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Child health outcomes and associated factors among under five years children in Ethiopia: a population attributable fractions analysis of Ethiopia demographic and health survey (2005–2016)

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Abstract

Introduction In Ethiopia, more than half (57%) of children aged 6–59 months were estimated to be anemic in 2016 alone. The country had about 37% of under-five children suffering from stunting and under-five mortality rate of 59 deaths per 1000 live births in 2019. The main purpose of this paper was to estimate the proportion of under-five children prevented from childhood undernutrition, anemia, and under-five mortality by removing the risk factors or inequalities.

Method This cross-sectional study was based on a pooled total sample of 29,831 children aged 0–59 months drawn from three rounds of the Ethiopian Demography and Health Surveys (2005–2016). We employed multiple logistic regression analysis to identify the modifiable risk factors associated with childhood anemia, undernutrition, and under-five mortality among under-five children. We also used Population Attributable Fractions (PAFs) to estimate the proportion of under-five children that could be prevented from childhood undernutrition, anemia, and under-five mortality by removing inequalities.

Result PAF analyses of risk factors of childhood anemia confirmed that 38.5% of occurrence of childhood anemia was attributed to five selected risk factors, which include having a large household size (5+), being in a poor household, being born from anemic and unemployed mothers, and being breastfed for less than six months. About 45.6% of occurrences of childhood undernutrition were attributed to unimproved toilet facility, solid cooking fuel, and home delivery. About 72% of the reported under-five mortality could possibly be averted by removing the use of unimproved toilet facilities, early age childbirth (< 18 years old mothers), and a large number of children ever born to mothers and less than six months breastfeeding practice at the population level.

Conclusion The present study suggests that a substantial reduction in the prevalence of childhood anemia, undernutrition, and under-five mortality in the country is attainable if child survival-focused program interventions and policies target households and mothers with low socioeconomic status and those who have low awareness of child healthcare, including breastfeeding practice and use of safe sanitation facilities.

Keywords Anemia, Childhood, Ethiopia, Mortality, Under-five, Undernutrition

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Introduction

Child health outcomes, including childhood anemia, undernutrition, and under-five mortality, continue to be significant public health concerns in developing countries [22, 34]. According to the World Health Organization (WHO), childhood anemia is a blood hemoglobin concentration of less than 11 g/dl [41]. Undernutrition is described as insufficient intake of nutritious food, leading to stunting (low height-for-age), wasting (low weight-for-height), and being underweight (low weight-for-age) [42]. Under-five mortality refers to the death of a child before the age of five [43].

Despite the progress and achievements made in the past two decades, a large number of children are suffering from childhood anemia, undernutrition, and under-five mortality worldwide. Globally, an estimated 148.1 million under-five children were affected by stunting in 2022 alone. Of these, 43% of stunted children lived in Africa [39]. In addition, about 269 under-five children were anemic in 2019, and more than 60% of anemic children also resided in Africa [32]. In addition, about 5.0 million children died before reaching their fifth birthday at the global level in 2021 [38]. Worryingly, children born in sub-Saharan Africa are subject to the highest under-five mortality rate of 74 deaths per 1000 live births, which is 15 times higher than the risk for children in Europe and Northern America and 19 times higher than children born in the region of Australia and New Zealand in 2021 [39]. Currently, the global Child Health Task Force is urging 54 African countries, including Ethiopia, to accelerate efforts to achieve the Sustainable Development Goal (SDG) 2030 targets of under-five mortality of 25 deaths or fewer per 1000 live births [6].

In Ethiopia, more than half (57%) of children aged 6–59 months were estimated to be anemic in 2016 [8]. The country had about 37% of under-five children suffering from stunting and under-five mortality rate of 59 deaths per 1000 live births in 2019 [11]. Based on the reported burden of global under-five mortality, the country ranked third in Africa and tenth in the world [10]. The Sustainable Development Index (SDI) is a measure that aims to assess a country's progress toward achieving SDGs in an integrated manner. It considers economic, social, and environmental dimensions of development, providing a more holistic view of a nation's development compared to GDP. According to the SDI score, Ethiopia is ranked 144 out of 166 countries with a 54.5 score of the SDI based on the 2023 Sustainable Development Goal monitoring report [29]. Understanding the key factors and their contribution to childhood morbidity (undernutrition and anemia) and mortality (under-five mortality) will be helpful to accelerate the reduction in childhood anemia, undernutrition, and under-five mortality, and further to achieve SDG targets related to child morbidity and mortality.

Previous studies [9, 16, 25, 30, 31, 40, 45] pointed out geographic location, place of residence, household asset-based wealth index, household size, maternal education, maternal age at birth, maternal employment status, and child size at birth as the key factors significantly associated with childhood undernutrition in Ethiopia. Some other studies [1, 18, 20, 26] documented that childhood anemia is significantly associated with location, place of residence, household asset-based wealth index, the household size, maternal education, maternal anemia and employment status, place of birth, age of child in months, and child size at birth as reported subjectively by mothers. Other studies [2, 3, 33, 44] also identified the household size, source of drinking water, parental and maternal education, maternal age at birth and employment status, child's size at birth, and duration of breastfeeding as the key associated factors with under-five mortality.

While substantial evidence exists on the major determinants of child survival, our understanding of how these factors contribute to the overall burden of childhood anemia, undernutrition, and under-five mortality in Ethiopia remains limited. Therefore, this study poses the question "*How much is the proportional reduction in childhood undernutrition, anemia, and under-five mortality by removing the key risk factors?*" The findings of the study will help identify the risk factors contributing to childhood undernutrition, anemia, and under-five mortality. This information will be valuable for development partners and policymakers to design and implement targeted, risk-specific interventions in the country.

Data source and methods

The study context

Ethiopia has a federal system with twelve regional states, including three recently emerged regions from the previous Southern Nations, Nationalities, and Peoples' Region (SNNPR), and two chartered city administrations. According to the 2022 United Nations Development Program (UNDP) estimate, the country's population was about 123 million with a 2.6% annual growth rate, and this makes the country the second most populous country in Africa [35]. Ethiopia is prone to natural and manmade shocks and stress that affect households, communities, and environmental system resilience [37]. The periodic occurrence of communicable disease outbreaks and the rise in non-communicable diseases present significant challenges to the country's health system [23]. The government of Ethiopia has shown commitment to global agendas, including Sustainable Development

Goals and Seqota Declarations to achieve child survival targets and end childhood undernutrition by 2030 [23]. To accelerate the reduction in childhood undernutrition, the country has developed and endorsed food and nutrition policies and strategies, including Food and Nutrition Policy [12], the National Nutrition Program (NNP) I [13], and NNP II [14] and National Strategy for Newborn and Child survival [15]. However, the country is still experiencing a range of challenges related to child survival contributing to the existing childhood anemia, undernutrition, and under-five mortality [8].

Data source

The study used nationally representative data from the three rounds of Ethiopian Demographic and Health Survey (EDHS), collected between 2005 and 2016. The datasets were obtained from the DHS website (http://dhsprogram.com) with secured online permission. The analysis focused on children's files which include information on socioeconomic, and demographic characteristics for under-five children, their parents, and their households. The pooled data from these three rounds of EDHS comprised 29,831 under-five children. Outcome and exposure variables were extracted from this combined dataset for analysis.

Study variables

Outcome variables

The study focused on three outcome variables: childhood undernutrition, childhood anemia, and under-five mortality. Childhood anemia was categorized into dummy variable where a child is considered to be anemic and assigned value of 1 if the child had severe, moderate or mild anemia level, and 0 if child is not anemic. Childhood undernutrition status was categorized as undernourished and coded as 1 if child had any form of anthropometric failure, and as nourished with assigned value of 0 if the child had no anthropometric failure. Anthropometric failure in this study refers to inadequate physical growth and body composition, assessed through indicators such as weight, height, and age. It includes wasting (low weight-for-height), stunting (low height-for-age), and underweight (low weight-for-age), which are critical measures of malnutrition and essential for assessing child survival and health outcomes [5]. Under-five mortality was coded as 1 if the child died between 0 and 59 months and 0 if the child was alive at least until age of 59 months [7].

Exposure variables

The framing and selection of the exposure variables were based on the well-known child survival conceptual framework developed by Mosley and Chen [24] and review of the related literature [1–3, 25, 26]. For analysis purposes, all exposure variables were coded dichotomously [28]. Accordingly, the eleven old administrative regions of Ethiopia were regrouped into two regional categories: emerging regions (Afar, Somali, Benishangul-Gumuz, and Gambella), and established regions (Amhara, Oromia, Harari, SNNPR and Tigray, including Addis Ababa and Dire Dawa City Administrations) [4]. In Ethiopia, an "emerging region" is an underdeveloped area with limited infrastructure, lower economic activity, and higher poverty rates compared to established regions, which have better infrastructure, diversified economies, and better-quality services. Assessing the gap between these regional categories is crucial for child survival and development.

The household asset-based wealth index's five quintiles were regrouped into two categories: poor (poorest/poorer) and non-poor (medium, richer and richest). Parental education (maternal/paternal) status was recategorized as (no formal education vs. primary+).

Additionally, the following exposure variables were included: place of residence (rural vs. urban), household size (< 5 vs. 5+), household head (male vs. female), source of drinking water (improved vs. unimproved), type of toilet facility (improved vs. unimproved), type of cooking fuel (cleaned vs. solid), maternal employment status (employed vs. unemployed), maternal anemia status (anemic vs. non-anemic), total children ever born (< 3 vs. 3+), antenatal visit (< 4 vs. 4+), place of birth (home vs. health facility), child sex (female vs. male), duration of breastfeeding (< 6 months vs. 6 + months), and child size at birth (small vs. average and above) were used as predictor variables for the present study. The study also included maternal age at child birth (< 18 vs. 18+), considering that a maternal age < 18 has strong correlation with increased risks of low birth weight, and child mortality [36].

Statistical analysis

We used STATA 17 for data management and analysis. Children with missing and unknown responses for source of drinking water, type of sanitation facility, type of cooking fuel, place of delivery, duration of breastfeeding, anthropometric measures (height/length/weight), and size at birth (accounting for less than 3% of the sample) were excluded from the statistical analysis. Descriptive analysis was performed to describe the background characteristics of the study participants, with data weighted for descriptive analysis per DHS recommendation. Multicollinearity effect of the predictor variables was tested using Variance Inflation Factor(VIF) with cutoff value of

2.5 [21]. The VIF values for each variable were less than 2.5, with mean VIF value of 1.33, 134 and 1.34 for childhood anemia, undernutrition, and under-five mortality, respectively, indicating no multicollinearity effect among predictor variables.

Bivariate logistic regression was employed to select the exposure variables with a p-value < 0.2. Multiple logistic regression analyses were conducted to explore the association between selected predictor variables and the three outcome variables. The Hosmer-Lemeshow test was used to test the goodness of fit for our models [19]. A p-value < 0.05 was considered statistically significant.

Population Attributable Fractions (PAFs) were calculated to estimate the proportion of associated risk factors for childhood anemia, undernutrition, and under-five mortality at the population level using STATA user command "punaf" [27] after running logistic regression models. "punaf" implements the method for estimating PAFs for cross-sectional studies recommended by Greenland and Drescher [17], suitable for large scale surveys with multiple risk factors as suggested by Ruckinger et al. [28].

Following the procedural steps provided by Ruckinger et al. [28] we:

1. Coded the risk factor as a binary variable. We assumed that all individuals were not exposed to the risk factor, regardless of their actual status.
2. Used the following formula to estimate the predicted probabilities for each-individual using the modified dataset:

$$pp_i = \frac{1}{1 + exp(-(\alpha + \beta' x_i))}$$

where α is the intercept, β is the vector of coefficients for the covariates, and xi is the vector of observations for the covariates, with the risk factor set to zero for all individuals.

3. Summed up all the predicted probabilities to get the adjusted number of cases of child survival that would occur if the risk factor was absent in the population.
4. Finally "punaf" Stata user command has been used to enable normalization and variance-stabilizing transformation with the following formula [27]:

$$\log(PUF) = \log(1 - PAF)$$

where PUF stands for Population Unattributable Fraction, and PAF refers to Population Attributable fraction.

Results

Descriptive analysis results

Table 1 describes the background characteristics of 29,831 participants. Notably, a substantial portion of the population resides in rural areas (83.97%), where access to improved drinking water (39.34%) and sanitation facilities (14.12%) remains limited. The prevalence of maternal and paternal education levels below primary education (70.78% and 53.82%, respectively) underscores potential challenges in health literacy and access to resources. Household poverty (49.31%) and large family sizes (73.45% with 5 + members) highlight economic vulnerabilities that may impact child health outcomes. Maternal anemia rates (30.49%) and high rates of home births (81.99%) suggest potential health risks related to maternal and neonatal health.

Bivariate logistic analysis results

Table 2 presents the results of bivariate logistic regression analysis involving 18 predictors selected for the study based on a literature review. Maternal age at childbirth and child sex did not show significant associations with childhood anemia. Similarly, region and sex of household head did not demonstrate associations with childhood undernutrition at a significance level of $p < 0.2$. Additionally, sex of household head and maternal employment status did not exhibit significant associations with under-five mortality at the $p < 0.2$ threshold. Due to their p-values exceeding 0.2, these variables were not included in the subsequent multivariable logistic regression analysis as detailed in Table 2.

Multivariate logistic regression analyses results

Table 3 presents the results of multivariable logistic regression analyses examining the associations of various factors with childhood anemia, undernutrition, and under-five mortality in Ethiopia. Significant associations were found for several predictors across the three outcomes. For childhood anemia, administrative region showed notable disparities, with children in emerging regions having 1.571 times higher odds of anemia compared to those in established regions (OR = 1.571, $p < 0.001$). Additionally, children from poor households were 1.391 times more likely to be anemic than those from non-poor households (OR = 1.391, $p < 0.001$). Maternal anemia significantly increased the odds of childhood anemia (OR = 1.808, $p < 0.001$), as did maternal unemployment (OR = 1.417, $p < 0.001$).

Regarding childhood undernutrition, significant associations were observed with place of residence, household size, type of toilet facility, type of cooking fuel, paternal and maternal education, maternal age at childbirth, maternal employment status, number of children ever born, child sex, place of birth, child size at birth, and breastfeeding duration (all $p < 0.05$). For example, children in rural areas had 1.276 times higher odds of

Table 1 Background characteristics of study participants, *N* = 29,831

Background Characteristics	*N*	%
Administrative regions		
Emerging	11,403	38.23
Established	18,428	61.77
Place of residence		
Rural	25,050	83.97
Urban	4,781	16.03
Household asset-based status		
Poor	14,710	49.31
Non-Poor	15.121	50.69
Household size		
< 5	7,919	26.55
5+	21,912	73.45
Household head		
Female	4,893	16.40
Male	24,938	83.60
Source of drinking water		
Improved	11,737	39.34
Unimproved	18,094	60.66
Type of toilet facility		
Improved	4,211	14.12
Unimproved	25,620	85.88
Type of cooking fuel		
Cleaned	1,179	3.95
Solid	28,652	96.05
Paternal Education		
No formal education	16,055	53.82
Primary and above	13,776	46.18
Maternal education		
No formal education	21,114	70.78
Primary and above	8,717	29.22
Maternal age at child birth		
< 18 years	1,828	6.13
18 years and above	28.003	93.87
Maternal anemia status		
Anemic	7,284	30.49
Non-anemic	16,608	69.51
Total children ever born		
< 3	8,701	29.17
3+	21,130	70.83
Maternal employment		
Unemployed	18,421	61.75
Employed	11,410	38.25
Child sex		
Female	15,294	51.27
Male	14,537	48.73
Place of birth		
Home	24,457	81.99
Health facility	5,374	18.01
Child size at birth		
Small	8,579	28.76
Average and above	21,252	71.24
Duration of breastfeeding		
< 6 months	14,312	47.98
6 months and above	15,519	52.02
Total	**29,831**	**100**

undernutrition compared to urban children (OR = 1.276, $p < 0.001$), and those from households using solid fuel for cooking had 1.696 times higher odds of undernutrition than those using clean fuel (OR = 1.696, $p < 0.001$).

In terms of under-five mortality, significant predictors included type of toilet facility, maternal age at childbirth, and number of children ever born (all $p < 0.001$). Children from households using unimproved toilet facilities had 1.318 times higher odds of mortality compared to those using improved facilities (OR = 1.318, $p < 0.001$), while children born to mothers under 18 years old had 1.690 times higher odds of mortality compared to those born to older mothers (OR = 1.690, $p < 0.001$). Moreover, having three or more children ever born significantly increased the odds of under-five mortality (OR = 3.036, $p < 0.001$).

These findings underscore the critical influence of socio-economic, environmental, and maternal health factors on childhood health outcomes in the country, highlighting the need for targeted interventions to mitigate these disparities and improve child survival and well-being across the country.

Population attributable fraction analysis results

Table 4 provides population attributable fractions (PAFs) for risk factors associated with childhood anemia, undernutrition, and under-five mortality in Ethiopia. These PAFs estimate the proportion of each outcome that can be attributed to specific risk factors.

For childhood anemia, significant risk factors contributing to PAFs include residence in emerging regions (7.1%), rural residence (4.7%), belonging to poor households (7.2%), having an anemic mother (7.2%), and maternal unemployment (8.6%). These factors collectively contribute to 51.9% of childhood anemia cases.

Regarding childhood undernutrition, risk factors such as rural residence (9.4%), belonging to poor households (4.8%), using unimproved toilet facilities (11.2%), maternal education (6.5%), maternal age at childbirth under 18 years (0.7%), and breastfeeding for less than 6 months (5.3%) contribute to a combined PAF of 73.9%.

Table 2 Bivariate logistic regression of predictors by childhood anemia, undernutrition and mortality in Ethiopia

Predictors	Anemia (*N*=19,731)			Undernutrition (*N*=20,777)			Under-five mortality (*N*=29,831)		
	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value
Regions									
Emerging	1.8211	1.72-1.93	0.000	1.023	0.97-1.08	0.412	1.118	1.03-1.22	0.011
Established(ref)									
Place of residence									
Rural	1.358	1.56-1,47	0.000	2.336	2.17-2.52	0.000	1.582	1.39-1.81	0.000
Urban (ref)									
Household status									
Poor	1.616	1.52-1.71	0.000	1.676	1.59-1.77	0.000	1.193	1.09-1.30	0.000
Non-Poor(ref)									
Household size									
< 5(ref)									
5+	1.104	1.03-1.18	0.003	1.176	1.11-1.25	0.000	0.519	0.47-0.57	0.000
Household head									
Female	1.121	1.04-1.21	0.002	0.97	0.91-1.04	0.386	0.978	0.87-1.09	0.692
Male(ref)									
Drinking water									
Unimproved	1.184	1.12-1.26	0.000	1.356	1.28-1.43	0.000	1.194	1.09-1.31	0.000
Improved(ref)									
Type of toilet facility									
Unimproved	1.198	1.10-1.30	0.000	2.168	2.01-2.34	0.000	1.672	1.45-1.93	0.000
Improved(ref)									
Type of cooking fuel									
Cleaned (ref)									
Solid	1.577	1.34-1.85	0.000	3.979	3.36-4.72	0.000	2.312	1.70-3.14	0.000
Paternal Education									
No formal education	1.314	1.24-1.39	0.000	1.633	1.55-1.72	0.000	1.344	1.23-1.48	0.000
Primary+(ref)									
Maternal education									
No formal education	1.297	1.22-1.38	0.000	1.777	1.67-1.88	0.000	1.391	1.26-1.54	0.000
Primary+(ref)									
Maternal age at birth									
< 18 years	0.975	0.86-1.10	0.678	1.251	1.11-1.40	0.000	1.686	1.46-1.95	0.000
18+ years (ref)									
Maternal anemia									
Anemic	1.978	1.85-2.11	0.000	1.092	1.03-1.16	0.003	1.254	1.13-1.39	0.000
Non-anemic(ref)									
Children ever born									
< 3(ref)									
3+	1.125	1.06-198	0.000	1.354	1.27-1.43	0.000	1.348	1.22-1.49	0.000
Maternal employment									
Unemployed	1.606	1.52-1.70	0.000	0.949	0.89-1.00	0.057	0.982	0.90-1.07	0.685
Employed(ref)									
Child sex									
Female	1.034	0.97-1.09	0.247	1.144	1.09-1.21	0.000	1.288	1.18-1.40	0.000
Male(ref)									
Place of birth									
Home	1.103	1.03-1.19	0.008	2.206	2.06-2.36	0.000	1.566	1.38-1.78	0.000
Health facility(ref)									

Table 2 (continued)

Predictors	Anemia (*N*=19,731)			Undernutrition (*N*=20,777)			Under-five mortality (*N*=29,831)		
	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value
Child size at birth									
Small	1.240	1.16-1.32	0.000	1.541	1.45-1.63	0.000	0,989	0.89-1.09	0.821
Average & above(ref)									
Breastfeeding duration									
< 6 months	1.692	1.59-1.79	0.000	1.696	1.60-1.80	0.000	0,848	0.78-0.93	0.000
6+ months(ref)									

For under-five mortality, key risk factors include residence in areas with unimproved toilet facilities (27.4%), maternal age at childbirth under 18 years (3.3%), having an anemic mother (4.4%), and having three or more children ever born (51.3%), leading to a total PAF of 72.5%.

These findings underscore the significant impact of socio-economic, environmental, and maternal health factors on childhood health outcomes in Ethiopia, emphasizing the need for targeted interventions to mitigate these risks and improve child survival rates across the country.

Discussion

This study represents a pioneering effort in examining the population-level impacts of key risk factors associated with childhood undernutrition, anemia, and under-five mortality in Ethiopia. Our findings from multivariate regression analyses underscored several significant risk factors contributing to these health outcomes. For childhood anemia, factors such as administrative region (emerging regions), rural residence, household poverty status, maternal anemia, maternal history of three or more children, and shorter breastfeeding duration (< 6 months) emerged as critical risk factors. Similarly, multivariable logistic regression highlighted rural residence, household poverty, use of unimproved toilet facilities, reliance on solid cooking fuels, lack of parental education, home deliveries, and smaller child size at birth as significant risk factors for childhood undernutrition. Additionally, our analysis revealed that children residing in households with unimproved sanitation facilities, born to younger mothers (< 18 years old), and mothers with three or more children faced increased likelihoods of under-five mortality compared to their counterparts. This underscores the modifiability of risk factors such as toilet facility quality, maternal age at childbirth, and number of children ever born in mitigating under-five mortality rates.

Furthermore, Population Attributable Fraction (PAF) analyses identified that 38.5% of childhood anemia cases could be attributed to factors such as larger household size (5+), household poverty, maternal anemia, maternal unemployment, and inadequate breastfeeding duration. Addressing these modifiable risk factors could potentially prevent a significant portion of childhood anemia burden at the population level. Similarly, PAF analysis indicated that approximately 45.6% of childhood undernutrition cases were linked to factors like unimproved sanitation facilities, solid cooking fuels, and home deliveries, highlighting substantial opportunities for intervention. Notably, controlling these factors could potentially reduce childhood undernutrition by nearly half (46%) in the target population. Moreover, our findings suggest that addressing factors such as maternal age at childbirth and number of children ever born could potentially avert 51.3% of reported under-five mortality cases, illustrating the critical role of maternal and child health interventions.

It is essential to note that our study did not directly compare PAF findings with previous studies due to varying prevalence rates of risk factors across different contexts [28].

Our findings underscore the significant impact of modifiable risk factors on child health outcomes, particularly highlighting the pervasive influence of poverty and inadequate maternal support. Key determinants such as educational attainment, access to maternal healthcare, anemia management, family planning services, and cultural factors like early marriage and childbearing were identified as critical contributors to child health disparities, consistent with existing literature.

However, our study acknowledges the need for further exploration within the broader socio-economic context. Future research should delve deeper into these well-established root causes to develop comprehensive strategies aimed at improving maternal health, reducing child mortality, and promoting gender equality. By enhancing our understanding of these complex relationships, researchers can design more effective interventions that address the fundamental issues identified in our study,

Table 3 Multiple logistic regression of predictors by childhood anemia, undernutrition and mortality, Ethiopia*N*=29,831

Predictors	Anemia (*N*=19,731)			Undernutrition (*N*=20,777)			Under-five mortality (*N*=29,831)		
	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value
Regions									
Emerging	1.571	1.47-1.68	0.000				1.059	0.95-1,18	0.298
Established(ref)									
Place of residence									
Rural	1.146	1.02-1.29	0.022	1.276	1.15-1.42	0.000	1.148	0.93-1.41	0.192
Urban(ref)									
Household status									
Poor	1.391	1.30-1.49	0.000	1.213	1.14-1.29	0.000	0.968	0.86-1.09	0.591
Non-poor(ref)									
Household size									
< 5 (ref)									
5+	1.102	1.01-1.21	0.039	0.974	0.89-1.06	0.539	0.278	0.24-0.32	0.102
Household head									
Female	1.044	0.96-1.14	0.318						
Male (ref)									
Source of drinking water									
Unimproved	0.972	0.91-1.14	0.437	0.927	0.86-0.99	0.024	1.032	0.92-1.16	0.607
Improved(ref)									
Type of toilet facility									
Unimproved	0.968	0.87-1.07	0.540	1.291	1.17-1.43	0.000	1.318	1.08-1.60	0.006
Improved(ref)									
Type of cooking fuel									
Cleaned (ref)									
Solid	1.045	0.86-1.27	0.653	1.696	1.38-2.08	0.000	1.290	0.83-2.00	0.256
Paternal Education									
No formal education	1.069	0.99-1.15	0.056	1.199	1.12-1.28	0.000	1.116	0.99-1.25	0.061
Primary and above(ref)									
Maternal education									
No formal education	1.033	0.95-1.12	0.413	1.214	1.13-1.31	0.000	1.043	0.91-1.19	0.538
Primary+(ref)									
Maternal age at birth									
< 18 years				1.332	1.16-1.53	0.000	1.690	1.38-2.07	0.000
18+ years (ref)									
Maternal anemia									
Anemic	1.808	1.68-1.93	0.000	0.983	0.92-1.05	0.603	1.130	1.01-1.26	0.030
Non-anemic(ref)									
Children ever born									
< 3(ref)									
3+	1.054	0.96-1.15	0.264	1.092	1.00-1.19	0.048	3.036	2.54-3.62	0.000
Maternal employment									
Unemployed	1.417	1.33-1.51	0.000	0.871	0.82-0.92	0.000			
Employed(ref)									
Child sex									
Female				1.185	1.12-1.26	0.000	1.278	1.15-1.42	0.201
Male(ref)									
Place of birth									
Home	0.838	0.76-0.92	0.000	1.384	1.26-1.51	0.000	1.147	0.97-1.36	0.118
Health facility(ref)									

Table 3 (continued)

Predictors	Anemia (*N*=19,731)			Undernutrition (*N*=20,777)			Under-five mortality (*N*=29,831)		
	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value	Odds ratio	95%CI	*p*-value
Child size at birth									
Small	1.146	1.07-1.23	0.000	1.486	1.39-1.58	0.000			
Average and above(ref)									
Breastfeeding duration									
< 6 months	1.888	1.77-2.01	0.000	0.791	0.75-0.84	0.000	0.717	0.64-0.79	0.000
6 months and above(ref)									
Constant	0.392	0.33-0.47	0.000	0.210	0.17-0.25	0.000	0.036	0.02-0.46	0.000
Hosmer-Lemeshow test		chi2 = 0.64	*p*=0.887	chi2 =4.09		*p*=0.252	chi2 =6.16		*p*=0.104

Table 4 Population attributable fractions for risk factors of childhood anemia, undernutrition and mortality, Ethiopia

Risk factors	Anemia (*N* = 19731)		Undernutrition(*N* = 20,777)		Under-five mortality (*N* = 29,831)	
	OR [95%, CI]	PAF (%)	OR [95%, CI]	PAF (%)	OR [95%, CI]	PAF (%)
Emerging regions	1.58[1.47,1.68]	7.1%	-	-	-	-
Rural residence	1.14[1.03,1.27]	4.7%	1.26[1.13,1.40]	9.4%	-	-
Poor households	1.40[1.31,1.50]	7.2%	1.21[1.14,1,29]	4.8%	-	-
Household size (5+)	1.14[1.06,1.23]	4.3%	-	-	-	-
Unimproved toilet facility	-	-	1.32[1,19,1,44]	11.2%	1.47[1.22,1.77]	27.4%
Solid fuel use for cooking	-	-	1.62[1,34,1.97]	22.2%	-	-
Parental education (no education)	-	-	1.19[1.12,1,27]	4.5%	-	-
Maternal education (no education)	-	-	1.21[1,12,1.30]	6.5%	-	
Mothers age at birth (< 18yrs)	-	-	1.33[1.16,1.51]	0.7%	1.72[1.41,2.11]	3.3%
Anemic mothers	1.82[1.69,1.95]	7.2%	-	-	1.16[1.04,1.29]	4.4%
Number of children ever born (3+)	-	-	1.07[0.99,1.15]	2.4%	3.19[2.68,3.79]	51.3%
Maternal employment(unemployed)	1.42[1.33,1.52]	8.6%	-	-	-	-
Home delivery	-	-	1.36[1.24,1.48]	12.2%	-	-
Child size at birth (small)	1.15[1.08,1,23]	1.6%	1.48[1.39,1.57]	5.3%	-	-
Breastfeeding for < 6 months	1.88[1.77,2.01]	11.2%	0.79[0.75,0.84]	-5.3%	0.71[0.64,0.79]	-13.9%
Total for all significant variables		**51.9%**		**73.9%**		**72.5%**

thereby enhancing their relevance and impact in diverse settings.

Strengths and limitations

The present study has examined the proportion of reduction on childhood anemia, undernutrition and under-five mortality by removing modifiable risk factors at population level in Ethiopia. The findings will undeniably contribute to the existing literature gap and could be used as evidence for child survival program implementers and interventions, policy makers and future researches as far as we used nationally representative surveys. However, this study is not free from limitations. Firstly, as we used cross-sectional data collected at a time specific point in time, it is difficult to draw causal relationship between the predictors and outcome variables. Secondly, while the survey year identified the DHS wave, the sensitivity analyses did not account for the impact of different survey years. This may affect the accuracy and reliability of our findings. Thirdly, the study acknowledges a limitation regarding the potential interactions between maternal age and the number of children ever born, which could impact the findings. Fourthly, some of the risk factors which were not included (especially macro level factors) in the multivariable regression models might have affected the estimated level of PAFs.

Conclusion

This study focused on key modifiable risk factors associated with childhood anemia, undernutrition and under-five mortality in Ethiopia. The estimated attributable

burdens of these modifiable risk factors were found to be substantial at population level. Therefore, the present study suggests that substantial reduction in the prevalence of childhood anemia, undernutrition and under-five mortality in the country is attainable if policies and child survival focused program interventions target low socioeconomic mothers and households and those who have low awareness on child health care, including breast feeding practice and use of safe sanitation facilities.

Abbreviations

CSA	Central Statistical Agency
DHS	Demographic and Health Survey
EDHS	Ethiopia Demographic and Health Survey
EPHI	Ethiopian Public Health Institute
FDRE	Federal Democratic Republic of Ethiopia
FMOH	Federal Ministry of Health
MOH	Ministry of Health
NNP	National Nutrition Program
PAFs	Population Attributable Fractions
SDG	Sustainable Development Goal
SNNPR	Southern Nations, Nationalities, and Peoples' Region
UNDP	United Nations Development Program
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
VIP	Variance Inflation Factor
WB	World Bank
WHO	World Health Organization

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
Conception and design of the study: NST & NRG; analysis and/or interpretation of data; drafting the manuscript: NST; revising the manuscript critically for important intellectual content: NRG. All authors have read and approved the final manuscript.

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Availability of data and materials
The dataset can be accessed at https://dhsprogram.com/data/available-datasets.cfm.

Declarations

Ethics approval and consent to participate
For the original conduct of the four rounds of Ethiopia Demographic and Health Surveys (EDHSs), ethical approval was obtained from the ethical committee of the ICF. The enumerators obtained informed consent and authorization to anonymously use the data from all survey participants. In our study, we obtained permission to use the data from the DHS program. Furthermore, local ethical approval was obtained from Addis Ababa University, College of Development Studies IRB, and the present study solely involved secondary data analysis of publicly available data that does not contain any identifiable information that links to the actual survey participants. The authors also confirm that all methods were carried out by relevant guidelines and regulations.

Consent for publication
Not Applicable.

Competing interests
The authors declare no competing interests.

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