Tracking Progress in Anthropometric Failure Among Under-five Children in Ethiopia: A Geospatial and Multilevel Analysis.

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Abstract

Background

Under-nutrition is a major public health concern among under-five children in many developing countries. This work evaluated the overall prevalence of under-nutrition by using a composite index of anthropometric failure (CIAF), which helps in the detection of children with multiple anthropometric failures. Additionally, this study provides a Spatio-temporal distribution and associated factors of childhood anthropometric failures across time.

Methods

Secondary data was obtained from the Ethiopian Demographic and Health Survey for the survey 2005, 2011, and 2016 years. Data included 23,864 samples of children between the ages of 0-59 months, which is a nationally representative sample in Ethiopia. Analytical methods used in this paper include multivariate multilevel logistic regression to identify associated factors and Getis-Ord spatial statistical tool to identify high and low hotspots areas of anthropometric failures.

Result

The prevalence obtained with CIAF in 2005, 2011, and 2016 was, 53.5%, 51%, and 46.2% of children were suffering from under-nutrition respectively. The spatial analysis revealed areas that are at a higher risk of anthropometric failures consistently were found in northern parts of the country, largely in the Amhara, Tigray, and Afar regions. Multilevel logistic regression analysis showed that the risk of anthropometric failure was higher among older children, had low birth weight, had a mother with low BMI, was in a rural area, had mothers and fathers without formal education.

Conclusion

In addition to identifying wasted, stunted, and overweight children, CIAF also identified children with multiple conditions, which are generally neglected in most nutritional surveys. As revealed by this composite index, the prevalence of anthropometric failure remains considerably high and its spatial distribution also significantly varied across the regions in the country. The identified socio-demographic characteristics and districts at an increased likelihood of anthropometric failure can inform localized intervention and prevention strategies to improve the nutritional status and healthcare of children in Ethiopia.

Background

Nutrition is to be understood as both an input to and an outcome of sustainable development [1]. Malnutrition includes several forms of under-nutrition as well as overweight and obesity. Under-nutrition in a population of under-five children are commonly measured by three anthropometric indicators, namely stunting (low height for age), wasting (low weight for height), and underweight (low weight for age).

Stunting and wasting reflect acute and chronic exposures for nutritional deficiency, respectively. As well, underweight reflect both acute and chronic exposures for nutritional deficiency [1, 2]. Moreover, anthropometric failures has both short term and long term negative consequences associated with it. In the short-term, it leads to ill health and mortality among children. In the long-term, it leads to impaired cognitive development, poorer educational achievement, and impeded economic productivity [1, 3].

Under-nutrition remains one of the biggest public health concerns in many lower and middle-income countries. Out of all the undernourished children in the world in 2016, around 88% live in developing countries. Between the years 2005 and 2016, more than 5 million under-five deaths occurred annually worldwide and anthropometric failures contribute a lot to this figure, where two regions Sub-Saharan Africa and Central and Southern Asia, account for more than 80 percent of under-five death. Ethiopia placed 6th by having 178 thousand under-five death alone in 2016 [4, 5]. Given the negative consequences of under-nutrition on child health outcomes, there is certainly a need for actions to drawn up policies and programs to identify and implement solutions that will prevent all forms of childhood under-nutrition.

According to the previous three Ethiopian Demographic and Health Surveys (EDHS) 2005 [6], 2011, [7] and 2016 [8] reports, showed that the prevalence of underweight, stunting, and underweight decreased over the past 16 years, however, the figure is still too large and we need to know the important factors affecting this status. Given these serious consequences of undernutrition, understanding its risk factors is essential to help policymakers to develop targeted prevention and intervention strategies for reducing the number of undernourished children. Previous studies have identified socio-demographic factors that are associated with anthropometric failures in developing countries. For example, the age of the women at the survey time, marital status, education level, employment status, and a total number of children have were reported to be significantly associated with an increased risk of undernutrition among under-five children [9–11]. However, the research findings in terms of the direction and the strength of the associations have been mixed.

In the context of Ethiopia, a lot of studies examined the prevalence of under-nutrition had focused on single conventional indicators such as wasting, stunting, and underweight as proposed by the World Health Organisation [12]. Studies have shown that conventional indicators when used alone, failed to give true estimates of the real burden of childhood under-nutrition [13]. This is because, these indicators may overlap, meaning that the same child could show signs of having two or more of these indicators simultaneously, and are therefore insufficient for determining the overall burden of under-nutrition among children. Nevertheless, no nationwide, population-based study has been conducted using CIAF, which classifies under-nutrition into mutually exclusive groups, enabling the identification of children with more than one form of anthropometric failures [13, 14].

Previous studies done on under-nutrition revealed that Poor socioeconomic conditions, food insecurity, poverty, and adverse conditions such as illness or inadequate feeding practices can drastically alter the growth pattern of children [9, 11, 15, 16]. Further, the social context in which the children are embedded

may also play a role in influencing their nutritional status and health outcomes. In this case, for children residing in the communities or neighborhoods that are in close proximity to each other, we would expect some degree of spatial correlation in the risk of anthropometric failures at the neighborhood level. If an outcome is geographically dependent, ignoring such correlation could lead to incorrect inference.

Despite the spatial analyses conducted in literature, there has been a limited attempt to use spatial analysis techniques to analyze geographical patterns of overall childhood anthropometric failures. This study attempts to contribute to this literature by uncovering the high-risk areas of childhood anthropometric failures can be very informative for designing localized intervention and prevention strategies that could guide policymakers in designing effective public health interventions to reduce under-nutrition related children morbidity and mortality.

The objectives of this paper are to examine the prevalence of childhood anthropometric failures and identify socio-demographic characteristics as well as spatial patterns in childhood anthropometric failures among children in Ethiopia based on nation-wide population-based data.

Method

Study design, setting and period

The survey-based cross-sectional study design was employed by using data that have been taken from the last three rounds of Ethiopian demographic and health survey (EDHS) 2005, 2011, and 2016 [6–8]. These surveys are a nationally representative study conducted in Ethiopia located at the horn of Africa (3°–14°N and 33°– 48°E). Administratively, Ethiopia has nine geographical regions and two administrative cities, each region is sub-divided into zones, districts, towns, and kebeles (the smallest administrative units). The DHS utilized a multistage stratified cluster sampling in which sample households are selected within clusters EAs (enumeration areas). In the selected households, measurements of height and weight were taken from children 0–59 month's age [8].

Accordingly, a total of 23,864 under-five children were screened for their anthropometry status. Of these, 4,130 were screened in 2005, 10,285 in 2011, and 9,449 in 2016. The detailed sampling procedure was presented in the full EDHS report [6–8]. For the spatial analysis, the geographic coordinate (longitude and latitude) data were taken from the selected EAs.

DHS granted permission to access the EDHSs data sets and the geographic coordinate data through the project title “Tracking Progress in Anthropometric Failure among Under-Five Children in Ethiopia: A Geospatial Analysis”. Data extraction was performed using STATA version 14.1 similarly, location data (latitude and longitudinal) were extracted from the downloaded excel file. Then after extraction, the missing values for the significant independent variables were excluded and the analysis was undertaken using a complete set of data.

Measurement of variables

Dependent variables

All children younger than five years of age were selected for anthropometry measurements. The outcome variable of this study was the nutritional status among children under 5 years measured using CIAF. CIAF is based on a cross-classification scheme, involving the categories obtained by applying the cut-off ± 2 standard deviation to the conventional indices underweight (weight-for-age), stunting (height-for-age), and wasting (weight-for-height). Children nutritional indicators were categorized into seven groups: (A) no failure; (B) wasting only; (C) wasting and underweight; (D) wasting, stunting, and underweight; (E) stunting and underweight; (F) stunting only; and (Y) underweight only. Therefore, a child is considered as undernourished, as measured in CIAF, if he or she is suffering from any anthropometric failure (B–Y) above [13].

Independent variables

Factors that have been associated with child under-nutrition based on the UNICEF general conceptual framework for causes of malnutrition [17] and a review of prior similar studies were included in the study [9, 11, 16, 18]. A series of information was extracted from three round of EDHSs including socio-demographic and economic characteristics: sex, age of the child, educational level of the mother, maternal age at first birth, place of residence, wealth index, place of delivery, maternal marital status, Body Mass Index (BMI) of the mother, ANC(Antenatal Care) visit, time of initiation of breastfeeding, maternal employment status, paternal employment status, number of children born, birth order, preceding birth interval, and symptom of fever, cough, and diarrhea in the child.

In the analyses, age was recoded as 0–5, 6–11, 12–23, 24–35, and, 36 above months. BMI of the mother was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Mothers were categorized according to three risk factors, 'underweight' were classified as having a $\text{BMI} < 18.5 \text{ kg}/\text{m}^2$ "normal" was classified as having $\text{BMI} 18.5\text{--}24.95 \text{ kg}/\text{m}^2$, and "overweight/obese" was classified as those having $\text{BMI} 25\text{--}29.9 \text{ kg}/\text{m}^2$ and above. The wealth index was divided into quintiles, and each household was assigned its corresponding category (1 being "Poorest" and 5 "Richest" in wealth). Birth order is the number of children a woman has; we have categorized it as "1–2", "3–4", "5 or more". Maternal and paternal education level were recoded into three, "no education", "primary", and "secondary and above education".

Data management and analysis

The data were cleaned using STATA 14.1 software and Microsoft excel. The data were weighted using sampling weight, primary sampling unit, and strata before any statistical analysis to restore the representativeness of the survey to take into account the sampling design when calculating standard errors to get reliable statistical estimates. Cross tabulations and summary statistics were conducted to describe the study population. Descriptive and summary statistics were conducted using STATA version 14.1, ArcGIS version 10.8, and SaTScan version 9.6 software.

Spatial analysis

ArcGIS version 10.8 software and SaTScan version 9.6 software were used to explore the Spatio-temporal distribution of anthropometric failure. The global spatial autocorrelation (Global Moran's I) was done to assess whether childhood anthropometric failures were dispersed, clustered, or randomly distributed in the study area. Moran's I is a correlation coefficient that measures the overall spatial autocorrelation of a data set. It is one way to test for autocorrelation and has a value from -1 to 1. A Moran's value of -1 is perfect clustering of dissimilar values (this can be called perfect dispersion), a value of 0 is no autocorrelation (perfect randomness.), and a value of +1 indicates perfect clustering of similar values (it's the opposite of dispersion). A statistically significant Moran's I ($p < 0.05$) showed that childhood anthropometric failure is non-random.

Getis-OrdGi* statistics were computed to measure how spatial autocorrelation varies over the study location by calculating Gi* statistic for each area. Z-score is computed to determine the statistical significance of clustering, and the p-value was computed for the significance. Statistical output with high Gi* indicates "hotspot" whereas low Gi* means a "cold spot". Hot spot areas indicated that there was a high proportion of anthropometric failure and the cold spot indicated that there was a low proportion of anthropometric failure.

Furthermore, the spatial interpolation technique was used to predict childhood anthropometric failure on the un-sampled areas in the country based on the value observed from sampled EAs. The Kriging interpolation method was employed to explore the burdens of childhood anthropometric failure in the unsampled areas of the country based on the observed data since it had low mean square error and residual as compared to the other interpolation techniques [19].

Cluster analysis

Spatial scan statistical analysis Bernoulli based model was employed to test for the presence of statistically significant spatial clusters of anthropometric failure using Kulldorff's Sat Scan version 9.6 software. The spatial scan statistic uses a circular scanning window that moves across the study area. Children with anthropometric failure were taken as cases and those who were free from anthropometric failure as controls to fit the Bernoulli model. The spatial cluster size of < 25% of the population was used, in order to include sparsely populated regions that may have similar risk factor profiles. The scanning window with maximum likelihood was the most likely performing cluster, and the p-value was assigned to each cluster using Monte Carlo hypothesis testing by comparing the rank of the maximum likelihood from the real data with the maximum likelihood from the random datasets. The primary and secondary clusters were identified and assigned p-values and ranked based on their likelihood ratio test, based on 999 Monte Carlo replications [20].

Multilevel logistic regression

Multivariable multilevel logistic regression was used to analyze factors associated with childhood stunting at two levels: individual and community (cluster) levels. Four models were fitted using **melogit**, a

STATA command. The first model without any explanatory variables, to evaluate the extent of the cluster variation on anthropometric failure. The second model with only individual-level variables, the third model with only community-level variables, and the fourth model both individual-level and community-level variables. A P-value of < 0.05 was used to define statistical significance. Adjusted Odds Ratios (AOR) with their corresponding 95% confidence intervals (CIs) were calculated to identify the independent predictors of anthropometric failure. Model comparison was conducted by using deviance and likelihood ratio.

The intra-cluster correlation coefficient (ICC), Median Odds Ratio (MOR), and proportional change in variance (PCV) statistics were calculated to measure the variation between clusters. ICC was used to explain cluster variation while MOR is a measure of unexplained cluster heterogeneity. ICC quantifies the degree of heterogeneity of childhood anthropometric failure between clusters (the proportion of the total observed individual variation in anthropometric failure that is attributable between cluster variations) but MOR is quantifying 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 anthropometric failure and cluster at low risk when randomly picking out two clusters (EAs) MOR. PCV measures the total variation attributed by individual-level factors and community-level factors in the multilevel model as compared to the null model PCV [21].

Result

The data set included 4,130 children in DHS conducted in 2005; 10, 285 children in 2011; and 9,449 children in 2016. Over the last decade, there has been a decline in the magnitude of anthropometric failures as Table 1 shows, the overall proportion of anthropometric failures among under-five children has been decreased from 53.5% (95% CI: 52.3, 55.5) in 2005 to 46.2% (95% CI: 45.5, 47.6) in 2016. When compared to conventional anthropometric indices CIAF identified more number of children who had one form of anthropometric failures, while conventional anthropometric indices underestimate the number of children with the nutritional problem (Table 2).

Table 1
Classification of children with CIAF and conventional indicators in Ethiopia (2005–2016).

Conventional categories	EDHS 2005	EDHS 2011	EDHS 2016
	n = 4130	n = 10285	n = 9449
Wasting	484(10.5)	1052(9.7)	1033(10)
Stunting	2133(46.5)	4834(44.4)	3980(38.4)
Underweight	1761(38.4)	3122(28.7)	2488(24)
CIAF Total	2211(53.5)	5249(51)	4364(46.2)

Table 2
Distribution of children under five years according to the seven categories of CIAF classification of nutritional status, based on data obtained from three surveys (2005–2016) conducted in Ethiopia

CIAF categories	EDHS 2005	EDHS 2011	EDHS 2016
	n = 4130	n = 10285	n = 9449
	n (%)	n (%)	n (%)
A No failure	1919(46.5)	5036(49)	5085(53.74)
B Wasting only	98(2.4)	340(3.31)	398(4.21)
C Wasting + underweight	182(4.4)	391(3.8)	362(3.83)
D Wasting + stunting + underweight	167(4)	460(4.4)	357(3.77)
E Stunting + underweight	1023(24.7)	2083(20.2)	1477(15.61)
F Stunting only	585(14.2)	1836(17.8)	1606(16.9)
Y Underweight only	156(3.8)	139(1.4)	164(1.7)
CIAF (%)	2211(53.5)	5249(51)	4364(46.2)
Total (%)	100	100	100

Trends of anthropometric failure

Table 3 shows the trend in anthropometric failures among under-five children in Ethiopia based on the child and maternal background characteristics reports from 2005–2016 EDHS. The result indicated a long term trend in children presented with diarrhea in the last 2 weeks was associated with anthropometric failure among children in all the survey years. Among children in the sample reported having been sick in the 2 weeks preceding the survey, 50.1%, 56%, and 49.4% had an anthropometric failure in 2005, 2011, and 2016 respectively. Place of delivery was also associated with anthropometric failure in children. Results show that among children who were born at home, 57% in 2005, 54% in 2011, and 51% in 2016 had an anthropometric failure. Maternal BMI was significantly associated with anthropometric failure in children; among children who had low BMI mothers, 58.3%, 57%, and 54% in the respective survey years had one form of anthropometric failure as well. The proportion of children who had an anthropometric failure in rural areas was higher than in urban areas in all three years, at 57.4%, 54.3%, and 49.2% respectively. The proportion of children with anthropometric failure was highest among children in the poorest households and lowest among children in the richest households across all the survey years. Further, the prevalence of childhood anthropometric failures shows a variation across regions; in 2016, for example, the range was from 56.9% in the Afar region to 18.02% in the Addis Ababa region (Fig. 1).

Table 3

Bivariate analysis showing the proportion of children age 6–59 months who had anthropometric failures by child and maternal background characteristics, EDHS 2005, 2011, 2016

Variables	2005 EDHS		2011 EDHS		2016 EDHS		Pooled data	
	p-value/	n	p-value/	n	p-value/	n	p-value/	n
	percent		percent		percent		percent	
Sex of child	0.175		0.000		0.000			
Male	54.99	1,075	52.79	2,539	47.9	2137	51.9	5751
Female	52.81	997	48.87	2,269	44.0	1890	48.5	5156
Age of child	0.000		0.000		0.000			
0-5m	16.51	54	26.67	264	27.6	252	23.6	570
6-11m	41.86	162	34.28	327	31.5	300	35.9	789
12-23m	62.77	472	52.87	931	47.4	842	54.3	2245
24-35m	59.33	445	60.67	1,120	55.2	937	58.4	2502
36 and above	57.71	939	55.51	2,166	49.6	1696	54.3	4801
Had cough in last two weeks	0.033		0.100		0.088			
Yes	50.08	1,753	52.53	1,018	48.0	696	50.2	3467
No	54.68	319	50.43	3,790	45.6	3331	50.2	7440
Had fever in last two weeks	0.727		0.000		0.008			
Yes	53.32	377	54.62	1,028	49.4	620	52.4	2025
No	54.05	1,695	49.93	3,780	45.4	3047	49.8	8522
Had diarrhea recently	0.033		0.000		0.021			
Yes	50.08	319	55.74	820	49.4	497	51.7	1636
No	54.68	1,753	49.96	3,988	45.6	3530	50.1	9271
Birth weight	0.037		0.002		0.000			
Low < 2500	40.00	12	36.27	37	46.0	93	40.8	142
Normal > = 2500	22.59	54	22.60	174	30.4	480	25.2	708
Age of mother at first birth	0.117		0.000		0.000			

Variables	2005 EDHS		2011 EDHS		2016 EDHS		Pooled data	
	p-value/ percent	n	p-value/ percent	n	p-value/ percent	n	p-value/ percent	n
< 20	54.95	1,549	52.19	3,560	47.8	3018	51.6	8127
20–34	51.18	520	47.38	1,232	41.4	1004	46.7	2756
35–49	50.00	2	62.50	10	25.0	5	45.8	17
Breastfeeding Initiation	0.080		0.031		0.155			
Within an hour	53.92	957	48.46	1,720	43.8	1890	48.7	4567
After an hour	47.75	191	50.27	835	46.8	552	48.3	1578
After one day	52.00	182	52.73	657	195	42.9	49.2	1034
Place of delivery	0.000		0.000		0.000			
Health facilities	28.80	106	31.39	382	35.8	995	31.9	1483
At home	56.60	1,937	53.67	4,362	50.8	2981	53.7	9280
Other places	57.14	28	62.37	58	49.5	51	56.3	137
Birth order	0.000		0.000		0.000			
1st	48.53	627	46.43	1,579	42.3	1367	45.8	3573
3–4	55.90	597	53.00	1,380	45.3	1089	51.4	3066
5 and more	57.27	847	53.70	1,843	50.4	1571	53.8	4261
Residence	0.000		0.000		0.000			
urban	32.58	172	32.94	499	31.8	512	36.0	1183
Rural	57.35	1,899	54.32	4,303	49.2	3515	53.6	9717
Household size	0.003		0.013		0.000			
1–4	50.56	448	48.87	1,123	42.5	1008	47.3	2579
5–9	55.69	1,493	51.93	3,317	47.2	2752	51.6	1562
10 and more	47.79	130	48.20	362	48.5	267	48.1	759
Mothers BMI	0.000		0.000		0.000			
Thin	58.27	511	56.99	1,410	53.7	1103	56.3	3024
Normal	53.87	1,490	50.38	3,206	45.9	2664	50.1	7360

Variables	2005 EDHS		2011 EDHS		2016 EDHS		Pooled data	
	p-value/ percent	n	p-value/ percent	n	p-value/ percent	n	p-value/ percent	n
Overweight	35.71	70	31.05	186	26.3	215	31.0	471
Mother educational level	0.000		0.000		0.000			
No education	58.15	1,705	54.76	3,598	50.83	232	54.6	5535
Primary	47.36	296	45.67	1,097	42.43	2,834	45.0	1409
Secondary and above	24.82	70	23.06	107	25.33	961	24.4	379
Wealth index	0.000		0.000		0.000			
Poorest	60.51	599	57.70	1,679	53.6	1682	57.3	3960
Poorer	59.83	429	56.89	995	51.8	794	56.2	2218
Middle	56.91	391	52.35	814	46.6	588	52.0	1793
Richer	53.19	358	49.58	772	40.4	446	47.7	1576
Richest	38.08	294	32.53	542	30.0	517	33.5	1353
Current marital status	0.424		0.095		0.895			
Currently not in union	56.43	136	54.08	345	46.3	224	52.3	705
Currently in union	53.78	1,935	50.65	457	45.9	3803	50.1	6195
Preceding birth interval	0.001		0.000		0.000			
≤ 24 months	60.88	445	56.02	1,014	51.4	892	56.1	2351
> 24 months	54.05	1,320	50.72	2,956	45.5	2407	50.01	6683
ANC visit	0.000		0.000		0.000			
Yes	44.04	377	42.31	1,226	41.4	1690	42.6	3293
No	57.09	962	55.61	1,993	50.1	1010	54.3	3965
Source of drinking water	0.283		0.000		0.000			
unimproved source	49.14	114	54.83	2,555	49.9	1710	51.3	4379
Improved source	52.84	1,154	47.04	2,232	43.5	2314	47.8	5700

Variables	2005 EDHS		2011 EDHS		2016 EDHS		Pooled data	
	p-value/ percent	n	p-value/ percent	n	p-value/ percent	n	p-value/ percent	n
No of children under five years in the household	0.225		0.012		0.000			
1	51.02	425	51.05	1,556	42.7	1313	48.3	3321
2	54.38	633	51.94	2,314	49.4	1929	51.9	4876
3	50.60	211	47.84	876	43.9	755	47.4	1842
Husband/partner's education	0.000		0.000		0.000			
No education	58.43	821	56.45	2,749	52.02	2,069	56.6	5639
Primary	52.55	309	48.74	1,702	43.48	1,197	48.3	3208
Secondary and above	31.34	139	31.78	321	34.17	505	32.4	965

The spatial trend of childhood anthropometric failure in Ethiopia

The spatial autocorrelation analysis revealed the presence of statistically significant clusters at a 0.01, level of significance in each survey (Table 4). The spatial analysis indicates there were regional variations, with Tigray, Amhara, Afar, and Benishangul-Gumuz regions having a higher proportion of anthropometric failures, while the lowest proportion of anthropometric failures was observed in Addis Ababa and Gambella Regions consistently over time (Figs. 2, 3 and 4).

Table 4

Spatial autocorrelation analysis of anthropometric failure from EDHS (2005, 2011 and 2016).

Survey	Pick Clustering distance in meters	Observed Moran's I	Expected Moran's I	Z-Score	P-value
EDHS, 2005	133994.0909	0.494	-0.001919	14.49	< 0.01
EDHS, 2011	95786.7875	0.9102	-0.001754	28.79	< 0.01
EDHS, 2016	121812.8929	0.4474	-0.00094	14.63	< 0.01

In the 2005 EDHS, all zones in Addis Ababa, Harari, and Dire Dawa were significantly clustered with a low prevalence of anthropometric failures (negative Z-score and Gipvalue < 0.05). Three zones in Oromia region (Jimma, Horo Guduru and West arsi) and three zones in Somali region (Liben, Afder and fafan) and four zones in SNNP region (Yem, Woliyta, Dawro and Sidama and West arsi) nine zones in Amhara region (Awi/agew, Oromia, North Shewa, North Gonder, South Gondar, West Gojjam, East Gojjam, North wollo, and South wollo), and Southern zone in Tigray region were significantly clustered with a high prevalence of anthropometric failures (Positive Z-score and Gipvalue < 0.05). The rest of the zones were not significantly clustered with either low or high prevalence of anthropometric failures (Fig. 2).

Figure 3 shows the spatial variation of anthropometric failures at zonal level in 2011 EDHS. The spatial analysis shows that a statistically significant high proportion of anthropometric failure was found in northern parts of the country (Amhara, Benishangul-Gumuz, Tigray and Affar regions), whereas statistically significant low spots of anthropometric failure were found in the western (Gambella), central oromia, Addis Ababa and eastern parts of the country.

In the 2016 EDHS, hot spot (high risk) areas for childhood anthropometric failures includes six zones in Tigray region (North-Western, Western, Southern, Eastern, Central, and East). North Gondar, South Gondar, West Gojam ,East Gojam, awi/agew, North and South wollo of Amhara region. All zone of Afar region, Metekel, and Asosa of Benshangul Gumuz region and Liben and Afder of Somali region (Fig. 4).

Spatial scan statistics

In the 2005 EDHS, the spatial scan statistics identified a total of 6 significant clusters of anthropometric failures. Of these, one was most likely (primary cluster), the spatial window was located in Amhara and southern part Tigray regions centered at (11.529743 N, 38.342559 E) with 162.07 -km radius, a Relative Risk (RR) of 1.40 and Log-Likelihood (LLR) of 40.6, at p-value < 0.01 which was detected as the most likely cluster with Maximum Likelihood. It showed that children within the spatial window had 1.4 times more likely a higher risk of anthropometric failures than the children outside areas of the spatial window. Whereas the secondary clusters were located in SNNP, the southern part of Oromia, and the southern part of the Somali region (Fig. 5).

In EDHS 2011, the spatial scan statistics identified a total of 3 significant clusters of anthropometric failures. Of these, one was most likely (primary cluster), the spatial window was located Amhara, Tigray, and afar regions centered at (11.646140 N, 39.234715 E) with 264.4-km radius, a Relative Risk (RR) of 1.3 and Log-Likelihood (LLR) of 75.8, at p-value < 0.01 which was detected as the most likely cluster with Maximum Likelihood. It showed that children within the spatial window had a 1.3 times higher likelihood of anthropometric failure as compared to children outside the spatial window. Whereas the secondary clusters were located in the Benishangul region. Which was centered at (9.981136 N, 35.224095 E) with a 55.24-km radius and LLR of 12.2 at p-value 0.003. It showed that children within the spatial window had 1.37 times higher risk of anthropometric failures than children outside the window (Fig. 6).

In the 2016 EDHS, a total of 8 clusters were identified and four of them were significant clusters with p -value < 0.05 . A total of 1236 locations/spots with a total sampled population of 2226 were found as primary cluster areas were identified using sat scan analysis with a p -value < 0.001 . The primary cluster spatial window was located mainly in Amhara, Tigray, and afar regions centered at (11.626646 N, 39.666951 E) with 280.04 km radius, a Relative Risk (RR) of 1.3 and Log-Likelihood (LLR) of 58.48, at p -value < 0.001 which was detected as the most likely cluster with Maximum Likelihood. It showed that children within the spatial window had a 1.31 times higher likelihood of anthropometric failures as compared to children outside the spatial window. Whereas the secondary clusters were located in Benishangul and the southern part of Somali regions (Fig. 7).

Spatial Interpolation

The kriging interpolation analysis mapped the estimated distributions of anthropometric failures interpolating the available data to the areas where data were not taken. From EDHS 2005 sampled data, the geostatistical analysis predicts that the highest prevalence of childhood anthropometric failures was detected in the Amhara and southern part of Tigray regions whereas, predicted relatively low anthropometric failures located in the Addis Ababa and central part of Oromia (Fig. 8). In 2011, Kriging interpolation revealed that the highest predicted prevalence of anthropometric failure was found in Amhara, Tigray, Afar, and Benishangul Gumuz regions. In contrast, predicted low anthropometric failure was detected in Addis Abeaba, the central part of Oromia, Harari, and Dire Dawa (Fig. 9). Based on EDHS 2016, Kriging interpolation predict that the highest prevalence of anthropometric failure was detected in the Amhara, the southern and central part of Tigray, and afar regions whereas, predicted relatively low anthropometric failures located in the Addis Ababa, central Oromia, and Gambella (Fig. 10).

Multilevel Analysis

Bi-variable multilevel logistic regression analysis was done to identify variables for multivariable multilevel logistic analysis and Variables with a p -value less than 0.2 were considered for multivariable analysis. In multivariable multilevel mixed-effect logistic regression analysis individual-level factors such as the age of the child, maternal BMI status, birth weight, initiation of breastfeeding, number of under-five children in the house, maternal and paternal educational level were a significant predictor of childhood anthropometric failure.

Children age between 6–11 months were 2.34 times (AOR = 2.34, 95%CI = 1.22–3.26), between 12–23 months 3.66 times (AOR = 3.66, 95% CI = 2.22–4.26), between 24–35 months 5.20 times (AOR = 5.20, 95%CI = 4.42–6.21), and above 36 months 4.12 times (AOR = 4.12, 95%CI = 3.11–5.22) more likely to develop anthropometric failures when compared with children age between 0–5 months. Children who had high birth weight were 25% (AOR = 1.25, 95% CI: 1.16–1.49) less likely to had anthropometric failure as compared with their counterparts. The odds of anthropometric failure for initiation of breastfeeding after an hour and after one day were 1.62 times (AOR = 1.62, 95%CI = 1.22–2.28) and, 1.51 times (AOR = 1.51, 95%CI = 1.06–2.11) higher as compared with breastfeeding initiation within an hour respectively. The odds of anthropometric failure of children born from mothers who had low BMI was 1.35 times

higher than that of children born from normal BMI mothers. Children with mothers who completed primary and secondary education level were 18% (AOR = 0.82, 95% CI: 0.66–0.96) and, 23% (AOR = 0.77, 95% CI: 0.62–0.95), less likely to had anthropometric failures respectively as compared to those children whose mothers had no formal education. Similarly, children with fathers who completed secondary and above educational level were 25% lower (AOR = 1.51, 95% CI: 1.07–2.12) to had anthropometric failure as compared with those children whose fathers had no formal education (Table 5).

Table 5
Factors associated with childhood anthropometric failures in Ethiopia by multilevel logistic regression analysis, EDHS 2016

Variables	Model 2 AOR(95% CI)	Model 3 AOR(95% CI)	Model 4 AOR(95% CI)
Individual level factors			
Child's age(months)			
0-5m	1.00	—	1.00
6-11m	2.52(3.22–5.11)	—	2.34[1.22–3.26]
12-23m	4.47(5.00-7.44)	—	3.66[2.22–4.26]
24-35m	4.22(5.00-7.25)	—	5.20[4.42–6.21]
Above 36 m	3.55(2.33–6.10)	—	4.12[3.11–5.22]
Birth weight			
Low < 2500	1.00	—	1.00
High > = 2500	1.40(1.05–1.89)	—	1.25[1.16–1.49]
Initiation of breast feeding			
Within an hour	1.00	—	1.32[1.16–1.54]
After an hour	1.42(1.12–1.56)	—	1.62[1.22–2.28]
After one day	1.33(1.1.88)	—	1.51[1.06–2.11]
No of children under-five in the house hold			
1	1.00	—	1.00
2	0.74(0.66–1.4)	—	0.89[0.69–1.03]
3	0.85(0.73–1.01)	—	0.96[0.79–1.12]
Maternal BMI			
Normal	1.00	—	1.00
Thin	1.22[1.01–2.2]	—	1.35[1.01–1.95]
Overweight	1.77[1.42–3.2]	—	0.79[0.52–0.95]
Maternal educational level			
No education	1.00	—	1.00
Primary	0.87[0.75–1.03]	—	0.82[0.66–0.96]

Variables	Model 2	Model 3	Model 4
	AOR(95% CI)	AOR(95% CI)	AOR(95% CI)
Secondary and above	0.66[0.36–1.03]	—	0.77[0.62–0.95]
Paternal educational level			
No education	1.00	—	1.00
Primary	0.92[0.88–1.22]	—	0.96[0.82–1.12]
Secondary and above	0.74[0.59–0.95]	—	0.75[0.46–0.89]
Community level factors			
Residence			
Urban	—	1.00	1.00
Rural	—	1.42[1.02–1.88]	1.38[1.07–2.21]
Region			
Dire Dawa	—	1.00	1.00
Tigray	—	5.35[4.65–8.01]	3.02[2.00-4.23]
Afar	—	1.45[1.05–2.01]	2.10[1.30–3.46]
Amhara	—	3.20[2.2–4.33]	4.65[3.22–5.35]
Oromiya	—	2.01[1.82–3.25]	2.01[1.52–3.15]
somali	—	3.05[2.11–5.02]	2.88[1.88–4.66]
Benishangul gumz	—	1.92[1.28–2.89]	1.96[1.42–2.84]
SNNP	—	1.23[1.00-1.67]	1.22[1.22–2.55]
Gambella	—	0.77[0.56–0.98]	0.67[0.37–0.95]
Harari	—	0.86[0.52–1.21]	0.71[0.46–1.20]
Addis Abeba	—	0.81[0.52-1.0.98]	0.57[0.37–0.89]

Community-level predictors for anthropometric failure.

In the multivariable multilevel logistic regression model place of residence and region of residence were significantly associated with childhood anthropometric failure.

Children from rural households had 38% higher odds (AOR = 1.38, 95% CI: 1.07–2.21) of anthropometric failure compared to children from urban households. The odds of childhood anthropometric failure in Tigray (AOR = 3.02; 95% CI: 2.00–4.23), Afar (AOR 2.10; 95% CI 1.30–3.46), Amhara (AOR 4.65; 95% CI 3.22–5.35) and Oromiya (AOR = 2.01; 95% CI: 1.52–3.15) were higher compared to Dire Dawa respectively. Similarly, the odds of anthropometric failure in Somali was 2.88 times (AOR = 2.88, 95% CI: 1.88–4.66), Benishangul gumz 1.96 times (AOR = 1.96, 95% CI: 1.42–2.84), and SNNP 1.22 times (AOR = 1.22, 95% CI: 1.02–2.55), more likely as compared to Dire Dawa. However, the odds of childhood anthropometric failure at Gambella and Addis Abeba regions were lower by 33% and 43% as compared to Dire Dawa (Table 5).

Discussion

This study tried to identify Spatio-temporal distribution and predictors of childhood anthropometric failures across the regions in Ethiopia. 2005, 2011, and, 2016 Ethiopian Demographic and Health Survey data were used in the analysis. In addition to identifying children with wasting, stunting, and overweight, the utilization of CIAF allowed the children's identification with multiple conditions of under-nutrition [13, 14], generally neglected in most nutritional surveys. Our analysis shows how the conventional indices of stunting, wasting, and underweight, when used on their own, miss significant numbers of children who experience multiple anthropometric deficits, which is similar to studies conducted using CIAF [11, 16].

Based on the findings of this study, the trend of anthropometric failures was decreased from 53.5–46.2% from 2005 to 2016. The study revealed that 46.2% [95% CI: 45.5, 47.6] of children had anthropometric failures in 2016 preceding the survey. This is higher compared to the prevalence reported by conventional indices of stunting wasting and underweight in Ethiopia [8, 22]. This prevalence was in line with a study done by CIAF in Ethiopia using 2014 mini demographic health survey 48.5% [23] and a study was done in Bangladesh 48.3% [24], whereas higher than the study done in Tanzania 38.2%, west Bengal India 32.7% [25]. However lower than the study done in Yemen 70.1 [16], southern India 58.59% [9]. Among children of 6–59 months of age, anthropometric failures are still considered to be a major public health problem in Ethiopia.

To date, few studies have explicitly examined the spatial disparity of anthropometric failures by taking into account the overall distribution of under-nutrition. The Moran's I statistics suggested strong spatial dependence in variation in levels of various anthropometric failures across the regions among children aged 0–59 months in Ethiopia, this highlights that geography plays a substantial role in the levels of anthropometric failures in an area. Furthermore, a clear spatial pattern of childhood anthropometric failures was observed across the districts of Ethiopia. The anthropometric failures showed significant clustering in the districts belonging to the regions of Tigray, Amhara, Afar, Somali, and Benishangul Gumz. Overall, Tigray, Amhara, and Afar regions were among the higher risk regions of anthropometric failures across time.

This study indicated that children in the youngest age group of 0–5 months had a lower risk of anthropometric failure than children in the older age group. This finding was consistent with studies conducted in Tanzania [11] and Yemen [16]. This could be explained by the fact that children at their younger stage are getting a diet that is richer and complete or vulnerable to disease when a child grows old. The failure may result from the termination of breastfeeding, increment of nutritional demand during rapid physical and mental growth might it be the possible reasons.

The finding of this study indicated that children whose mothers are a thin BMI below 18.5 had more anthropometric failures as compared to children whose mothers had normal body weight BMI 18.5-24.95. This finding is in line with other studies conducted in sub-Saharan Africa [11, 26] and India [15]. This group consists of more at-risk population segments for children anthropometric failure. Aside from, poor nutritional status of mothers leads to raising the infant's risk of low birth weight and infant deficiency, as a result, these conditions might lead to anthropometric failure.

We also found that childhood anthropometric failures is significantly associated with maternal education. Previous studies conducted have shown that maternal education has a positive effect in decreasing childhood anthropometric failure [11, 15]. The knowledge that mothers acquire from formal education could help them to adopt essential nutrition and hygiene behaviors that may prevent anthropometric failures. Another reason might be that educated mothers have a better understanding of maternal and childcare education and information provided through media as compared to uneducated mothers which can help to avert anthropometric failures. Further paternal education was also positively associated with reducing childhood anthropometric failures [9]. Those children whose fathers had attended formal education had less chance to had anthropometric failures. Similar findings have been reported by other studies. Those fathers with formal education might be more knowledgeable on proper child feeding and hygiene practices, which have a positive effect to avert these failures. In Ethiopia lack of education is a widespread problem, which could be the possible factor for the prevention of anthropometric failures Ethiopia.

This research study has a few limitations. Even though, the Analysis of the prevalence and spatial trends included three surveys while factors associated with CIAF were only assessed only using the recent survey. In addition, the cross-sectional nature of the study prevents causality from being inferred between the independent and dependent variables. Another limitation is the respondents' files that didn't have longitude and latitude data were excluded from the spatial analysis which could affect the generalizability of the findings. Despite the above limitations, the representativeness of the data with a large sample size, as well as a nationally representative population-based study with a high response rate are strengths of this study that give high statistical power to infer the characteristics of the study population. Another important strength of this study is the use of multilevel logistic regression analysis, which was able to identify other factors beyond individual-level factors that would not be identified by using standard logistic regression analysis. The use of a combination of methods the spatial and regression statistics were also allowed cross-validation of the identified hotspots and cold spot areas.

Conclusions

Findings from this study indicated that the prevalence of childhood anthropometric failures as measured by CIAF shows a significant decrease from the 2005 to 2016 surveys in Ethiopia. The spatial pattern of child anthropometric failures in Ethiopia was non-random among the three consecutive surveys with the global Moran's I value of 0.494, 0.910, and 0.447 in EDHS 2005, 2011, and 2016 respectively. Our study revealed that children in Ethiopia, who had a lower wealth index, had an uneducated mother/father, had low birth weight, or had a mother with low BMI are at a higher risk of anthropometric failures. This study has underlined that the district-specific variation is substantial in modeling the risk of anthropometric failures. The identified socio-demographic characteristics and districts at an increased likelihood of anthropometric failure can inform localized intervention and prevention strategies to improve the nutritional status and healthcare of children in Ethiopia.

List Of Abbreviations

AOR-Adjusted Odds Ratio, ANC- Antenatal Care, CSA-Central Statics Agency, CI-Confidence Interval, CIAF- Composite index of anthropometric failure, COR-Crude Odds Ratio, EDHS-Ethiopia Demographic and Health Survey, 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.

Declarations

Ethics approval and consent to participate

Since the study was a secondary data analysis of publically available survey data from the DHS program, ethical approval and participant consent were not necessary for this particular study. We requested DHS Program and permission was granted to download and use the data for this study from <http://www.dhsprogram.com>. There are no names of individuals or household addresses in the data files. The geographic identifiers only go down to the regional level (where regions are typically very large geographical areas encompassing several states/provinces. In surveys that collect GIS coordinates in the field, the coordinates are only for the enumeration area (EA) as a whole, and not for individual households, and the measured coordinates are randomly displaced within a large geographic area so that specific enumeration areas cannot be identified.

Consent for publication

Not applicable.

Availability of data and materials

Data we used for this study are publicly available in the MEASURE DHS program and you can access it from www.measuredhs.com after explaining the objectives of the study. Then after receiving the authorization letter, the data is accessible and freely downloaded.

Competing interests

The authors declare that they have no competing interests.

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Authors' Contributions

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

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Figures

Figure 1

Trends of anthropometric failure overtime across regions in Ethiopia, EDHS 2005-2016.

Hot spot analysis of Anthropometric failure among under-five children in Ethiopia, 2005

Figure 2

Hotspot and cold spot analysis of anthropometric failure in Ethiopia, EDHS 2005. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Hot spot analysis of Anthropometric failure among under-five children in Ethiopia, 2011

Source: Shape file form Ethiopian Central Statistical Agency (CSA), 2013

Figure 3

Hotspot and cold spot analysis of anthropometric failure in Ethiopia, EDHS 2011. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Hot spot analysis of Anthropometric failure among under-five children in Ethiopia, 2016

Source: Shape file form Ethiopian Central Statistical Agency (CSA), 2013

Figure 4

Hotspot and cold spot analysis of anthropometric failure in Ethiopia, EDHS 2016. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Anthropometric failure clusters, 2005

Source: Shape file form Ethiopian Central Statistical Agency (CSA), 2013

Figure 5

SaTScan scan statistics analysis of anthropometric failure in Ethiopia, EDHS 2005. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Anthropometric failure clusters, 2011

Source: Shape file form Ethiopian Central Statistical Agency (CSA), 2013

Figure 6

SaTScan scan statistics analysis of anthropometric failure in Ethiopia, EDHS 2011. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Antropometric failure clusters 2016

Source: Shape file form Ethiopian Central Statistical Agency (CSA), 2013

Figure 7

SaTScan scan statistics analysis of anthropometric failure in Ethiopia, EDHS 2016. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Spatial Interpolation of Anthropometric failure among under-five children in Ethiopia, 2005

Source: Shape file from Ethiopian Central Statistical Agency (CSA), 2013

Figure 8

Ordinary Kriging interpolation of anthropometric failure in Ethiopia, EDHS 2005. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Spatial Interpolation of Anthropometric failure among under-five children in Ethiopia, 2011

Figure 9

Ordinary Kriging interpolation of anthropometric failure in Ethiopia, EDHS 2011. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Spatial Interpolation of Antropometric failure among under-five children in Ethiopia,2016

Figure 10

Ordinary Kriging interpolation of anthropometric failure in Ethiopia, EDHS 2016. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.