Burden and Trend of Nutritional deficiency across regions in Ethiopia: A systematic subnational analysis in Global Burden of Disease 2019 study

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Abstract

Background: In Ethiopia, nutritional deficiency has contributed to high child and maternal morbidity and mortality. Understanding the burden and trends of nutrition deficiency across the region helps policymakers and programmers to devise context-specific interventions. Therefore, this study estimated bthe burden and trends of nutritional deficiency at national and regional levels from 1990 to 2019.

Methods: This analysis is part of Global Burden of Diseases 2019 Study that estimated deaths, Years of Life Lost (YLL), Years Lived with Disability (YLD), and Disability Adjusted Life Years (DALYs) attributable to protein energy malnutrition and common micro-nutrient deficiencies, and incidence and prevalence for Ethiopia at national and sub-national levels by sex, years and all age groups. The study used causes of death ensemble model (CODEm) and a Bayesian meta-regression disease modeling (DisMod-MR 2.1) techniques to aanalyzeall accessible protein energy malnutrition and common micro-nutrient deficiencies related data sources. We calculated 95% uncertainty intervals (UI) for the point estimates.

Result: In 2019, the age-standardized death rate due to protein energy malnutrition was 12.9 per 100,000 population. Age-standardizedized DALYs rate due to protein energy malnutrition was estimated to be 492 per 100,000 populations [95%UI: 381.4-654.7] in Ethiopia. The highest DALYs rate attributed to protein energy malnutrition was reported in Somali 1214 per 100,000 populations [95% UI: 804.6-1747.3], Benishangul-Gumuz 1088.5[95% UI: 771.0-1474.7], and Afar 998.0 [95% UI: 759.7-1281.0] regions. The prevalence of Iodine deficiency per 100, 000 populations was 9,671 [95%UI: 7,799- 12,099], 221 [95%UI:132-338], and 15451 [95%UI: 12,272-19,615] among all age groups, children under five years of age and reproductive age women, respectively. The prevalence rate of Vitamin A deficiency declined by 56% from 1990 to 2019. In 2019, the prevalence of dietary iron deficiency was highest in under-five children.

Conclusion: Reproductive-age women, children under five, and elderly people are disproportionately affected by protein-energy malnutrition. The prevalence of dietary iron, and Iodine deficiency was higher in all regions of Ethiopia and needs targeted intervention. [*Ethiop. J. Health Dev.* 2023;37 (SI-2)]

Keywords: Disability-adjusted life years, Nutritional deficiency disorders, Years of life lost, Years lived with disability, prevalence, Death, Ethiopia

Introduction

Malnutrition occurs when the required nutrients by the body is rarely satisfied (1, 2). Nutritional deficiencies are widely prevalent in low- andmiddle-income countries and contribute to maternal and child morbidity and mortality (3, 4). The WHO estimates that about 60% of all diseases occurring among children under five years in developing countries, could be attributed to malnutrition (14). Specifically, protein energy malnutrition (PEM) is a major health burden and the most important factor for illnesses and diseases, especially among young children. It is associated with 50–60% of under-five mortality (5). Nearly 90% of global chronically malnourished (stunted) is to be found in children living in Asia and Africa. A number of African and Asian countries have wasting rates that exceed 15%, including Bangladesh (17%), India (20%) and Sudan (16%) (20).

On the other hand, studies showed that eliminating PEM decreases the global disease burden by 32% (6). In this regard, a systematic review showed that socioeconomic, environmental and behavioural factors are the major contributors to child malnutrition [8]. The prevalence or incidence of a child under malnutrition was higher among children whose caretakers has no formal education, less access to basic sanitation facilities, practiced sub-optimal feeding, and used unclean energy for cooking, and being from malnourished mothers (13).

Micronutrient deficiencies (MNDs) also have great public health and socioeconomic importance worldwide. They affect low-income countries but are also a significant factor in health problems in industrialized societies with impacts among wide, vulnerable groups in the population, including women, children, the middle-aged, and the elderly (17). Especially, children and mothers who are deficient in micronutrients can suffer devastating consequences (7).

In Ethiopia, both protein energy malnutrition and common micronutrient deficiencies are significant public health problems across populations (8). Most common micronutrient deficiencies include vitamin A, Iodine, iron, and zinc (5). The prevalence of anaemia was higher among rural Ethiopian residents of reproductive women, which ranged from 18% to 34% (9). The prevalence of subclinical vitamin A deficiency was 14%, 10.9% and 3.4% in preschool-age children, school-age children, and women of reproductive age, respectively while national supplementation coverage in preschool-age children was 63% (16). The prevalence of iodine deficiency among school-age

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children whose mean urinary iodine concentration was below the cut-off (48%). In women of reproductive age, the prevalence of iodine deficiency was 52% and only 26% of the total households were getting adequately iodized salt though national salt coverage has been 85% (10). Several strategies have been implemented to reverse the trend of macro and micronutrient deficiency in Ethiopia, however, PEM and micronutrient deficiencies remain major public health problems (11). Therefore, this study aimed to estimate the national and regional burden and trends of nutritional deficiencies in Ethiopia to support policy and practice at different levels.

Methods

Study Setting-Ethiopia is a landlocked country located in the Horn of Africa on the continent's northeast coast, bordering Sudan, South Sudan, Kenya, Djibouti, Somalia, and Eritrea (12). Ethiopia is Africa's second most populous country with an estimated population of 107 million in 2019(12). Ethiopia, with a federal system of government, comprises 11 regions (Afar, Amhara, Benishangul-Gumuz, Gambella, Harari, Oromia, Somali, Sidama, South West Ethiopia People's, Southern Nations and Nationalities and People (SNNP), and Tigray) and two chartered cities (Addis Ababa and Dire Dawa) in 2020 (8).

Case Definitions

Protein-energy undernutrition, previously called protein-energy malnutrition, is a lack of energy due to the deficiency of all the macronutrients and many micronutrients (13).

Maternal Anaemia was defined as the percentage of women with Hb levels less than 12 g/dL. (10)

Child anaemia was defined as the percentage of children (6-59 months with Hb levels less than <11 g/dL (10)

Micronutrients are vitamins and minerals needed by the body in very small amounts (23)

Data sources

The National Data Management and Analytics Center (NDMC) at Ethiopian Public Health Institute (EPHI), in collaboration with Institute for Health Metrics and Evaluation (IHME), gathered all accessible data sources by location for Ethiopia and all regions and cities that included census, demographic surveillance and survey, household nutrition surveys, socio-economic surveys, health service utilization and other data for this analysis. A comprehensive description of data sources, quality, and modeling for GBD 2019 has been reported here http://ghdx.healthdata.org/gbd-2019/data-input-sources.

Overall GBD methods and tools

The details of GBD study were described elsewhere (15), and we summarized methods and tools relevant to this analysis. The GBD used a modeling platform called the cause of death ensemble model (CODEm) to estimate child and maternal mortality by age, sex, geography, and year. Child and maternal morbidity including incidence was modeled using a meta-regression platform known as Disease Modeling and Meta Regression (DisMod-MR) method Bayesian mixed-effects meta-regression method. YLLs were computed by multiplying cause-specific deaths by the life expectancy at the age of death. Years lived with disability from nutritional deficiency is measured by taking the condition's prevalence multiplied by the disability weight for that condition (15). Then YLD and YLL were added to calculate DALYs for each regional state by sex, year, and age group. Population risk evaluations over time and among risks were estimated using the comparative risk assessment (CRA) approach created for the GBD study (8). GBD diseases and injuries were organized into a leveled cause hierarchy from the three biggest causes of death and disability at Level one to the foremost particular causes at Level four. There were 174 Level three causes among the three Level one causes (communicable, maternal, neonatal, and nutritional disease; non-communicable diseases; and injuries). The GBD risk factors were also organized into a leveled hierarchy; Level one risk factors are behavioral, environmental and occupational, and metabolic; Level two risk factors include 20 clusters of risks; Level three includes 52 clusters of risks, and Level four includes 69 specific risk factors. The GBD 2019 has estimated the burden of child and maternal for both national and regional states of Ethiopia. Crude and age-adjusted PEM and micronutrient deficiency rates were computed with 95% uncertainty intervals (UI), and we used level III categories in this paper.

Presentation and interpretation of results

In this paper the researchers reported that the GBD 2019 collaborative study results for national and regional PEM and micronutrient deficiency-related fatal and non-fatal health outcomes by sex, age group, and location from 1990-2019. This paper has included crude and age-adjusted rates for national and regional child morbidity and mortality attributable to PEM and micronutrient deficiencies estimates. The findings of the study were summarized and presented using tables and figures as appropriate.

Ethics Statement

This study was conducted as part of the GBD Collaborator Network and under the GBD Protocol (IHME ID 4239-GBD2019-042022). For GBD studies, a waiver of informed consent was reviewed and approved by the Institutional Review Board of the University of Washington (https://www.healthdata.org/gbd/2019).

Results

Burden and trend of Protein Energy Malnutrition (PEM. Nationally, age standardized prevalence of PEM was 1671.1 (95% UI: 1564.7-1797.1) per 100,000 populations in 2019. The prevalence of PEM per 100, 000 was higher (2649.3, 95% UI: 2490.7-2827) in Somali Region (than the national average and all other regions. The lowest prevalence (1077.2 , 95% UI: 967.7-1204.9) of PEM was observed in Addis Ababa. In 2019, age-standardised death rate attributed to PEM was 12.9[95% UI: 9.8-16.7] per 100,000 populations. The highest death rate attributed to PEM was observed in Afar region [35.56, 95% UI: 27.5-45.5] per 100,000 populations **(Table 1).**

In 2019, Ethiopia's age standardized DALYs rate due to PEM was 492 per 100,000 populations [95% UI: 381.4-654.7] (**Table 1**). In 2019, Somali, Benishangul-Gumuz and Afar regions had the highest DALYs rate attributable to PEM with 1214 [95% UI: 804.6-1747.3]; 1088.5[95% UI: 771.0-1474.7], and 998.0 [95% UI: 759.7-1281.0] per 100,000 population, respectively. In Ethiopia, DALYs rate attributed to PEM declined by an annual rate of 87.7% between 1990 and 2019.

Table 1: **The national and sub-national age-standardized YLLs, YLDs, DALYs and Death rates per 100,000 population due to protein-energy malnutrition in 1990 and 2019.**

Location	1990 Prevalence	YLLs	YLDs	DALYs	Death	2019 Prevalence	YLLs	YLDs	DALYs	Death
Addis Ababa	1337.5 (1205.5-1485.2)	1601.4 (1204.5-2083.0)	40.8 (26.2-58.4)	1642.2 (1241.2-2117.8)	44.0 (35.6-54.3)	1077.2 (967.7-1204.9)	229.0 (186.8-280.3)	31.0 (19.4-44.3)	260.0 (214.7-312.5)	11.2(9.2-13.4)
Afar	2658.2 (2468.7-2880.1)	7861.1 (3775.3-12887.2)	94.3 (61.0-130.8)	7955.4 (3888.512967.4)	224.8 (91.5-368.0)	2176.3 (2034.9-2323.0)	923.3 (690.6-1193.6(	74.6 (48.1-106.2)	998.0 (759.6-1281.0)	35.6(27.5-45.5)
Amhara	2115.9 (1943.8-2299.8)	2871.9 (1945.0-4014.1)	63.0 (40.9-89.1)	2934.9 (2007.7-4085.8)	49.7 (37.9-63.6)	1688.1 (1563.4-1824.9)	233.5 (94.7-473.9)	47.7 (31.1-67.4)	281.1 (142.6-518.6)	5.9(2.5-11.1)
Benishangul-Gumuz	1935.6 (1758.7-2121.7)	7033.1 (4332.8-10951.4)	63.9 (41.2-90.2)	7097.0 (4400.611025.0)	170.5 (86.9-266.3)	1448.7 (1332.0-1574.3)	1044.3 (736.2-1426.4)	44.2 (27.8-62.3)	1088.5 (771.0-1474.7)	27.5(21.1-34.2)
Dire Dawa	1976.5 (1807.7-2167.2)	3540.5 (2305.2-5731.0)	52.7 (34.1-73.2)	3593.2 (2347.9-5791.1)	80.7 (55.8-116.0)	1527.9 (1409.9-1672.4)	339.4 (211.7-544.9)	37.1 (23.7-53.4)	376.5 (247.1-588.1)	12.6(8.9-18.6)
Gambella	2274.7 (2111.4-2450.0)	3578.9 (2451.3-5031.6)	70.2 (45.4-98.7)	3649.1 (2523.1-5119.7)	80.7 (59.2-109.9)	1877.6 (1747.0-2020.4)	289.9 (194.2-416.2)	53.5 (34.2-76.7)	343.5 (248.4-468.9)	12.9(8.8-17.0)
Harari	1626.1 (1482.9-1782.7)	3151.9 (2206.4-4440.8)	41.3 (26.3-58.5)	3193.2 (2242.8-4492.9)	72.4 (50.0-98.8)	1319.3 (1203.9-1436.3)	323.3 (201.5-527.1)	32.1 (20.6-44.7)	355.4 (233.4-560.0)	12.2(8.5-18.1)
Oromia	1896.9 (1746.1-2075.2)	4814.8 (2940.7-7663.1)	52.8 (34.4-74.0)	4867.6 (2989.1-7703.8)	94.8 (59.7-143.6)	1536.4 (1413.7-1671.0)	477.7 (335.8-649.8)	40.7 (25.9-57.5)	518.4 (377.0-688.3)	14.2(10.7-17.9)
Somali	2927.2 (2747.2-3119.9)	4179.2 (2228.6-6911.5)	93.7 (61.0-132.1)	4272.8 (2318.9-7022.3)	131.5 (64.1-218.8)	2649.3 (2490.7-2827.0)	1133.4 (724.2-1669.5)	80.7 (53.0-113.6)	1214.1 (804.6-1747.3)	33.3(23.1-46.0)
SNNP	1916.6 (1776.1-2085.0)	4029.8 (2623.6-5638.1)	54.9 (35.6-76.8)	4084.7 (2682.1-5711.9)	100.3 (55.2-143.0)	1626.1 (1506.0-1763.6)	436.1 (304.5-641.8)	44.6 (28.6-62.9)	480.7 (344.6-680.9)	13.9(10.2-18.6)
Tigray	1974.9 (1816.2-2145.7)	4367.6 (2479.1-6616.4)	47.0 (30.4-66.7)	4414.6 (2530.0-6671.1)	100.4 (57.4-141.1)	1592.2 (1463.3-1730.2)	258.1 (182.3-359.4)	35.3 (22.9-49.1)	293.4 (215.9-396.7)	11.1(8.2-14.9)
Ethiopia	2025.1 (1883.7-2183.6)	3944.3 (2737.1-5634.0)	58.7 (38.2-82.1)	4003.0 (2783.5-5698.5)	83.0 (55.8-117.6)	1671.1 (1564.7-1797.1)	446.0 (336.3-605.0)	46.1 (29.8-64.0)	492.1 (381.4-654.7)	12.9(9.8-16.7)

Burden and Trend of Micronutrient Deficiency

In 2019, the prevalence of dietary iron deficiency per 100, 000 populations was 14,575 [95%UI: 13506-15653] among all age groups, 38,526 [95%UI:35,708-41,207] among under-five children, and 4,324 [95%UI: 3794-4880], among reproductive age women, The prevalence of vitamin A deficiency per 100, 000 populations among all ages, children under the age of five years, and reproductive age women was 21,019 [95%UI: 17556-24,716], 33,151 [95%UI: 22,093-46597] and 18,869 [95%UI: 14986-23500], respectively. The prevalence of Iodine deficiency per 100, 000 populations was 9,671 [95%UI: 7,799-12,099], 221 [95%UI:132-338], and 15451 [95%UI: 12,272-19,615] among all age groups, children under five years of age and reproductive age women, respectively. From 1990 to 2019, the prevalence rate of dietary Iron, vitamin A, and Iodine deficiencies decreased by an average annual rate of 16%, 56%, and 35%, respectively.

Nationally, age standardized YLDs due to dietary iron, vitamin A and iodine deficiency was 396.0 [95%UI: 261.8-579.2], 127.0 [95%UI: 66.5-236.4] and 39.8 [95%UI: 26.3-58.0] per 100,000 populations respectively. Higher YLDs due to dietary Iron 880.5 [95%UI: 584.8-1267.9], Iodine 150.4 [95%UI: 77.7-279.3] and Vitamin A 71.9[95%UI: 45.9-109.2] deficiency was observed in Somali region. Nationally, the age-standardized YLDs due to dietary iron, vitamin A, and iodine deficiencies decreased by an annual rate of 24%, 41%, and 51%, respectively **[Table2].**

Table 2: **The national and sub-national age-standardized YLDs rates per 100,000 population due to dietary iron, iodine and vitamin A deficiencies from 1990-2019.**

Location	Dietary Iron 1990	Dietary Iron 2019	Rate of Change 1990-2019	Iodine 1990	Iodine 2019	Rate of Change 1990-2019	Vitamin A 1990	Vitamin A 2019	Rate of change 1990-2019
Addis Ababa	417.7 (274.6-611.4)	270.8 (170.9-410.0)	-0.35 [-0.46-(-0.22)]	49.8(26.6-88.7)	46.7(23.9-85.8)	-0.06 [-0.21-0.05]	29.7(19.1-43.3)	8.7(5.5-13.0)	-0.71 [-0.78-(-0.61)]
Afar	732.2 (472.7-1069.8)	677.3 (445.8-1002.2)	-0.07 [-0.21-0.09]	238.2 (129.2-417.4)	134.7 (68.7-250.2)	-0.43 [-0.50-(-0.38)]	102.9(68.8-148.0)	59.1(36.7-93.0)	-0.43 [-0.59-(-0.21)]
Amhara	417.3 (264.7-613.8)	279.3 (178.4-425.2)	-0.33 [-0.46-(-0.19)]	224.9 (125.9-399.7)	130.0 (66.7-240.2)	-0.42 [-0.49-(-0.37)]	75.2(49.6-108.8)	32.6(20.5-49.8)	-0.57 [-0.68-(-0.42)]
Benishangul Gumuz	445.7 (282.5-647.8)	295.4 (188.7-443.8)	-0.34 [-0.48-(-0.14)]	230.1 (126.6-406.5)	136.2 (69.6-253.4)	-0.41 [-0.48-(-0.35)]	75.5(50.6-110.1)	33.6(21.2-51.8)	-0.55 [-0.67-(-0.37)]
Diredawa	805.4 (532.2-1151.4)	655.8 (428.2-947.9)	-0.19 [-0.32-9-0.03)]	75.5 (42.2-129.7)	60.9 (32.4-112.8)	-0.19 [-0.32-(-0.09)]	62.6(41.5-92.1)	23.1(14.6-34.1)	-0.63 [-0.73-(-0.51)]
Gambella	542.4 (340.3-786.0)	385.0 (238.0-575.8)	-0.29 [-0.48-(-0.09)]	178.9 (99.4-315.1)	107.2 (55.0-196.4)	-0.40 [-0.47-(-0.34)]	75.0(48.4-107.5)	26.5(16.7-40.4)	-0.65 [-0.74-(-0.51)]
Harari	644.2 (422.4-936.0)	498.5 (309.9-740.6)	-0.23 [-0.38-(-0.03)]	86.3 (47.8-149.0)	63.1 (32.6-118.0)	-0.27 [-0.38-(-0.18)]	62.5(40.9-93.0)	25.8(16.2-38.9)	-0.59 [-0.69-(-0.44)]
Oromia	591.4 (385.7-855.2)	420.0 (271.4-623.8)	-0.29 [-0.40-(-0.15]	219.2 (120.4-389.9)	127.1 (65.7-235.0)	-0.42 [-0.48-9-0.37)]	84.3(56.1-122.5)	38.6(24.2-58.0)	-0.54 [-0.65-(-0.41)]
Somali	919.9 (618.1-1298.7)	880.5 (584.8-1267.9)	-0.04 [-0.17-0.10]	246.8 (136.2-438.1)	150.4 (77.7-279.3)	-0.39 [-0.46-(-0.34)]	120.0(83.0-168.0)	71.9(45.9-109.2)	-0.40 [-0.56-(-0.19)]
SNNP	425.1 (284.0-616.1)	317.8 (203.9-467.9)	-0.25 [-0.39-(-0.09)]	233.9 (127.6-415.1)	141.8 (73.2-265.0)	-0.39 [-0.46-(-0.34)]	79.8(52.9-114.0)	42.3(27.7-62.5)	-0.47 [-0.58-(-0.32)]
Tigray	466.6 (302.4-683.2)	363.8 (229.3-542.9)	-0.22 [-0.36-(-0.06)]	188.3 (103.8-333.5)	112.6 (58.5-213.8)	-0.40 [-0.47-(-0.35)]	77.1(51.0-112.5)	29.8(18.1-46.0)	-0.61 [-0.73-(-0.48)]
Ethiopia	518.3 (339.0-747.6)	396.0 (261.8-579.2)	-0.24 [-0.31-(-0.16)]	214.9 (119.2-381.0)	127.0 (66.5-236.4)	-0.41 [-0.47-(-0.37)]	81.3(55.6-114.7)	39.8(26.3-58.0)	-0.51 [-0.61-(-0.40)]

Sex-Specific Patterns of PEM and MNDs

In 2019, the prevalence and DALYs rates of PEM were substantially higher in females 1647.1[95% UI: 1508.5-1793.4] per 100,000 population than in males 1580.4[95% UI: 1458.2-1716.7] per 100,000 population. Overall, the burden of MNDs is substantially higher among females than males at a national and regional level. In 2019, the age-standardized YLDs rate due to dietary iron deficiency among females and males was 422.7 per 100,000 [95%UI: 282.1–611.0] and 370.5[244.0-548.6] at national level (**Table 3**). Similarly, the age standardized YLDs rate of Iodine was substantially higher among females 139.9 per 100,000 population [95% UI: 71.6-263.4] than males 114.1[95% UI: 59.8-209.5] at national level and had a similar trend in regions [**Table 4**]. Age-standardized YLDs rate of Vitamin A deficiency among females was slightly lower 37.9 per 100,000 population [95% UI: 24.7-56.1] than males 41.7[95% UI: 25.8-63.0] at national level The differences in age standardized YLD rate between male and female was observed at all subnational levels in Ethiopia (**Table 5**).

Table 3: **Age standardized YLD, prevalence and incidence rate per 100,1000 populations of dietary iron in male and female in 2019, Ethiopia**

Location	Dietary Iron			
	Age standardized YLDs rate		Age Standardized Prevalence rate	
	Male	Female	Male	Female
Addis Ababa	184.6[113.7-280.5]	350.9[215.0-535.7]	8450.8[7143.8-9952.5]	12097.6[10627.7-13664.1]
Afar	651.9[415.7-993.0]	715.3[470.5-1066.8]	23423.6[21073.8-25997.7]	21514.4[19290.7-23687.2]
Amhara	275.5[171.3-429.9]	282.5[178.9-424.9]	13086.8[11088.8-15050.2]	10267.8[8926.8-11683.8]
Benishangul-Gumuz	271.1[164.3-412.2]	324.1[205.8-490.3]	13481.2[11367.3-15536.7]	11148.9[9328.9-13005.0]
Dire Dawa	635.6[412.5-925.1]	678.4[429.3-995.2]	20698.0[18338.0-23097.9]	19425.0[17257.5-21654.0]
Gambella	352.5[206.6-549.4]	412.1[248.0-621.7]	14512.0[11841.9-16930.4]	14477.2[11505.9-16707.9]
Harari	513.3[325.4-768.7]	480.7[298.5-717.7]	18963.0[16466.5-21328.5]	15575.0[13257.1-17934.3]
Oromia	418.2[261.3-627.5]	422.9[273.6-627.0]	17007.6[14849.7-19011.2]	14095.1[12496.5-15937.8]
Somali	651.1[410.7-982.3]	1168.8[790.8-1671.8]	22176.1[19814.9-24616.9]	27071.5[24845.2-29174.8]
SNNP	269.6[166.5-414.5]	368.0[236.3-554.7]	12871.9[11075.7-14883.1]	12336.6[10758.7-13924.4]
Tigray	384.2[233.2-584.2]	342.3[210.9-515.6]	16216.1[13983.2-18586.3]	12045.3[10323.6-13819.9]
Ethiopia	370.5[244.0-548.6]	422.7[281.0-611.0]	15483.4[14369.7-16592.9]	13563.5[12690.7-14412.5]

Table 4: **Age standardized YLD, prevalence and incidence rate per 100,1000 populations of Iodine in male and female in 2019, Ethiopia**

Location	Iodine					
	Age Standardized YLDs rate		Age Standardized Prevalence rate		Age Standardized Incidence.	
	Male	Female	Male	Female	Male	Female
Addis Ababa	41.3[21.6-75.8]	51.4[25.6-95.7]	3294.1[2626.4-4152.7]	4266.4[3328.7-5447.5]	142.8[109.8-181.3]	181.4[138.9-234.6]
Afar	121.8[63.4-227.7]	150.3[77.3-285.1]	9945.7[7941.2-12433.4]	12805.0[10130.1-16063.1]	376.0[292.7-473.0]	477.5[372.1-607.8]
Amhara	116.2[61.3-216.6]	143.5[72.8-266.7]	9486.1[7565.0-11916.2]	12214.4[9710.5-15355.8]	360.2[280.1-462.4]	457.5[356.7-582.8]
Benishangul-Gumuz	122.2[61.7-229.1]	151.3[76.9-280.8]	9970.6[7936.5-12703.7]	12868.9[10251.5-16198.0]	376.3[292.2-482.5]	480.2[375.1-611.0]
Dire Dawa	54.4[28.9-98.8]	67.2[34.7-127.2]	4317.5[3337.0-5486.0]	5581.9[4428.3-7019.8]	179.7[136.5-233.6]	228.8[176.6-291.9]
Gambella	95.2[49.6-174.4]	118.0[58.9-215.9]]	7706.8[6098.4-9685.7]	9975.0[7957.2-12372.1]	298.8[231.1-381.7]	381.5[295.4-493.3]
Harari	56.3[28.8-103.0]	70.1[36.6-132.1]	4462.1[3531.5-5608.8]	5816.7[4555.4-7353.5]	184.5[141.3-234.9]	237.3[182.4-301.9]
Oromia	114.2[58.7-209.2]	140.3[70.4-262.6]	9289.9[7429.1-11718.2]	11908.0[9449.7-14949.3]	353.3[270.2-452.3]	447.0[349.4-583.5]
Somali	136.7[70.8-252.8]	167.0[85.6-315.3]	11175.1[8971.0-14092.0]	14321.4[11225.5-18031.4]	418.4[324.7-527.9]	529.2[412.1-668.1]
SNNP	126.6[66.8-229.1]	156.7[79.6-292.1]	10354.5[8248.5-13303.4]	13382.4[10638.2-16698.2]	389.5[304.4-504.3]	497.6[384.7-634.8]
Tigray	100.4[51.7-186.9]	124.263.3-233.1]	8115.5[6415.1-10135.7]	10496.4[8382.7-13086.5]	313.1[242.2-393.1]	399.7[310.6-506.6]
Ethiopia	114.1[59.8-209.5]	139.9[71.6-263.4]	9292.2[7490.0-11581.6]	11891.2[9551.2-14769.8]	357.8[278.6-453.0]	451.6[354.2-572.8]

Table 5: **Age standardized YLD, prevalence and incidence rate per 100,1000 populations of Vitamin A deficiency in male and female in 2019, Ethiopia**

Location	Vitamin A					
	Age Standardized YLDs rate		Age Standardized Prevalence rate		Age Standardized Incidence.	
	Male	Female	Male	Female	Male	Female
Addis Ababa	7.9[4.7-12.4]	9.5[5.9-14.5]	4062.0[2541.2-6387.7]	3647.0[2600.4-4891.3]	4062.0[2541.2-6387.7]	3647.0[2600.4-4891.3]
Afar	61.9[35.0-106.2]	56.0[32.8-92.2]	35620.8[25425.3-46145.9]	27800.6[21175.2-35731.5]	35620.8[25425.3-46145.9]	27800.6[21175.2-35731.5]
Amhara	35.2[20.1-57.6]	30.0[17.9-46.4]	29479.7[22335.6-38176.2]	21703.9[16801.9-27033.1]	29479.7[22335.6-38176.2]	21703.9[16801.9-27033.1]
Benishangul-Gumuz	33.8[18.6-57.0]	33.5[20.5-51.4]	28385.1[19722.0-38078.7]	21889.0[16084.7-29000.4]	28385.1[19722.0-38078.7]	21889.0[16084.7-29000.4]
Dire Dawa	21.5[12.3-34.0]	24.8[15.2-37.6]	9886.8[6419.8-14351.1]	8233.5[6019.9-11332.6]	9886.8[6419.8-14351.1]	8233.5[6019.9-11332.6]
Gambella	25.7[13.9-42.6]	27.5[17.0-42.6]	16686.7[11038.0-23816.2]	12813.7[9448.0-17207.0]	16686.7[11038.0-23816.2]	12813.7[9448.0-17207.0]
Harari	23.9[13.8-38.2]	27.8[17.1-42.1]	10132.6[6572.7-15251.0]	8225.0[5989.9-11230.3]	10132.6[6572.7-15251.0]	8225.0[5989.9-11230.3]
Oromia	41.7[24.2-65.8]	35.4[21.8-54.5]	27186.3[20172.4-35357.7]	20443.0[15749.7-25564.0]	27186.3[20172.4-35357.7]	20443.0[15749.7-25564.0]
Somali	76.5[43.3-125.1]	66.8[39.6-104.9]	44149.8[34029.1-55418.7]	33727.6[26388.4-41958.5]	44149.8[34029.1-55418.7]	33727.6[26388.4-41958.5]
SNNP	40.0[23.7-61.7]	44.8[28.6-67.1]	26745.4[19464.0-34519.4]	20542.7[15616.4-25940.2]	26745.4[19464.0-34519.4]	20542.7[15616.4-25940.2]
Tigray	32.5[17.5-54.6]	27.1[16.2-44.3]	22544.7[15665.7-30726.1]	16961.5[12739.3-22340.6]	22544.7[15665.7-30726.1]	16961.5[12739.3-22340.6]
Ethiopia	41.7[25.8-63.0]	37.9[24.7-56.1]	27823.1[22280.8-34568.7]	20767.1[17008.0-24915.3]	27823.1[22280.8-34568.7]	20767.1[17008.0-24915.3]

Age-specific patterns of PEM and MNDs
Overall, the burden of PEM and MND were higher among children under one year compared to other age groups. In 2019, the DALYs rate of PEM was substantially higher 6369.9 per 100,000 populations [95% UI: 4233.1-9506.9] among Early-neonatal children than other age groups 13236.6 per 100,000 populations [95% UI: 6464.3-230443.3] at national level.

In 2019, the highest prevalence (2321.6 per 100,000 [95% UI: 1496.5-3409.9]) of dietary iron deficiency was observed among neonates at national and regional level. Under five children were highly affected by VAD. The highest (36041.1 [95%UI: 23677.0-50883.2]) per 100,000 incidence rate of VAD was reported among under five children at national level. Among regions, Afar region stands first with 48231.6 [26615-67523.1] and the lowest incidence rate was observed in Diredawa with 12638.4[4902-26739.1]. The prevalence rate of iodine deficiency increased with age. It is more prevalent among 35-39 years old adults at national level.

PEM and MNDs Burden Comparison with the Eastern sub-Saharan Africa and Global Estimate
The prevalence of PEM in Ethiopia was persistently higher than in Eastern sub-Saharan Africa (ESSA) and the global prevalence from 1990 to 2005, but it became lower after 2005 **(Figure1)**. **Figure 3** shows a continuous decreasing trend of prevalence of dietary Iron deficiency globally, in Ethiopia and most regions. In ESSA and some regions like Addis Ababa and Afar, the dietary Iron deficiency trend declined from 1990 to 2010, but rise between 2010 and 2015. In 2019, age-standardized prevalence rate in Ethiopia was lower than the ESSA and the regions such as Afar, Dire Dawa, Harari, and Somali. **Figure 4** shows a steady declining trend of Iodine deficiency prevalence globally and an alternative upward and downward trend in the regions of Ethiopia and ESSA. In 2019, Ethiopia had the lowest prevalence rate estimate than Global, ESSA, and the regions. Lastly, **Figure 5** shows the decrease in the prevalence of VAD globally, in ESSA, Ethiopia, and subnational regional states. The prevalence of VAD in Ethiopia is consistently higher than the estimates from the ESSA and the globe.

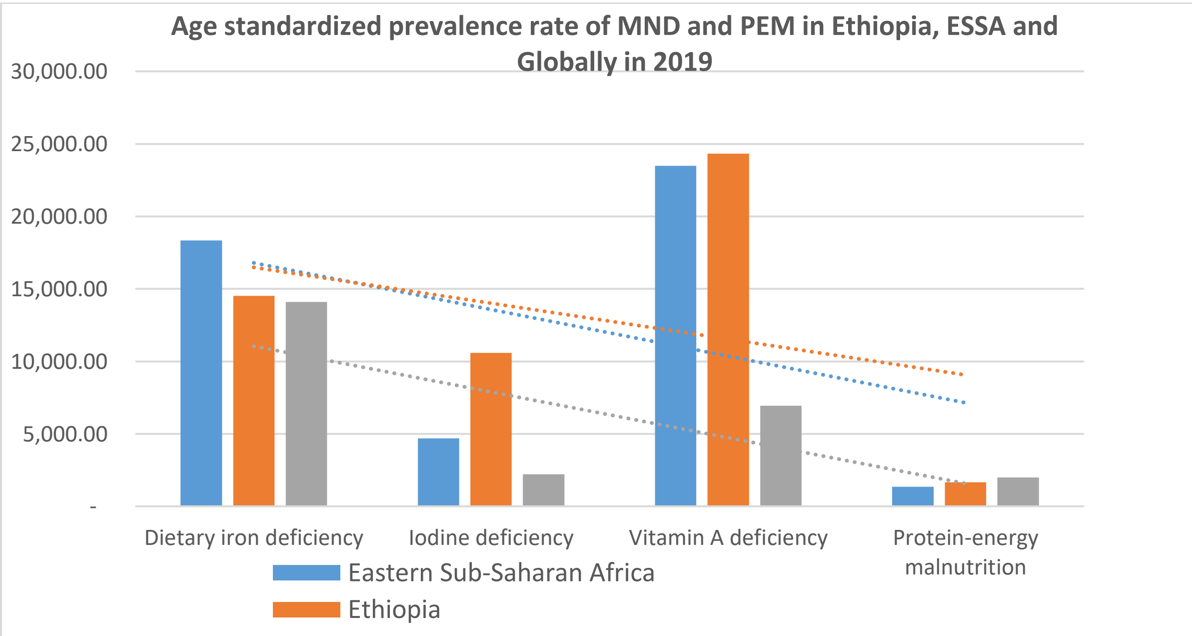

Figure 1: **Age standardized prevalence rate of MND and PEM in Ethiopia, ESSA and Global in 2019**

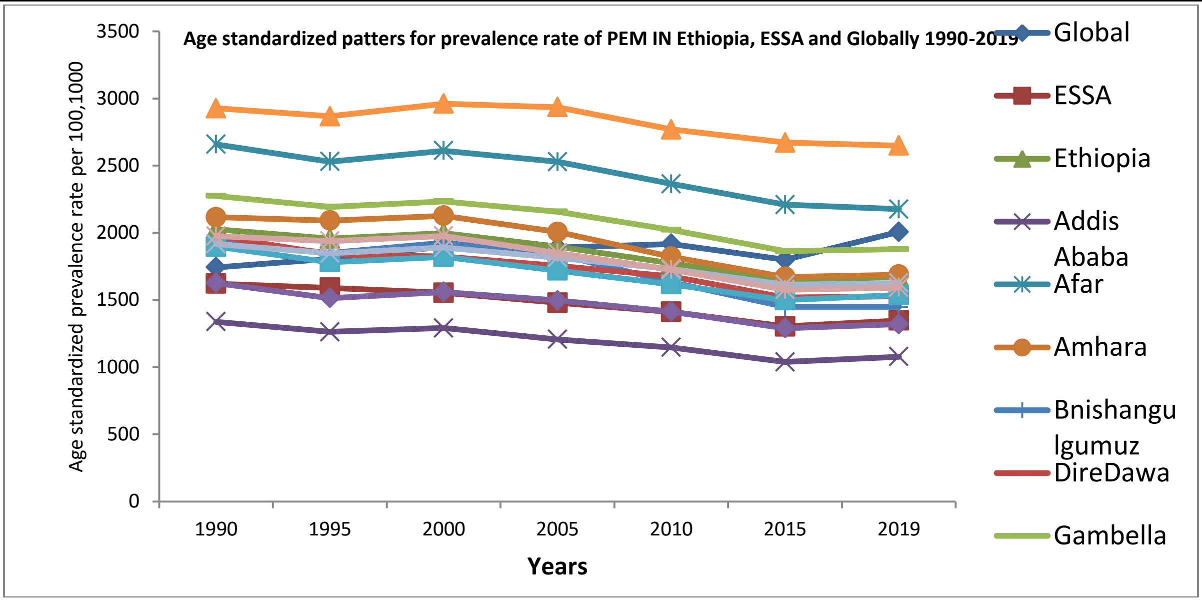

Figure 2: **Trend of Age-standardized PEM prevalence in subnational regional states, Ethiopia, ESSA, and Globally from 1990-2019**

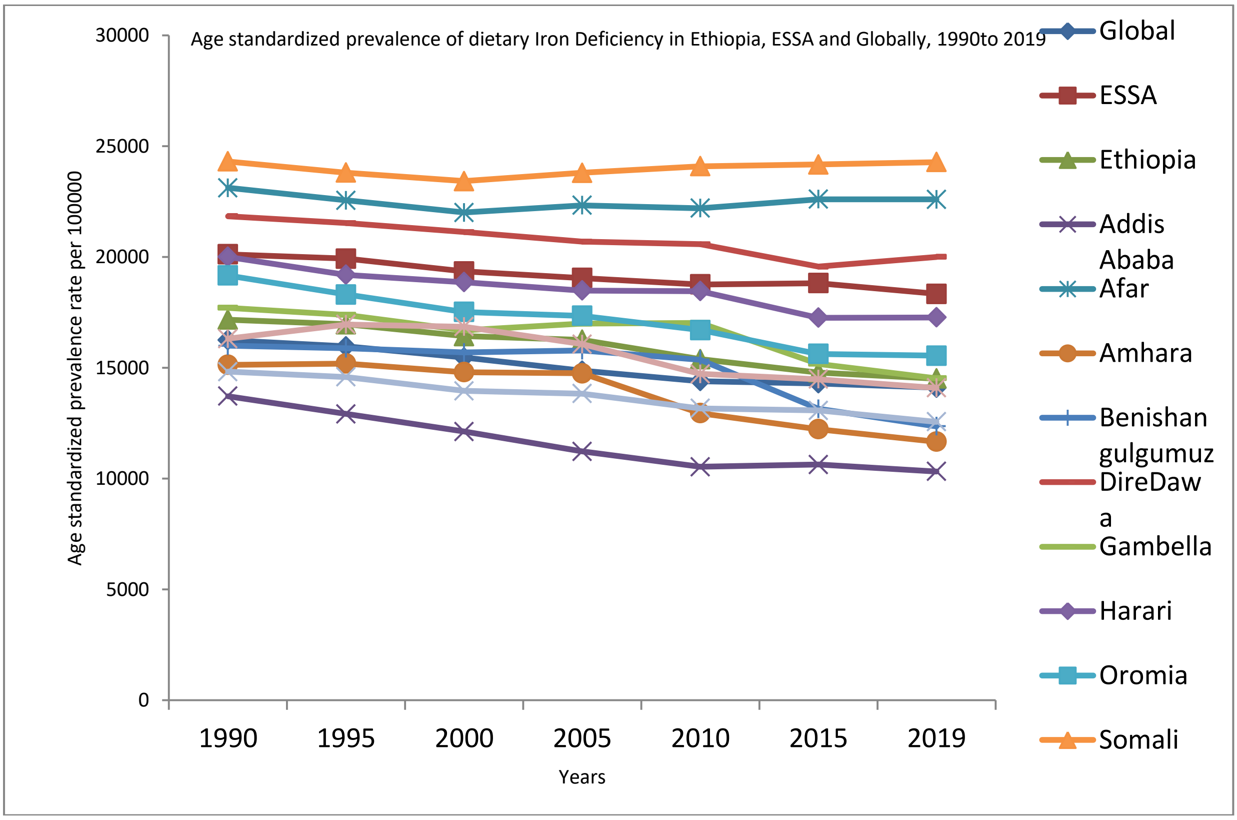

Figure 3: Trend of Age-standardized dietary Iron deficiency prevalence in subnational regional states, Ethiopia, ESSA and Globally from 1990-2019

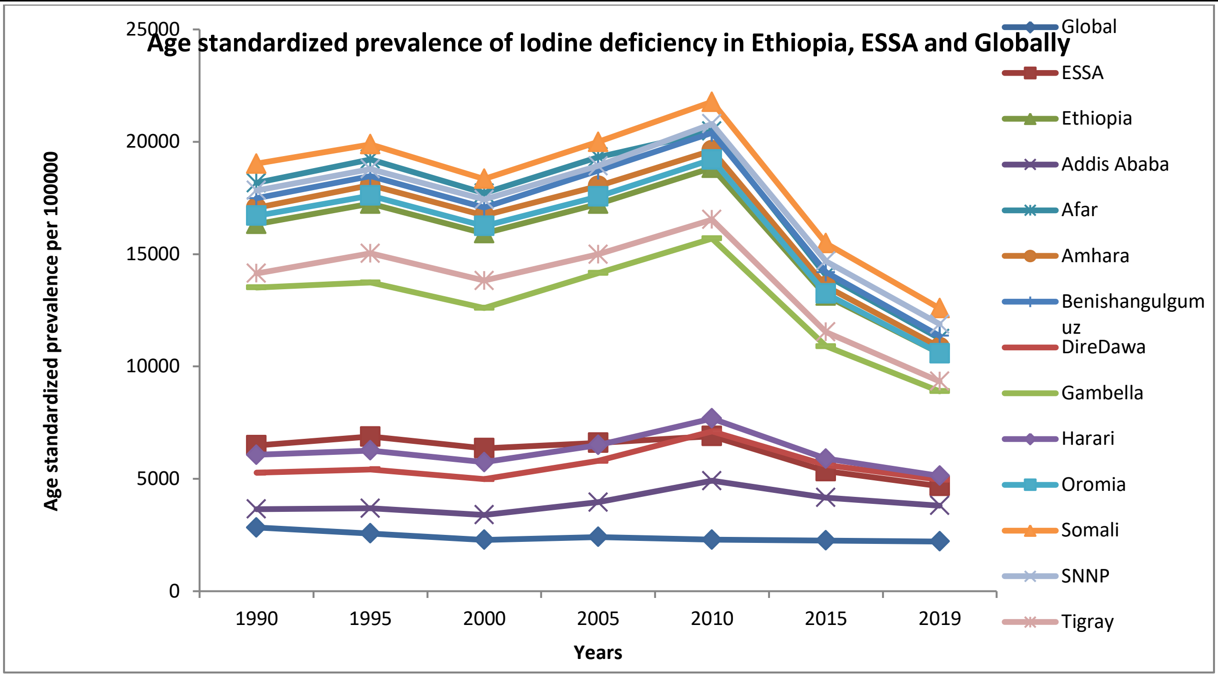

Figure 4: **Trend of Age-standardized Iodine deficiency prevalence in subnational regional states, Ethiopia, ESSA and Globally from 1990-2019**

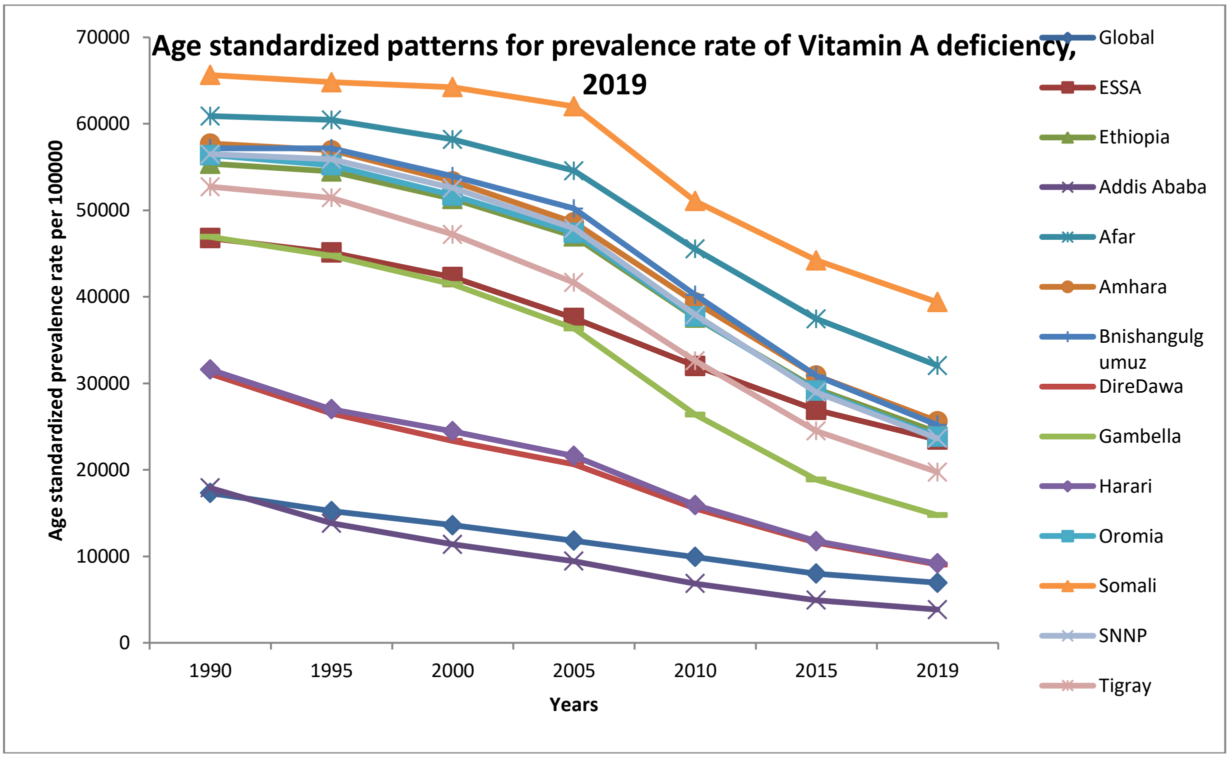

Figure 5: **Trend of Age standardized Vitamin A deficiency prevalence in subnational regional states, Ethiopia, ESSA and Globally from 1990-2019**

Discussion

This study comprehensively describes the burden of nutritional deficiency, both protein-energy malnutrition (PEM) and common micronutrient deficiencies (MND) in Ethiopia. The prevalence and DALYs rate of PEM in Ethiopia has shown a significant decline between 1990 and 2019, but conflicts and the COVID-19 pandemic for the last three years could negatively affect the progress. The PEM is highly prevalent and a leading nutritional deficiency cause of death and premature mortality in Ethiopia and across the regions.

The PEM prevalence rate declined among under five-year-old children from 1990 to 2019. This finding is similar to stunting and wasting data of the 2000 to 2016 EDHS and 2019 Mini Ethiopian Demography and Health Survey (EDHS) (14, 15, 16, 17). The decrement in the burden of PEM may be attributed to the implementations of declarations, programs, strategies, and frameworks for action and inter-sectoral collaborative actions taken by the country to reduce malnutrition. Contrarily, a meta-analysis of 18 observational studies conducted in 2017 in Ethiopia revealed that the trend of under-nutrition was increasing in recent years, and the prevalence rate of under-nutrition remained extremely high (18). The difference could be because of methodology and data source differences.

In 2019, this study showed that Ethiopia had the lowest prevalence of Iodine deficiency than the Global or Eastern sub-Saharan Africa (ESSA) estimates. A decline in the age-standardized incidence and prevalence of iodine deficiency was observed from 1990 to 2019 in general and from 2010 to 2019 in particular at the national and regional level. This could be due to the salt iodization program, which was started before 1990 (35). Iodization of salt started in 1988 in Ethiopia, and the production and sale of non-iodized salt was banned in 1996. In between, there was an alarming increase between 2000 and 2010, possibly due to the interruption of salt iodization in 2000 due to the Ethio-Eritrea war (19, 20). The universal salt iodization (USI) program resumed again in 2011 (21). A survey, conducted in 2015, showed that 84.6% of salts in the country contain Iodine (22). However, the coverage of iodized salt at the household level in most rural parts of the country is still very low. This means only 26% of the households were getting the required amount (more than 15 ppm) of Iodine in the salt (23, 24).

This study has also shown that females were disproportionately affected by a higher prevalence of iodine deficiency. Several studies in many parts of the country also found such sex variation (25, 26, 27, 28, 29). The difference could be due to the stimulatory effect of androgen hormone in males and the inhibitory effect of estrogen hormone in females on thyroid growth (30, 31). The reproductive age group observed the highest number of iodine deficiency cases. This could be due to the Iodine status difference in men and women (32), and the significantly increased requirement of Iodine during pregnancy. Further, the high prevalence in females has a devastating effect on maternity and can lead to abortion, stillbirth, congenital anomalies, neurological cretinism, and increased perinatal and infant mortality.

For dietary iron deficiency, there was a continuous declining prevalence trend globally, in Ethiopia and most of its subnational regional states. The age-standardized national prevalence of dietary iron deficiency declined from 1990 to 2015 rose from 2015 to 2017, and then declined to 2019 in national and subnational regional states except in Diredawa, Harari, and Somali, where it continued rising between 2015 and 2019. The decline between 1990 and 2015 was (-10.4) whereas the change rate between 2015 and 2019 was -5.7 at the national level.

The public health impact of iron deficiency is more pronounced in females as it results in an intergenerational deficiency in the future offspring unless timely measures are taken (33, 34, 35, 36). Concerning age-specific patterns, the prevalence of dietary iron deficiency is higher among late neonates and reproductive-age women at the national and regional levels. This could be because lower coverage of optimal dose of iron supplementation in the country. This finding supports the 2019 Mini EDHS study that only 10% of pregnant women took Iron and folic acid tablets for 90+ days during pregnancy of last birth (37).

There was a decrease in the prevalence of Vitamin A deficiency (VAD) in the regional states, national, ESSA, and globally. National prevalence rate has shown a 56% decline between 1990 and 2019, however, the prevalence is higher than the estimates from the ESSA and the globe. In 2019, Ethiopia held the 5th position in VAD from Eastern Sub-Saharan African countries. This finding is supported by national surveys of VAD conducted in 2005 (38) and in 2015 (10) that reported high prevalence of 37.7% and 13.9% , respectively. In Ethiopia, only 45% of children ages 6-59 months received vitamin A supplements in 2016 (17). The prevalence of VAD is higher among males than females, and there are large variations across age groups, in which children of 1 to 4years of age are the most affected group. In general, higher prevalence is observed in children, increasing susceptibility to infection, leading to increased morbidity and premature death rates.

The results of this study were affected by the overall limitation of GBD study, and the study borrows strength from geographic locations and time of the analysis. Limitations specific to the findings in this study include relatively scarce data availability on protein energy malnutrition and, micronutrient deficiency, and low birth weight in Ethiopia. We used periods to present the rate of change in trends for malnutrition indicators because they are easy to understand. This paper mainly focused on undernutrition in Ethiopia, and the burden of overnutrition was not included in this paper. There are indications of the rising double burden of malnutrition especially in children and women and we recommend researchers explore the over nutrition problem in Ethiopia.

Conclusion
Micronutrient deficiency and PEM were high in Ethiopia in all age groups. Reproductive-age women, children under the age of five, and the elderly were highly affected by the burden of dietary iron, and Iodine deficiency that needs targeted intervention. There were regional disparities in the burden of both PEM and micronutrients deficiency. So, government programs, National Nutrition Program (NNP II), the Food and Nutrition Policy (FNP), the Seqota Declaration, and other initiatives should be strengthened to address the burden of PEM and micronutrient deficiency challenges. There should be close follow up on the implementation of such programs and strategies and strong collaborations between health, agriculture, education and other sectors in implementing the programs.

Ethical Approval and consent to participate
Not Applicable

Availability of data and materials
The data sets generated during and or analyzed for the study are available in the IHME data repository and can be accessed directly from http://ghdx.647healthdata.org/gbd-results-tool

Conflict of interest: The authors declare that they have no conflict of interest.

Acknowledgements: The authors thank the National Data Management and Analytics Center for Health under Ethiopian Public Health Institute, the Institute for Health Metrics and Evaluation at University of Washington and GBD Collaborators Network of Experts for the collaborative initiative.

Funding
EPHI and IHME collaborative GBD 2019 Bill and Melinda Gates Foundation funds national and subnational burden of disease study. The funder of this study had no role in study design, data collection, data analysis, data interpretation, or the writing of the report.

Contributions of Authors : WT and MA have conceptualized and drafted the manuscript, YA, AA, TMB, ST, MD, AW, AW, MN and AM have reviewed the manuscript critically for important intellectual content and approved the final manuscript.

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