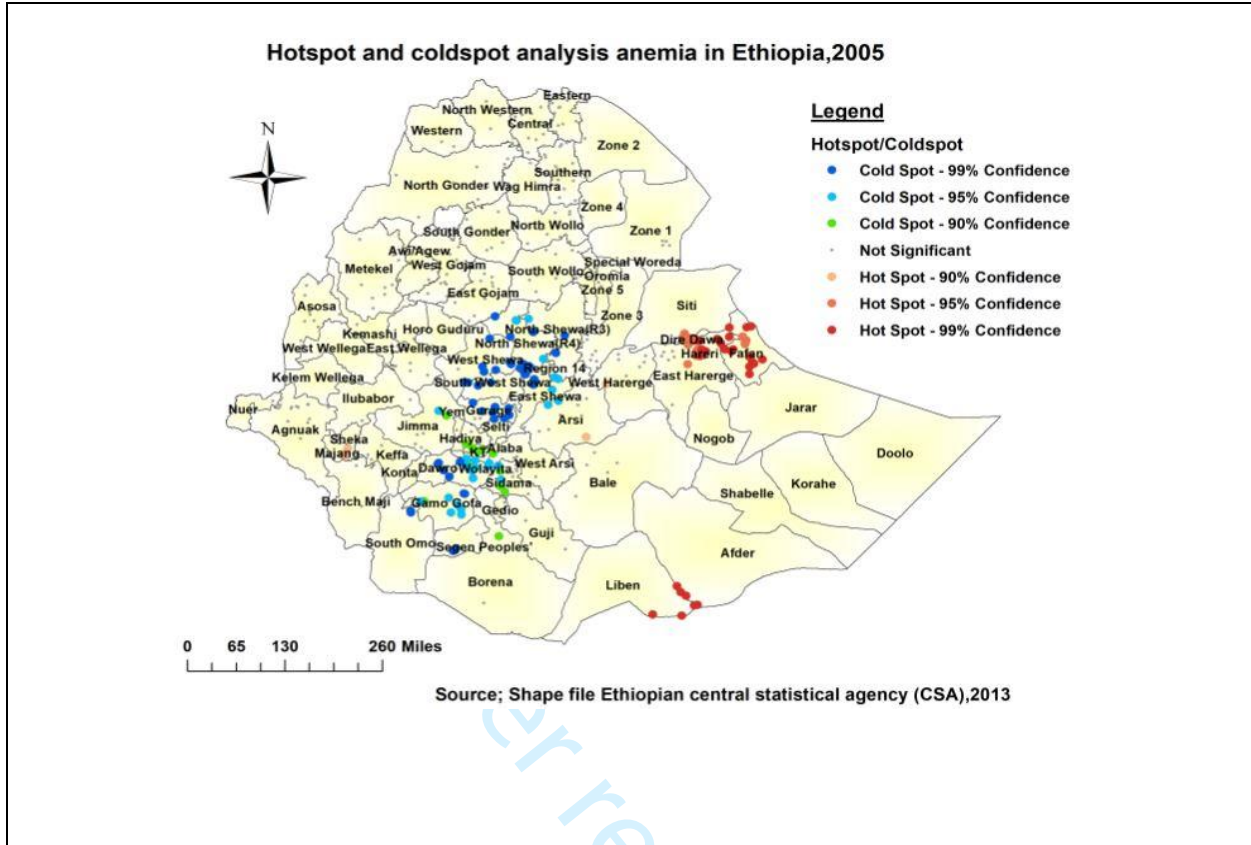


Figure 1: Trends in anemia overtime across the regions in Ethiopia, EDHS 2005 to 2016



1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

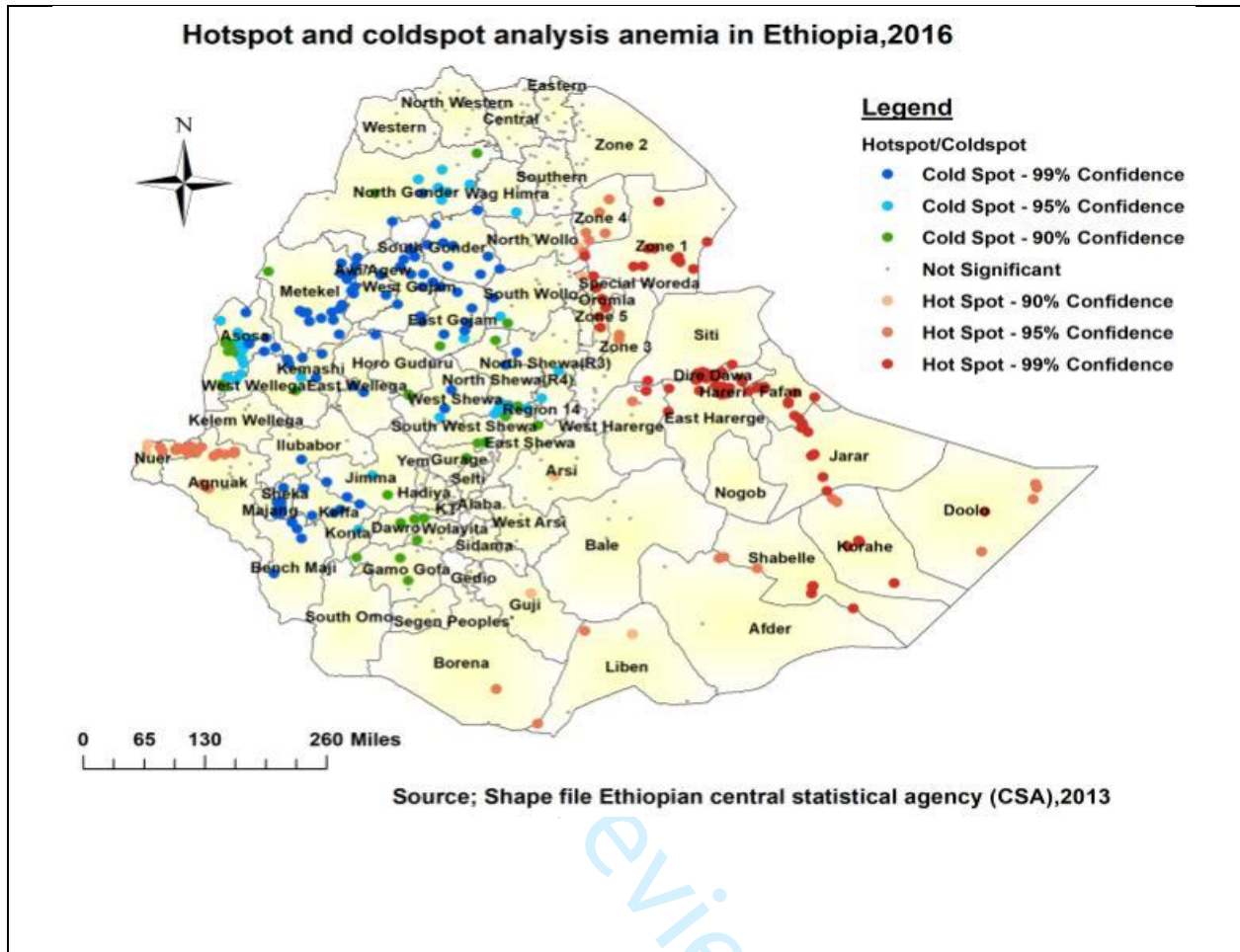
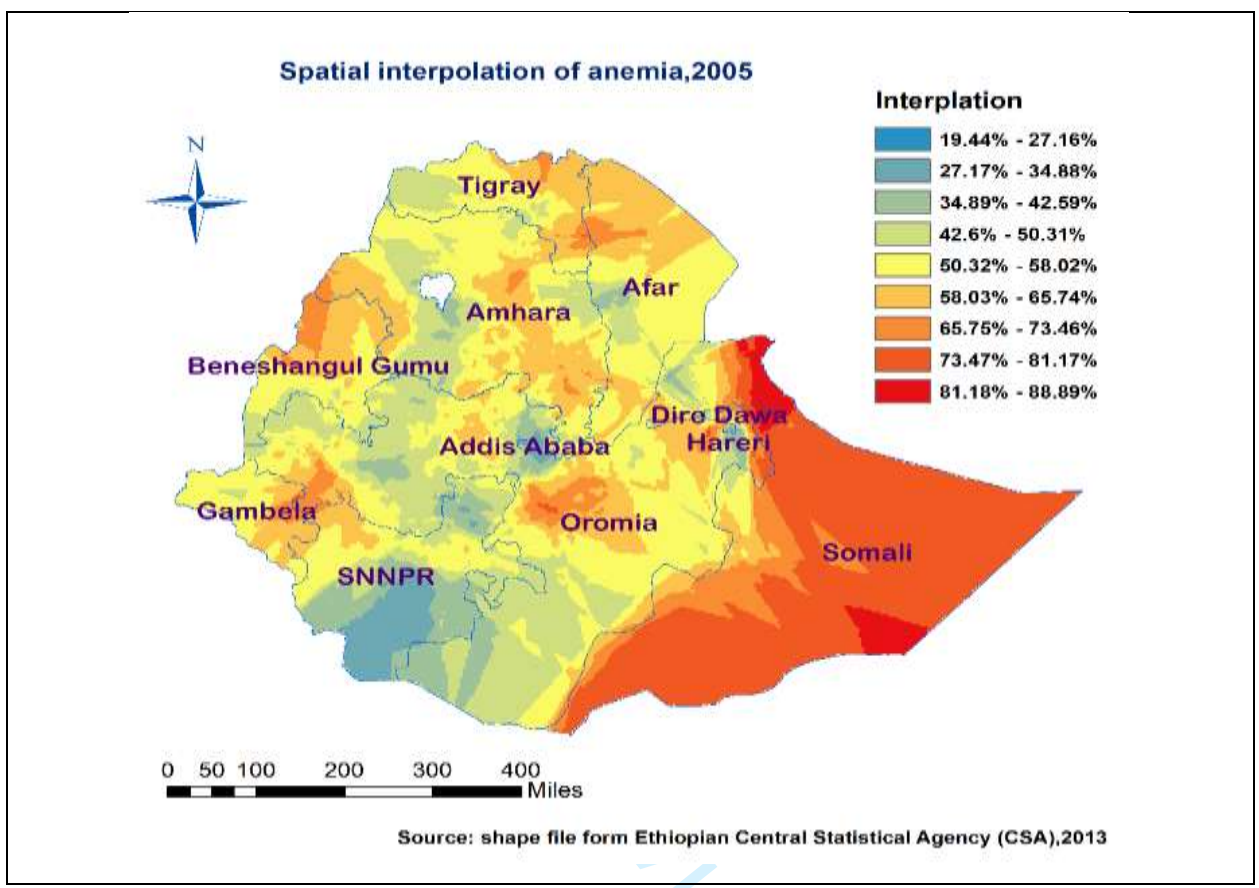


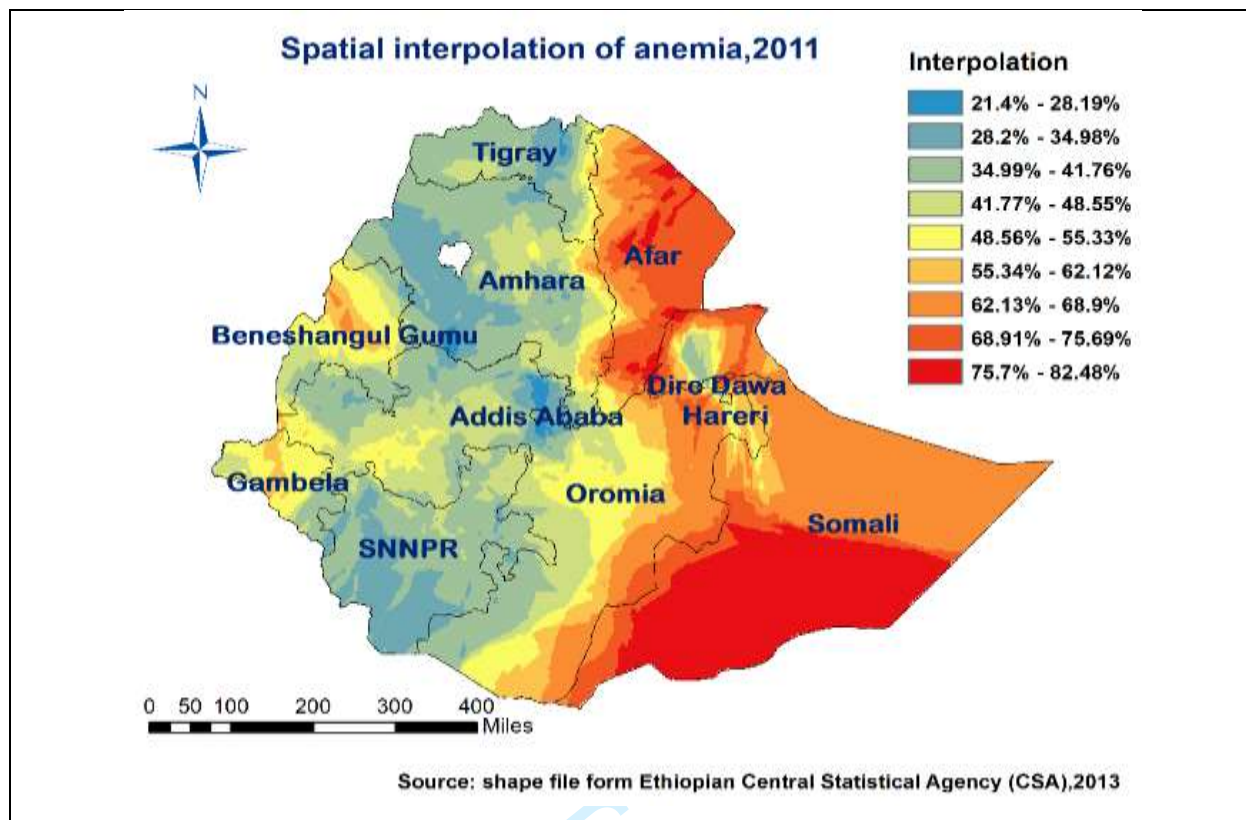
Figure 2: Hot spot and cold spot analysis of anemia in Ethiopian, EDHS 2005 to 2016

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60



Review only

BMJ Open: first published as 10.1136/bmjopen-2020-045544 on 17 August 2021. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.



1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

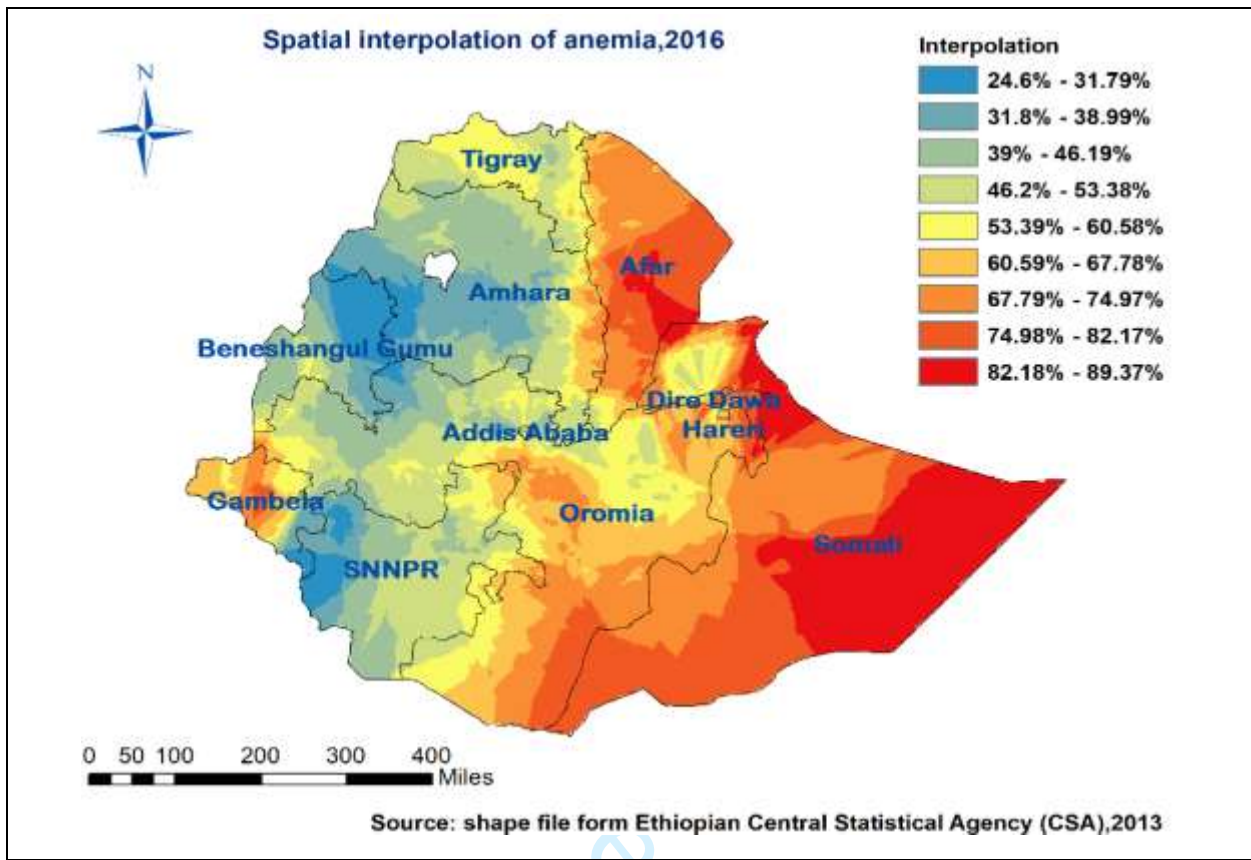
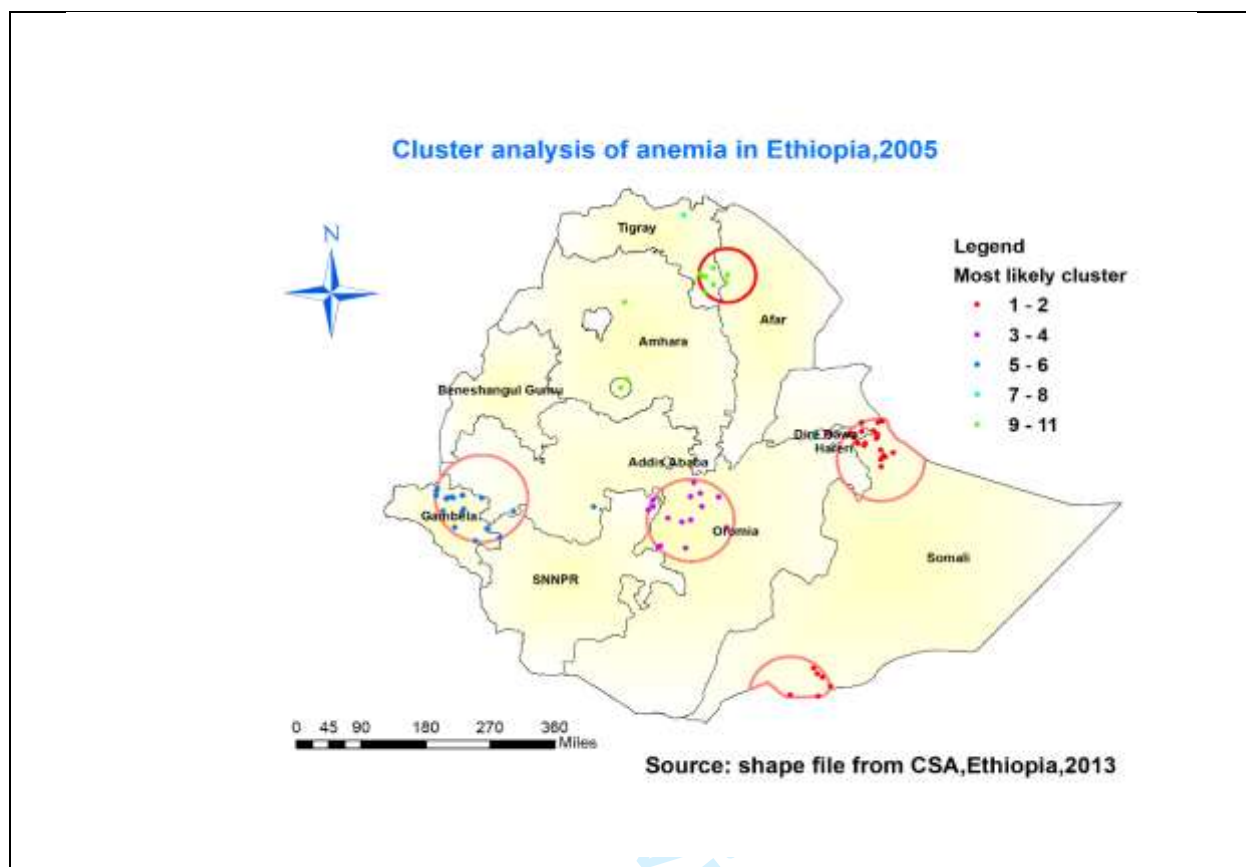


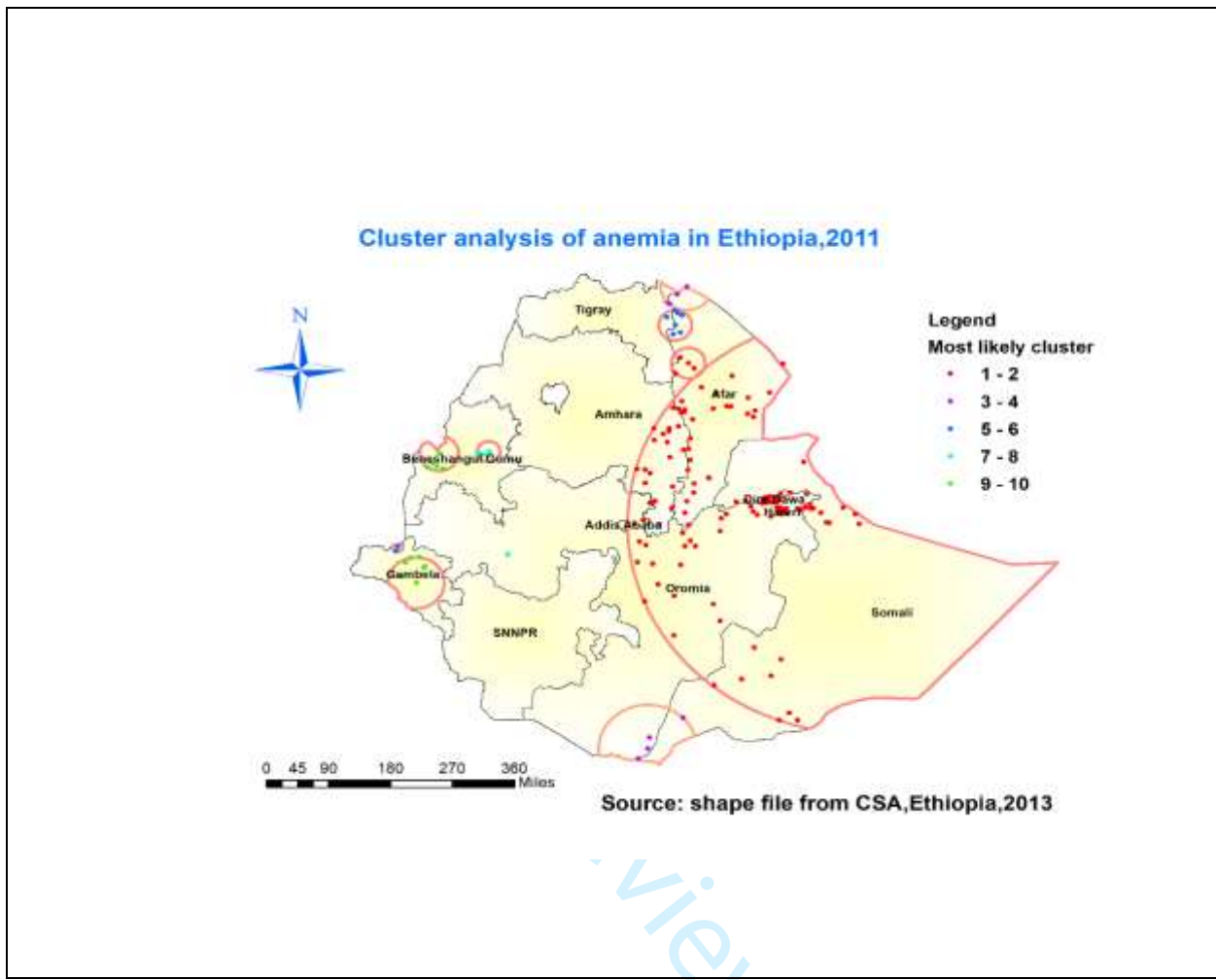
Figure 3: Ordinary Kriging interpolation of anemia in Ethiopia, EDHS 2005 to 2016

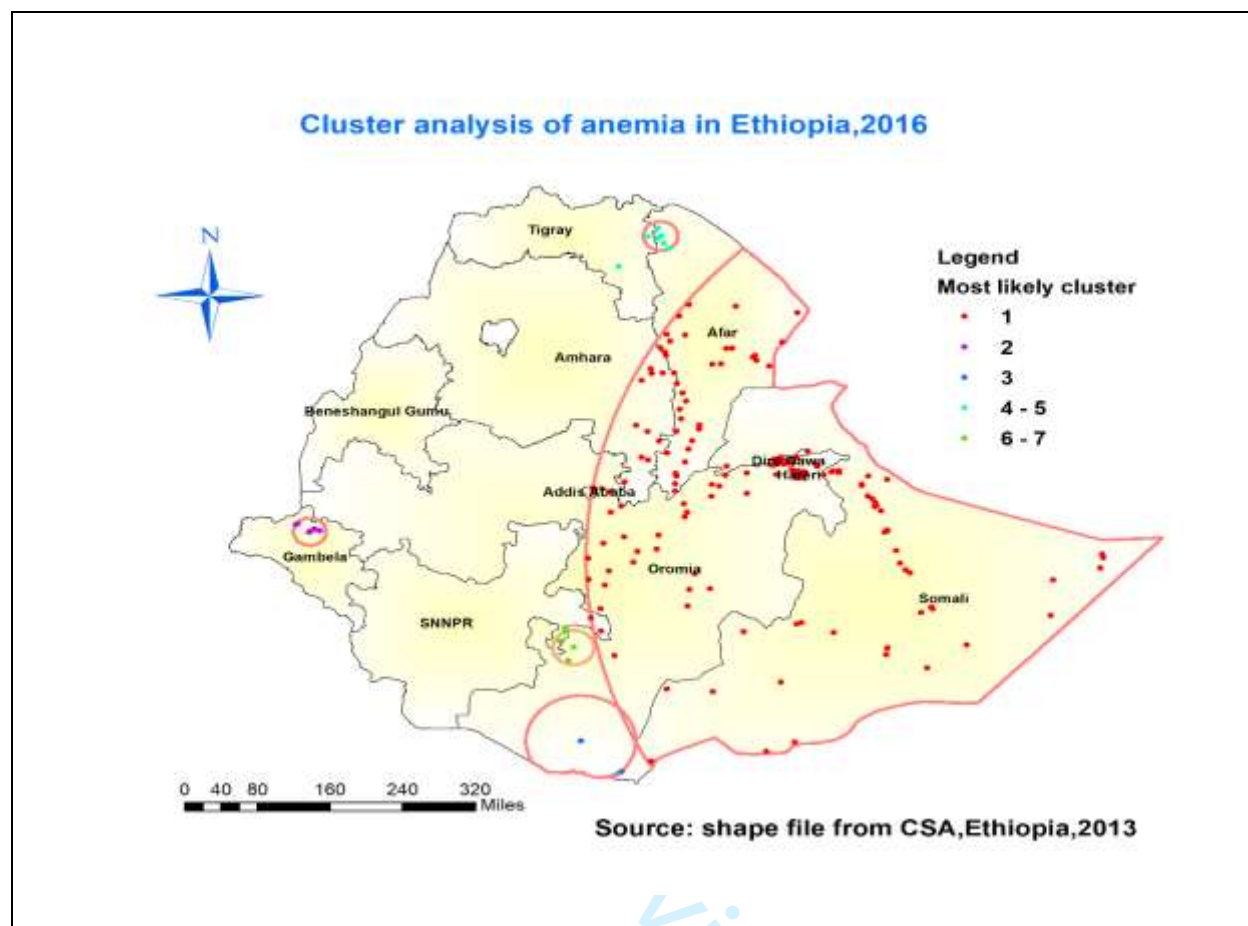
BMJ Open: first published as 10.1136/bmjopen-2020-045544 on 17 August 2021. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.





1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60





34 Figure 4: SaTScan scan statistics analysis of anemia in Ethiopia, EDHS, 2005-2016

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	<b>Item No</b>	<b>Recommendation</b>
<b>Title and abstract</b>	1	Cross-sectional study design Aimed Spatiotemporal distribution and factors associated to childhood anaemia Spatial analysis revealed that the spatial distribution of anaemia varied across the country In mixed effect model Child age, women age, maternal anaemia status, wealth index, birth order, fever, stunting, wasting status, and region were significant predictors of childhood anaemia.
<b>Introduction</b>		
Background/rationale	2	Though childhood anaemia is a major public health problem in Ethiopia, there is limited evidence on the spatio-temporal variability of childhood anaemia overtime. study attempts to fill the gap by investigating the spatio-temporal distribution of anaemia and its associated factors using multilevel model, since its hierarchical nature.
Objectives	3	Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anaemia using the Ethiopian Demographic and health survey (EDHS) data from 2005-2016
<b>Methods</b>		
Study design	4	Survey-based cross-sectional study design was employed for the EDHS
Setting	5	All nine regions and two city administrations of Ethiopia in 2005, 2011 and 2016.
Participants	6	The source population for this study was all 6–59 months of children in Ethiopia. A total of 21,302 children aged 6-59 months were included in this study.
Variables	7	<b>Outcome measure:</b> The outcome variable was child anaemia status <b>Independent:</b> sociodemographic (religion, mother age, marital status, educational status, husband education, wealth index, mothers working status, numbers of under five children) Maternal and Child- related (child sex, age, birth size, birth order, maternal BMI, maternal anaemia, breastfeeding, fever, diarrhoea, vitamin supplement, stunting and wasting). Community-level (residence, region, community women education and community women poverty).
Data sources/ measurement	8*	DHS program (Demographic and Health Survey) website( <a href="http://www.measuredhsprogram.com">www.measuredhsprogram.com</a> ) after obtaining the necessary permissions for the download and further analyses.
Bias	9	Cross-sectional nature of the data prevents causality from being inferred between the independent and dependent variables
Study size	10	A total of 21,302 children (3,868 in 2005, 8,958 - in 2011, and 8476 in 2016) were included in this study
Quantitative variables	11	Quantitative variables were handled in three level Level-0 intercept model Level-1 cluster with individual variables Level -2 community- level with cluster Level -3 mixed level individuals with community
Statistical methods	12	Multilevel model for associated factors, we use mixed effect to control confounding than traditional regression model.

		Spatial analysis was performed
		For associated factor predictors with missing dropped and for spatial analysis without spatial information was dropped
		Secondary data analysis and participants were selected based on a stratified two-stage cluster sampling technique
		Spatiotemporal pattern analysis was done for three-year data
<b>Results</b>		
Participants	13*	A total of 21,302 children Secondary data analysis Simply we take from EDHS
Descriptive data	14*	A total of 21,302 children with known haemoglobin levels (3,868 in 2005, 8,958 in 2011, and 8467 in 2016) were included in this study. The prevalence of anaemia for the three consecutive surveys was 53.9%, 44.6%, and 57.6% in 2005, 2011, and 2016 EDHS data respectively The majority of children were from rural residency in five years preceding the survey in three surveys. About 78.6%, 70%, and 67% of women were unable to read and write in 2005, 2011, and 2016 survey respectively. Children from poor and middle-class families were more anaemic than children from rich families across the three EDHS survey Husband educational level was missing data
Outcome data	15*	The dependent variable was child anaemia status, categorized as “anaemic/not-anaemic” for this study.
Main results	16	The spatial distribution of childhood anaemia in Ethiopia was non-random in all three consecutive surveys. The global Moran’s I test value was 0.176 (P-value <0.001) in 2005, 0.18 (P-value < 0.001) in 2011, and 0.09(P-value < 0.005) in 2016 Ethiopian Demographic and health surveys. In multivariable multilevel mixed-effect logistic regression analysis, individual-level factors such as the age of the child, wealth index, mother age, maternal anaemic status, birth order, fever, stunting, and wasting status were significant predictor of childhood anaemia. Not-applicable Not-applicable
Other analyses	17	Different spatial technique spatial autocorrelation, hotspot/cold spot analysis, interpolation, and sat scan analysis
<b>Discussion</b>		
Key results	18	This study tried to identify spatio-temporal distribution and predictors of childhood anaemia across the regions in Ethiopia. 2005, 2011, and, 2016 Ethiopian Demographic and Health Survey data were used. In this study, anaemia's trend was decreased from 2005 to 2011, while the rate significantly increased from 2011 to 2016. The study revealed that 57.56% [CL: 0.56-0.59] of children were anaemic in 2016, preceding the survey. This finding was in line with a study done in Gondar, Northwest Ethiopia 58.6%

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

The spatial pattern shows the geographical inequality of anaemia by using sat scan and GIS spatial techniques like cluster mapping tools and interpolation techniques. The spatial analysis indicates that the distribution of childhood anaemia was non-random across the country with a global Moran's I index of 0.176 in 2005, 0.18 in 2011, and 0.09 in 2016 with a significant p-value, which indicates substantial-considerable clustering areas. This study's findings were in line with a study done in Nigeria, Malawi, Tanzania, and Uganda

Limitations	19	The cross-sectional nature of the data prevents causality from being inferred between the independent and dependent variables  Respondents' without coordinate (longitude and latitude) were excluded from the spatial analysis, which could affect the generalizability of the findings
Interpretation	20	Prevalence of childhood anaemia decreased between the 2005-2011 survey while the prevalence increased from 2011-2016 EDHS. The spatial pattern of child anaemia in Ethiopia was non-random among the three consecutive surveys with the global Moran's I value of 0.176, 0.18, and 0.09 in EDHS 2005, 2011, and 2016.  In line study done Cape Verde, west Africa, Nigeria, Malawi, Tanzania, and Uganda
Generalisability	21	Policymakers and health planners should design effective intervention strategies for the identified hot spot areas and individual and community-level factors to anaemia. For health care community, and researcher to alleviate the problem.
<b>Other information</b>		
Funding	22	No funding

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).

# BMJ Open

## Spatio-temporal distribution and associated factors of anaemia among children aged 6–59 months in Ethiopia: Based on the EDHS 2005– 2016: A spatial and multilevel analysis

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-045544.R2
Article Type:	Original research
Date Submitted by the Author:	29-Jun-2021
Complete List of Authors:	Samuel, Hailegebreal; Arba Minch University, Department of Health Informatics Nigatu, Araya; University of Gondar, Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia Mekonnen, Zeleke; Ethiopia Ministry of Health, Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia; Endehabtu, Berhanu; University of Gondar, Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia
<b>Primary Subject Heading</b>:	Paediatrics
Secondary Subject Heading:	Public health
Keywords:	Anaemia < HAEMATOLOGY, PAEDIATRICS, Community child health < PAEDIATRICS

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.



1 Spatio-temporal distribution and associated factors of anaemia among children aged 6–59  
2 months in Ethiopia: Based on the EDHS 2005- 2016: A spatial and multilevel analysis  
3  
4  
5  
6 Samuel Hailegebreal<sup>1\*</sup>, Araya Mesfin Nigatu<sup>2</sup>, Zeleke Abebaw Mekonnen<sup>2,3</sup>, Berhanu Fikadie  
7  
8 Endehabtu<sup>2</sup>  
9

## 10 11 **Affiliation**

12  
13  
14 <sup>1</sup>Arba Minch University, College of Medicine and Health Sciences, School of Public Health  
15  
16 Department of Health Informatics, Ethiopia  
17

18  
19 <sup>2</sup>Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia  
20

21  
22 <sup>3</sup>Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia  
23  
24

## 25 26 27 28 **Corresponding author**

29  
30 Samuel Hailegebreal  
31

32  
33 Email: [samuastd@gmail.com](mailto:samuastd@gmail.com)  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## Abstract

**Objectives:** Anaemia is a global public health problem with major health and socio-economic consequences. Though childhood anaemia is a major public health problem in Ethiopia, there is limited evidence on the spatio-temporal variability of childhood anaemia overtime in the country. Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anaemia using the Ethiopian Demographic and Health Survey (EDHS) data from 2005-2016.

**Design:** Survey-based cross-sectional study design was employed for the EDHS.

**Setting:** Data were collected in all nine regions and two city administrations of Ethiopia in 2005, 2011 and 2016.

**Participants:** The source population for this study was all 6–59 months of children in Ethiopia. A total of 21,302 children aged 6-59 months were included in this study.

**Outcome measure:** The outcome variable was child anaemia status.

**Results:** The prevalence of anaemia declined from 53.9% in 2005 to 44.6% in 2011, but it showed an increment in 2016 to 57.6%. The spatial analysis revealed that the spatial distribution of anaemia varied across the regions. The spatial scan statistics analysis indicated, a total of 22 clusters (RR= 1.5, P-value < 0.01) in 2005, 180 clusters (RR = 1.4, P-value < 0.01) in 2011, and 219 clusters (RR = 1.4, P-value < 0.01) in 2016 significant primary clusters were identified. Child age, women age, maternal anaemia status, wealth index, birth order, fever, stunting, wasting status, and region were significant predictors of childhood anaemia.

**Conclusions:** In this study, childhood anaemia remains a public health problem. The spatial distribution of childhood anaemia was significantly varied across the country. Individual-level and community-level factors were associated with childhood anaemia. Therefore, in regions

1 45 with a high risk of childhood anaemia, individual and community level factors should be  
2  
3 46 intensified by allocating additional resources and providing appropriate and tailored strategies.  
4  
5

6 47 **Keywords:** Anaemia, Childhood, EDHS, Spatial, Multilevel, Ethiopia  
7  
8

9 48  
10  
11  
12 49 **Strengths and limitations of this study**  
13

- 14 50 • This study applied different methods of spatial pattern, trend and a multilevel logistic  
15  
16 51 regression models accounting for the nested nature of EDHS data  
17  
18
- 19 52 • The study was based on three consecutive EDHS dataset's representing the whole  
20  
21 53 country of Ethiopia  
22
- 23 54 • The cross-sectional nature of the data prevents causality from being inferred between  
24  
25 55 the independent and dependent variables  
26  
27
- 28 56 • Respondents without coordinate (longitude and latitude) were excluded from the spatial  
29  
30 57 analysis, which could affect the generalizability of the findings  
31  
32  
33  
34 58  
35 59  
36  
37  
38 60  
39  
40  
41 61  
42  
43  
44 62  
45  
46  
47 63  
48  
49  
50 64  
51  
52  
53 65  
54  
55  
56 66  
57  
58  
59  
60

## 67 **Background**

68 Anaemia is a condition characterized by a low level of haemoglobin in the blood(1). Over 273  
69 million under-five children suffer from anaemia worldwide(2). Sub-Saharan Africa is one of the  
70 most affected regions, accounting for about 53.8%(2). World Health Organization (WHO) had  
71 developed a classification system to facilitate international comparisons of anaemia as public  
72 health crises. The problem was considered severe if anaemia prevalence is  $\geq 40\%$ , moderate  
73 from 20% to 39.9%, and mild from 5% to 19.9%(3). The high prevalence of anaemia and its  
74 consequences on children's health, especially on their growth and development, have made it  
75 important public health problem, It also increases the risk of mortality and morbidity that come  
76 from other diseases(4,5).

77 Anaemia is a public health problem that affects populations in both industrialized and non-  
78 industrialized countries which touches all segments of the population. It is frequently observed  
79 among children and pregnant women who are the most vulnerable group because their iron  
80 requirements are higher than any other group(6). Anaemia is defined as a haemoglobin level  
81 below 11.0 g/dl for children age 6-59 month. Childhood anaemia is mainly caused by dietary  
82 iron deficiency, foliate, vitamin B12, vitamin A deficiencies, chronic inflammation, parasitic  
83 infections, nutritional deficiencies, hemoglobinopathies and inherited disorders were contribute  
84 to childhood anaemia (7,8).

85 The 2015 WHO report, from the global anaemia prevalence in 2011 showed that Africa, south  
86 east Asia, America, and European regions were, 62.3%, 53.8%, 23.3%, and 22.9%,  
87 respectively(3). In Sub-Saharan Africa, anaemia is a significant public health problem  
88 associated with an increased risk of death and impaired cognitive development(9).

89 Various-studies showed that the prevalence of anaemia among 6-59-month children is high  
90 and a severe public health problem. Evidence from various studies indicated that women age,

1 91 residence, maternal education status(10), an introduction of complementary foods, poor  
2  
3 92 breastfeeding practice, poor utilization of folic acid by mothers(11), maternal anaemia(12),  
4  
5 93 unemployment of the parent, and presence of sickle haemoglobin, household wealth index,  
6  
7  
8 94 and sex of the child were associated with childhood anaemia(13) . Few studies have been  
9  
10 95 done on factors associated with anaemia in Ethiopia, to date; the risk areas (hot spot) of  
11  
12 96 anaemia among children are not identified. Thus, this study aimed to assess the  
13  
14  
15 97 spatiotemporal patterns of anaemia among under five children in Ethiopia over the last one  
16  
17 98 and half-decades to point out whether there was either the shift or improvement in anaemia  
18  
19 99 risk areas following intervention programs in between the survey periods in Ethiopia.  
20  
21  
22 100 Geographical differences in the causes of anaemia can be partially explained by large-scale  
23  
24 101 variability in environmental drivers, particularly nutritional and infectious causes(14). The risk  
25  
26 102 of malaria is known to be associated with elevation and land surface temperature(15).  
27  
28  
29 103 Environmental drivers of anaemia tend to show a high degree of spatial dependency.  
30  
31 104 Therefore, detecting the geographic variation of anaemia during childhood is important to  
32  
33 105 prioritize and design targeted intervention programs to reduce anaemia especially in those  
34  
35 106 areas with a consistently higher risk of anaemia over time. Therefore, this study attempts to fill  
36  
37  
38 107 the gap by investigating the spatio-temporal distribution of anaemia and its associated factors  
39  
40 108 using multilevel model analysis in Ethiopia using the EDHS survey between 2005-2016 data.

## 42 109 **Methods and materials**

### 45 110 **Study design, setting and period**

47 111 The survey-based cross-sectional study design was employed using the 2005, 2011, and  
48  
49 112 2016 EDHS. Data access, extraction, and analysis were conducted from January to June 2020.

52 113 The study was conducted in Ethiopia located at the horn of Africa (3°-14°N and 33° – 48°E).

54 114 Administratively, the country is divided into nine regions and two city administrations. Each

1 115 region is sub-divided into zones, districts, towns, and kebeles (the smallest administrative  
2  
3 116 units).

### 6 117 **Source and study population**

9 118 All 6–59 months children in Ethiopia were the source population for this study whereas all  
10  
11 119 children aged from 6-59 months in the selected enumeration areas within five years before the  
12  
13  
14 120 survey were the study population.

### 17 121 **Sample size and sampling technique**

19 122 A total of 21,302 children (3,868 in 2005, 8,958 in 2011, and 8476 in 2016) were included in  
20  
21 123 this study. Children's record (KR) dataset was used for analysis. The survey covered all nine  
22  
23  
24 124 regions and the two city administrations of Ethiopia. Participants were selected based on a  
25  
26 125 stratified two-stage cluster sampling technique in each survey year. After excluding clusters  
27  
28 126 with zero coordinates and missing information, a total of 503 clusters in 2005, 569 clusters in  
29  
30  
31 127 2011, and 615 clusters in 2016 were used for analysis. The detailed sampling procedure was  
32  
33 128 available in each survey years report(16–18)

### 35 129 **Data collection tools and procedures**

37 130 The data for this analysis were extracted from Demographic and Health Survey (DHS) program  
38  
39  
40 131 website ([www.measuredhsprogram.com](http://www.measuredhsprogram.com)) after obtaining the necessary permissions for the  
41  
42 132 download and further analyses. Similarly, spatial location data (latitude and longitudinal) were  
43  
44 133 extracted from the downloaded excel file. After extraction, the missing values for the significant  
45  
46  
47 134 independent variables were excluded and the analysis was undertaken using a complete data  
48  
49 135 set. In all survey years for all children age 6-59 month from whom consent was obtained from  
50  
51 136 their parents. Blood samples were drawn from the drop of blood taken from a finger prick or a  
52  
53  
54 137 heel prick in the case of 6-11 month, and collected in a microcuvette. Haemoglobin analysis  
55  
56 138 was carried out on-site using a battery-operated portable HemoCue analyzer.

## 1 139 **Key variables and measurements**

2  
3 140 **Dependent variable:** The study variables were grouped into dependent and independent  
4  
5  
6 141 variables. The dependent variable is childhood anaemia status, categorized as “anaemic or  
7  
8 142 not-anaemic”. Children whose haemoglobin level was less than 11g/dl were considered  
9  
10 143 anaemic and not anaemic otherwise.

### 12 144 **Independent variables:**

14  
15 145 sociodemographic (religion, women age, marital status, educational status, husband  
16  
17 146 education, wealth index, women working status, numbers of under five children) Maternal and  
18  
19  
20 147 Child- related (child sex, age, birth size, birth order, maternal BMI, maternal anaemia,  
21  
22 148 breastfeeding, fever, diarrhoea, vitamin supplement, stunting and wasting). Community-level  
23  
24 149 variables (residence, region, community women education and community women poverty).

25  
26 150 We created community women education and community women poverty variables by  
27  
28  
29 151 aggregating the individual characteristics within their clusters. The aggregates were computed  
30  
31 152 using the median values of the proportions of women in each category of a given variable. We  
32  
33  
34 153 categorized the aggregate values of a cluster into groups based on national median values,  
35  
36 154 since all aggregates were not normally distributed.

37  
38  
39 155 **Community women’s education:** was defined as the proportion of women who attended  
40  
41 156 primary, secondary and higher education within the cluster. The aggregate of individual  
42  
43 157 primary, secondary and higher educational attainment can show the overall educational and  
44  
45  
46 158 academic status of women within the cluster. They were categorized into two categories a  
47  
48 159 higher proportion of women’s education within the cluster and a lower proportion of women  
49  
50 160 education based on the national median value.

51  
52  
53 161 **Community women’s poverty status:** defined as the proportion of poor and poorest mothers  
54  
55 162 within the cluster. For each cluster, the proportion of poor and poorest as-was aggregated and  
56  
57  
58  
59  
60

1 163 show overall poverty status within the cluster. It was categorized into two categories based on  
2  
3 164 national median value as higher proportion of poor/poorest mother's and lower proportion of  
4  
5 165 mothers within a cluster.  
6  
7

### 8 166 **Data management and analysis**

9

10 167 The data were cleaned using STATA 14.1 software and Microsoft excel. The data were  
11  
12 168 weighted using sampling weight, primary sampling unit, and strata before any statistical  
13  
14  
15 169 analysis to restore the representativeness of the survey to take into account the sampling  
16  
17 170 design when calculating standard errors to get reliable statistical estimates.  
18  
19

### 20 171 **Spatial analysis**

21

22 172 For the spatial analysis, ArcGIS V.10.7 software was used to evaluate whether the pattern was  
23  
24 173 clustered, dispersed or random across the study area, and SaTScan™ software, version 9.6.1,  
25  
26  
27 174 was used for the local cluster detection analysis. It uses a circular window that moves  
28  
29 175 systematically throughout the study area to identify a significant spatial clustering of childhood  
30  
31 176 anaemia.  
32  
33

### 34 177 **Spatial autocorrelation analysis**

35

36  
37 178 The spatial autocorrelation (Global Moran's I) statistic measures whether childhood anaemia  
38  
39 179 patterns were dispersed, clustered or randomly distributed in the study area. Moran's I output  
40  
41 180 value ranges from (-1 to +1). Values close to -1 indicate anaemia dispersed, whereas Moran's  
42  
43  
44 181 I close to +1 indicate childhood anaemia clustered and distributed randomly if I value zero.  
45  
46 182 Anselin Local Moran's I was used to indicate the local level cluster locations of anaemia  
47  
48 183 positively correlated (high-high and low-low) clusters or negatively correlated (high-low and  
49  
50  
51 184 low-high).  
52

### 53 185 **Hot spot analysis (Getis-Ord Gi\* statistic)**

54  
55  
56  
57  
58  
59  
60



1 186 Local Moran's I, Gettis-OrdGi\* statistics was computed to measure how spatial autocorrelation  
2  
3 187 of anaemia among under-five children varies across different locations in Ethiopia. Hotspot  
4  
5 188 analysis computes Z-score and p-value to determine the statistical significance of the  
6  
7  
8 189 clustering of anaemia over the study area at different significance levels simultaneously.  
9  
10 190 Statistical output with high GI\* indicates "hotspot" whereas low GI\* means a "cold spot". hot  
11  
12 191 spot areas showed that there was a high proportion of anaemia and the cold spot indicated a  
13  
14  
15 192 low proportion of anaemia.

### 18 193 **Spatial interpolation**

19  
20 194 There are various deterministic and geostatistical interpolation methods. Among all of the  
21  
22 195 methods, ordinary Kriging and empirical Bayesian Kriging are considered the best methods  
23  
24 196 since they incorporate spatial autocorrelation and statistically optimize the weight. Ordinary  
25  
26  
27 197 Kriging spatial interpolation method was used for this study for predictions of childhood  
28  
29 198 anaemia in unobserved areas of Ethiopia since it had low mean square error and residual as  
30  
31 199 compared to the other interpolation techniques.  
32  
33

### 34 200 **Spatial scan statistical analysis**

35  
36  
37 201 Spatial scan statistical analysis used to Identifying most likely(primary) and secondary spatial  
38  
39 202 clusters. This method is widely recommended as it is very important in detecting local clusters  
40  
41 203 and has higher power than other available spatial statistical methods. Bernoulli based model  
42  
43  
44 204 was employed to test for statistically significant spatial clusters of anaemia using Kulldorff's  
45  
46 205 SaTScan™ version 9.6.1, software. Children with anaemia were taken as cases, and were  
47  
48 206 not-anaemic as controls to fit the Bernoulli model. The default maximum spatial cluster size of  
49  
50 207 <50% of the population was used. The scanning window with maximum likelihood was the  
51  
52  
53 208 most likely cluster, and the p-value was assigned to each cluster using Monte Carlo hypothesis  
54  
55  
56  
57  
58  
59

1 209 testing. The primary and secondary clusters were identified and assigned p-values and ranked  
 2  
 3 210 based on their likelihood ratio test, based on 999 Monte Carlo replications(19).  
 4  
 5

## 6 211 **Associated factors of anaemia**

8  
 9  
 10 212 Four models were fitted using **melogit**, a STATA command, the null model without predictors,  
 11  
 12 213 model I with only individual-level variables, model II with only community-level variables, and  
 13  
 14 214 Model III both individual-level and community-level variables. Model comparison was  
 15  
 16 215 conducted by using deviance and likelihood ratio.  
 17  
 18

19 216 Intra-class correlation (ICC), median odds ratio (MOR), and proportional change in variance  
 20  
 21 217 (PCV) were computed to measure the variation between clusters. The intra-class correlation  
 22  
 23 218 coefficient (ICC) quantifies the degree of heterogeneity of childhood anaemia between clusters  
 24  
 25 219 (the proportion of the total observed individual variation in anaemia that is attributable between  
 26  
 27 220 cluster variations) calculated as  
 28  
 29

30  
 31 221  $ICC = \frac{\sigma^2}{(\sigma^2 + \sigma_b^2)}$  (20), where,  $\sigma^2$  is the community level variance and  $\sigma_b^2$  indicates individual level  
 32  
 33  
 34 222 variance. The individual variance ( $\sigma_b^2$ ) equal to  $\pi^2/3$ .  
 35  
 36

37 223 but MOR is quantifying the variation or heterogeneity in outcomes between clusters and is  
 38  
 39 224 defined as the median value of the odds ratio between the cluster at high risk of anaemia and  
 40  
 41 225 cluster at lower risk when randomly picking out two clusters (EAs).  
 42  
 43

44 226  $MOR = e^{(0.95 * \text{sqrt}(\sigma^2))}$ (21) where,  $\sigma^2$  indicates that cluster level variance.  
 45  
 46

47 227 PCV measures the total variation attributed by individual-level factors and community-level  
 48  
 49 228 factors in the multilevel model compared to the null model PCV. In the multivariable multilevel  
 50  
 51 229 logistic regression analysis variables with a p-value of <0.05 were considered as statistically  
 52  
 53 230 significant. Adjusted Odds Ratio (AOR) with their corresponding 95% confidence interval was  
 54  
 55 231 determined to identify factors associated with anaemia. After comparing all models, a model  
 56  
 57  
 58  
 59

with low deviance was considered a better fitted model. Multicollinearity was checked using the Variance Inflation Factor (VIF). VIF less than 10% was taken as no multicollinearity.

## Ethics and confidentiality

Ethical clearance was obtained from the ethical review board of the University of Gondar Institute of Public Health, CMHS. Permission for data access was obtained from the measure demographic and health survey through an online request by a written letter of objective and significance of the study from (<http://www.dhsprogram.com>)

## Patient and public involvement

This study did not involve patients and the public

## Results

### Descriptive characteristics of the study population

A total of 21,302 children with known haemoglobin levels (3,868 in 2005, 8,958 in 2011, and 8467 in 2016) were included in this study. The prevalence of anaemia for the three consecutive surveys was 53.9%, 44.6%, and 57.6% in 2005, 2011, and 2016 EDHS data respectively. The majority of the participants were in the age group of 36-47 (23.7%), 36-47 (24.4%), and, 48-59 (22.9%) in EDHS 2005, 2011, and 2016 survey respectively. The mean age of children was  $32.6 \pm 15.6$ -SD,  $32.6 \pm 15.4$ -SD, and  $31.7 \pm 15.6$ -SD in 2005, 2011, and 2016 respectively. Among children involved in the analysis, male participants were higher in 2011 and 2016 EDHS compared to 2005 survey periods. The majority of children were from rural resident in three surveys. About 78.6%, 70.1%, and 67.1% of women were unable to read and write in 2005, 2011, and 2016 survey respectively. Children from poor and middle-class wealth index families were more anaemic than children from rich families across the three EDHS survey (Table 1).

1 254 During the study period, the trends in the prevalence of childhood anaemia in Ethiopia, were  
 2  
 3 255 fluctuates across regions (Fig.1).  
 4  
 5

6 256 **Table 1: Descriptive characteristics of study participants included in the analysis for**  
 7  
 8 257 **childhood anaemia five years preceding the survey from EDHS 2005-2016 in Ethiopia**  
 9

10 Variables	2005 (N, 3868)	2011 (N, 8958)	2016 (N, 8476)
11	Frequency (%)	Frequency (%)	Frequency (%)
12 Sex of child			
13 Male	1,931(49.9)	4,500(51.4)	4,395(51.9)
14 Female	1,937(50.1)	4,358(48.7)	4,081(48.2)
15 Age of child in month			
16 6-11	418 (10.8)	1,029(11.5)	1,000(11.8)
17 12-23	842 (21.76)	1,804(20.14)	1,902(22.4)
18 24-35	825 (21.3)	1,895(21.2)	1,803(21.3)
19 36-47	919 (23.7)	2,184(24.4)	1,832(21.6)
20 48-59	864 (22.3)	2,047(22.9)	1,939(22.9)
21 Mean ± SD	<b>32.6 ±15.6</b>	<b>32.6±15.4</b>	<b>31.7±15.6</b>
22 Residence			
23 Urban	244 (6.3)	1,047(11.7)	857(10.1)
24 Rural	3,624 (93.7)	7,911(88.3)	7,619(89.9)
25 Religion			
26 Orthodox	1,624 (42.0)	3,416(38.1)	2,913(34.4)
27 Muslim	1,276 (33.0)	3,108(34.7)	3,432(40.5)
28 Protestant	836 (22.0)	2,151(24.0)	1,874(22.1)

1	Others	133 (3.0)	283(3.2)	258(3.0)
2				
3	Women age			
4				
5	15-29	1,930(49.9)	4,908(54.9)	4,356(51.4)
6				
7	30-39	1,474(38.1)	3,223(36.0)	3,335(39.3)
8				
9	40-49	464(12.0)	828(9.1)	785(9.3)
10				
11	Women education			
12				
13	No education	3,042 (78.6)	6,285(70.1)	5,685(67.1)
14				
15	Primary	684 (17.7)	2,389(26.7)	2,275(26.8)
16				
17	Secondary	136 (3.5)	168(1.9)	346(4.1)
18				
19	Higher	7 (0.2)	117(1.3)	170(2.0)
20				
21	Marital status			
22				
23	Single	7(0.2)	50(0.6)	45(0.5)
24				
25	Married	3,704(95.7)	8,425(94.0)	8,129(95.9)
26				
27	Widowed	80(2.1)	178(2.0)	93(1.1)
28				
29	Divorced	78(2.0)	306 (3.4)	210(2.5)
30				
31	Husband education			
32				
33	No-education	2,235 (58.0)	4,532(50.9)	4,333(51.1)
34				
35	Primary	1,233(32.0)	3,710(41.7)	3,273(38.6)
36				
37	Secondary	362(9.0)	412(4.6)	572(6.8)
38				
39	Higher education	31(1.0)	255 (2.8)	300(3.5)
40				
41	Wealth index			
42				
43	Poor	1,697(43.7)	4,048(45.2)	3,977(46.9)
44				
45	Middle	854(22.1)	1,873(20.9)	1,821(21.5)
46				
47				
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				

1	Rich	1,318(34.1)	3,038 (33.9)	2,678(31.6)
2				
3	Women working status			
4				
5	Not working	2,841(73.5)	5,793(64.7)	6,140(72.4)
6				
7	Working	1,027(26.5)	3,165(35.3)	2,336(27.6)
8				
9	Total	3,868(100)	8,958(100)	8,476(100)
10				
11				
12				
13	258			
14				
15				
16	259			

### Community-level characteristics of the study population

Findings from this study revealed a regional variation of childhood anaemia, with 83.3% in Somali, 75.5%, in Afar, 74.5% in Dire Dawa, and 68.8% in Harari. However, Amhara, and Benishangul with 42.5%, which was relatively low compared to other regions.

Childhood anaemia varies by urban-rural of residence. Children residing in communities with low women poverty level had a lower percent of anaemia (51.2%) than high community poverty level (62.5%). Children from low community women education level (59.5%) were more anaemic than children resided with high community women (53.6%) educational level (Table 2).

**Table 2: Community-level factors of under five children participated in EDHS (2016), Ethiopia. (N, 8476)**

Community-level factors	Not-anaemic (%)	Anaemic (%)	Total (100%)
Residence			
Urban	435(50.6)	424(49.4)	857
Rural	3164(41.5)	4455(58.5)	7619
Region			
Tigray	263(46.0)	309(54.0)	572

1	Afar	21(25.3)	62(74.5)	83
2				
3	Amhara	950(57.5)	703(42.5)	1653
4				
5	Oromia	1273(34.2)	2446(65.8)	3719
6				
7				
8	Somali	58(16.7)	290(83.3)	348
9				
10	Beneshangul	51(56.6)	39(43.4)	90
11				
12				
13	SNNPR	875(49.1)	906(50.9)	1781
14				
15	Gambela	8(42.1)	11(57.9)	19
16				
17	Harari	5(31.2)	11(68.8)	16
18				
19				
20	Addis Ababa	82(50.9)	79(49.1)	161
21				
22	Dire Dawa	9(28.1)	23(71.9)	32
23				
24				
25	Community women education			
26				
27	Low	2281(40.5)	3358(59.5)	5639
28				
29	High	1315(46.4)	1520(53.6)	2837
30				
31				
32	Community women poverty			
33				
34	Low	1815(48.8)	1905(51.2)	3719
35				
36	High	1782(37.5)	2974(62.5)	4756
37				
38				
39	270			
40				
41				
42	271			
43				
44				
45	272			
46				
47				
48	273			
49				
50	274			
51				
52	275			
53				
54				
55				
56				
57				
58				
59				
60				

## 271 Spatio-temporal distribution of anaemia among children age 6-59 months in Ethiopia

272 The spatial distribution of childhood anaemia varied across regions in all surveys. The spatial  
 273 autocorrelation analysis result indicated that childhood anaemia had spatial dependency in  
 274 2005, 2011 and 2016 (Moran's I: 0.176, 0.18, and 0.09, respectively at P-value < 0.01).

### 275 Hot spot analysis of the three surveys

1 276 The spatial distribution of childhood anaemia in Ethiopia was different in all the three survey  
2  
3 277 periods. In EDHS 2005, a high proportion of childhood anaemia was detected in Dire Dawa,  
4  
5 278 Harari, eastern Oromia, Beneshangul in Metekel zone, Gambela, southern and eastern Tigray,  
6  
7  
8 279 and Somali region mainly Liben, Afdar, and Fafna zone which was hotspot area within 95%  
9  
10 280 confidence level. On the counterpart, GamoGofa, Wolayita, Hadiya, Southern Omo, and  
11  
12 281 Segen zone of SNNPR, Addis Ababa, central Oromia, Jima, north Shewa zone were cold spot  
13  
14  
15 282 area. In EDHS 2011, a highly significant clustering of childhood anaemia was detected in  
16  
17 283 Somali, Dire Dawa, Harari, Afar, Gambela, Beneshangul, eastern Oromia, Bale, Arsi zone  
18  
19 284 were the hotspot areas within 95% level of confidence. The low hotspot area of childhood  
20  
21  
22 285 anaemia was detected in central Tigray, East and West Gojam, North Gondar, a central part  
23  
24 286 of Oromia, Addis Ababa and SNNPR were areas identified as the low percentage of childhood  
25  
26 287 anaemia in the 2011 EDHS survey.

28  
29 288 In EDHS-2016 sampled data, hot spot (high risk) regions for childhood anaemia were observed  
30  
31  
32 289 in Somali, Dire Dawa, Harari, Gambela, eastern, and Southern part of Oromia. However,  
33  
34 290 Amhara, Beneshangul, and SNNPR were identified as cold spot (low risk) regions for childhood  
35  
36 291 anaemia within a 95% confidence interval (**Fig.2**)

### 39 292 **Spatial interpolation**

40  
41 293 Based on EDHS-2005 sampled data, the geostatistical analysis predicts that the highest  
42  
43  
44 294 prevalence of childhood anaemia (65.75%-88.89%) was detected in east Oromia, Ilubabur,  
45  
46 295 Arsi, some parts of Beneshangul, Agnuak zone in Gambela, north Shewa Amhara region,  
47  
48 296 south and central Tigray, Afar in zone2, some parts of Dire Dawa and Somali. In EDHS-2011  
49  
50  
51 297 Geostatistical analysis, a high percentage of anaemia was detected in Afar, most parts of  
52  
53 298 Somali, Oromia in east Harerge and Borena, some part of Dire Dawa, and the Meketel zone  
54  
55 299 in Beneshangul. In 2016 EDHS most of Somali, some parts of Gambela, Guji and some parts  
56  
57  
58  
59



of Borena, ast Shewa, East Harerge and Arsi in Oromia and part of Dire Dawa were highly prevalent areas in childhood anaemia (**Fig.3**)

### **Spatial scan statistics**

In 2005 EDHS, a total of 3 significant clusters were identified, one most likely (primary) cluster and two were secondary clusters of spatial scan analysis. The primary cluster spatial window was located in Somali, which was centered at (9.018373 N, 43.110635 E) of geographic location with a 97.93 km radius, and Log-Likelihood ratio (LLR) of 20.03, at  $p < 0.01$  which was detected as the most likely cluster with maximum likelihood. It showed that children within the spatial window had 1.5 times more likely a higher risk of anaemia than the children outside the spatial window areas. The secondary clusters scanning window was located in the southern part of Somali region, which was centered at (3.998656 N, 41.240691 E) with a 92.08 km radius and LLR of 1.7 at  $p\text{-value} < 0.01$ . It showed that children within the spatial window had a 1.7 times higher risk of anaemia than children outside the window.

In 2011 EDHS, 10 clusters were identified and five of them were significant clusters with a  $p\text{-value} < 0.05$ . A total of 180 locations/spots with a total sampled population of 2478 were found in the primary cluster spatial window with a significant  $p\text{-value} < 0.01$ . The primary cluster spatial window was located mainly in Somali, Afar, eastern Oromia, Dire Dawa, and Harari. The primary cluster spatial window was centered at (8.975207 N, 43.790264 E) / 540.29 km, with a relative risk (RR) of 1.4 and a log-likelihood ratio (LLR) of 127.79. It showed that children within the spatial window had 1.4 times more likely a higher risk of anaemia than the children outside the spatial window areas. The secondary cluster spatial window was located mainly in Afar region. The secondary cluster spatial window was centered at (12.758587 N, 40.175990 E) / 39.58 km, with a relative risk (RR) of 1.7 and a log-likelihood ratio (LLR) of 21.5  $P\text{-value} < 0.01$ .

1 324 In 2016 EDHS, 7 clusters (one most likely cluster) were located in Somali, Afar, eastern  
2  
3 325 Oromia, Dire Dawa, and Harari. The cluster window was centered with a radius at (7.650693  
4  
5 326 N, 47.007920 E) / 912.19 km with a relative risk (RR) of 1.4. The Log-Likelihood ratio (LLR) for  
6  
7  
8 327 the most likely cluster was 182.86, P-value<0.01. It showed that children within the spatial  
9  
10 328 window had a 1.4 times higher risk of anaemia than outside the window. Secondary clusters  
11  
12 329 were located in Gambela which was centered at (8.195862 N, 34.289837 E) with a radius of  
13  
14  
15 330 29.01 km, and LLR of 18.80 at p-value < 0.01(**Fig.4**).

### 18 331 **Multilevel Analysis**

19  
20  
21 332 The intra-cluster correlation coefficient (ICC) in the empty model indicated that 19% of the total  
22  
23 333 variability for childhood anaemia was due to differences between clusters. The remaining  
24  
25 334 unexplained 81% were attributable to individual differences. The median odds ratio for  
26  
27  
28 335 anaemia was 2.3 in the null model, indicating variation between clusters. If we randomly select  
29  
30 336 children from two different clusters children at the cluster with a higher risk of anaemia had 2.3  
31  
32 337 times higher odds of experiencing anaemia than children at the cluster with a lower risk of  
33  
34  
35 338 anaemia.

36  
37  
38 339 Bi-variable multilevel logistic regression analysis was done to identify variables for  
39  
40 340 multivariable multilevel logistic analysis, and variable with a p-value less than 0.25 were  
41  
42 341 considered for multivariable analysis.

### 45 342 **Individual-level predictors for anaemia**

46  
47  
48 343 In multivariable multilevel mixed-effect logistic regression analysis, individual-level factors such  
49  
50 344 as the age of the child, wealth index, mother age, maternal anaemia status, birth order, fever,  
51  
52  
53 345 stunting, and wasting status were significant predictor of childhood anaemia.

Children age between 12–23 months (AOR = 0.66, 95%CI = 0.53-0.81), between 24–35 months (AOR= 0.35, 95% CI = 0.28-0.43), between 36–47 months (AOR = 0.23-95%CI = 0.19-0.29), and between 48–59 months (AOR = 0.15, 95%CI = 0.12-0.19) were less likely to develop anaemia compared with children age between 6–11 months.

The likelihood of developing anaemia for those children residing with the family wealth index of middle and rich were lower by 21% (AOR=0.79, 95%CI = 0.67-0.94), and 23% (AOR=0.77, 95%CI = 0.65-0.91), respectively as compared with children with low wealth index. Children whose mother's age were between 40-49 had 25% decreased odds of developing childhood anaemia compared to age 15-29, (AOR=0.75, 95%CI = 0.59-0.95).

The odds of experiencing anaemia for those birth orders 4-5, six and above six were 1.22 times (AOR=1.22, 95%CI = 1.01-1.47) and, 1.35 times (AOR=1.35, 95%CI = 1.08-1.67) higher as compared with first-order respectively. The odds of developing anaemia of children born from anaemia history mother were 1.39 higher more elevated than those born from not anaemic history before. Children who had fever were 39% (AOR =1.39, 95% CI: 1.24-1.58) more likely to develop anaemia than their counterparts. Children with moderate and severe stunting status were 35% (AOR=1.35, 95% CI: 1.17-1.54) and, 96% (AOR=1.95, 95% CI: 1.68-2.28), more likely to develop anaemia respectively, compared to no stunting status. Similarly, children who had to sever wasting status were 51% more (AOR =1.51, 95% CI: 1.07-2.12) likely to develop anaemia compared with those children who had no wasting.

### Community-level predictors for anaemia

The multivariable multilevel logistic regression analysis region was significantly associated with community-level factors for childhood anaemia.

Odds of children live in Somali were 5.65 times (AOR=5.65, 95% CI: 3.92-8.16), Dire Dawa 3.45 times (AOR=3.45, 95% CI: 2.27-5.26), Afar 3 times (AOR=3.00, 95% CI: 2.09-4.34), and

1 370 Oromia 2.34 times (AOR=2.34, 95% CI: 1.73-3.18) had more likely to develop childhood  
 2  
 3 371 anaemia compared to Amhara region. Similarly, the odds of developing anaemia in Addis  
 4  
 5 372 Ababa were 2 times (AOR=2.00, 95% CI: 1.40-3.16), Gambella 1.94 times (AOR=1.94, 95%  
 6  
 7  
 8 373 CI: 1.32-2.84), and Tigray 1.46 times (AOR=1.46, 95% CI: 1.08-1.98), more likely as compared  
 9  
 10 374 to Amhara region. Beneshangul and SNNPR had not significantly different in the prevalence  
 11  
 12 375 of anaemia than the reference region Amhara (Table 3).

15 376 **Table 3: Multilevel logistic regression analysis result of both individual and community-**  
 16  
 17 377 **level factors associated with anaemia in Ethiopia, EDHS 2016**

Variables	Null Model	Model I AOR (95% CI)	Model II AOR (95% CI)	Model III AOR (95% CI)
Individual-level factors				
Age of child in month				
6-11	-	1	-	1
12-23	-	0.66[0.54-0.82] **	-	0.66 [0.53-0.81] **
24-35	-	0.35[0.28-0.44] **	-	0.35 [0.28-0.43] **
36-47	-	0.23[0.18-0.28] **	-	0.23 [0.19-0.29] **
48-59	-	0.15[0.12-0.19] **	-	0.15 [0.12-0.19] **
Religion				
Orthodox	-	1	-	1
Muslim	-	2.07[1.77-2.47] **	-	1.21 [0.97-1.46]
Protestant	-	1.20 [1.00-1.48] *	-	1.10 [0.86-1.37]
Others	-	1.55[1.07-2.32] *	-	1.44[0.96-2.13]
Wealth status				
Poor	-	1	-	1

Middle	-	0.71[0.61-0.84] **	-	0.79 [0.67-0.94] *
Rich	-	0.72[0.63-0.85] **	-	0.77 [0.65-0.91] *
Child size at birth				
Small	-	1	-	1
Average	-	0.96[0.84-1.09]	-	0.93 [0.80-1.07]
Large	-	0.94[0.81-1.08]	-	0.96 [0.84-1.10]
Birth order				
1 <sup>st</sup>	-	1	-	1
2-3	-	1.09[0.94-1.28]	-	1.13[0.97-1.32]
4-5	-	1.17[0.97-1.40]	-	1.22 [1.01-1.47] *
6 and above	-	1.30[1.05-1.62]	-	1.35 [1.08-1.67] **
No of children under 5				
1-2 children	-	1	-	1
≥ 3 children	-	1.22[1.1-1.4] *	-	1.09 [0.94-1.27]
Maternal anaemia				
Not anaemic	-	1	-	1
Anaemic	-	1.51[1.34, 1.72] **	-	1.39 [1.24-1.58] **
Maternal BMI				
≥18.5 kg/m <sup>2</sup>	-	1	-	1
<18.5 kg/m <sup>2</sup>	-	1.12[0.97-1.26]	-	1.05 [0.92-1.19]
Women working status				
Not-working	-	1	-	1
Working	-	0.88[0.77-0.99] *	-	0.92 [0.81-1.04]

Women age				
15-29	-	1		1
30-39	-	0.91[0.71-1.06]	-	0.90 [0.78-1.04]
40-49	-	0.75[0.59-1.12] *	-	0.75 [0.59-0.95] *
Breastfeeding				
No	-	1	-	
Yes	-	0.92[0.81-1.04]	-	0.98 [0.87-1.12]
Vitamins in last 6 month				
No	-	1	-	
Yes	-	0.90[0.81-1.09]	-	0.93 [0.84-1.05]
Diarrhea last 2 week				
No	-	1	-	1
Yes	-	0.88[0.73, 1.04]	-	0.90 [0.76-1.07]
Fever in last 2 weeks				
No	-	1	-	1
Yes	-	1.35[1.15-1.59] **	-	1.32 [1.13-1.56] *
Stunting status				
No-stunting	-	1	-	1
Moderate stunting	-	1.27[1.10-1.46] **	-	1.35 [1.17-1.54] **
Severely stunting	-	1.81[1.55-2.11] **	-	1.96 [1.68-2.28] **
Wasting status				
No-wasting	-	1	-	1
Moderate wasting	-	1.27[1.11-1.45]	-	0.98 [0.80-1.19]

Severe wasting	-	1.68[1.55-2.10] *	-	1.51 [1.07-2.12] *
Community/cluster-level factors				
Region				
Amhara	-	-	1	1
Tigray	-	-	1.46[1.09-1.97] **	1.46 [1.08-1.98] **
Afar	-	-	3.90 [2.84-5.35] **	3.00 [2.09-4.34] **
Oromia	-	-	2.48 [1.89-3.25] **	2.34 [1.73-3.18] **
Somali	-	-	6.34[4.65-8.63]	5.65 [3.92-8.16] **
Beneshangul	-	-	0.86 [0.62-1.17]	0.81 [0.58-1.15]
SNNPR	-	-	1.33 [1.00-1.76]	1.30 [0.94-1.80]
Gambela	-	-	1.93 [1.38-2.69] **	1.94 [1.32-2.84] **
Harari	-	-	3.08 [2.15-4.43] **	2.98 [1.99-4.46] **
Addis Ababa	-	-	1.91[1.29-2.83] **	2.10 [1.40-3.16] **
Dire dawa	-	-	3.92 [2.67-5.77] **	3.45 [2.27-5.26] **
Residence				
Urban	-	-	1	1
Rural	-	-	1.40[1.12-1.78]	1.28 [0.99-1.64]
Community women education				
Low	-	-	1	1
High	-	-	1.07[0.90-1.26]	1.13[0.94-1.34]
Community women poverty				
Low	-	-	1	1
High	-	-	1.41[1.17-1.68] *	1.15[0.94-1.40]

Model comparison and random effect				
ICC	0.19	0.12	0.08	0.07
Log-likelihood	-4981.63	-4513.17	-4836.83	-4436.60
Deviance	9963.26	9026.34	9673.66	8873.20
MOR	2.30	1.72	1.42	1.38
PVC (%)	Ref	41.20	60.10	62.59

**\*Key: 1: reference group; p-value 0.05-0.01 \*: p-value < 0.01 \*\***

### Multicollinearity

Multicollinearity was checked for those variables included in the final model using VIF. Accordingly, the VIF for all predictor variables included in the final model was below 10 indicating the absence of multicollinearity among the predictor variables.

### Comparison of models

Deviance was used to compare the models, and the lowest value of deviance (Model III) was considered the better mode.

### Discussion

This study tried to identify spatio-temporal distribution and predictors of childhood anaemia across the regions in Ethiopia. The 2005, 2011, and, 2016 Ethiopian Demographic and Health Survey data were used. In this study, anaemia trend was decreased from 2005 to 2011, while the rate significantly increased from 2011 to 2016. The study revealed that 57.56% [CL: 0.56-0.59] of children were anaemic in 2016, preceding the survey. This finding was in line with a study done in Gondar, Northwest Ethiopia 58.6%(22), whereas higher than the study done in cape Verde, west Africa 51.8%(23), and southern Ethiopia(24). Among children of 6–59 months, anaemia is still considered a significant public health problem in Ethiopia. Though the



1 397 levels of anaemia among children vary by background characteristics like region and lowest  
2  
3 398 household wealth index and maternal related factors, more of the children in Ethiopia were  
4  
5 399 suffering anaemia.  
6  
7

8 400 The spatial pattern shows the geographical inequality of anaemia by using different spatial  
9  
10 401 analysis techniques like cluster mapping tools and interpolation techniques. The spatial  
11  
12 402 analysis indicates that the distribution of childhood anaemia was non-random across the  
13  
14 403 country with a global Moran's I index of 0.176 in 2005, 0.18 in 2011, and 0.09 in 2016 with a  
15  
16 404 significant p-value <0.01, which indicates substantial-considerable clustering areas. This  
17  
18 405 findings were in line with a study done in Nigeria, Malawi, Tanzania, and Uganda (25,26).  
19  
20  
21

22  
23 406 The spatial pattern of scan statistical analysis showed that Eastern Somali region were primary  
24  
25 407 (most likely) cluster and secondary cluster also located in the southern part of Somali in 2005  
26  
27 408 sat scan analysis. In 2011 Somali, Afar, Eastern Oromia, Dire Dawa, and Harari were located  
28  
29 409 in the primary window and centered at (8.975207 N, 43.790264 E/ 540.29 km with a significant  
30  
31 410 p-value. Similarly, spatial sat scan analysis showed that Somali, Afar, Eastern Oromia, Dire  
32  
33 411 Dawa, Harari were hotspot areas in the 2016 EDHS spatial analysis. In addition, this study  
34  
35 412 revealed that eastern parts of the country had similar spatiotemporal trend over the study  
36  
37 413 periods.  
38  
39  
40  
41

42 414 The spatial analysis indicated the hotspots areas of anaemia were situated in the East,  
43  
44 415 Northeast, and Western parts, whereas, Central area, and South, and Northwest parts were  
45  
46 416 cold spot parts of Ethiopia. The observed variability of childhood anaemia might be attributed  
47  
48 417 to the regional deference of economy, healthcare facility and food availability(27).  
49  
50  
51

52 418 This study indicated that children age 12-59 months were less affected by childhood anaemia.  
53  
54 419 This finding was consistent with studies conducted in Ethiopia and Togo (28–30). This could  
55  
56 420 be explained by the fact that children who are getting older receive a richer and complete diet,  
57  
58  
59

1 421 with a sufficient intake of iron which could prevent the occurrence of iron deficiency anaemia.  
2  
3 422 The deficiency may result from inadequate dietary intake of iron, malabsorption of iron an  
4  
5 423 increased iron demand during rapid growth might it be the possible reason (31). The finding of  
6  
7  
8 424 this study indicated that children whose women age was between 40-49 were less anaemic as  
9  
10 425 compared to age 15-29. This finding was consistent with other studies conducted in Sub-  
11  
12 426 Saharan Africa and Ghana (12,32).  
13  
14  
15 427 This group consists of more at-risk population segments (Adolescent) for anaemia. They are  
16  
17 428 vulnerable to malnutrition because they are growing faster than at any time after their first year  
18  
19 429 of life which contributes to the intergenerational cycle of malnutrition and most common forms  
20  
21 430 of malnutrition among Ethiopian adolescent girls is iron deficiency anaemia. Aside from,  
22  
23 431 growing adolescent mother and her baby's bodies may compete for nutrients, raising the  
24  
25 432 infant's risk of low birth weight; however, the lack of such nutrients might lead to anaemia.  
26  
27  
28  
29 433 Children from households of middle and rich wealth indexes were less affected by childhood  
30  
31 434 anaemia as compared to children from a poor household. This finding in line with similar  
32  
33 435 studies in Nigeria and Northern Ethiopia (25,33). This is due to the reason that children from  
34  
35 436 poor households are less likely to get iron-rich foods like animal foods and vitamin-rich foods  
36  
37 437 especially vitamins A and C which are very important for iron absorption.  
38  
39  
40  
41 438 Maternal anaemia was highly associated with the occurrence of childhood anaemia. This  
42  
43 439 finding was in line with a study done in South Africa, Haiti, and India(34–36).  
44  
45  
46  
47 440 This might be explained that mothers and children share a common home environment,  
48  
49 441 socioeconomic, and dietary conditions, and maternal and child anaemia may reflect the  
50  
51 442 household common nutritional status, and poor maternal iron intake during pregnancy, reduce  
52  
53 443 breast milk might be the possible reason.  
54  
55  
56  
57  
58  
59  
60

1 444 The EDHS data set indicated that the incidence of fever had an impact on childhood anaemia.  
2  
3 445 This is in line with studies done in Ghana and South Ethiopia Wolaita (24,37). This result  
4  
5 446 showed that children who had a fever in the last two weeks before the survey had had a higher  
6  
7  
8 447 likelihood of anaemia than the counterpart. This could be attributed to the infectious cause of  
9  
10 448 childhood fever mainly malaria, tuberculosis, and Leishmaniasis which cause anaemia by  
11  
12 449 destructing red blood cells or other related mechanisms.

15 450 The nutritional status of children had a significant association with childhood anaemia. The  
16  
17  
18 451 stunting status of children had significant association with childhood anaemia. This finding in  
19  
20 452 line with previous similar finding conducted in South Africa(36), Bangladesh(38,39), and  
21  
22 453 Ethiopia(40,41). This might be explained that children suffering from nutritional deficiency were  
23  
24  
25 454 more likely to have weak immune systems, making them vulnerable to various illnesses and  
26  
27 455 healthiness such as parasitic infections or chronic inflammation; many of these conditions  
28  
29 456 reduce the haemoglobin level in the blood leading to increased childhood anaemia(42)

32 457 Furthermore, severely wasting children were more likely to be anaemic than their counterpart.  
33  
34  
35 458 Consistent with other previous studies(43,44). This is due to the fact that malnutrition leads to  
36  
37 459 both macronutrient and micronutrient deficiencies, such as protein, iron, and vitamin A, which  
38  
39 460 are responsible for iron deficiency. Odds of experiencing anaemia for those birth order four up  
40  
41 461 to five and six and greater than six were higher than those of the first order. This finding was  
42  
43  
44 462 similar to a studies done in Indian(12,45). This could be due to the distribution of scarce  
45  
46 463 resources within the family and related to the maternal exhaustion of micronutrient feeding  
47  
48 464 practices.

51 465 In a multivariable multilevel analysis, the odds of developing childhood anaemia were higher  
52  
53  
54 466 among children who lived in Somali, Dire Dawa, Afar, and Gambela compared to Amhara  
55  
56 467 region. This might be due to the unavailability and inaccessibility of health facilities as

1 468 compared to the regions. Regional variation in the nutrient intake can cause significant health  
2  
3 469 disparity, and this variability may be mediated by factors such as food availability, food  
4  
5 470 customs, and culture.  
6  
7

8 471 This study, used different methodologies; spatial pattern, trends, and a multilevel regression  
9  
10 472 model because of nested or cluster samples to show the effect of individual predictors and  
11  
12 473 community-level variables on the outcome variable. The study was based on a large dataset  
13  
14 474 representing the whole country of Ethiopia and which was weighted to make it nationally  
15  
16 475 representative and adjusted for the design to get a reliable estimate. However, there were  
17  
18 476 some limitations to this study. The cross-sectional nature of the data prevents causality from  
19  
20 477 being inferred between the independent and dependent variables. Also, respondents' data that  
21  
22 478 didn't have files (longitude and latitude) were excluded from the spatial analysis which could  
23  
24 479 affect the overall result and the generalizability of the findings.  
25  
26  
27  
28  
29

## 30 480 **Conclusion**

31  
32 481 through declining prevalence of childhood anaemia was observed from 2005 to 2011, it  
33  
34 482 increases from 2011-2016 survey. Besides, it was spatially clustered across regions in  
35  
36 483 Ethiopia. The most prominent risk areas of anaemia were detected in Afar, Somali, Dire Dawa  
37  
38 484 and Oromia regions more or less consistently overtime in the last one and half-decade. Child  
39  
40 485 age, women age, wealth index, maternal anaemia, fever, birth order, stunting, wasting and  
41  
42 486 region were significant predictors among 6-59 months. Therefore, public health intervention  
43  
44 487 actions intended in a targeted approach to bearing high-risk populations as well as geographic  
45  
46 488 regions were vital to reduce childhood anaemia in Ethiopia.  
47  
48  
49  
50  
51

52 489  
53  
54 490  
55  
56  
57  
58  
59

## 491 Abbreviations

492 AOR-Adjusted Odds Ratio, CSA-Central Statics Agency, CI-Confidence Interval, CMHS-  
493 College of Medicine and Health Science COR-Crude Odds Ratio, EDHS-Ethiopia  
494 Demographic and Health Survey, GPS-Global Positioning System, ICC-Intra Class Correlation  
495 Coefficient, LLR-Log-Likelihood Ratio, MOR-Median odds ratio, OR-Odds Ratio, RR-Relative  
496 Risk, PVC-Proportional Change in Variance, SNNPR- Southern Nations, Nationalities, and  
497 Peoples' Region.

## 498 Declarations

### 499 Onset to participate

500 The institutional ethical review committee board approved the study. Ethical clearance was  
501 obtained from ethical review board of the University of Gondar. Upon this clearance, the study  
502 was conducted. The congeniality of the data was maintained by using the extracted data only  
503 for the study purpose and keeping the data from a third party.

### 504 Consent for publication

505 Not-applicable

### 506 Data sharing statement

507 The data in which the authors used to produce this manuscript are available upon reasonable  
508 request

### 509 Competing interests

510 The authors declare that they have no competing interests.

## 511 Funding

512 No funding

## 513 Contributors

1 514 Proposal preparation, acquisition of data, analysis, and interpretation of data was done by SH,  
2  
3 515 AM, ZM and BF guided the study design data collection and analysis. SH drafted the  
4  
5 516 manuscript and all authors have a substantial contribution in revising and finalizing the  
6  
7  
8 517 manuscript. All authors read and approved the final manuscript.  
9

## 10 518 **Acknowledgments**

11  
12  
13 519 The authors gratefully acknowledge the support received from the University of Gondar. We  
14  
15 520 also thank the Ethiopian Central Statistics Agency for providing us with the data and shape  
16  
17  
18 521 files for this study.  
19  
20 522  
21  
22 523  
23  
24 524  
25  
26 525  
27  
28 526  
29  
30 527  
31  
32 528  
33  
34 529  
35  
36 530  
37  
38 531  
39  
40 532  
41  
42 533  
43  
44 534  
45  
46 535  
47  
48 536  
49  
50 537  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

1 538

3 539

## References

1. WHO. Nutritional Anaemias : Tools for Effective Prevention. World Health Organization. 2017. 1–83 p.
2. WHO. Global estimates of the prevalence of anaemia in infants and children aged 6 – 59 months , 2011 Global estimates of the prevalence of anaemia , all women of reproductive age , 15 – 49 years , 2011. *Scaling Up Nutr* [Internet]. 2015; Available from: [http://www.who.int/nutrition/publications/micronutrients/global\\_prevalence\\_anaemia\\_2011\\_maps.pdf?ua=1](http://www.who.int/nutrition/publications/micronutrients/global_prevalence_anaemia_2011_maps.pdf?ua=1)
3. WHO. The global prevalence of anaemia in 2011. *Who* [Internet]. 2011;1–48. Available from: <https://apps.who.int?iris/handle/10665/177094>
4. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of anaemia, WHO vitamin and mineral nutrition information system, 1993–2005. *Public Health Nutr*. 2009;12(4):444–54.
5. Malkanthi RLDK, Silva KDRR, Jayasinghe-Mudalige UK. Risk Factors Associated with High Prevalence of Anemia among Children under 5 Years of Age in Paddy-Farming Households in Sri Lanka. *Food Nutr Bull*. 2010;31(4):475–82.
6. Olivares M, Walter T, Hertrampf E, Pizarro F. Anaemia and iron deficiency disease in children. *Br Med Bull* [Internet]. 1999 Sep 1;55(3):534–43. Available from: <https://doi.org/10.1258/0007142991902600>
7. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. *Public Health Nutr*. 2009;12(4):444–54.
8. Leal LP, Batista Filho M, de Lira PIC, Figueiroa JN, Osório MM. Temporal trends and anaemia-associated factors in 6- to 59-month-old children in Northeast Brazil. *Public Health Nutr*. 2012;15(9):1645–52.
9. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study. *BMJ Open* [Internet]. 2018 May 1;8(5):e019654. Available from: <http://bmjopen.bmj.com/content/8/5/e019654.abstract>
10. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: analysis from Togo demographic and health survey data, 2013–2014. *BMC Public Health*. 2019;19(1):1–9.
11. Malako BG, Teshome MS, Belachew T. Anemia and associated factors among children aged 6-23 months in Damot Sore District, Wolaita Zone, South Ethiopia. *BMC Hematol*. 2018;18(1):1–9.
12. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: A cross-sectional study. *BMJ Open*. 2018;8(5):1–14.
13. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns of anaemia among young children in nigeria: A bayesian semi-parametric modelling. *Int Health*. 2014;6(1):35–45.
14. Desalegn A, Mossie A, Gedefaw L. Nutritional Iron Deficiency Anemia: Magnitude and Its Predictors among School Age Children, Southwest Ethiopia: A Community Based Cross-Sectional Study. *PLoS One* [Internet]. 2014 Dec 1;9(12):e114059. Available

- 1 585 from: <https://doi.org/10.1371/journal.pone.0114059>
- 2 586 15. Guerra CA, Snow RW, Hay SI. Defining the global spatial limits of malaria transmission  
3 587 in 2005. *Adv Parasitol.* 2006;62:157–79.
- 4 588 16. Central Statistical Agency, ORC Macro. Ethiopia Demographic and Health Survey  
5 589 2005. Heal San Fr [Internet]. 2006;(September):[446]. Available from:  
6 590 [http://www.measuredhs.com/pubs/pdf/FR179/FR179\[23June2011\].pdf](http://www.measuredhs.com/pubs/pdf/FR179/FR179[23June2011].pdf)
- 7 591 17. Central Statistical Agency [Ethiopia], ICF International. Ethiopia Demographic and  
8 592 Health Survey 2011. 2012;1–452.
- 9 593 18. ECSA. Ethiopian Demographic Health Survey 2016. 2016. 161 p.
- 10 594 19. Kulldorff M. *SatScan user guide* 2006. 2018;
- 11 595 20. Bartko JJ. The Intraclass Correlation Coefficient as a Measure of Reliability. *Psychol*  
12 596 *Rep.* 1966 Aug;19(1):3–11.
- 13 597 21. Assessment IS. Understanding Variability in Multilevel Models Sophia Rabe-Hesketh  
14 598 Example : PISA ( Programme for International Student Assessment ) PISA :  
15 599 Distribution of SES.
- 16 600 22. Enawgaw B, Workineh Y, Tadesse S, Mekuria E, Addisu A, Genetu M. Prevalence of  
17 601 anemia and associated factors among hospitalized children attending the University of  
18 602 Gondar Hospital, Northwest Ethiopia. *Electron J Int Fed Clin Chem Lab Med.*  
19 603 2019;30(1):35–47.
- 20 604 23. Semedo RML, Santos MMAS, Baião MR, Luiz RR, Da Veiga G V. Prevalence of  
21 605 Anaemia and Associated Factors among Children below Five Years of Age in Cape  
22 606 Verde, West Africa. *J Heal Popul Nutr.* 2014;32(4):646–57.
- 23 607 24. Tiku YS, Mekonnen TC, Workie SB, Amare E. Does Anaemia Have Major Public  
24 608 Health Importance in Children Aged 6–59 Months in the Duggina Fanigo District of  
25 609 Wolaita Zone, Southern Ethiopia? *Ann Nutr Metab [Internet].* 2018;72(1):3–11.  
26 610 Available from: <https://www.karger.com/DOI/10.1159/000484324>
- 27 611 25. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns  
28 612 of anaemia among young children in Nigeria: a Bayesian semi-parametric modelling.  
29 613 *Int Health [Internet].* 2014 Jan 31;6(1):35–45. Available from:  
30 614 <https://doi.org/10.1093/inthealth/iht034>
- 31 615 26. Roberts DJ, Matthews G, Snow RW, Zewotir T, Sartorius B. Investigating the spatial  
32 616 variation and risk factors of childhood anaemia in four sub-Saharan African countries.  
33 617 *BMC Public Health.* 2020;20(1):126.
- 34 618 27. Diao X, Taffesse AS, Thurlow J, Pratt AN, Yu B, Orkin K, et al. NEWSLETTER -  
35 619 Ethiopia Strategy Support Program II ( ESSP-II ) Highlights of Presentations Summer –  
36 620 Fall 2010 : h NEWSLETTER - Ethiopia Strategy Support Program II ( ESSP-II )  
37 621 Capacity Building Initiatives 2010 : 2010;(December).
- 38 622 28. Gebreweld A, Ali N, Ali R, Fisha T. Prevalence of anemia and its associated factors  
39 623 among children under five years of age attending at Gugufu health center, South  
40 624 Wollo, Northeast Ethiopia. *PLoS One [Internet].* 2019 Jul 5;14(7):e0218961. Available  
41 625 from: <https://doi.org/10.1371/journal.pone.0218961>
- 42 626 29. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged  
43 627 from 6 to 59 months in Togo: analysis from Togo demographic and health survey data,  
44 628 2013–2014. *BMC Public Health [Internet].* 2019;19(1):215. Available from:  
45 629 <https://doi.org/10.1186/s12889-019-6547-1>
- 46 630 30. Mohammed SH, Habtewold TD, Esmailzadeh A. Household, maternal, and child  
47 631 related determinants of hemoglobin levels of Ethiopian children: Hierarchical  
48 632 regression analysis. *BMC Pediatr.* 2019;19(1):1–10.
- 49 633 31. Keikhaei B, Zandian K, Ghasemi A, Tabibi R. Iron-Deficiency Anemia among Children  
50 634



- in Southwest Iran. *Food Nutr Bull.* 2007 Dec;28(4):406–11.
32. Campbell JR, Holland J. Development research. *Focaal.* 2007;2005(45):3–17.
  33. Gebreegziabiher G, Etana B, Niggusie D. Determinants of Anemia among Children Aged 6–59 Months Living in Kilte Awulaelo Woreda, Northern Ethiopia. Benz EJ, editor. *Anemia [Internet].* 2014;2014:245870. Available from: <https://doi.org/10.1155/2014/245870>
  34. Ayoya MA, Ngnie-Teta I, Séraphin MN, Mamadoulaibou A, Boldon E, Saint-Fleur JE, et al. Prevalence and risk factors of anemia among children 6-59 months old in Haiti. *Anemia.* 2013;2013:2–5.
  35. Pasricha SR, Black J, Muthayya S, Shet A, Bhat V, Nagaraj S, et al. Determinants of anemia among young children in rural India. *Pediatrics.* 2010;126(1).
  36. Ntenda PAM, Nkoka O, Bass P, Senghore T. Maternal anemia is a potential risk factor for anemia in children aged 6–59 months in Southern Africa: a multilevel analysis. *BMC Public Health [Internet].* 2018;18(1):650. Available from: <https://doi.org/10.1186/s12889-018-5568-5>
  37. Shenton LM, Jones AD, Wilson ML. Factors Associated with Anemia Status Among Children Aged 6–59 months in Ghana, 2003–2014. *Matern Child Health J.* 2020;24(4):483–502.
  38. Khan JR, Awan N, Misu F. Determinants of anemia among 6–59 months aged children in Bangladesh: evidence from nationally representative data. *BMC Pediatr [Internet].* 2016;16(1):3. Available from: <https://doi.org/10.1186/s12887-015-0536-z>
  39. Rahman MS, Mushfiquie M, Masud MS, Howlader T. Association between malnutrition and anemia in under-five children and women of reproductive age: Evidence from Bangladesh Demographic and Health Survey 2011. *PLoS One.* 2019 Jul;14(7):e0219170–e0219170.
  40. Belachew A, Tewabe T. Under-five anemia and its associated factors with dietary diversity, food security, stunted, and deworming in Ethiopia: systematic review and meta-analysis. *Syst Rev.* 2020 Feb;9(1):31.
  41. Malako BG, Asamoah BO, Tadesse M, Hussen R, Gebre MT. Stunting and anemia among children 6–23 months old in Damot Sore district, Southern Ethiopia. *BMC Nutr.* 2019;5(1):1–11.
  42. Pelletier DL, Frongillo Jr EA, Schroeder DG, Habicht JP. The effects of malnutrition on child mortality in developing countries. *Bull World Health Organ.* 1995;73(4):443–8.
  43. Takele WW, Baraki AG, Wolde HF, Desyibelew HD, Derseh BT, Dadi AF, et al. Anemia and Contributing Factors in Severely Malnourished Infants and Children Aged between 0 and 59 Months Admitted to the Treatment Centers of the Amhara Region, Ethiopia: A Multicenter Chart Review Study. Hassen K, editor. *Anemia [Internet].* 2021;2021:6636043. Available from: <https://doi.org/10.1155/2021/6636043>
  44. Caulfield LE, Richard SA, Rivera JA, Musgrove P, Black RE. Chapter 28. Stunting, Wasting, and Micronutrient Deficiency Disorders. *Dis Control Priorities Dev Ctries (2nd Ed.* 2006;551–68.
  45. Goswami S, Das KK. Socio-economic and demographic determinants of childhood anemia. *J Pediatr (Rio J).* 2015;91(5):471–7.

## Figure legend/caption

Figure 1: Trends in anaemia overtime across the regions in Ethiopia, EDHS 2005 to 2016

- 1 682 Figure 2: Hot spot and cold spot analysis of anaemia in Ethiopian, EDHS 2005 to 20016
- 2
- 3 683 Figure 3: Ordinary Kriging interpolation of anaemia in Ethiopia, EDHS 2005 to 2016
- 4
- 5 684 Figure 4: Spatial scan statistics analysis of anaemia in Ethiopia, EDHS, 2005-2016
- 6
- 7 685
- 8
- 9 686
- 10
- 11 687
- 12 688
- 13 689
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24
- 25
- 26
- 27
- 28
- 29
- 30
- 31
- 32
- 33
- 34
- 35
- 36
- 37
- 38
- 39
- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

For peer review only

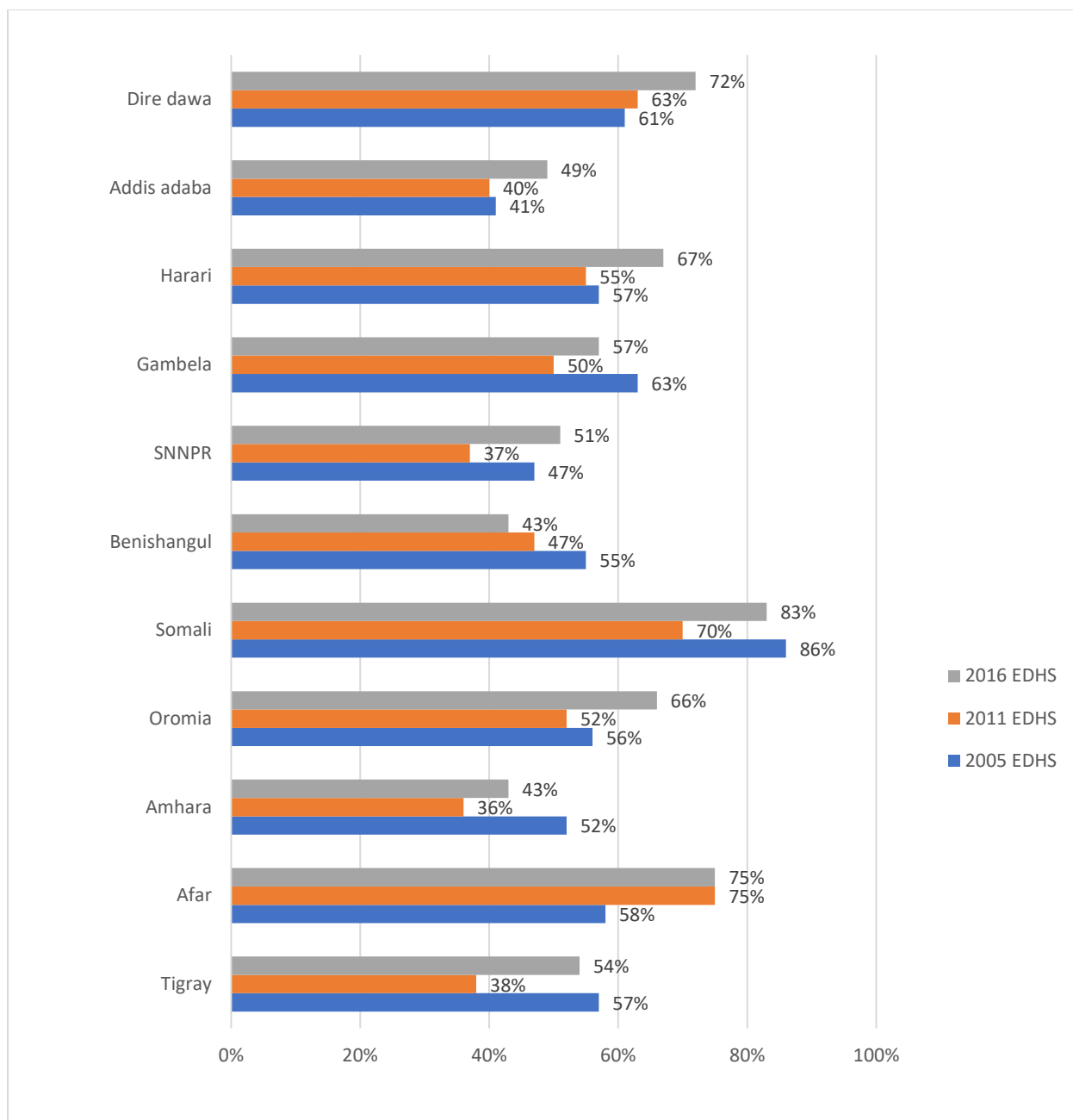


Figure 1: Trends in anaemia overtime across the regions in Ethiopia, EDHS 2005 to 2016

136/bmjopen-2020-045544 on 17 August 2024. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.

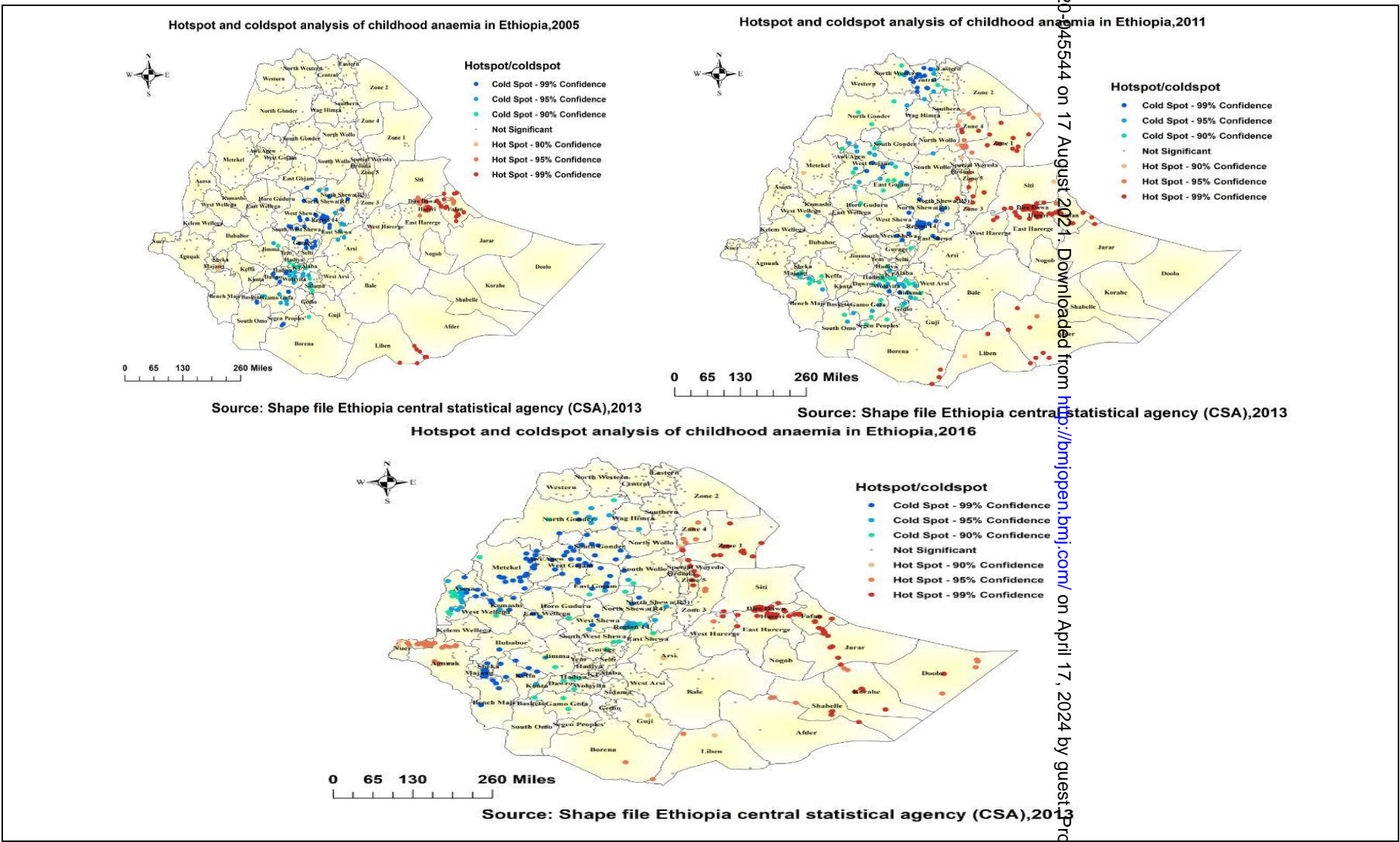


Figure 2: Hot spot and cold spot analysis of anaemia in Ethiopian, EDHS 2005 to 2016

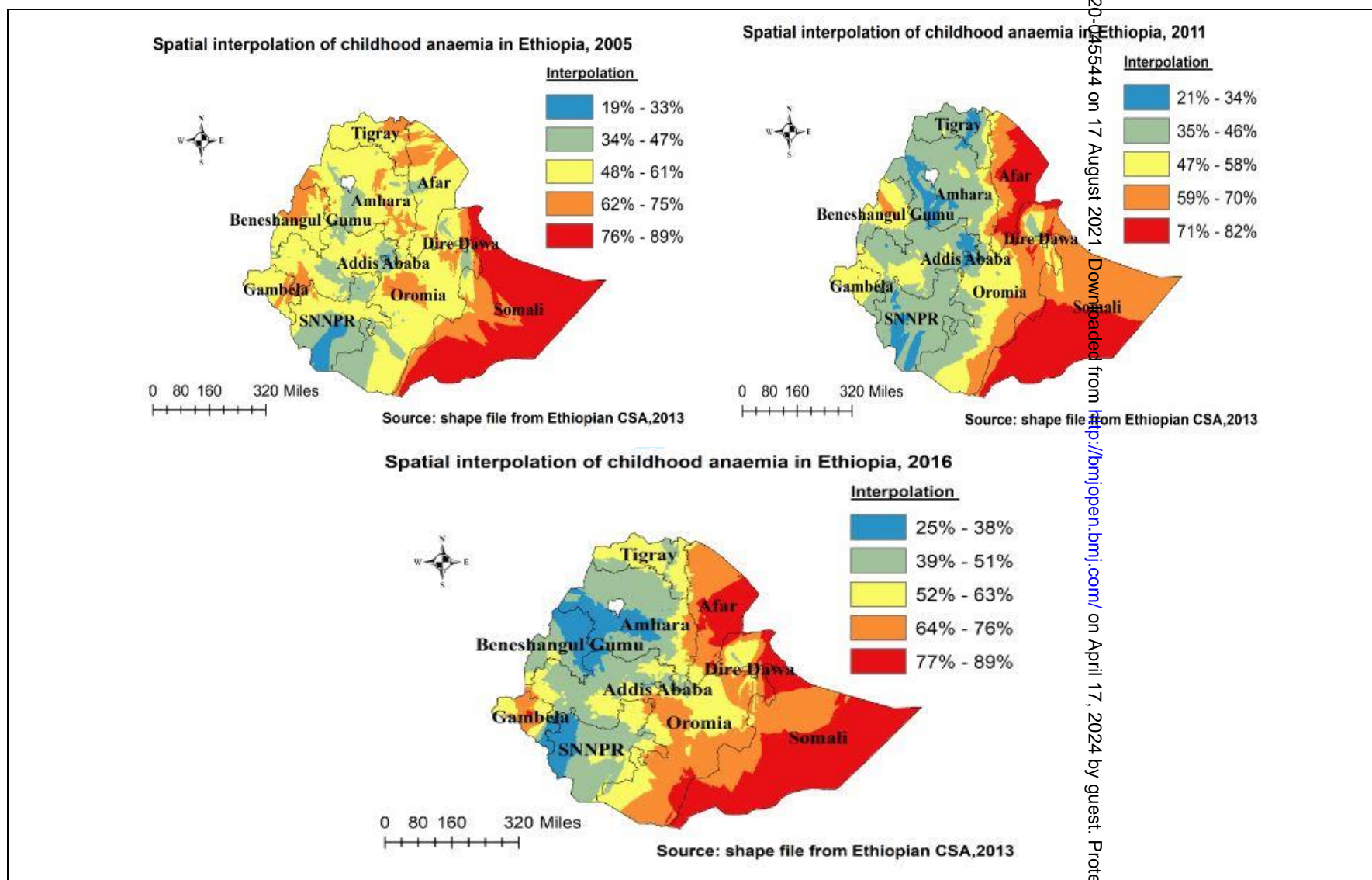


Figure 3: Ordinary Kriging spatial interpolation of anaemia in Ethiopia, EDHS 2005 to 2016

136/bmjopen-2020-045544 on 17 August 2021. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.

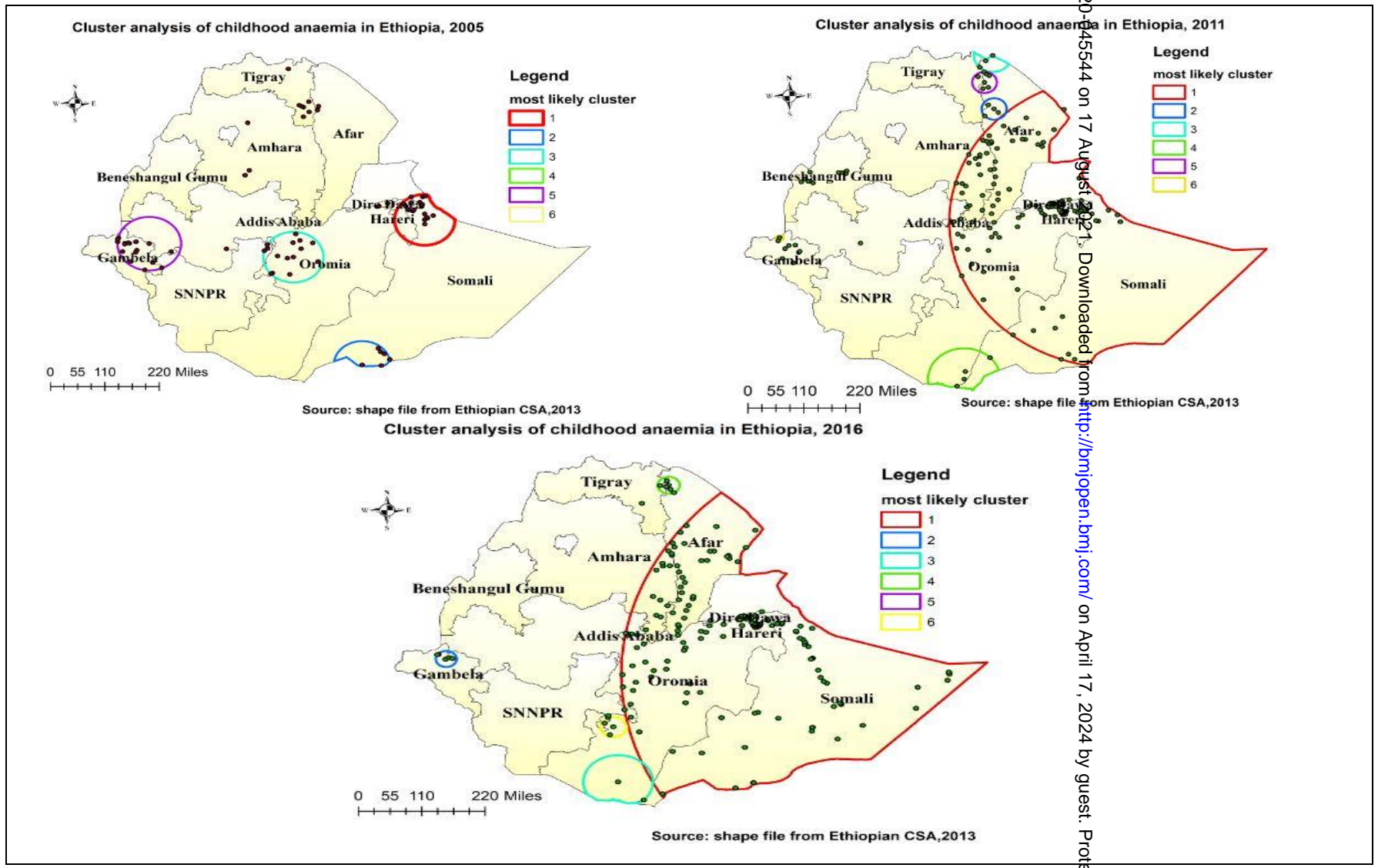


Figure 4: Spatial scan statistics analysis of anaemia in Ethiopia, EDHS, 2005-2016

# BMJ Open

## Spatio-temporal distribution and associated factors of anaemia among children aged 6–59 months in Ethiopia: a spatial and multilevel analysis based on the EDHS 2005–2016

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-045544.R3
Article Type:	Original research
Date Submitted by the Author:	20-Jul-2021
Complete List of Authors:	Samuel, Hailegebreal; Arba Minch University, Department of Health Informatics Nigatu, Araya; University of Gondar, Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia Mekonnen, Zeleke; Ethiopia Ministry of Health, Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia; Endehabtu, Berhanu; University of Gondar, Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia
<b>Primary Subject Heading</b>:	Public health
Secondary Subject Heading:	Public health, Health informatics
Keywords:	PAEDIATRICS, Community child health < PAEDIATRICS, Anaemia < HAEMATOLOGY, EPIDEMIOLOGY

SCHOLARONE™  
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.



1 Spatio-temporal distribution and associated factors of anaemia among children aged 6–59  
2 months in Ethiopia: a spatial and multilevel analysis based on the EDHS 2005- 2016

3 Samuel Hailegebreal<sup>1\*</sup>, Araya Mesfin Nigatu<sup>2</sup>, Zeleke Abebaw Mekonnen<sup>2,3</sup>, Berhanu Fikadie  
4 Endehabtu<sup>2</sup>

### 5 **Affiliation**

6 <sup>1</sup>Arba Minch University, College of Medicine and Health Sciences, School of Public Health  
7 Department of Health Informatics, Ethiopia

8 <sup>2</sup>Department of Health Informatics, Institute of Public Health, University of Gondar, Ethiopia

9 <sup>3</sup>Health System Directorate, Ministry of Health, Addis Ababa, Ethiopia

### 11 **Corresponding author**

12 Samuel Hailegebreal

13 Email: [samuastd@gmail.com](mailto:samuastd@gmail.com)

## Abstract

**Objectives:** Anaemia is a global public health problem with major health and socio-economic consequences. Though childhood anaemia is a major public health problem in Ethiopia, there is limited evidence on the spatio-temporal variability of childhood anaemia over time in the country. Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anaemia using the Ethiopian Demographic and Health Survey (EDHS) data from 2005-2016.

**Design:** Survey-based cross-sectional study design was employed for the EDHS.

**Setting:** Data were collected in all nine regions and two city administrations of Ethiopia in 2005, 2011 and 2016.

**Participants:** The source population for this study was all 6–59 months of children in Ethiopia. A total of 21,302 children aged 6-59 months were included in this study.

**Outcome measure:** The outcome variable was child anaemia status.

**Results:** The prevalence of anaemia declined from 53.9% in 2005 to 44.6% in 2011, but it showed an increase in 2016 to 57.6%. The spatial analysis revealed that the spatial distribution of anaemia varied across the regions. The spatial scan statistics analysis indicated a total of 22 clusters (RR= 1.5, P-value < 0.01) in 2005, 180 clusters (RR = 1.4, P-value < 0.01) in 2011, and 219 clusters (RR = 1.4, P-value < 0.01) in 2016 significant primary clusters were identified. The child's age, age of the mother, maternal anaemia status, wealth index, birth order, fever, stunting, wasting status, and region were significant predictors of childhood anaemia.

**Conclusions:** In this study, childhood anaemia remains a public health problem. The spatial distribution of childhood anaemia varied significantly across the country. Individual-level and

1 45 community-level factors were associated with childhood anaemia. Therefore, in regions with a  
2  
3 46 high risk of childhood anaemia, individual and community level factors should be intensified by  
4  
5 47 allocating additional resources and providing appropriate and tailored strategies.  
6  
7

8 48 **Keywords:** Anaemia, Childhood, EDHS, Spatial, Multilevel, Ethiopia  
9

### 10 11 49 **Strengths and limitations of this study**

- 12 50 • This study applied different methods to analyses spatial patterns, trends, and used  
13  
14 51 multilevel logistic regression models, accounting for the nested nature of EDHS data  
15  
16 52 • The study was based on three consecutive EDHS datasets representing the whole  
17  
18 53 country of Ethiopia  
19  
20 54 • The cross-sectional nature of the data prevents causality from being inferred between  
21  
22 55 the independent and dependent variables  
23  
24 56 • Respondents without coordinate (longitude and latitude) were excluded from the spatial  
25  
26 57 analysis, which could affect the generalizability of the findings  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

## 69 **Background**

70 Anaemia is a condition characterized by a low level of haemoglobin in the blood(1). Over 273  
71 million children age under five years suffer from anaemia worldwide(2). Sub-Saharan Africa is  
72 one of the most affected regions, accounting for 53.8% of childhood anaemia(2). World Health  
73 Organization (WHO) had developed a classification system to facilitate international  
74 comparisons of anaemia as public health crises. The problem is considered severe if anaemia  
75 prevalence is  $\geq 40\%$ , moderate from 20% to 39.9%, and mild from 5% to 19.9%(3). The high  
76 prevalence of anaemia and its consequences for child health, especially on their growth and  
77 development, have made it an important public health problem. Anaemia also increases the  
78 risk of mortality and morbidity that come from other diseases(4,5).

79 Anaemia is a public health problem that affects populations in both industrialized and non-  
80 industrialized countries which touches all segments of the population. It is frequently observed  
81 among children and pregnant women who are the most vulnerable group because their iron  
82 requirements are higher than any other group(6). Anaemia is defined as a haemoglobin level  
83 below 11.0 g/dl for children age 6-59 months. Childhood anaemia is mainly caused by dietary  
84 iron deficiency, foliate, vitamin B12, vitamin A deficiencies, chronic inflammation, parasitic  
85 infections, nutritional deficiencies, hemoglobinopathies and inherited disorders (7,8).

86 A report from WHO in 2015 regarding global anaemia prevalence, using data for 2011, has  
87 shown that prevalence for Africa, southeast Asia, America and the European regions was  
88 62.3%,53.8%,23.3%, and 22.9% respectively(3). In Sub-Saharan Africa, anaemia is a  
89 significant public health problem associated with an increased risk of death and impaired  
90 cognitive development(9).

91 Various studies showed that the prevalence of anaemia among children aged 6-59-months  
92 was high and a severe public health problem. Evidence from various studies indicated that age

1 93 of the mother , residence, maternal education status(10), an introduction of complementary  
2  
3 94 foods, poor breastfeeding practice, poor utilization of folic acid by mothers(11), maternal  
4  
5 95 anaemia(12), unemployment of the parent, and presence of sickle haemoglobin, household  
6  
7  
8 96 wealth index, and sex of the child were associated with childhood anaemia(13) . Few studies  
9  
10 97 have been done on factors associated with anaemia in Ethiopia, to date; the risk areas (hot  
11  
12 98 spot) of anaemia among children are not identified. Thus, this study aimed to assess the  
13  
14  
15 99 spatiotemporal patterns of anaemia among children aged under five years in Ethiopia over the  
16  
17 100 last 15 years to evaluate whether there have been improvements in anaemia risk areas  
18  
19 101 following intervention programs in between the survey periods in Ethiopia. Geographical  
20  
21 102 differences in the causes of anaemia can be partially explained by large-scale variability in  
22  
23  
24 103 environmental drivers, particularly nutritional and infectious causes(14). The risk of malaria is  
25  
26 104 known to be associated with elevation and land surface temperature(15). Environmental  
27  
28 105 drivers of anaemia tend to show a high degree of spatial dependency. Therefore, detecting the  
29  
30  
31 106 geographic variation of anaemia during childhood is important to prioritize and design targeted  
32  
33 107 intervention programs to reduce anaemia especially in those areas with a consistently higher  
34  
35 108 risk of anaemia over time. Therefore, this study attempts to fill the gap by investigating the  
36  
37  
38 109 spatio-temporal distribution of anaemia and its associated factors using multilevel model  
39  
40 110 analysis in Ethiopia using the EDHS survey between 2005-2016 data.

## 111 **Methods and materials**

### 112 **Study design, setting and period**

113 A cross sectional survey data from three consecutive EDHS (2005, 2011 and 2016) were used  
114 for this study. The surveys were conducted at 5-year interval at the national level. Ethiopia is  
115 situated in the Horn of Africa (3°-14°N and 33° – 48°E). Administratively, the country is divided  
116 into nine regions (Afar, Amhara, Benishangul-Gumuz, Gambela, Harari, Oromia, Somali,

1 117 Southern Nations, Nationalities, and People's Region (SNNPR), and Tigray) and two cities  
2  
3 118 administration (Addis Ababa and Dire-Dawa). Each region is sub-divided into zones, districts,  
4  
5 119 towns, and kebeles (the smallest administrative units).  
6  
7

### 8 120 **Source and study population**

9  
10  
11 121 All children aged 6-59-months in Ethiopia were the source population for this study whereas  
12  
13  
14 122 all children aged 6-59 months in the selected enumeration areas within five years before the  
15  
16 123 survey were the study population.  
17  
18

### 19 124 **Sample size and sampling technique**

20  
21 125 For the current study, a total of 21,302 children aged 6-59-months were extracted from three  
22  
23  
24 126 surveys and included in the analysis. Children's record (KR) datasets were used for this  
25  
26 127 analysis. The survey covered all nine regions and the two city administrations of Ethiopia.  
27  
28 128 Participants were selected based on a stratified two-stage cluster sampling technique in each  
29  
30  
31 129 survey year. After excluding clusters with zero coordinates and missing information, a total of  
32  
33 130 503 clusters in 2005, 569 clusters in 2011, and 615 clusters in 2016 were used for analysis.  
34  
35 131 The detailed sampling procedure was available in each survey years report(16–18)  
36  
37

### 38 132 **Data collection tools and procedures**

39  
40 133 The data for this analysis were extracted from Demographic and Health Survey (DHS) program  
41  
42  
43 134 website ([www.measuredhsprogram.com](http://www.measuredhsprogram.com)) after obtaining the necessary permissions for the  
44  
45 135 download and further analyses. Similarly, spatial location data (latitude and longitudinal) were  
46  
47 136 extracted from the DHS website. After extraction, the missing values for the significant  
48  
49  
50 137 independent variables were excluded and the analysis was undertaken using a complete data  
51  
52 138 set. Blood specimens for anaemia testing were collected from all children age 6-59 months for  
53  
54 139 whom consent was obtained from their parents or other adults responsible for them. Blood  
55  
56  
57 140 samples were drawn from a drop of blood taken from a finger prick or a heel prick in the case  
58  
59

1 141 of children age 6-11 months and collected in a microcuvette. Haemoglobin analysis was carried  
2  
3 142 out on-site using a battery-operated portable HemoCue analyser.

### 6 143 **Key variables and measurements**

8 144 **Dependent variable:** The study variables were grouped into dependent and independent  
9  
10 145 variables. The dependent variable is childhood anaemia status, categorized as “anaemic or  
11  
12 146 not-anaemic”. Children whose haemoglobin level was less than 11g/dl were considered  
13  
14  
15 147 anaemic and not anaemic otherwise.

### 17 148 **Independent variables:**

19  
20 149 sociodemographic (religion, age of mother, marital status, educational status, husband  
21  
22 150 education, wealth index, mothers working status, numbers of under five children) Maternal and  
23  
24 151 Child- related (child's sex, child's age, birth size, birth order, maternal BMI, maternal anaemia  
25  
26 152 status, breastfeeding, fever, diarrhoea, vitamin supplement, stunting status and wasting  
27  
28 153 status). Community-level variables (residence, region, community women education and  
29  
30  
31 154 community women poverty).

33  
34 155 We created community women education and community women poverty variables by  
35  
36 156 aggregating the individual characteristics within their clusters. The aggregates were computed  
37  
38 157 using the median values of the proportions of women in each category of a given variable. We  
39  
40 158 categorized the aggregate values of a cluster into groups based on national median values,  
41  
42  
43 159 since all aggregates were not normally distributed.

45  
46 160 **Community women education:** was defined as the proportion of women who attended  
47  
48 161 primary, secondary, and higher education within the cluster. The aggregate of individual  
49  
50 162 primary, secondary, and higher educational attainment can show the overall educational and  
51  
52  
53 163 academic status of women within the cluster. They were categorized into two categories a

1 164 higher proportion of women education within the cluster and a lower proportion of women  
2  
3 165 education based on the national median value.

5 166 **Community women poverty status:** defined as the proportion of poor and poorest mothers  
7  
8 167 within the cluster. For each cluster, the proportion of poor and poorest as-was aggregated and  
9  
10 168 show overall poverty status within the cluster. It was categorized into two categories based on  
11  
12 169 national median value as higher proportion of poor/poorest mother's and lower proportion of  
13  
14 170 mothers within a cluster.

### 17 171 **Data management and analysis**

19 172 The data were cleaned using STATA version 14.1 software and microsoft excel. The data were  
20  
21 173 weighted using sampling weight, primary sampling unit, and strata before any statistical  
22  
23 174 analysis to restore the representativeness of the survey and take into account the sampling  
24  
25 175 design to obtain reliable statistical estimates.

### 29 176 **Spatial analysis**

31 177 For the spatial analysis, ArcGIS V.10.7 software, and SaTScan V.9.6 software were used.

34 178 The spatial scan statistics uses a circular scanning window that moves across the study area  
35  
36 179 to identify a significant spatial clustering of childhood anaemia.

### 40 180 **Spatial autocorrelation analysis**

42 181 The spatial autocorrelation (Global Moran's I) statistic measures whether childhood anaemia  
43  
44 182 patterns were dispersed, clustered or randomly distributed in the study area. Moran's I is a  
45  
46 183 spatial statistic used to measure spatial autocorrelation by taking the entire dataset and  
47  
48 184 produce a single output value that ranges from -1 to +1. Moran's I values close to -1  
49  
50 185 indicate the spatial distribution of anaemia was dispersed, whereas Moran's I close to +1  
51  
52 186 indicate the spatial distribution of anaemia was clustered, and an I value of 0 means anaemia  
53  
54  
55  
56  
57  
58  
59



1 187 is distributed randomly. Anselin's Local Moran's  $I$  (ALMI) identifies High-High clusters, Low-  
2  
3 188 Low clusters, and spatial outliers (High-Low and Low-High).  
4  
5

### 6 189 **Hot spot analysis (Getis-Ord $G_i^*$ statistic)**

  
7

8  
9 190 Local Moran's  $I$ , Gettis-Ord $G_i^*$  statistics was computed to measure how spatial autocorrelation  
10  
11 191 of anaemia among children age under five years varies across the regions. In this analysis,  
12  
13 192 Z-score and p-value were computes to determine the statistical significance of the clustering.  
14  
15 193 Statistical output with high  $G_i^*$  indicates 'hotspot' (high-risk areas) of childhood anaemia,  
16  
17  
18 194 whereas low  $G_i^*$  shows a 'cold spot' (low-risk areas) of anaemia in Ethiopia.  
19  
20

### 21 195 **Spatial interpolation**

  
22

23 196 The unsampled areas of Ethiopia were also predicted by using data from sampled locations  
24  
25 197 through the spatial interpolation technique. There are various deterministic and geostatistical  
26  
27  
28 198 interpolation methods. Among all of the methods, ordinary Kriging and empirical Bayesian  
29  
30 199 Kriging are considered the best methods since they incorporate spatial autocorrelation and  
31  
32 200 statistically optimize the weight. Ordinary Kriging spatial interpolation method was used for this  
33  
34  
35 201 study for predictions of childhood anaemia in unobserved areas of Ethiopia since it had low  
36  
37 202 mean square error and residual as compared to the other interpolation techniques.  
38  
39

### 40 203 **Spatial scan statistical analysis**

  
41

42 204 Spatial scan statistical analysis was employed to Identifying most likely(primary) and  
43  
44 205 secondary spatial clusters of childhood anaemia. This method is widely recommended as it is  
45  
46  
47 206 very important in detecting local clusters and has higher power than other available spatial  
48  
49 207 statistical methods. Bernoulli based model was employed to test for statistically significant  
50  
51 208 spatial clusters of anaemia using Kulldorff's SaTScan V.9.6 software. Children age under five  
52  
53  
54 209 years with anaemia were taken as cases, and those who are not-anaemic as controls to fit the  
55  
56 210 Bernoulli model. The default maximum spatial cluster size of <50% of the population was used.  
57  
58  
59

1 211 The scanning window with maximum likelihood was the most likely cluster, and the p-value  
 2  
 3 212 was assigned to each cluster based on Monte Carlo hypothesis testing(19).  
 4  
 5

### 6 213 **Associated factors of anaemia**

8  
 9 214 Four models were constructed for multilevel logistic regression analysis using **melogit** STATA  
 10 215 command. The first model (a random intercept model) was null model without predictors to  
 11  
 12 216 determine the extent of cluster variations in anaemia. The second model (model I) was  
 13  
 14 217 adjusted with individual-level variables. The third model (model II) was adjusted for community-  
 15  
 16 218 level variables, while the fourth model (model III) was fitted with both individual-level and  
 17  
 18 219 community-level variables simultaneously. For model comparison, we used Log-Likelihood  
 19  
 20 220 Ratio (LLR) and deviance.  
 21  
 22  
 23  
 24  
 25

26 221 Intra-class correlation (ICC), median odds ratio (MOR), and proportional change in variance  
 27  
 28 222 (PCV) were computed to measure the variation between clusters. The intra-class correlation  
 29  
 30 223 coefficient (ICC) quantifies the degree of heterogeneity of childhood anaemia between clusters  
 31  
 32 224 (the proportion of the total observed individual variation in anaemia that is attributable between  
 33  
 34 225 cluster variations) calculated as  
 35  
 36  
 37

38  
 39 226  $ICC = \frac{\sigma^2}{(\sigma^2 + \sigma_b^2)}$  (20), where,  $\sigma^2$  is the community level variance and  $\sigma_b^2$  indicates individual level  
 40  
 41 227 variance. The individual variance ( $\sigma_b^2$ ) equal to  $\pi^2/3$ .  
 42  
 43  
 44

45 228 Median Odds Ratio (MOR) is quantifying the variation of the odds ratio between the cluster at  
 46  
 47 229 high risk of anaemia and cluster at lower risk when randomly picking out two clusters (EAs).  
 48

49 230  $MOR = e^{(0.95 * \text{sqrt}(\sigma^2))}$ (21) where,  $\sigma^2$  indicates that cluster level variance.  
 50  
 51

52  
 53 231 Proportional Change in Variance (PCV) the proportion of the total observed individual variation  
 54  
 55 232 of childhood anaemia that is attributable to between cluster variations. In the multivariable  
 56  
 57  
 58  
 59

1 233 multilevel logistic regression analysis variables with a p-value of <0.05 were considered as  
2  
3 234 statistically significant. Adjusted Odds Ratio (AOR) with their corresponding 95% confidence  
4  
5 235 interval was determined to identify factors associated with anaemia. Multicollinearity was  
6  
7  
8 236 checked using the variance inflation factor (VIF), which indicates that there is no  
9  
10 237 multicollinearity because all variables have VIF less than 10%. The final model was the best  
11  
12 238 fitted model since it had the highest log-likelihood and the lowest deviance value.

## 16 239 **Patient and public involvement**

18 240 This study did not involve patients and the public

## 21 241 **Results**

### 24 242 **Descriptive characteristics of the study population**

27 243 A total of 21,302 children with known haemoglobin levels (3,868 in 2005, 8,958 in 2011, and  
28  
29 244 8467 in 2016) were included in this study. The prevalence of anaemia for the three consecutive  
30  
31 245 surveys was 53.9%, 44.6%, and 57.6% in 2005, 2011, and 2016 EDHS data respectively. The  
32  
33 246 majority of the participants were in the age group of 36-47 (23.7%), 36-47 (24.4%), and, 48-59  
34  
35 (22.9%) in EDHS 2005, 2011, and 2016 survey respectively. The mean age of children was  
36 247  
37 32.6 ±15.6-SD, 32.6±15.4-SD, and 31.7±15.6-SD in 2005, 2011, and 2016 respectively.  
38 248  
39 Among the three survey, male participants were higher in 2011 and 2016 compared to 2005  
40 249  
41 EDHS survey. The majority of children were from rural resident in three surveys. The  
42 250  
43 educational status of women was 78.6%, 70.1%, and 67.1% were unable to read and write in  
44 251  
45 2005, 2011, and 2016 survey years respectively. Children from poor and middle class wealth  
46 252  
47 index families were more anaemic than children from rich families across the three EDHS  
48 253  
49 survey years (Table 1). In this study, the trends in the childhood anaemia rate were fluctuates  
50 254  
51 across regions (**Fig.1**).

1 256 **Table 1: Descriptive characteristics of study participants included in the analysis for**  
 2  
 3 257 **childhood anaemia five years preceding the survey from EDHS 2005-2016 in Ethiopia**

Variables	2005 (N, 3868)	2011 (N, 8958)	2016 (N, 8476)
	Frequency (%)	Frequency (%)	Frequency (%)
<b>Sex of child</b>			
Male	1,931(49.9)	4,500(51.4)	4,395(51.9)
Female	1,937(50.1)	4,358(48.7)	4,081(48.2)
<b>Age of child in month</b>			
6-11	418 (10.8)	1,029(11.5)	1,000(11.8)
12-23	842 (21.76)	1,804(20.14)	1,902(22.4)
24-35	825 (21.3)	1,895(21.2)	1,803(21.3)
36-47	919 (23.7)	2,184(24.4)	1,832(21.6)
48-59	864 (22.3)	2,047(22.9)	1,939(22.9)
<b>Mean ± SD</b>	<b>32.6 ±15.6</b>	<b>32.6±15.4</b>	<b>31.7±15.6</b>
<b>Residence</b>			
Urban	244 (6.3)	1,047(11.7)	857(10.1)
Rural	3,624 (93.7)	7,911(88.3)	7,619(89.9)
<b>Religion</b>			
Orthodox	1,624 (42.0)	3,416(38.1)	2,913(34.4)
Muslim	1,276 (33.0)	3,108(34.7)	3,432(40.5)
Protestant	836 (22.0)	2,151(24.0)	1,874(22.1)
Others	133 (3.0)	283(3.2)	258(3.0)
<b>Women age</b>			
15-29	1,930(49.9)	4,908(54.9)	4,356(51.4)

1	30-39	1,474(38.1)	3,223(36.0)	3,335(39.3)
2				
3	40-49	464(12.0)	828(9.1)	785(9.3)
4				
5	Women education			
6				
7				
8	No education	3,042 (78.6)	6,285(70.1)	5,685(67.1)
9				
10	Primary	684 (17.7)	2,389(26.7)	2,275(26.8)
11				
12	Secondary	136 (3.5)	168(1.9)	346(4.1)
13				
14	Higher	7 (0.2)	117(1.3)	170(2.0)
15				
16	Marital status			
17				
18				
19	Single	7(0.2)	50(0.6)	45(0.5)
20				
21	Married	3,704(95.7)	8,425(94.0)	8,129(95.9)
22				
23	Widowed	80(2.1)	178(2.0)	93(1.1)
24				
25	Divorced	78(2.0)	306 (3.4)	210(2.5)
26				
27	Husband education			
28				
29				
30	No-education	2,235 (58.0)	4,532(50.9)	4,333(51.1)
31				
32	Primary	1,233(32.0)	3,710(41.7)	3,273(38.6)
33				
34	Secondary	362(9.0)	412(4.6)	572(6.8)
35				
36	Higher education	31(1.0)	255 (2.8)	300(3.5)
37				
38	Wealth index			
39				
40				
41	Poor	1,697(43.7)	4,048(45.2)	3,977(46.9)
42				
43	Middle	854(22.1)	1,873(20.9)	1,821(21.5)
44				
45	Rich	1,318(34.1)	3,038 (33.9)	2,678(31.6)
46				
47	Women working status			
48				
49	Not working	2,841(73.5)	5,793(64.7)	6,140(72.4)
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				

1	Working	1,027(26.5)	3,165(35.3)	2,336(27.6)
2				
3	Total	3,868(100)	8,958(100)	8,476(100)
4				
5				
6	258			
7				
8				

9 259 **Community-level characteristics of the study population** This study revealed that there  
 10  
 11 260 was a significant regional variation of childhood anaemia, with 83.3%, 75.5%,74.5%, and  
 12  
 13 261 68.8% in Somali, Afar, Dire Dawa and Harari respectively. However, Amhara, and Benishangul  
 14  
 15 262 regions were relatively low compared to other regions.

16  
 17  
 18 263 Also, childhood anaemia varies by place of residence. Children residing in communities with  
 19  
 20 264 low women poverty level had a lower percent of anaemia (51.2%) than high community poverty  
 21  
 22 265 level (62.5%). Children from low community women education (59.5%) were more anaemic  
 23  
 24  
 25 266 than children resided from high community women educational (53.6%) (Table 2).

267 **Table 2: Community-level factors of under five children participated in EDHS (2016),**  
 28  
 29 **Ethiopia. (N, 8476)**  
 30

31	Community-level factors	Not-anaemic (%)	Anaemic (%)	Total (100%)
32	Residence			
33				
34	Urban	435(50.6)	424(49.4)	857
35				
36	Rural	3164(41.5)	4455(58.5)	7619
37				
38	Region			
39	Tigray	263(46.0)	309(54.0)	572
40				
41	Afar	21(25.3)	62(74.5)	83
42				
43	Amhara	950(57.5)	703(42.5)	1653
44				
45	Oromia	1273(34.2)	2446(65.8)	3719
46				
47	Somali	58(16.7)	290(83.3)	348
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				

1	Beneshangul	51(56.6)	39(43.4)	90
2				
3	SNNPR	875(49.1)	906(50.9)	1781
4				
5	Gambela	8(42.1)	11(57.9)	19
6				
7	Harari	5(31.2)	11(68.8)	16
8				
9	Addis Ababa	82(50.9)	79(49.1)	161
10				
11	Dire Dawa	9(28.1)	23(71.9)	32
12				
13	Community women education			
14				
15	Low	2281(40.5)	3358(59.5)	5639
16				
17	High	1315(46.4)	1520(53.6)	2837
18				
19	Community women poverty			
20				
21	Low	1815(48.8)	1905(51.2)	3719
22				
23	High	1782(37.5)	2974(62.5)	4756
24				
25				
26				
27				
28				
29				
30	269			
31				
32				
33	270			
34				
35				
36	271			
37				
38	272			
39				
40	273			
41				
42				
43	274			
44				
45	275			
46				
47				
48	276			
49				
50	277			
51				
52	278			
53				
54				
55	279			
56				
57				
58				
59				
60				

## 270 Spatio-temporal distribution of anaemia among children age 6-59 months in Ethiopia

271 The spatial distribution of childhood anaemia varied across regions in all surveys. The spatial  
 272 autocorrelation analysis result indicated that childhood anaemia had spatial dependency in  
 273 2005, 2011, and 2016 (Moran's I: 0.176, 0.18, and 0.09, respectively at P-value < 0.01).

### 274 Hot spot analysis of the three surveys

275 The spatial distribution of childhood anaemia in Ethiopia was different in all the three survey  
 276 periods. In EDHS 2005, a high proportion of childhood anaemia was detected in Dire Dawa,  
 277 Harari, eastern Oromia, Beneshangul in Metekel zone, Gambela, southern and eastern Tigray,  
 278 and Somali region mainly Liben, Afdar, and Fafna zone which was hotspot area within 95%  
 279 confidence level. On the counterpart, GamoGofa, Wolayita, Hadiya, Southern Omo, and

1 280 Segen zone of SNNPR, Addis Ababa, central Oromia, Jima, north Shewa zone were cold spot  
2  
3 281 area. In EDHS 2011, a highly significant clustering of childhood anaemia was detected in  
4  
5 282 Somali, Dire Dawa, Harari, Afar, Gambela, Beneshangul, eastern Oromia, Bale, Arsi zone  
6  
7  
8 283 were the hotspot areas within 95% level of confidence. The low hotspot area of childhood  
9  
10 284 anaemia was detected in central Tigray, East and West Gojam, North Gondar, a central part  
11  
12 285 of Oromia, Addis Ababa and SNNPR were areas identified as the low percentage of childhood  
13  
14  
15 286 anaemia in the 2011 EDHS survey.

16  
17  
18 287 In 2016 EDHS sampled data, hot spot (high risk) regions for childhood anaemia were observed  
19  
20 288 in Somali, Dire Dawa, Harari, Gambela, eastern, and Southern part of Oromia. However,  
21  
22 289 Amhara, Beneshangul, and SNNPR were identified as cold spot (low risk) regions for childhood  
23  
24  
25 290 anaemia within a 95% confidence interval (**Fig.2**)

### 26 27 28 291 **Spatial interpolation**

29  
30 292 Based on 2005 EDHS sampled data, the geostatistical analysis predicts that the highest  
31  
32 293 prevalence of childhood anaemia (65.75%-88.89%) was detected in east Oromia, Ilubabur,  
33  
34 294 Arsi, some parts of Beneshangul, Agnuak zone in Gambela, north Shewa Amhara region,  
35  
36  
37 295 south and central Tigray, Afar in zone2, some parts of Dire Dawa and Somali. In EDHS-2011  
38  
39 296 Geostatistical analysis, a high percentage of anaemia was detected in Afar, most parts of  
40  
41 297 Somali, Oromia in east Harerge and Borena, some part of Dire Dawa, and the Meketel zone  
42  
43  
44 298 in Beneshangul. In 2016 EDHS most of Somali, some parts of Gambela, Guji and some parts  
45  
46 299 of Borena, ast Shewa, East Harerge and Arsi in Oromia and part of Dire Dawa were highly  
47  
48 300 prevalent areas in childhood anaemia (**Fig.3**)

### 49 50 51 301 **Spatial scan statistics**

52  
53  
54 302 In 2005 EDHS, a total of 3 significant (one most likely/primary and two secondary) clusters  
55  
56 303 were identified in spatial scan analysis. The primary cluster spatial window was located in



1 304 Somali. It was centered at (9.018373 N, 43.110635 E) with a radius of 97.93 km, a relative risk  
2  
3 305 (RR) of 1.5, a Log-Likelihood ratio (LLR) of 20.03, at  $p < 0.01$ . It showed that children within  
4  
5 306 the spatial window had 1.5 times more likely a higher risk of anaemia than the children outside  
6  
7  
8 307 the spatial window areas. The secondary clusters scanning window was located in the  
9  
10 308 southern part of Somali region. It was centered at (3.998656 N, 41.240691 E) with a radius of  
11  
12 309 92.08 km, a relative risk (RR) of 1.7 at  $p$ -value  $< 0.01$ . It showed that children within the spatial  
13  
14  
15 310 window had a 1.7 times higher risk of anaemia than children outside the window.

16  
17  
18 311 In 2011 EDHS, 10 clusters were identified and five of them were significant clusters at a  $p$ -  
19  
20 312 value  $< 0.05$ . A total of 180 locations/spots with a total sampled population of 2478 were found  
21  
22 313 in the primary cluster spatial window with a significant  $p$ -value  $< 0.01$ . The primary cluster  
23  
24 314 spatial window was located mainly in Somali, Afar, eastern Oromia, Dire Dawa, and Harari. It  
25  
26 315 was centered at (8.975207 N, 43.790264 E) with a radius of 540.29 km, a relative risk (RR) of  
27  
28 316 1.4, a log-likelihood ratio (LLR) of 127.79 at  $p$ -value  $< 0.01$ . It showed that children within the  
29  
30 317 spatial window had 1.4 times more likely a higher risk of anaemia than the children outside the  
31  
32  
33 318 spatial window areas. The secondary cluster spatial window was located mainly in Afar region.  
34  
35 319 It was centered at (12.758587 N, 40.175990 E) with a radius of 39.58 km, a relative risk (RR)  
36  
37 320 of 1.7, a log-likelihood ratio (LLR) of 21.5 at  $P$ -value  $< 0.01$ .

38  
39  
40  
41 321 In 2016 EDHS, 7 clusters (one most likely cluster) located in Somali, Afar, eastern Oromia,  
42  
43 322 Dire Dawa, and Harari. It was centered at (7.650693 N, 47.007920 E) with a radius 912.19 km,  
44  
45 323 a relative risk (RR) of 1.4 and a Log-Likelihood ratio (LLR) of 182.86 at  $P$ -value  $< 0.01$ . It showed  
46  
47 324 that children within the spatial window had a 1.4 times higher risk of anaemia than outside the  
48  
49  
50 325 window. Secondary clusters spatial window was located in Gambela. It was centered at  
51  
52 326 (8.195862 N, 34.289837 E) with a radius of 29.01 km, a log-likelihood ratio (LLR) of 18.80 at  
53  
54  
55 327  $p$ -value  $< 0.01$  (**Fig.4**).

## Multilevel Analysis

The intra-cluster correlation coefficient (ICC) in the null model indicated that 19% of the total variability for childhood anaemia was due to differences between clusters. The remaining unexplained 81% were attributable to individual differences. The median odds ratio for anaemia was 2.3 in the null model, indicating variation between clusters. If we randomly select children from two different clusters children at the cluster with a higher risk of anaemia had 2.3 times higher odds of experiencing anaemia than children at the cluster with a lower risk of anaemia. A bivariable analysis was done to identify variables for multivariable multilevel logistic analysis. A variable with a p-value < 0.25 were considered for multivariable logistic regression analysis.

### Individual-level predictors for anaemia

In multivariable multilevel mixed-effect logistic regression analysis child's age, wealth index, age of mother, maternal anaemia status, birth order, fever, stunting, and wasting status were significant predictor of childhood anaemia.

Children age between 12–23 months (AOR = 0.66, 95%CI = 0.53-0.81), between 24–35 months (AOR= 0.35, 95% CI = 0.28-0.43), between 36–47 months (AOR = 0.23-95%CI = 0.19-0.29), and between 48–59 months (AOR = 0.15, 95%CI = 0.12-0.19) were less likely to develop anaemia compared with children age between 6–11 months.

The likelihood of developing anaemia for those children residing with the family wealth index of middle and rich were lower by 21% (AOR=0.79, 95%CI = 0.67-0.94), and 23% (AOR=0.77, 95%CI = 0.65-0.91), respectively as compared with children with low wealth index. Children whose mother age were between 40-49 had 25% decreased odds of developing childhood anaemia compared to age 15-29, (AOR=0.75, 95%CI = 0.59-0.95).

1 351 The odds of experiencing anaemia for those birth orders 4-5, six and above six were 1.22 times  
2  
3 352 (AOR=1.22, 95%CI = 1.01-1.47) and, 1.35 times (AOR=1.35, 95%CI = 1.08-1.67) higher as  
4  
5 353 compared with first-order respectively. The odds of developing anaemia of children born from  
6  
7  
8 354 anaemia history mother were 1.39 higher more elevated than those born from not anaemic  
9  
10 355 history before. Children who had fever were 39% (AOR =1.39, 95% CI: 1.24-1.58) more likely  
11  
12 356 to develop anaemia than their counterparts. Children with moderate and severe stunting status  
13  
14  
15 357 were 35% (AOR=1.35, 95% CI: 1.17-1.54) and, 96% (AOR=1.95, 95% CI: 1.68-2.28), more  
16  
17 358 likely to develop anaemia respectively, compared to no stunting status. Similarly, children who  
18  
19 359 had to sever wasting status were 51% more (AOR =1.51, 95% CI: 1.07-2.12) likely to develop  
20  
21  
22 360 anaemia compared with those children who had no wasting.  
23

### 24 361 **Community-level predictors for anaemia**

25  
26  
27 362 The multivariable multilevel logistic regression analysis region was significantly associated with  
28  
29  
30 363 community-level factors for childhood anaemia.  
31

32 364 Odds of children live in Somali were 5.65 times (AOR=5.65, 95% CI: 3.92-8.16), Dire Dawa  
33  
34 365 3.45 times (AOR=3.45, 95% CI: 2.27-5.26), Afar 3 times (AOR=3.00, 95% CI: 2.09-4.34), and  
35  
36  
37 366 Oromia 2.34 times (AOR=2.34, 95% CI: 1.73-3.18) had more likely to develop childhood  
38  
39 367 anaemia compared to Amhara region. Similarly, the odds of developing anaemia in Addis  
40  
41 368 Ababa were 2 times (AOR=2.00, 95% CI: 1.40-3.16), Gambella 1.94 times (AOR=1.94, 95%  
42  
43  
44 369 CI: 1.32-2.84), and Tigray 1.46 times (AOR=1.46, 95% CI: 1.08-1.98), more likely as compared  
45  
46 370 to Amhara region. Beneshangul and SNNPR had not significantly different in the prevalence  
47  
48 371 of anaemia than the reference region Amhara (Table 3).  
49

### 50 372 **Table 3: Multilevel logistic regression analysis result of both individual and community-** 51 52 373 **level factors associated with anaemia in Ethiopia, EDHS 2016** 53 54

55 374

Variables	Null Model	Model I AOR (95% CI)	Model II AOR (95% CI)	Model III AOR (95% CI)
<b>Individual-level factors</b>				
<b>Age of child in month</b>				
6-11	-	1	-	1
12-23	-	0.66[0.54-0.82] **	-	0.66 [0.53-0.81] **
24-35	-	0.35[0.28-0.44] **	-	0.35 [0.28-0.43] **
36-47	-	0.23[0.18-0.28] **	-	0.23 [0.19-0.29] **
48-59	-	0.15[0.12-0.19] **	-	0.15 [0.12-0.19] **
<b>Religion</b>				
Orthodox	-	1	-	1
Muslim	-	2.07[1.77-2.47] **	-	1.21 [0.97-1.46]
Protestant	-	1.20 [1.00-1.48] *	-	1.10 [0.86-1.37]
Others	-	1.55[1.07-2.32] *	-	1.44[0.96-2.13]
<b>Wealth status</b>				
Poor	-	1	-	1
Middle	-	0.71[0.61-0.84] **	-	0.79 [0.67-0.94] *
Rich	-	0.72[0.63-0.85] **	-	0.77 [0.65-0.91] *
<b>Child size at birth</b>				
Small	-	1	-	1
Average	-	0.96[0.84-1.09]	-	0.93 [0.80-1.07]
Large	-	0.94[0.81-1.08]	-	0.96 [0.84-1.10]
<b>Birth order</b>				
1 <sup>st</sup>	-	1	-	1
2-3	-	1.09[0.94-1.28]	-	1.13[0.97-1.32]
4-5	-	1.17[0.97-1.40]	-	1.22 [1.01-1.47] *
6 and above	-	1.30[1.05-1.62]	-	1.35 [1.08-1.67] **
<b>No of children under 5</b>				
1-2 children	-	1	-	1
≥ 3 children	-	1.22[1.1-1.4] *	-	1.09 [0.94-1.27]
<b>Maternal anaemia</b>				
Not anaemic	-	1	-	1
Anaemic	-	1.51[1.34, 1.72] **	-	1.39 [1.24-1.58] **

1	<b>Maternal BMI</b>				
2	<b>≥18.5 kg/m<sup>2</sup></b>	-	1	-	1
3	<b>&lt;18.5 kg/m<sup>2</sup></b>	-	1.12[0.97-1.26]	-	1.05 [0.92-1.19]
4					
5					
6	<b>Women working status</b>				
7	<b>Not-working</b>	-	1	-	1
8	<b>Working</b>	-	0.88[0.77-0.99] *	-	0.92 [0.81-1.04]
9					
10					
11	<b>Women age</b>				
12	<b>15-29</b>	-	1	-	1
13	<b>30-39</b>	-	0.91[0.71-1.06]	-	0.90 [0.78-1.04]
14	<b>40-49</b>	-	0.75[0.59-1.12] *	-	0.75 [0.59-0.95] *
15					
16					
17					
18	<b>Breastfeeding</b>				
19	<b>No</b>	-	1	-	
20	<b>Yes</b>	-	0.92[0.81-1.04]	-	0.98 [0.87-1.12]
21					
22					
23					
24	<b>Vitamins in last 6 month</b>				
25	<b>No</b>	-	1	-	
26	<b>Yes</b>	-	0.90[0.81-1.09]	-	0.93 [0.84-1.05]
27					
28					
29	<b>Diarrhea last 2 week</b>				
30	<b>No</b>	-	1	-	1
31	<b>Yes</b>	-	0.88[0.73, 1.04]	-	0.90 [0.76-1.07]
32					
33					
34	<b>Fever in last 2 weeks</b>				
35	<b>No</b>	-	1	-	1
36	<b>Yes</b>	-	1.35[1.15-1.59] **	-	1.32 [1.13-1.56] *
37					
38					
39	<b>Stunting status</b>				
40	<b>No-stunting</b>	-	1	-	1
41	<b>Moderate</b>	-	1.27[1.10-1.46] **	-	1.35 [1.17-1.54] **
42	<b>stunting</b>				
43	<b>Severely</b>	-	1.81[1.55-2.11] **	-	1.96 [1.68-2.28] **
44	<b>stunting</b>				
45					
46					
47					
48					
49	<b>Wasting status</b>				
50	<b>No-wasting</b>	-	1	-	1
51	<b>Moderate</b>	-	1.27[1.11-1.45]	-	0.98 [0.80-1.19]
52	<b>wasting</b>				
53					
54					
55					
56					
57					
58					
59					
60					

1	<b>Severe wasting</b>	-	1.68[1.55-2.10] *	-	1.51 [1.07-2.12] *
2					
3					
4					
5	<b>Region</b>				
6	<b>Amhara</b>	-	-	1	1
7	<b>Tigray</b>	-	-	1.46[1.09-1.97] **	1.46 [1.08-1.98] **
8	<b>Afar</b>	-	-	3.90 [2.84-5.35] **	3.00 [2.09-4.34] **
9	<b>Oromia</b>	-	-	2.48 [1.89-3.25] **	2.34 [1.73-3.18] **
10	<b>Somali</b>	-	-	6.34[4.65-8.63]	5.65 [3.92-8.16] **
11	<b>Beneshangul</b>	-	-	0.86 [0.62-1.17]	0.81 [0.58-1.15]
12	<b>SNNPR</b>	-	-	1.33 [1.00-1.76]	1.30 [0.94-1.80]
13	<b>Gambela</b>	-	-	1.93 [1.38-2.69] **	1.94 [1.32-2.84] **
14	<b>Harari</b>	-	-	3.08 [2.15-4.43] **	2.98 [1.99-4.46] **
15	<b>Addis Ababa</b>	-	-	1.91[1.29-2.83] **	2.10 [1.40-3.16] **
16	<b>Dire dawa</b>	-	-	3.92 [2.67-5.77] **	3.45 [2.27-5.26] **
17					
18	<b>Residence</b>				
19	<b>Urban</b>	-	-	1	1
20	<b>Rural</b>	-	-	1.40[1.12-1.78]	1.28 [0.99-1.64]
21					
22	<b>Community women education</b>				
23	<b>Low</b>	-	-	1	1
24	<b>High</b>	-	-	1.07[0.90-1.26]	1.13[0.94-1.34]
25					
26	<b>Community women poverty</b>				
27	<b>Low</b>	-	-	1	1
28	<b>High</b>	-	-	1.41[1.17-1.68] *	1.15[0.94-1.40]
29					
30	<b>Model comparison and random effect</b>				
31	<b>ICC</b>	0.19	0.12	0.08	0.07
32	<b>Log-likelihood</b>	-4981.63	-4513.17	-4836.83	-4436.60
33	<b>Deviance</b>	9963.26	9026.34	9673.66	8873.20
34	<b>MOR</b>	2.30	1.72	1.42	1.38
35	<b>PVC (%)</b>	Ref	41.20	60.10	62.59

\*Key: 1: reference group; p-value 0.05-0.01 \*: p-value < 0.01 \*\*

## Discussion

This study tried to identify spatio-temporal distribution and predictors of childhood anaemia across the regions in Ethiopia. The 2005, 2011, and, 2016 Ethiopian Demographic and Health Survey data were used for this analysis. The anaemia trend over these years was decreased from 2005 to 2011, while the rate significantly increased from 2011 to 2016. The study revealed that 57.56% [CL: 0.56-0.59] of children were anaemic in 2016. This finding is in line with a study done in Gondar, Northwest Ethiopia 58.6%(22), higher than the study done in cape Verde, west Africa 51.8%(23), and southern Ethiopia(24). Among children aged 6-59-months, anaemia is still considered as a significant public health problem in Ethiopia, and consequent by various factors. Childhood anaemia in this study was influenced by background characteristics such as child's age, age of the mother, region, wealth status, and maternal related factors.

The spatial analysis found that the spatial pattern of childhood anaemia across the country was substantially varied. The spatial autocorrelation analysis result indicated that childhood anaemia had spatial dependency in 2005, 2011, and 2016 (Moran's I: 0.176, 0.18, and 0.09, respectively at P-value < 0.01). These findings are in line with a studies done in Nigeria, Malawi, Tanzania, and Uganda (25,26).

Scan statistical analysis showed that Eastern Somali and the southern part of Somali region were primary (most likely) and secondary clusters in 2005 respectively. Whereas, in 2011 the spatial window was located in Somali, Afar, Eastern Oromia, Dire Dawa, and Harari region. It was centered at (8.975207 N, 43.790264 E) with radius of 540.29 km with a significant p-value. Similarly, spatial sat scan analysis showed that Somali, Afar, Eastern Oromia, Dire Dawa, and Harari regions were hotspot areas in the 2016 EDHS survey. In addition, this study

1 402 revealed that eastern parts of the country had similar spatiotemporal trend over the study  
2  
3 403 periods.  
4  
5

6 404 The spatial analysis indicated the hotspots areas of anaemia were situated in the East,  
7  
8 405 Northeast, and Western parts, whereas, Central area, and South, and Northwest parts were  
9  
10  
11 406 cold spot parts of Ethiopia. The observed variability of childhood anaemia might be attributed  
12  
13 407 to the regional deference of economy, healthcare facility and food availability(27).  
14  
15

16 408 This study indicated that children age 12-59 months were less affected by childhood anaemia.  
17  
18 409 This finding was consistent with studies conducted in Ethiopia and Togo (28–30)(31). This  
19  
20  
21 410 could be explained by the fact that children who are getting older receive a richer and complete  
22  
23 411 diet, with a sufficient intake of iron which could prevent the occurrence of iron deficiency  
24  
25 412 anaemia. The finding of this study indicated that children whose women age was between 40-  
26  
27  
28 413 49 were less anaemic as compared to age 15-29. This finding was consistent with other  
29  
30 414 studies conducted in Sub-Saharan Africa and Ghana (12,32).  
31  
32

33 415 Women with the age group of 15-29 are consists adolescent population group who are more  
34  
35 416 at-risk population segments for anaemia. They are vulnerable to malnutrition because they are  
36  
37  
38 417 growing faster than at any time after their first year of life which contributes to the  
39  
40 418 intergenerational cycle of malnutrition. Iron deficiency is one of the most common forms of  
41  
42 419 malnutrition among Ethiopian adolescent girls that result iron deficiency anaemia. Aside from,  
43  
44 420 growing adolescent mother and her baby's bodies may compete for nutrients, raising the  
45  
46  
47 421 infant's risk of low birth weight; however, the lack of such nutrients might lead to anaemia.  
48  
49

50 422 Children from households of middle and rich wealth indexes were less affected by childhood  
51  
52 423 anaemia as compared to children from a poor household. This finding is in line with studies in  
53  
54 424 Nigeria and Northern Ethiopia (25,33). This is due to the reason that children from poor  
55  
56  
57 425 households are less likely to get iron-rich foods like animal foods and vitamin-rich foods  
58  
59



1 426 especially vitamins A and C which are very important for iron absorption.

2  
3  
4 427 Maternal anaemia was highly associated with the occurrence of childhood anaemia. This  
5  
6 428 finding was in line with a study done in South Africa, Haiti, and India(34–36). This might be  
7  
8  
9 429 explained that mothers and children share a common home environment, socioeconomic, and  
10  
11 430 dietary conditions, and maternal and child anaemia may reflect the household common  
12  
13 431 nutritional status, and poor maternal iron intake during pregnancy, reduce breast milk might be  
14  
15 432 the possible reason.

16  
17  
18 433 The findings from this study data set indicated that the incidence of fever had an impact on  
19  
20 434 childhood anaemia. This is in line with studies done in Ghana and South Ethiopia Wolaita  
21  
22 (24,37). This could be attributed to the infectious cause of childhood fever mainly malaria,  
23 435 tuberculosis, and Leishmaniasis which cause anaemia by destructing red blood cells or other  
24  
25 436 related mechanisms.  
26  
27  
28 437

29  
30  
31 438 The nutritional status of children had a significant association with childhood anaemia. The  
32  
33 439 stunting status of children had significant association with childhood anaemia. This finding is  
34  
35 440 in line with previous studies conducted in South Africa(36), Bangladesh(38,39), and  
36  
37 441 Ethiopia(40,41). This might be explained that children suffering from nutritional deficiency were  
38  
39  
40 442 more likely to have weak immune systems, making them vulnerable to various illnesses and  
41  
42 443 healthiness such as parasitic infections or chronic inflammation; many of these conditions  
43  
44 444 reduce the haemoglobin level in the blood leading to increased childhood anaemia(42)

45  
46  
47 445 Furthermore, severely wasting children were more likely to be anaemic than their counterpart.  
48  
49 446 This finding is consistent with previous studies(43,44). This is due to the fact that malnutrition  
50  
51  
52 447 leads to both macronutrient and micronutrient deficiencies, such as protein, iron, and vitamin  
53  
54 448 A, which are responsible for iron deficiency anaemia. Birth order of four up to five and six and  
55  
56  
57 449 greater than six were higher than those of the first order. This finding was similar to a studies

1 450 done in Indian(12,45). This could be due to the distribution of scarce resources within the  
2  
3 451 family and related to the maternal exhaustion of micronutrient feeding practices.  
4  
5

6 452 In the multilevel analysis, different individual and community factors were significantly  
7  
8 453 associated with anaemia. Among the community-level variables, it was found that the odds of  
9  
10  
11 454 anaemia among children lived in the Somali, Dire Dawa, Afar, and Gambela were higher than  
12  
13 455 in the Amhara region. This might be due to the regional variation in the nutrient intake can  
14  
15 456 cause significant health disparity, and this variability may be mediated by factors such as food  
16  
17  
18 457 availability, food customs, and culture.  
19

20  
21 458 The potential strength of our study is the use of different methodologies spatial pattern, trends,  
22  
23 459 and a multilevel regression model because of nested or cluster samples to show the effect of  
24  
25 460 individual predictors and community-level variables on the outcome variable. The study was  
26  
27  
28 461 based on a large dataset representing the whole country of Ethiopia and which was weighted  
29  
30 462 to make it nationally representative and adjusted for the design to get a reliable estimate.  
31  
32 463 However, there were some limitations to this study. The cross-sectional nature of the data  
33  
34 464 prevents causality from being inferred between the independent and dependent variables.  
35  
36  
37 465 Also, respondents' data that didn't have files (longitude and latitude) were excluded from the  
38  
39 466 spatial analysis which could affect the overall result and the generalizability of the findings.  
40  
41

42 467  
43  
44

## 45 468 **Conclusion**

46

47 469 Though, declining prevalence of childhood anaemia was observed from 2005 to 2011, it  
48  
49  
50 470 increases from 2011-2016 survey. Besides, it was spatially clustered across regions in  
51  
52 471 Ethiopia. The most prominent risk areas of anaemia were detected in Afar, Somali, Dire Dawa  
53  
54 472 and Oromia regions more or less consistently over the last 15 years. child's age, age of the  
55  
56  
57 473 mother, wealth index, maternal anaemia, fever, birth order, stunting, wasting and region were  
58

26

1 474 significant predictors among 6-59 months. Therefore, public health intervention actions  
2  
3 475 intended in a targeted approach to bearing high-risk populations as well as geographic regions  
4  
5 476 were vital to reduce childhood anaemia in Ethiopia.  
6  
7

## 8 477 **Abbreviations**

10  
11 478 AOR-Adjusted Odds Ratio, CSA-Central Statics Agency, CI-Confidence Interval, CMHS-  
12  
13 479 College of Medicine and Health Science COR-Crude Odds Ratio, EDHS-Ethiopia  
14  
15 480 Demographic and Health Survey, GPS-Global Positioning System, ICC-Intra Class Correlation  
16  
17 481 Coefficient, LLR-Log-Likelihood Ratio, MOR-Median odds ratio, OR-Odds Ratio, RR-Relative  
18  
19 482 Risk, PVC-Proportional Change in Variance, SNNPR- Southern Nations, Nationalities, and  
20  
21 483 Peoples' Region.  
22  
23  
24  
25

## 26 484 **Declarations**

### 29 485 **Ethics statements**

### 32 486 **Patient consent for publication**

35 487 Not required.  
36  
37

### 38 488 **Ethics approval**

41 489 Permission for data access was obtained from a major Demographic and Health Survey  
42  
43 490 through an online request at (<http://www.dhsprogram.com>). The data used for this study were  
44  
45 491 publicly available with no personal identifier. Our study was based on secondary data from  
46  
47 492 Ethiopian Demographic and Health Survey and we have secured the permission letter from  
48  
49 493 the main Demographic Health and Survey.  
50  
51  
52

### 53 494 **Consent for publication**

56 495 Not-applicable  
57  
58  
59  
60

**Data sharing statement**

The data in which the authors used to produce this manuscript are available upon reasonable request

**Competing interests**

The authors declare that they have no competing interests.

**Funding**

No funding

**Contributors**

Proposal preparation, acquisition of data, analysis, and interpretation of data was done by SH, AM, ZM and BF guided the study design data collection and analysis. SH drafted the manuscript and all authors have a substantial contribution in revising and finalizing the manuscript. All authors read and approved the final manuscript.

**Acknowledgments**

The authors gratefully acknowledge the support received from the University of Gondar. We also thank the Ethiopian Central Statistics Agency for providing us with the data and shape files for this study.

## References

1. WHO. Nutritional Anaemias : Tools for Effective Prevention. World Health Organization. 2017. 1–83 p.
2. WHO. Global estimates of the prevalence of anaemia in infants and children aged 6 – 59 months , 2011 Global estimates of the prevalence of anaemia , all women of reproductive age , 15 – 49 years , 2011. Scaling Up Nutr [Internet]. 2015; Available from: [http://www.who.int/nutrition/publications/micronutrients/global\\_prevalence\\_anaemia\\_2011\\_maps.pdf?ua=1](http://www.who.int/nutrition/publications/micronutrients/global_prevalence_anaemia_2011_maps.pdf?ua=1)
3. WHO. The global prevalence of anaemia in 2011. Who [Internet]. 2011;1–48. Available from: <https://apps.who.int/iris/handle/10665/177094>
4. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of anaemia, WHO vitamin and mineral nutrition information system, 1993–2005. *Public Health Nutr.* 2009;12(4):444–54.
5. Malkanthi RLDK, Silva KDRR, Jayasinghe-Mudalige UK. Risk Factors Associated with High Prevalence of Anemia among Children under 5 Years of Age in Paddy-Farming Households in Sri Lanka. *Food Nutr Bull.* 2010;31(4):475–82.
6. Olivares M, Walter T, Hertrampf E, Pizarro F. Anaemia and iron deficiency disease in children. *Br Med Bull [Internet].* 1999 Sep 1;55(3):534–43. Available from: <https://doi.org/10.1258/0007142991902600>
7. McLean E, Cogswell M, Egli I, Wojdyla D, De Benoist B. Worldwide prevalence of anaemia, WHO Vitamin and Mineral Nutrition Information System, 1993-2005. *Public Health Nutr.* 2009;12(4):444–54.
8. Leal LP, Batista Filho M, de Lira PIC, Figueiroa JN, Osório MM. Temporal trends and anaemia-associated factors in 6- to 59-month-old children in Northeast Brazil. *Public Health Nutr.* 2012;15(9):1645–52.
9. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study. *BMJ Open [Internet].* 2018 May 1;8(5):e019654. Available from: <http://bmjopen.bmj.com/content/8/5/e019654.abstract>
10. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged from 6 to 59 months in Togo: analysis from Togo demographic and health survey data, 2013–2014. *BMC Public Health.* 2019;19(1):1–9.
11. Malako BG, Teshome MS, Belachew T. Anemia and associated factors among children aged 6-23 months in Damot Sore District, Wolaita Zone, South Ethiopia. *BMC Hematol.* 2018;18(1):1–9.
12. Moschovis PP, Wiens MO, Arlington L, Antsygina O, Hayden D, Dzik W, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: A cross-sectional study. *BMJ Open.* 2018;8(5):1–14.
13. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns of anaemia among young children in nigeria: A bayesian semi-parametric modelling. *Int Health.* 2014;6(1):35–45.
14. Desalegn A, Mossie A, Gedefaw L. Nutritional Iron Deficiency Anemia: Magnitude and Its Predictors among School Age Children, Southwest Ethiopia: A Community Based Cross-Sectional Study. *PLoS One [Internet].* 2014 Dec 1;9(12):e114059. Available from: <https://doi.org/10.1371/journal.pone.0114059>
15. Guerra CA, Snow RW, Hay SI. Defining the global spatial limits of malaria transmission in 2005. *Adv Parasitol.* 2006;62:157–79.
16. Central Statistical Agency, ORC Macro. Ethiopia Demographic and Health Survey

- 1 571 2005. Heal San Fr [Internet]. 2006;(September):[446]. Available from:  
 2 572 [http://www.measuredhs.com/pubs/pdf/FR179/FR179\[23June2011\].pdf](http://www.measuredhs.com/pubs/pdf/FR179/FR179[23June2011].pdf)  
 3 573 17. Central Statistical Agency [Ethiopia], ICF International. Ethiopia Demographic and  
 4 574 Health Survey 2011. 2012;1–452.  
 5 575 18. ECSA. Ethiopian Demographic Health Survey 2016. 2016. 161 p.  
 6 576 19. Kulldorff M. SatScan user guide 2006. 2018;  
 7 577 20. Bartko JJ. The Intraclass Correlation Coefficient as a Measure of Reliability. Psychol  
 8 578 Rep. 1966 Aug;19(1):3–11.  
 9 579 21. Assessment IS. Understanding Variability in Multilevel Models Sophia Rabe-Hesketh  
 10 580 Example : PISA ( Programme for International Student Assessment ) PISA :  
 11 581 Distribution of SES.  
 12 582 22. Enawgaw B, Workineh Y, Tadesse S, Mekuria E, Addisu A, Genetu M. Prevalence of  
 13 583 anemia and associated factors among hospitalized children attending the University of  
 14 584 Gondar Hospital, Northwest Ethiopia. Electron J Int Fed Clin Chem Lab Med.  
 15 585 2019;30(1):35–47.  
 16 586 23. Semedo RML, Santos MMAS, Baião MR, Luiz RR, Da Veiga G V. Prevalence of  
 17 587 Anaemia and Associated Factors among Children below Five Years of Age in Cape  
 18 588 Verde, West Africa. J Heal Popul Nutr. 2014;32(4):646–57.  
 19 589 24. Tiku YS, Mekonnen TC, Workie SB, Amare E. Does Anaemia Have Major Public  
 20 590 Health Importance in Children Aged 6–59 Months in the Duggina Fanigo District of  
 21 591 Wolaita Zone, Southern Ethiopia? Ann Nutr Metab [Internet]. 2018;72(1):3–11.  
 22 592 Available from: <https://www.karger.com/DOI/10.1159/000484324>  
 23 593 25. Gayawan E, Arogundade ED, Adebayo SB. Possible determinants and spatial patterns  
 24 594 of anaemia among young children in Nigeria: a Bayesian semi-parametric modelling.  
 25 595 Int Health [Internet]. 2014 Jan 31;6(1):35–45. Available from:  
 26 596 <https://doi.org/10.1093/inthealth/iht034>  
 27 597 26. Roberts DJ, Matthews G, Snow RW, Zewotir T, Sartorius B. Investigating the spatial  
 28 598 variation and risk factors of childhood anaemia in four sub-Saharan African countries.  
 29 599 BMC Public Health. 2020;20(1):126.  
 30 600 27. Diao X, Taffesse AS, Thurlow J, Pratt AN, Yu B, Orkin K, et al. NEWSLETTER -  
 31 601 Ethiopia Strategy Support Program II ( ESSP-II ) Highlights of Presentations Summer –  
 32 602 Fall 2010 : h NEWSLETTER - Ethiopia Strategy Support Program II ( ESSP-II )  
 33 603 Capacity Building Initiatives 2010 : 2010;(December).  
 34 604 28. Gebreweld A, Ali N, Ali R, Fisha T. Prevalence of anemia and its associated factors  
 35 605 among children under five years of age attending at Guguftu health center, South  
 36 606 Wollo, Northeast Ethiopia. PLoS One [Internet]. 2019 Jul 5;14(7):e0218961. Available  
 37 607 from: <https://doi.org/10.1371/journal.pone.0218961>  
 38 608 29. Nambiema A, Robert A, Yaya I. Prevalence and risk factors of anemia in children aged  
 39 609 from 6 to 59 months in Togo: analysis from Togo demographic and health survey data,  
 40 610 2013–2014. BMC Public Health [Internet]. 2019;19(1):215. Available from:  
 41 611 <https://doi.org/10.1186/s12889-019-6547-1>  
 42 612 30. Mohammed SH, Habtewold TD, Esmailzadeh A. Household, maternal, and child  
 43 613 related determinants of hemoglobin levels of Ethiopian children: Hierarchical  
 44 614 regression analysis. BMC Pediatr. 2019;19(1):1–10.  
 45 615 31. Keikhaei B, Zandian K, Ghasemi A, Tabibi R. Iron-Deficiency Anemia among Children  
 46 616 in Southwest Iran. Food Nutr Bull. 2007 Dec;28(4):406–11.  
 47 617 32. Campbell JR, Holland J. Development research. Focaal. 2007;2005(45):3–17.  
 48 618 33. Gebreegiabiher G, Etana B, Niggusie D. Determinants of Anemia among Children  
 49 619 Aged 6–59 Months Living in Kilte Awulaelo Woreda, Northern Ethiopia. Benz EJ,  
 50 619

- 1 620 editor. Anemia [Internet]. 2014;2014:245870. Available from:  
 2 621 <https://doi.org/10.1155/2014/245870>
- 3 622 34. Ayoya MA, Ngnie-Teta I, Séraphin MN, Mamadoultai bou A, Boldon E, Saint-Fleur JE,  
 4 623 et al. Prevalence and risk factors of anemia among children 6-59 months old in Haiti.  
 5 624 Anemia. 2013;2013:2–5.
- 6 625 35. Pasricha SR, Black J, Muthayya S, Shet A, Bhat V, Nagaraj S, et al. Determinants of  
 7 626 anemia among young children in rural India. *Pediatrics*. 2010;126(1).
- 8 627 36. Ntenda PAM, Nkoka O, Bass P, Senghore T. Maternal anemia is a potential risk factor  
 9 628 for anemia in children aged 6–59 months in Southern Africa: a multilevel analysis. *BMC*  
 10 629 *Public Health* [Internet]. 2018;18(1):650. Available from:  
 11 630 <https://doi.org/10.1186/s12889-018-5568-5>
- 12 631 37. Shenton LM, Jones AD, Wilson ML. Factors Associated with Anemia Status Among  
 13 632 Children Aged 6–59 months in Ghana, 2003–2014. *Matern Child Health J*.  
 14 633 2020;24(4):483–502.
- 15 634 38. Khan JR, Awan N, Misu F. Determinants of anemia among 6–59 months aged children  
 16 635 in Bangladesh: evidence from nationally representative data. *BMC Pediatr* [Internet].  
 17 636 2016;16(1):3. Available from: <https://doi.org/10.1186/s12887-015-0536-z>
- 18 637 39. Rahman MS, Mushfiquie M, Masud MS, Howlader T. Association between malnutrition  
 19 638 and anemia in under-five children and women of reproductive age: Evidence from  
 20 639 Bangladesh Demographic and Health Survey 2011. *PLoS One*. 2019  
 21 640 Jul;14(7):e0219170–e0219170.
- 22 641 40. Belachew A, Tewabe T. Under-five anemia and its associated factors with dietary  
 23 642 diversity, food security, stunted, and deworming in Ethiopia: systematic review and  
 24 643 meta-analysis. *Syst Rev*. 2020 Feb;9(1):31.
- 25 644 41. Malako BG, Asamoah BO, Tadesse M, Hussen R, Gebre MT. Stunting and anemia  
 26 645 among children 6–23 months old in Damot Sore district, Southern Ethiopia. *BMC Nutr*.  
 27 646 2019;5(1):1–11.
- 28 647 42. Pelletier DL, Frongillo Jr EA, Schroeder DG, Habicht JP. The effects of malnutrition on  
 29 648 child mortality in developing countries. *Bull World Health Organ*. 1995;73(4):443–8.
- 30 649 43. Takele WW, Baraki AG, Wolde HF, Desyibelew HD, Derseh BT, Dadi AF, et al. Anemia  
 31 650 and Contributing Factors in Severely Malnourished Infants and Children Aged between  
 32 651 0 and 59 Months Admitted to the Treatment Centers of the Amhara Region, Ethiopia: A  
 33 652 Multicenter Chart Review Study. Hassen K, editor. Anemia [Internet].  
 34 653 2021;2021:6636043. Available from: <https://doi.org/10.1155/2021/6636043>
- 35 654 44. Caulfield LE, Richard SA, Rivera JA, Musgrove P, Black RE. Chapter 28.  
 36 655 Stunting, Wasting, and Micronutrient Deficiency Disorders. *Dis Control Priorities Dev*  
 37 656 *Ctries* (2nd Ed. 2006;551–68.
- 38 657 45. Goswami S, Das KK. Socio-economic and demographic determinants of childhood  
 39 658 anemia. *J Pediatr (Rio J)*. 2015;91(5):471–7.

## 47 660 Figure legend/caption

48 661 Figure 1: Trends in anaemia overtime across the regions in Ethiopia, EDHS 2005 to 2016

49 662 Figure 2: Hot spot and cold spot analysis of anaemia in Ethiopian, EDHS 2005 to 20016

50 663 Figure 3: Ordinary Kriging interpolation of anaemia in Ethiopia, EDHS 2005 to 2016

51 664 Figure 4: Spatial scan statistics analysis of anaemia in Ethiopia, EDHS, 2005-2016

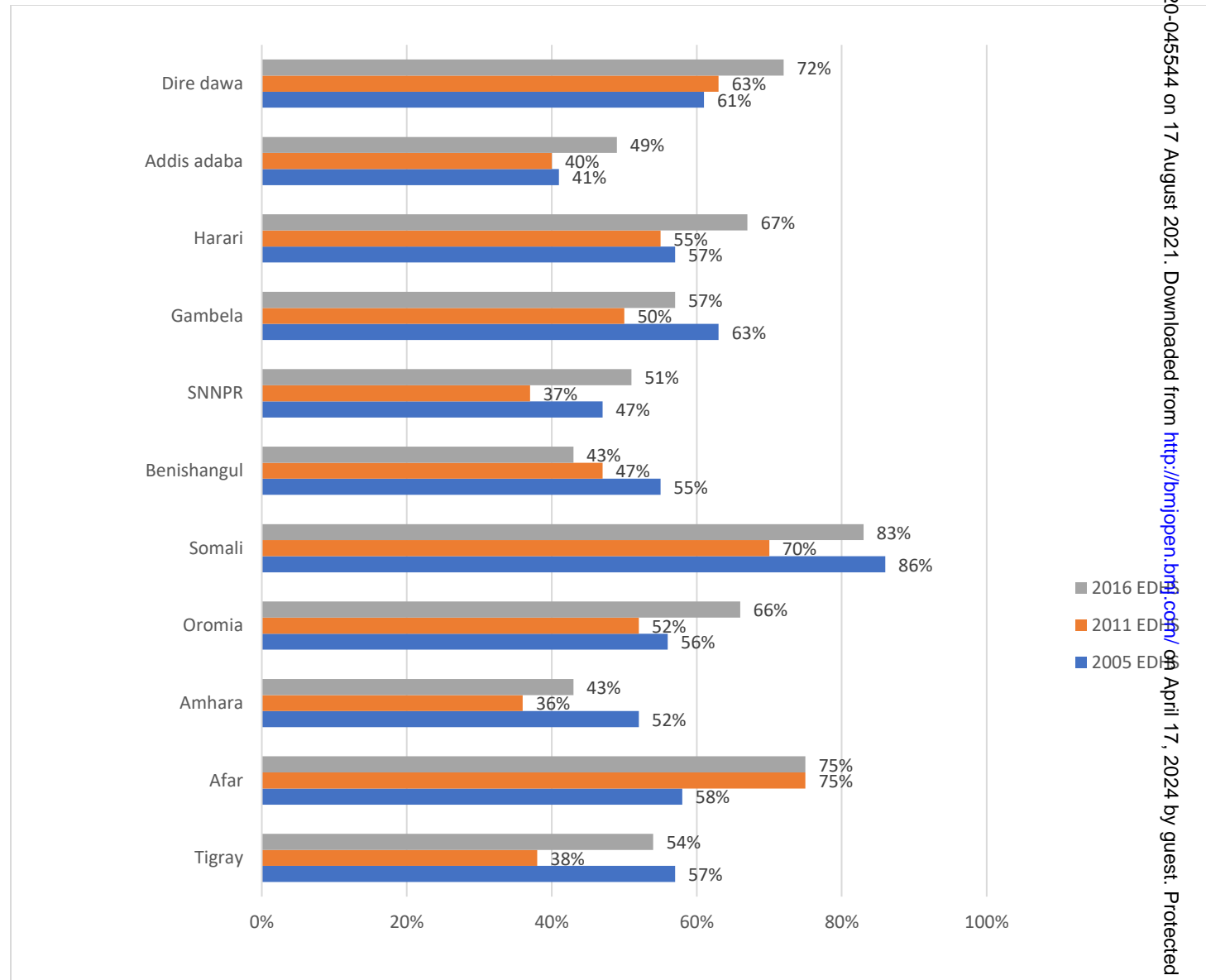


Figure 1: Trends in anaemia over time across the regions in Ethiopia, EDHS 2005 to 2016



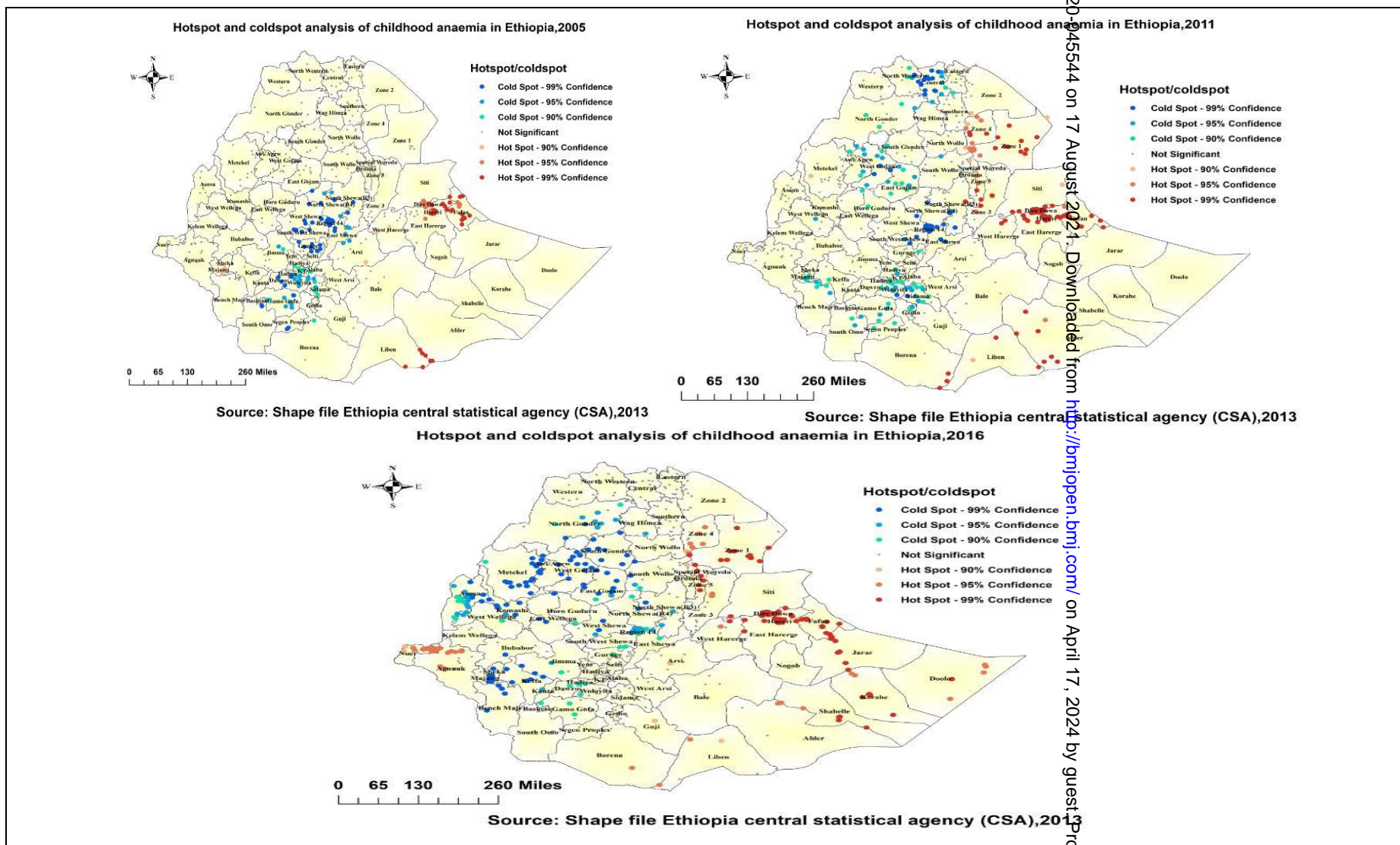


Figure 2: Hot spot and cold spot analysis of anaemia in Ethiopian, EDHS 2005 to 2016

1361bmjopen-2020-045544 on 17 August 2024. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.

136/bmjopen-2020-015544 on 17 August 2021. Downloaded from <http://bmjopen.bmj.com/> on April 17, 2024 by guest. Protected by copyright.

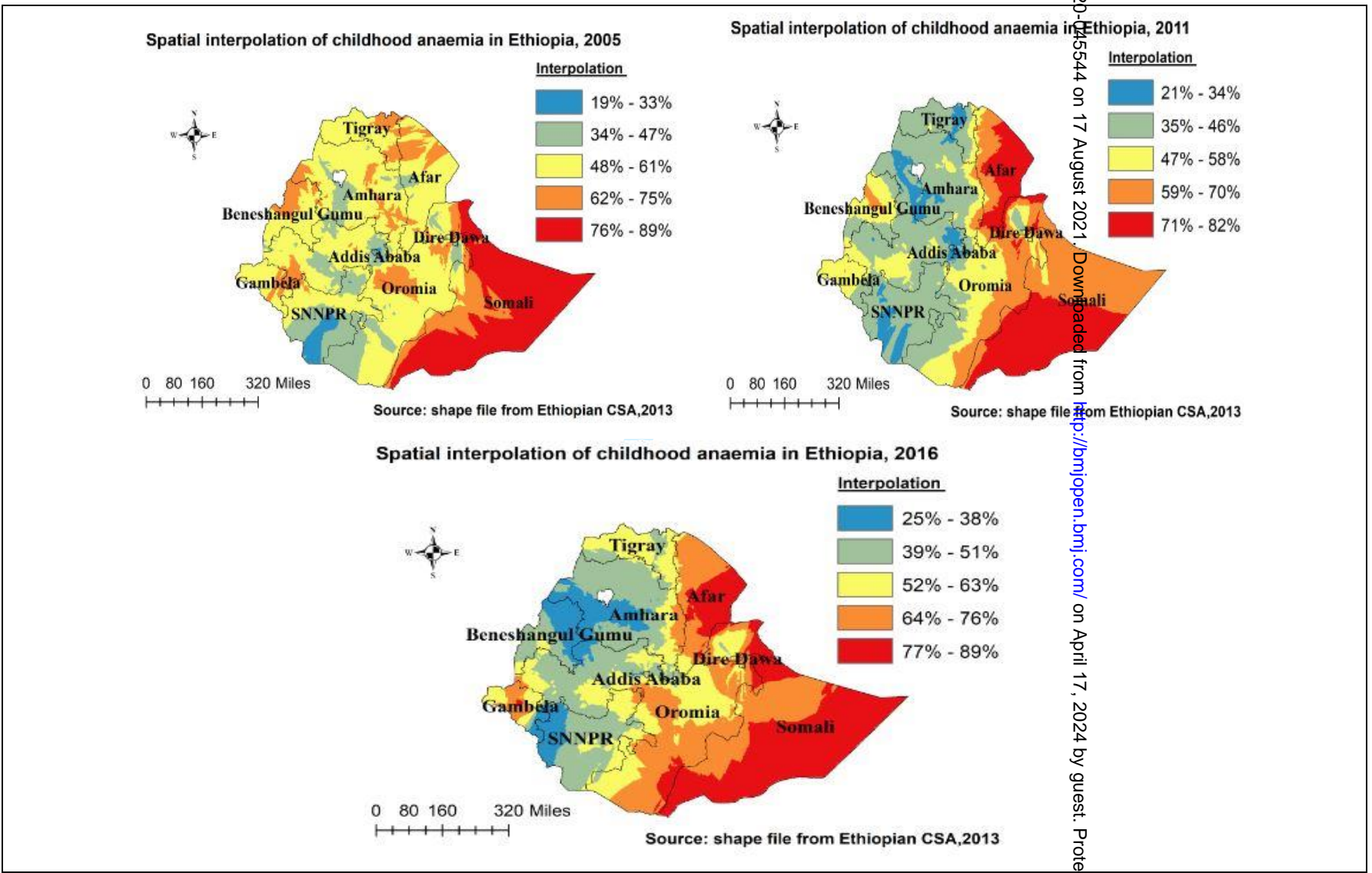


Figure 3: Ordinary Kriging spatial interpolation of anaemia in Ethiopia, EDHS 2005 to 2016

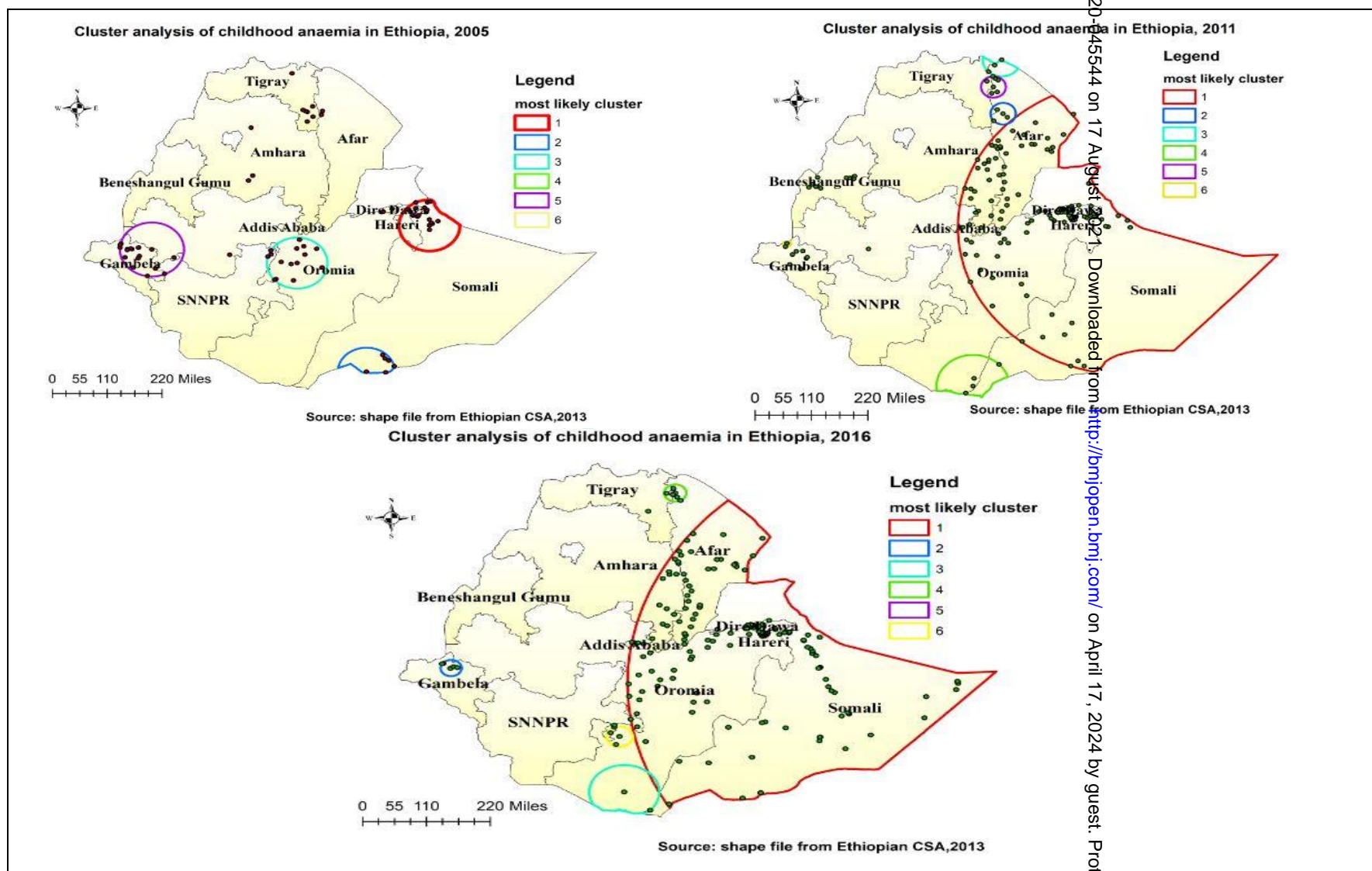


Figure 4: Spatial scan statistics analysis of anaemia in Ethiopia, EDHS, 2005-2016

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60STROBE Statement—Checklist of items that should be included in reports of *cross-sectional studies*

	Item No	Recommendation	
Title and abstract	1	Spatio-temporal distribution and associated factors of anaemia among children aged 6–59 months in Ethiopia: a spatial and multilevel analysis based on the EDHS 2005- 2016	Page1
		Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anaemia using the Ethiopian Demographic and Health Survey (EDHS) data from 2005-2016.  In mixed effect model Child age, age of mother, maternal anaemia status, wealth index, birth order, fever, stunting, wasting status, and region were significant predictors of childhood anaemia.	Page2
<b>Introduction</b>			
Background/rationale	2	Childhood anaemia is a major public health problem in Ethiopia, there is limited evidence on the spatio-temporal variability of childhood anaemia over time. study attempts to fill the gap by investigating the spatio-temporal distribution of anaemia and its associated factors using multilevel model, since its hierarchical nature.	Page 5
Objectives	3	Therefore, this study aimed to assess the spatio-temporal distribution and associated factors of childhood anaemia using the Ethiopian Demographic and health survey (EDHS) data from 2005-2016	Page 5
<b>Methods</b>			
Study design	4	Survey-based cross-sectional study design was employed for the EDHS	Page 5
Setting	5	All nine regions and two city administrations of Ethiopia in 2005, 2011 and 2016.	Page 5-6
Participants	6	The source population for this study was among children aged 6–59 months in Ethiopia. A total of 21,302 children aged 6-59 months were included in this study.	Page 6
Variables	7	<b>Outcome measure:</b> The outcome variable was child anaemia status <b>Independent:</b> sociodemographic (religion, mother age, marital status, educational status, husband education, wealth index, mothers working status, numbers of under five children) Maternal and Child- related (child sex, age, birth size, birth order, maternal BMI, maternal anaemia, breastfeeding, fever, diarrhoea, vitamin supplement, stunting and wasting). Community-level (residence, region, community women education and community women poverty).	Page 7
Data sources/ measurement	8*	DHS program (Demographic and Health Survey) website( <a href="http://www.measuredhsprogram.com">www.measuredhsprogram.com</a> ) after obtaining the necessary permissions for the download and further analyses.	Page 6
Bias	9	Cross-sectional nature of the data prevents causality from being inferred between the independent and dependent variables	Page 26
Study size	10	A total of 21,302 children (3,868 in 2005, 8,958 - in 2011, and 8476 in 2016)	Page 11

		were included in this study	
Quantitative variables	11	Quantitative variables were handled in three level Four models were constructed for multilevel logistic regression analysis using <b>melogit</b> STATA command. The first model (a random intercept model) was null model without predictors to determine the extent of cluster variations in anaemia. The second model (model I) was adjusted with individual-level variables. The third model (model II) was adjusted for community-level variables, while the fourth model (model III) was fitted with both individual-level and community-level variables simultaneously.	Page 10
Statistical methods	12	Multilevel model for associated factors, we use mixed effect to control confounding than traditional regression model.	Page 10-11
		Spatial analysis was performed	
		For associated factor predictors with missing dropped and for spatial analysis without spatial information was dropped	
		Secondary data analysis and participants were selected based on a stratified two-stage cluster sampling technique	
		Spatiotemporal pattern analysis was done for three-year data	
<b>Results</b>			
Participants	13*	A total of 21,302 children Secondary data analysis, simply we take from EDHS	Page 11
Descriptive data	14*	A total of 21,302 children with known haemoglobin levels (3,868 in 2005, 8,958 in 2011, and 8467 in 2016) were included in this study. The prevalence of anaemia for the three consecutive surveys was 53.9%, 44.6%, and 57.6% in 2005, 2011, and 2016 EDHS data respectively The majority of children were from rural residency in five years preceding the survey in three surveys. About 78.6%, 70%, and 67% of women were unable to read and write in 2005, 2011, and 2016 survey respectively. Children from poor and middle-class families were more anaemic than children from rich families across the three EDHS survey	Page 11-12
		Husband educational level was missing data	
Outcome data	15*	The dependent variable was child anaemia status, categorized as “anaemic/not-anaemic” for this study.	Page 7
Main results	16	The spatial distribution of childhood anaemia varied across regions in all surveys. The spatial autocorrelation analysis result indicated that childhood anaemia had spatial dependency in 2005, 2011, and 2016 (Moran’s I: 0.176, 0.18, and 0.09, respectively at P-value <0.01). In multivariable multilevel mixed-effect logistic regression analysis, individual-level factors such as the age of the child, wealth index, mother age, maternal anaemic status, birth order, fever, stunting, and wasting status were significant predictor of childhood anaemia.	Page 15-17
		Not-applicable	
		Not-applicable	
Other analyses	17	Different spatial technique spatial autocorrelation, hotspot/cold spot analysis, interpolation, and sat scan analysis	Page 15

<b>Discussion</b>			
Key results	18	<p>This study tried to identify spatio-temporal distribution and predictors of childhood anaemia across the regions in Ethiopia. 2005, 2011, and, 2016 Ethiopian Demographic and Health Survey data were used. In this study, anaemia's trend was decreased from 2005 to 2011, while the rate significantly increased from 2011 to 2016. The study revealed that 57.56% [CL: 0.56-0.59] of children were anaemic in 2016, preceding the survey. This finding was in line with a study done in Gondar, Northwest Ethiopia 58.6%</p> <p>The spatial pattern shows the geographical inequality of anaemia by using sat scan and GIS spatial techniques like cluster mapping tools and interpolation techniques. The spatial analysis indicates that the distribution of childhood anaemia was non-random across the country with a global Moran's I index of 0.176 in 2005, 0.18 in 2011, and 0.09 in 2016 with a significant p-value, which indicates substantial-considerable clustering areas. This study's findings were in line with a study done in Nigeria, Malawi, Tanzania, and Uganda</p>	Page 23-26
Limitations	19	The cross-sectional nature of the data prevents causality from being inferred between the independent and dependent variables. Also, respondents' data that didn't have files (longitude and latitude) were excluded from the spatial analysis which could affect the overall result and the generalizability of the findings.	Page 26
Interpretation	20	<p>Prevalence of childhood anaemia decreased between the 2005-2011 survey while the prevalence increased from 2011-2016 EDHS. The spatial pattern of child anaemia in Ethiopia was non-random among the three consecutive surveys with the global Moran's I value of 0.176, 0.18, and 0.09 in EDHS 2005, 2011, and 2016.</p> <p>In line study done Cape Verde, west Africa, Nigeria, Malawi, Tanzania, and Uganda</p>	Page 26
Generalisability	21	<p>Policymakers and health planners should design effective intervention strategies for the identified hot spot areas and individual and community-level factors to anaemia.</p> <p>For health care community, and researcher to alleviate the problem.</p>	Page 26
<b>Other information</b>			
Funding	22	No funding	

\*Give information separately for exposed and unexposed groups.

**Note:** An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at <http://www.plosmedicine.org/>, Annals of Internal Medicine at <http://www.annals.org/>, and Epidemiology at <http://www.epidem.com/>). Information on the STROBE Initiative is available at [www.strobe-statement.org](http://www.strobe-statement.org).