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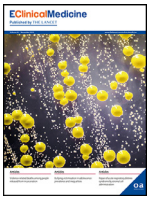

Research paper

Prevalence and changes of anemia among young children and women in 47 low- and middle-income countries, 2000-2018

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ABSTRACT

Background: Anemia remains a major public health issue, particularly for children and women in low- and middle-income countries (LMICs). However, the current prevalence and recent changes of anemia among young children and women of reproductive age, particularly for pregnant women in different trimesters are unclear. We examined the current prevalence of anemia among children aged less than 5 years by age (6-35 months vs. 36-59 months) and women of reproductive age by pregnant status (pregnant vs. non-pregnant) and trimesters (the third vs. the second vs. the first trimester) between 2010 and 2018 and further examined changes in the prevalence from 2000-2009 to 2010-2018.

Methods: Data were from the cross-sectional Demographic and Health Surveys performed between 2000 and 2018. A total of 47 countries were included to examine the current prevalence of anemia (weighted prevalence and 95% confidence interval [CI]) among young children aged less than 5 years (N = 459,785) and 46 countries among women of reproductive age (N = 1,079,805) between 2010 and 2018. To examine changes in the prevalence of anemia, a total of 29 countries with at least two Demographic and Health Surveys performed between 2000 and 2009 (children: N = 130,772; women: N = 371,845) and 2010-2018 (children: N = 386,202; women: N = 928,889) were included. Modified Poisson regression analyses with robust error variance were used to examine changes in anemia between 2000-2009 and 2010-2018 in participants by child age (6-5 months vs. 36-59 months), women pregnant status (pregnant vs. non-pregnant), trimesters (the second or third trimester vs. the first trimester) with the adjustment for potential covariates.

Findings: In 47 LMICs for children aged less than 5 years between 2010 and 2018, the total prevalence of anemia was 56.5% (95% CI 56.2, 56.8). Younger children aged 6-35 months were more likely to have anemia than older children aged 36-59 months (adjusted odds ratio [OR] 1.38, 95% CI 1.36-1.39, $P < 0.001$). In 46 LMICs for women of reproductive age, the total prevalence was 40.4% (95% CI 40.1, 40.7). Pregnant women were more likely to have anemia than non-pregnant women (adjusted OR 1.14, 1.12-1.16, $P < 0.001$). Moreover, pregnant women in the third trimester (adjusted OR 1.55, 1.48-1.62, $P < 0.001$) and the second trimester (adjusted OR 1.51, 1.45-1.58, $P < 0.001$) were more likely to have anemia than those in the first trimester. Among 29 included countries, although there was a decreasing change (absolute change, relative change, and average annual rate of reduction) in young children and women between 2000-2009 and 2010-2018 in a majority of countries, the current prevalence of anemia remained at a high level.

Interpretation: The prevalence of anemia among children aged less than 5 years and women of reproductive age was still high in LMICs, particularly for younger children and pregnant women. The relative change among women of reproductive age was far away from the WHO goal of reduction of anemia by 50% by 2025 (i.e., prevalence reduction to about 15.2% by 2025 from 30.3% at 2012 baseline). Continued and effective efforts, particularly for high-risk populations, are needed to improve the general health of the population.

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Research in context

Evidence before this study

Several previous publications have examined the prevalence of anemia among non-pregnant women and children less than 5 years in low- and middle-income countries (LMICs). However, most studies were based on old data before 2011 or did not focus on specific populations, like pregnant women in different trimesters and infants and toddlers within the period from conception to 2 years of life.

Added value of this study

We examined the recent prevalence of anemia during 2010-2018 and found that 56.5% of children aged less than 5 years and 40.4% of women of reproductive age had anemia in 47 LMICs. The anemia was more prevalent and severe among younger children aged 6–35 months and pregnant women (particularly for the second and third trimesters vs. the first trimester) in most LMICs compared with older children aged 36-59 months and non-pregnant women. The relative decrease among women was far from the WHO goal of reduction by 50% by 2025 (i.e., prevalence reduction to about 15.2% by 2025 from 30.3% at 2012 baseline).

Implications of all the available evidence

Although some achievements have been made, the current situation of anemia in both children and women of reproductive age remains poor, and that in women is far below the WHO target. Continued efforts, particularly targeting high-risk populations including younger children and pregnant women, are needed to improve the anemia status in LMICs.

1. Introduction

Anemia, defined as the reduction of hemoglobin, contributes substantially to the global burden of chronic diseases. The World Health Organization (WHO) estimated that anemia affected 42% of young children aged less than 5 years and 40% of women of reproductive age globally in 2016 [1]. In recent decades, anemia has been a leading cause of years lived with disability among children aged less than 5 years and women [2,3].

Young children and women of reproductive age are two critical populations vulnerable to anemia. As a major cause of maternal and child morbidity and mortality, [4] anemia can cause adverse pregnancy outcomes (e.g., prematurity and fetal death), [5] impaired neurological development, impaired cardiac function, and undergrowth [6,7]. The World Health Assembly has established a nutrition goal that anemia in women should reduce by 50% by 2025 (i.e., prevalence reduction to about 15.2% by 2025 from 30.3% at 2012 baseline) [8].

Although previous studies have assessed the prevalence of anemia in non-pregnant women and children aged less than 5 years in low- and middle-income countries (LMICs), [9,10] relatively old data were used or specific populations were not targeted, like infants and toddlers within the period from conception to 2 years of life and different trimesters of pregnant women. The first 2 years of life are critical periods for child development when nutrients are easily deficient [11] and demands for iron are higher in the later trimester than former trimester among pregnant women [12]. In addition, children and pregnant women are more infected by malaria particularly in the region of African, which might be the main cause of iron deficiency [13,14]. Therefore, regular surveillance of the global epidemic status of anemia among children in the early years and pregnant women is needed to inform the development of intervention strategies.

In this study, we evaluated the prevalence of anemia among children aged less than 5 years and women of reproductive age in 47 LMICs, stratified by child age, pregnancy status of women, and pregnant trimesters using data from the Demographic and Health Surveys during 2010 and 2018. We further examined changes in the prevalence from 2000-2009 to 2010-2018.

2. Methods

2.1. Study design and study population

Data were from the nationally representative and cross-sectional Demographic and Health Surveys, which were available at https://dhsprogram.com/. This study adheres to the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology. Oral informed consent was provided by all participants or their guardians. The non-identifiable data are publicly available and there is no need for the ethical committee of Shandong University to grant access for use of these data.

We assessed the prevalence of anemia in children aged 6 to 59 months and women of reproductive age in 47 LMICs with complete data (1 country in 2010, 6 in 2011, 4 in 2012, 6 in 2013, 6 in 2014, 7 in 2015, 8 in 2016, 5 in 2017, 4 in 2018, respectively). In addition, to determine changes in the prevalence of anemia, we included 29 of the 47 countries (for the beginning of survey years: 6 countries in 2000, 2 in 2001, 1 in 2002, 2 in 2003, 4 in 2004, 8 in 2005, 2 in 2006, 1 in 2007, 2 in 2008, and 1 in 2009, respectively) which had two Demographic and Health Surveys during 2000–2009 and 2010–2018.

2.2. Information on hemoglobin and definition of anemia

Hemoglobin was tested through finger prick or heel prick blood tests among participants using the HemoCue blood hemoglobin testing system. The detailed process has been shown on the website: https://dhsprogram.com/topics/Anemia.cfm. Anemia was defined as the concentration of blood hemoglobin less than 110 g/L for pregnant women and children, and less than 120 g/L for non-pregnant women according to recommendations from the WHO [15]. The severity of anemia was classified as mild (children aged 6-59 months: 100-109 g/L; non-pregnant women: 110-119 g/L; pregnant women: 100-109 g/L), moderate (children aged 6-59 months: 70-99 g/L; non-pregnant women: 80-109 g/L; pregnant women: 70-99 g/L), and severe (children aged 6-59 months: less than 70 g/L; non-pregnant women: less than 80 g/L; pregnant women: less than 70 g/L) status based on age-specific cut-offs according to recommendations from the WHO [15].

2.3. Statistical analysis

The global, WHO regional, and national prevalence with 95% confidence intervals (95% CI) of anemia during 2010 and 2018 among children aged 6 to 59 months and women of reproductive age were calculated by considering sampling weights, strata, and primary sampling units from the Demographic and Health Surveys, as well as the subgroup analyses stratified by child age and pregnant status of women. The weighted national prevalence was calculated according to original sampling weights for each country, and the weighted global and regional prevalence was calculated by the rescaled weights to reduce the influence of large samples in the Demographic and Health Surveys with the consideration of the arbitrary differences in sample sizes across surveys. Chi-square test was used to compare the prevalence between groups. P-value < 0.0011 and < 0.0017 based on Bonferroni-adjusted alpha value of 47 countries and 29

countries (calculation of changes in the prevalence of anemia) respectively with non-overlapped 95% CIs indicate significant difference [16,17]. A modified Poisson regression analysis with robust error variance that used new indicators for strata, cluster, and sampling weight and the equation of "average annual rate of reduction [AARR] =1-EXP(β)" derived by United Nations International Children's Emergency Fund [UNICEF] (available at: https://data.unicef.org/resources/technical-note-calculate-average-annual-rate-reduction-aarr-underweight-prevalence/) were applied to estimate changes in prevalence of anemia between 2000-2009 and 2010-2018 in participants by child age, women pregnant status, and trimesters with the adjustment for potential variables including age, sex, wealth index (i.e., an indicator related to the socioeconomic status such as availability of community-level services and household ownership of selected assets), gross domestic product per capita on purchasing power parity, residence, country, and survey time and to estimate the association between periods and anemia at a national level with the adjustment for age and survey time. SAS version 9.4 (SAS Institute Inc, Cary, North Carolina) was used for all data analyses.

2.4. Role of funding sources

The funder of the study had no role in study design, data collection, data analyses, data interpretation, or writing of the report. The corresponding author (BX) had full access to all of the data and the final responsibility to submit for publication.

3. Results

A total of 459,785 children aged 6 to 59 months and 1,079,805 women of reproductive age in the 47 countries were included in the analysis of prevalence during 2010–2018. 130,772 children aged 6 to 59 months and 371,845 women of reproductive age in 29 LMICs from 2000 to 2009 and 386,202 children and 928,889 women from 2010 to 2018 were included to examine changes in the prevalence of anemia (**Fig. 1**).

A total of 47 countries from 5 WHO regions were included in this study with 29 countries from the African region, 4 countries from the American region, 3 countries from the Eastern Mediterranean region, 4 countries from the European region, and 7 countries from the South-East Asia/Western Pacific region (**Table S1**).

3.1. Prevalence of anemia among children aged 6 to 59 months of age, 2010-2018

During 2010 and 2018, among 47 LMICs, the overall prevalence of anemia among children aged 6 to 59 months was 56.5%, higher among those aged 6 to 35 months (64.3%) than those aged 36 to 59 months (46.8%, $P < 0.001$). Younger children were more likely to have anemia than older children (adjusted odds ratio [OR] 1.38, 95% confidence intervals (CIs) 1.36-1.39, $P < 0.001$) (**Table 1**).

There was substantial heterogeneity across countries for the prevalence of anemia in children aged less than 5 years (African region: highest in Burkina Faso [87.7%] and lowest in Rwanda [36.5%]; American region: highest in Haiti [66.4%] and lowest in Honduras [29.1%]; Eastern Mediterranean: highest in Yemen [86.4%] and lowest in Egypt [27.2%]; European region: highest in the Kyrgyz Republic [42.5%] and lowest in Armenia [15.6%]; South-East Asia/Western Pacific: highest in India [58.5%] and lowest in Timor-Leste [40.3%], **Fig. 2A and Table 2**). When stratified by child age, more countries (32 countries: from 62.0% in Bangladesh to 92.8% in Burkina Faso) had a prevalence of anemia above 60% in younger children (aged 6–35 months) compared with older children (aged 36-59 months, 12 countries: from 60.2% in Nigeria to 81.4% in Burkina Faso, **Table S1**). The prevalence of anemia among children aged 6 to 59 months across different regions, income levels, and severity levels has been shown in **Table S2**.

3.2. The weighted prevalence of anemia among women of reproductive age, 2010-2018

During 2010 and 2018, among 46 LMICs, the prevalence of anemia among women of reproductive age was 40.4%. Pregnant women (48.7%) were more likely to have anemia than non-pregnant women (39.7%) (adjusted OR 1.14, 95% CI 1.12–1.16, $P < 0.001$, **Table 1**). Pregnant women in the third trimester (54.5%, adjusted OR 1.55, 95%

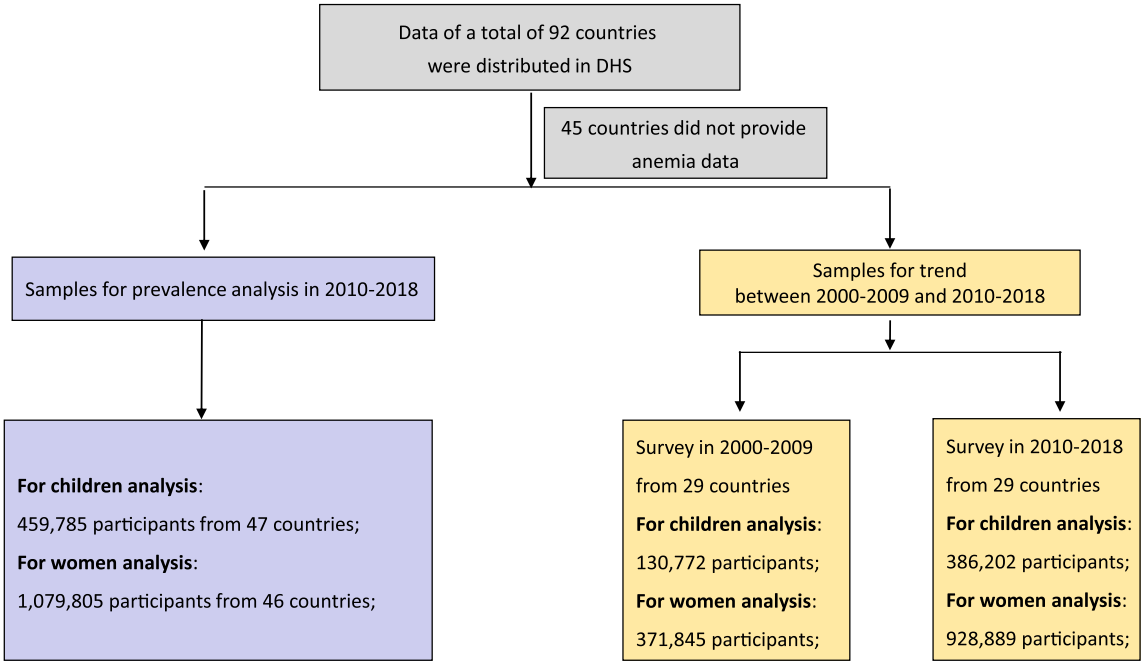

Fig. 1. Flowchart of samples included in this study.

Table 1
The weighted prevalence of anemia in children aged less than 5 years by age during 2010–2018 in 47 low- and middle-income countries.

Group	% (95% CI)	Standard deviation	OR_{adj} (95%CI)	*P*-$value_{adj}$
Children aged less than 5 years				
Total	56.5 (56.2–56.8)	17.1		
6–35 months	64.3 (63.9–64.7)	16.5	1.38 (1.36–1.39)	<0.001
36–59 months (ref.)	46.8 (46.3–47.3)	18.2		
Women of reproductive age				
Total	40.4 (40.1–40.7)	14.8		
Pregnant women	48.7 (47.9–49.5)	15.4	1.14 (1.12–1.16)	<0.001
Non-pregnant women(ref.)	39.7 (39.4–40.0)	14.8		
First trimester(ref.)	35.2 (33.9–36.5)	15.1		
Second trimester	53.2 (52.0–54.4)	16.9	1.51 (1.45–1.58)	<0.001
Third trimester	54.5 (53.2–55.8)	15.9	1.55 (1.48–1.62)	<0.001

Adjusted OR (95%CI) and *P*-value $_{adj}$ were calculated with adjustment for sex, age, wealth index, residence, gross domestic product per capita on purchasing power parity, country, and survey time, with the group of 36–59 months as the reference. Data are shown as mean prevalence estimates and 95% confidence intervals.

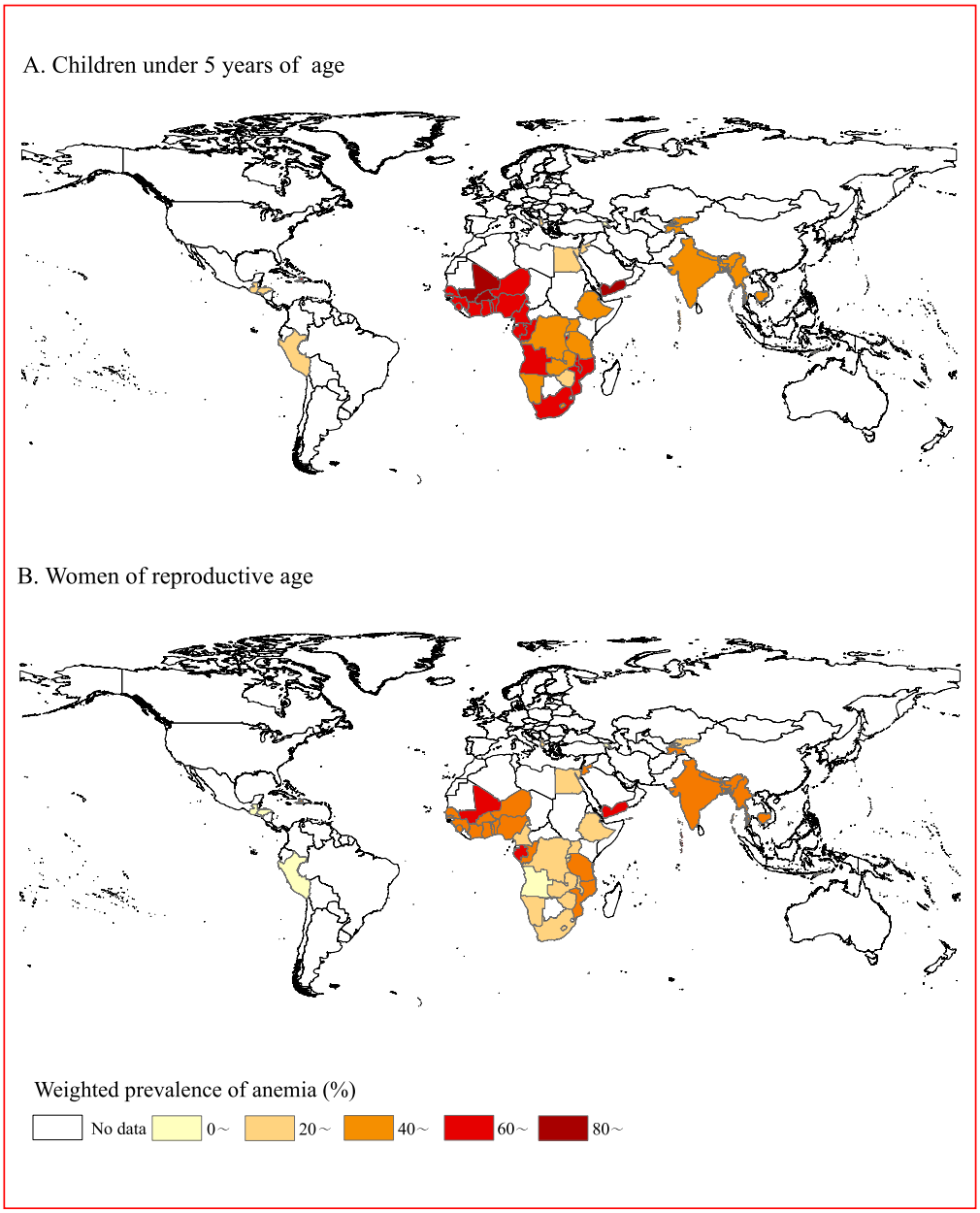

Fig. 2. Weighted national prevalence of anemia during 2010-2018; **A,** children aged less than 5 years; **B,** women of reproductive age. Note: deeper color represents a higher prevalence of anemia.

Table 2
Weighted prevalence of anemia in children aged 6–59 months and women of reproductive age during 2010–2018 in each country.

WHO Region, Country	World Bank Income	Survey year	Young children aged 6–59 months			Women of reproductive age		
			Sample size	No. of cases	Prevalence,%	Sample size	No. of cases	Prevalence,%
African								
Angola	UM	2015	6854	4392	64.6 (62.5–66.7)	–	–	–
Burkina Faso	LI	2010	6286	5545	87.7 (86.6–88.8)	8376	4033	48.8 (47.2–50.4)
Benin	LI	2017	6253	4477	71.5 (69.9–73.1)	8011	4618	57.7 (56.2–59.2)
Burundi	LI	2016	5767	3410	61.0 (59.2–62.8)	8539	3176	39.3 (37.7–40.9)
Congo Democratic Republic	LI	2013	8266	5189	59.9 (57.6–62.2)	9328	3775	38.4 (36.2–40.6)
Congo	LM	2011	4457	2943	66.8 (64.1–69.5)	5562	2941	54.2 (52.1–56.3)
Cote d'Ivoire	LM	2011	3403	2547	74.9 (73.0–76.8)	4678	2471	53.7 (51.4–56.0)
Cameroon	LM	2011	5476	3365	60.4 (58.6–62.2)	7815	3128	39.5 (37.9–41.1)
Ethiopia	LI	2016	8525	5107	56.8 (54.3–59.3)	14,489	3929	23.6 (22.0–25.2)
Gabon	UM	2012	3849	2420	60.2 (57.8–62.6)	5484	3202	60.6 (58.3–62.9)
Ghana	LM	2014	2736	1878	65.9 (63.1–68.7)	4704	1984	42.4 (40.5–44.3)
Gambia	LI	2013	3422	2502	70.8 (68.4–73.2)	4558	2811	59.0 (56.3–61.7)
Guinea	LI	2018	3610	2656	74.6 (72.8–76.4)	5262	2363	45.8 (44.0–47.6)
Lesotho	LM	2014	1766	901	51.0 (47.9–54.1)	3349	866	27.3 (25.3–29.3)
Mali	LI	2018	4349	3464	81.8 (80.3–83.3)	5090	3199	63.4 (61.4–65.4)
Malawi	LI	2015	5276	3301	62.5 (60.6–64.4)	7970	2690	32.7 (31.3–34.1)
Mozambique	LI	2011	4923	3222	68.5 (66.4–70.6)	13,537	7100	54.0 (52.4–55.6)
Nigeria	LM	2018	11,230	7708	67.9 (66.5–69.3)	14,750	8557	57.8 (56.7–58.9)
Niger	LI	2012	4827	3590	73.4 (71.6–75.2)	5050	2238	45.8 (43.5–48.1)
Namibia	UM	2013	2342	1143	47.5 (44.9–50.1)	4327	899	20.7 (19.3–22.1)
Rwanda	LI	2014	3532	1264	36.5 (34.7–38.3)	6692	1281	19.2 (18.0–20.4)
Sierra Leone	LI	2013	5290	4229	79.9 (78.4–81.4)	7848	3573	44.8 (42.4–47.2)
Senegal	LI	2017	10,896	7991	70.9 (69.6–72.2)	8013	4293	54.1 (52.2–56.0)
Togo	LI	2013	3240	2277	70.2 (68.2–72.2)	4802	2210	48.1 (46.3–49.9)
Tanzania	LI	2015	9323	5358	57.8 (56.2–59.4)	13,102	6092	44.8 (43.4–46.2)
Uganda	LI	2016	4806	2578	52.9 (50.8–55.0)	6031	1945	31.7 (30.2–33.2)
South Africa	UM	2016	1160	705	61.5 (57.5–65.5)	2974	945	33.2 (30.5–35.9)
Zambia	LM	2018	8707	5004	58.0 (56.5–59.5)	13,226	4020	31.1 (29.7–32.5)
Zimbabwe	LI	2015	5326	1946	36.5 (34.8–38.2)	9265	2531	26.8 (25.5–28.1)
American								
Guatemala	LM	2014	10,943	3664	32.4 (31.0–33.8)	25,422	3733	13.6 (12.9–14.3)
Honduras	LM	2011	9560	2865	29.1 (27.8–30.4)	21,594	3331	15.1 (14.4–15.8)
Haiti	LI	2016	6092	4022	66.4 (64.6–68.2)	9513	4561	49.0 (47.4–50.6)
Peru	UM	2012	8974	3190	32.6 (31.2–34.0)	24,273	4642	17.6 (16.8–18.4)
Eastern Mediterranean								
Egypt	LM	2014	4702	1337	27.2 (25.4–29.0)	7189	1720	25.2 (23.8–26.6)
Jordan	UM	2017	8815	2934	31.6 (29.8–33.4)	7110	3183	43.5 (41.3–45.7)
Yemen	LM	2013	3892	3435	86.4 (84.9–87.9)	4904	3674	71.4 (69.5–73.3)
European								
Albania	LM	2017	2057	573	24.4 (21.9–26.9)	10,461	2427	22.7 (21.4–24.0)
Armenia	LM	2015	1373	220	15.6 (13.4–17.8)	5807	788	13.4 (11.9–14.9)
Kyrgyz Republic	LI	2012	4213	1822	42.5 (40.0–45.0)	8048	2768	35.2 (33.5–36.9)
Tajikistan	LI	2017	5496	2221	41.5 (39.2–43.8)	10,618	4366	41.1 (39.3–42.9)
South-East Asia/Western Pacific								
Bangladesh	LI	2011	2432	1254	51.2 (48.7–53.7)	5666	2364	42.4 (40.6–44.2)
India	LM	2015	220,487	126,602	58.5 (58.1–58.9)	684,904	352,570	53.1 (52.9–53.3)
Myanmar	LM	2015	4003	2181	57.8 (55.8–59.8)	12,516	5629	46.5 (45.1–47.9)
Maldives	UM	2016	2064	977	49.7 (47.1–52.3)	6867	4016	63.0(61.1–64.9)
Nepal	LI	2016	2232	1162	52.9 (50.2–55.6)	6423	2609	40.8 (38.6–43.0)
Timor-Leste	LM	2016	2041	794	40.3 (37.2–43.4)	4268	887	22.7 (21.1–24.3)
Cambodia	LI	2014	4512	2463	55.5 (53.5–57.5)	11,390	4988	45.4 (44.2–46.6)

LI: low-income countries; LM: low-middle-income countries; UM: upper-middle-income countries.

CI 1.48–1.62) and the second trimester (53.2%, adjusted OR 1.51, 95% CI 1.45–1.58, $P < 0.001$, Table 1) were more likely to have anemia than those in the first trimester (35.2%). Similar changes were observed at the national level (**Fig. S1**).

There was substantial heterogeneity across countries for the prevalence of anemia in women of reproductive age (African region: highest in Mali [63.4%] and lowest in Rwanda [19.2%]; American region: highest in Haiti [49.0%] and lowest in Honduras [15.1%]; Eastern Mediterranean: highest in Yemen [71.4%] and lowest in Egypt; European region: highest in Tajikistan [41.1%] and lowest in Armenia [13.4%]; South-East Asia/Western Pacific: highest in Maldives [63.0%] and lowest in Timor-Leste [22.7%] Fig. 2**B and** Table 2). When stratified by pregnancy status of women, more counties (9 countries: from 61.1% in Nigeria to 78.2% in Yemen) had a prevalence of anemia above 60% in pregnant women compared with non-pregnant women (4 countries including Yemen [70.4%], Maldives [63.1%], Mali [62.6%], and Gabon [60.9%]) (**Table S1**). The prevalence of anemia among women of reproductive age across different regions, income levels, and severity levels has been shown in **Tables S3, S4.**

3.3. Changes in the prevalence of anemia among children less than 5 years of age and women of reproductive age in 29 LMICs, 2000-2009 to 2010-2018

At a national level, there were downward changes in the prevalence of anemia among children in 21 (of 29) LMICs and among women in 23 (of 29) LMICs. The AARR changed from 0.1% in Mali to 4.5% in Zimbabwe and Honduras among children, and from 0.2% in Mali and 0.3% in Sierra Leone to 5.2% in the Congo Democratic Republic among women (Table 3 **and** Fig. 3), which were similar to results

Table 3
Change in weighted prevalence of anemia in children aged 6–59 months and women of reproductive age from 2000 to 2009 to 2010–2018 in each country.

WHO Region, Country	Survey year	Income	Children aged 6–59 months								Women of reproductive age							
			Sample size	No. of cases	Prevalence,%	Absolute change,%	Relative change,%	*P*-value	Average annual rate of reduction (95%CI)	$P\text{-value}_{ad}$	Sample size	No. of cases	Prevalence,%	Absolute change,%	Relative change,%	*P*-value	Average annual rate of reduction (95%CI)	$P\text{-cvalue}_{adj}$
African																		
Benin	2001	LI	2292	1876	81.9 (79.9–83.9)						3124	2010	64.3 (62.0–66.6)					
	2017	LI	6253	4477	71.5 (69.9–73.1)	−10.4	−12.70%	<0.001	−0.8 (−1.1,−0.6)	<0.001	8011	4618	57.7 (56.2–59.2)	−6.6	−10.30%	<0.001	−0.7 (−1.0,−0.4)	<0.001
Burkina Faso	2003	LI	2770	2535	91.5 (90.1–92.9)						4211	2244	53.7 (51.7–55.7)					
	2010	LI	6286	5545	87.7 (86.6–88.8)	−3.8	−4.20%	<0.001	−0.6 (−0.9,−0.3)	<0.001	8376	4033	48.8 (47.2–50.4)	−4.9	−9.10%	<0.001	−1.4 (−2.1,−0.6)	<0.001
Cameroon	2004	LI	3572	2461	68.2 (66.1–70.3)						5137	2318	44.9 (43.1–46.7)					
	2011	LM	5476	3365	60.4 (58.6–62.2)	−7.8	−11.40%	<0.001	−1.7 (−2.4,−1.1)	<0.001	7815	3128	39.5 (37.9–41.1)	−5.4	−12.00%	<0.001	−1.8 (−2.7,−0.9)	<0.001
Congo	2005	LM	2021	1320	64.6 (61.0–68.2)						3246	1856	57.0 (54.5–59.5)					
	2011	LM	4457	2943	66.8 (64.1–69.5)	2.2	3.40%	0.353	0.5 (−0.7,1.7)	0.404	5562	2941	54.2 (52.1–56.3)	−2.8	−4.90%	0.091	−0.8 (−1.8,0.2)	0.100
Congo Democratic Republic	2007	LI	3566	2516	71.8 (68.2–75.4)						4632	2316	53.0 (49.6–56.4)					
	2013	LI	8266	5189	59.9 (57.6–62.2)	−11.9	−16.60%	<0.001	−2.9 (−4.0,−1.9)	<0.001	9328	3775	38.4 (36.2–40.6)	−14.6	−27.50%	<0.001	−5.2 (−6.6,−3.8)	<0.001
Ethiopia	2005	LI	3616	1969	53.3 (51.0–55.6)						5963	1654	26.6 (24.6–28.6)					
	2016	LI	8525	5107	56.8 (54.3–59.3)	3.5	6.60%	0.04	0.5 (−0.1,1.1)	0.102	14,489	3929	23.6 (22.0–25.2)	−3	−11.30%	0.026	−1.1 (−2.0,−0.1)	0.031
Ghana	2003	LI	3240	2497	76.0 (74.2–77.8)						5278	2395	44.6 (42.8–46.4)					
	2014	LM	2736	1878	65.9 (63.1–68.7)	−10.1	−13.30%	<0.001	−1.3 (−1.7,−0.8)	<0.001	4704	1984	42.4 (40.5–44.3)	−2.2	−4.90%	0.089	−0.4 (−1.0,0.1)	0.117
Guinea	2005	LI	2591	1969	76.6 (74.6–78.6)						3881	2069	53.3 (51.2–55.4)					
	2018	LI	3610	2656	74.6 (72.8–76.4)	−2	−2.60%	0.153	−0.2 (−0.4,0.1)	0.258	5262	2363	45.8 (44.0–47.6)	−7.5	−14.10%	<0.001	−1.2 (−1.6,−0.7)	<0.001
Lesotho	2004	LI	1553	735	48.6 (45.3–51.9)						3061	955	32.9 (30.6–35.2)					
	2014	LM	1766	901	51.0 (47.9–54.1)	2.4	4.90%	0.31	0.5 (−0.4,1.5)	0.260	3349	866	27.3 (25.3–29.3)	−5.6	−17.00%	<0.001	−1.9 (−2.9,−0.8)	<0.001
Malawi	2004	LI	2303	1689	73.3 (71.0–75.6)						2749	1234	44.3 (41.9–46.7)					
	2015	LI	5276	3301	62.5 (60.6–64.4)	−10.8	−14.70%	<0.001	−1.3 (−1.7,−0.9)	<0.001	7970	2690	32.7 (31.3–34.1)	−11.6	−26.20%	<0.001	−2.7 (−3.4,−2.1)	<0.001
Mali	2001	LI	2791	2321	82.8 (79.6–86.0)						118,728	80,276	65.5 (61.3–69.7)					
	2018	LI	4349	3464	81.8 (80.3–83.3)	−1	−1.20%	0.588	−0.1 (−0.3,0.2)	0.630	5090	3199	63.4 (61.4–65.4)	−2.1	−3.20%	0.377	−0.2 (−0.7,0.2)	0.316
Niger	2006	LI	3589	2957	83.9 (82.0–85.8)						4276	1885	45.8 (43.3–48.3)					
	2012	LI	4827	3590	73.4 (71.6–75.2)	−10.5	−12.50%	<0.001	−2.1 (−2.7,−1.6)	<0.001	5050	2238	45.8 (43.5–48.1)	0	0.00%	0.981	0.0 (−1.2,1.3)	0.990
Rwanda	2005	LI	3583	1855	51.7 (49.5–53.9)						5638	1428	25.6 (24.0–27.2)					
	2014	LI	3532	1264	36.5 (34.7–38.3)	−15.2	−29.40%	<0.001	−3.7 (−4.5,−3.0)	<0.001	6692	1281	19.2 (18.0–20.4)	−6.4	−25.00%	<0.001	−3.2 (−4.2,−2.1)	<0.001
Senegal	2005	LI	2742	2284	82.6 (80.5–84.7)						4355	2609	59.1 (56.9–61.3)					
	2017	LI	10,896	7991	70.9 (69.6–72.2)	−11.7	−14.20%	<0.001	−1.2 (−1.5,−0.9)	<0.001	8013	4293	54.1 (52.2–56.0)	−5	−8.50%	0.001	−0.7 (−1.1,−0.3)	<0.001
Sierra Leone	2008	LI	2516	1891	75.7 (73.2–78.2)						3364	1509	45.2 (42.9–47.5)					
	2013	LI	5290	4229	79.9 (78.4–81.4)	4.2	5.50%	0.004	1.1 (0.3,2.0)	0.006	7848	3573	44.8 (42.4–47.2)	−0.4	−0.90%	0.796	−0.3 (−1.8,1.3)	0.738
Tanzania	2004	LI	7284	5230	71.9 (70.1–73.7)						10,132	5066	48.4 (46.3–50.5)					
	2015	LI	9323	5358	57.8 (56.2–59.4)	−14.1	−19.60%	<0.001	−1.9 (−2.3,−1.6)	<0.001	13,102	6092	44.8 (43.4–46.2)	−3.6	−7.40%	0.007	−0.7 (−1.2,−0.1)	0.012
Uganda	2000	LI	5403	3709	71.0 (68.7–73.3)						6485	2250	36.7 (34.3–39.1)					
	2016	LI	4806	2578	52.9 (50.8–55.0)	−18.1	−25.50%	<0.001	−1.7 (−2.1,−1.4)	<0.001	6031	1945	31.7 (30.2–33.2)	−5	−13.60%	<0.001	−0.9 (−1.4,−0.4)	0.001
Zimbabwe	2005	LI	4436	2561	58.4 (56.3–60.5)						7893	2944	37.7 (35.8–39.6)					
	2015	LI	5326	1946	36.5 (34.8–38.2)	−21.9	−37.50%	<0.001	−4.5 (−5.0,−3.9)	<0.001	9265	2531	26.8 (25.5–28.1)	−10.9	−28.90%	<0.001	−3.4 (−4.1,−2.7)	<0.001
American																		
Haiti	2000	LI	3030	1804	62.1 (59.5–64.7)						4778	2644	55.5 (52.8–58.2)					
	2016	LI	6092	4022	66.4 (64.6–68.2)	4.3	6.90%	0.007	0.5 (0.2,0.8)	0.002	9513	4561	49.0 (47.4–50.6)	−6.5	−11.70%	<0.001	−0.8 (−1.2,−0.4)	<0.001
Honduras	2005	LM	9284	3537	37.2 (35.7–38.7)						18,883	3457	18.7 (17.7–19.7)					
	2011	LM	9560	2865	29.1 (27.8–30.4)	−8.1	−21.80%	<0.001	−4.5 (−5.4,−3.5)	<0.001	21,594	3331	15.1 (14.4–15.8)	−3.6	−19.30%	<0.001	−3.6 (−4.8,−2.3)	<0.001
Peru	2000	LM	2334	1147	49.6 (46.8–52.4)						6211	1929	31.6 (29.9–33.3)					
	2012	UM	8974	3190	32.6 (31.2–34.0)	−17	−34.30%	<0.001	−3.5 (−4.0,−2.9)	<0.001	24,273	4642	17.6 (16.8–18.4)	−14	−44.30%	<0.001	−4.8 (−5.4,−4.2)	<0.001
Eastern Mediterranean																		
Egypt	2000	LM	4786	1463	30.3 (28.6–32.0)						7584	2109	27.7 (26.3–29.1)					
	2014	LM	4702	1337	27.2 (25.4–29.0)	−3.1	−10.20%	0.014	−0.8 (−1.4,−0.1)	0.021	7189	1720	25.2 (23.8–26.6)	−2.5	−9.00%	0.014	−0.7 (−1.3,−0.1)	0.019
Jordan	2002	LM	1510	531	34.5 (31.1–37.9)						1831	530	29.1 (26.0–32.2)					
	2017	UM	8815	2934	31.6 (29.8–33.4)	−2.9	−8.40%	0.134	−0.4 (−1.1,0.4)	0.350	7110	3183	43.5 (41.3–45.7)	14.4	49.50%	<0.001	2.6 (1.8,3.4)	<0.001

(*continued on next page*)

Table 3 (*Continued*)

WHO Region, Country	Survey year	Income	Children aged 6–59 months								Women of reproductive age							
			Sample size	No. of cases	Prevalence,%	Absolute change,%	Relative change,%	P-value	Average annual rate of reduction (95%CI)	$P\text{-value}_{ad}$	Sample size	No. of cases	Prevalence,%	Absolute change,%	Relative change,%	P-value	Average annual rate of reduction (95%CI)	$P\text{-cvalue}_{adj}$
European																		
Albania	2008	UM	1404	263	17.4 (14.8–20.0)						7467	1330	19.0 (17.5–20.5)					
	2017	LM	2057	573	24.4 (21.9–26.9)	7	40.20%	<0.001	3.1 (1.0,5.2)	0.004	10,461	2427	22.7 (21.4–24.0)	3.7	19.50%	<0.001	1.9 (0.8,3.1)	0.001
Armenia	2000	LI	1384	341	24.0 (21.7–26.3)						6137	802	12.4 (11.4–13.4)					
	2015	LM	1373	220	15.6 (13.4–17.8)	−8.4	−35.00%	<0.001	−3.1 (−4.3,−1.8)	<0.001	5807	788	13.4 (11.9–14.9)	1	8.10%	0.269	0.5 (−0.6,1.6)	0.363
South-East Asia/ Western Pacific																		
India	2005	LI	37,999	24,486	69.4 (68.6–70.2)						112,714	58,650	55.3 (54.7–55.9)					
	2015	LM	220,487	126,602	58.5 (58.1–58.9)	−10.9	−15.70%	<0.001	−1.7 (−1.8,−1.6)	<0.001	684,904	352,570	53.1 (52.9–53.3)	−2.2	−4.00%	<0.001	−0.4 (−0.5,−0.3)	<0.001
Nepal	2006	LI	4995	2388	48.6 (46.4–50.8)						10,661	3718	36.2 (31.8–40.6)					
	2016	LI	2232	1162	52.9 (50.2–55.6)	4.3	8.80%	0.014	0.6 (−0.1,1.4)	0.090	6423	2609	40.8 (38.6–43.0)	4.6	12.70%	0.085	1.2 (−0.3,2.7)	0.105
Timor-Leste	2009	LM	2591	1070	38.5 (36.2–40.8)						4117	911	21.3 (19.8–22.8)					
	2016	LM	2041	794	40.3 (37.2–43.4)	1.8	4.70%	0.358	0.6 (−0.9,2.1)	0.433	4268	887	22.7 (21.1–24.3)	1.4	6.60%	0.199	0.9 (−0.6,2.5)	0.226
Cambodia	2000	LI	1587	1015	63.4 (60.5–66.3)						3666	2146	58.8 (56.7–60.9)					
	2014	LI	4512	2463	55.5 (53.5–57.5)	−7.9	−12.50%	<0.001	−1.1 (−1.5,−0.6)	<0.001	11,390	4988	45.4 (44.2–46.6)	−13.4	−22.80%	<0.001	−1.8 (−2.2,−1.5)	<0.001

$P\text{-Value}_{adj}$ was calculated with adjustment for child or women age, child sex, wealth index, residence, gross domestic product per capita on purchasing power parity, country, and survey time.
LI: low-income countries; LM: low-middle-income countries; UM: upper-middle-income countries.

of absolute downward change and relative change between 2000-2009 and 2010–2018. The AARR in anemia from 2000-2009 to 2010–2018 among children aged 6-35 months (ranging from −0.1% in Nepal to −4.3% in Honduras) and those aged 36–59 months (ranging from −0.4% in Mali to −6.3% in Zimbabwe) at the national level were shown in **Fig. S2**, changes among pregnant women (ranging from −0.1% in Mali to −5.3% in Congo Democratic Republic) and non-pregnant women (ranging from −0.2% in Mali to −5.2% in Congo Democratic Republic) shown in **Fig. S3**, and changes among pregnant women in different trimesters shown in **Fig. S4** (first trimester: ranging from −0.3% in Mali to −10.3% in Zimbabwe; second trimester: from −0.1% in Benin to −6.0% in Congo Democratic Republic; third trimester: from −0.1% in Tanzania and Lesotho to −4.1% in Congo Democratic Republic). The change in anemia among children aged less than 5 years and women of reproductive age across different regions, income levels, and severity levels has been shown in **Table S5 and Fig. S5**.

4. Discussion

The prevalence of anemia was high among both children aged less than 5 years and women of reproductive age in 47 LMICs, particularly for younger children aged 6 to 35 months and pregnant women. Additionally, moderate and severe anemia was more prevalent among younger children and pregnant women in the second and third trimesters. The prevalence of anemia among children and women varied across countries. Although the prevalence decreased or did not change from 2000-2009 to 2010–2018 in both children and women in most LMICs, the absolute, relative, or AARR varied across countries and the relative change among women was far from the WHO goal.

In this study, the prevalence of anemia among women (40.4%) in the 47 LMICs was similar to the global prevalence in 2016 (40.0%); however, in children aged less than 5 years, it was higher (56.5%) than the global prevalence (42.0%) [1]. We further found that anemia was more prevent among younger children and pregnant women. The countries with a high prevalence of anemia (more than 60%) in this study were mainly from the African and South-East Asia/Western Pacific regions, which might be due to endemic schistosomiasis in the African region [18] and the Asian-Pacific region [19–21]. Besides, sickle cell disease is a common health problem for children living in Saharan Africa [22,23] and Asian, amplified by those with malaria susceptibility candidate locus [24] or migration [22]. Therefore, schistosomiasis and sickle cell disease might be the core mission of anemia mitigation in these two regions.

The worse status of anemia among younger children might be due to that the period from conception to 2 years of life is a critical window when the needs of nutrition must be ensured; if not, child morbidity or mortality may occur [11]. In the first 4–6 months of term-born infants, iron, as a major factor of anemia, is sufficient with unimpaired intrauterine supply, whereas after 6 months, owing to rapid growth (rapid brain development, physical growth, and early learning capacity), the iron supplied by intrauterine means becomes insufficient, that can cause absolute deficiency [25,26].

For women of reproductive age, we not only found a worse status of anemia among pregnant women compared with non-pregnant women (except for several countries, such as Jordan and Egypt in the Eastern Mediterranean region and Armenia in European region, which might be influenced by iron supplementation during pregnancy, socioeconomic factors, culture, and religion) but also observed that the prevalence was higher during the second and third trimesters than the first trimester. During pregnancy, the blood volume expands more than 1 liter [27] and the iron needs are tripled that of non-pregnancy [28]. The increase of plasma volume with the progress of pregnancy may greatly exceed change of red cell mass, leading to physiologic fall in hemoglobin concentration [29]. In addition, the

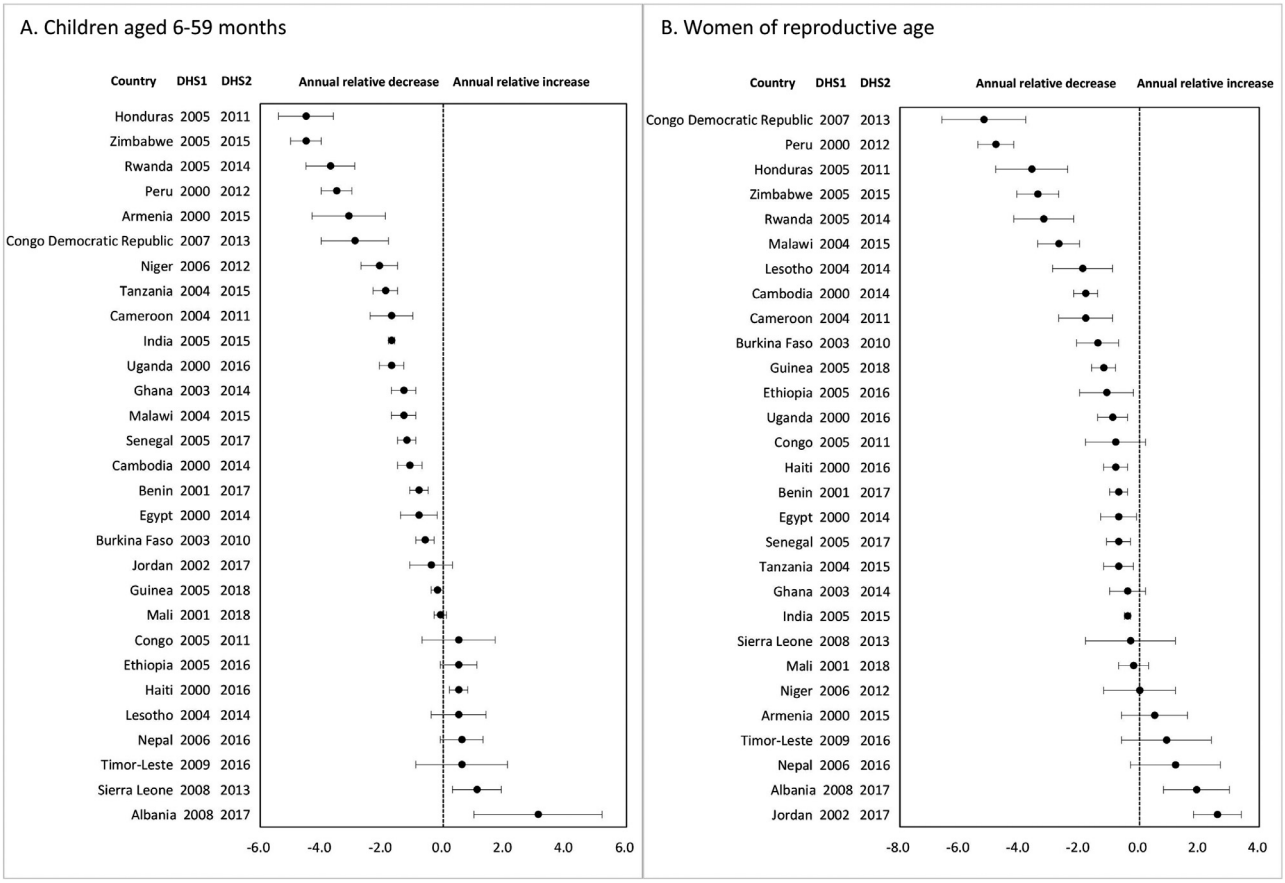

Fig. 3. National change in weighted prevalence of anemia from 2000 to 2009 to 2010-2018; **A,** children aged less than 5 years; **B,** women of reproductive age.

demand for iron ensuring the growth of the placenta, fetus, and other maternal tissues increases from 0.8 mg/day during the first trimester to 7.5 mg/day during the third trimester [12]. On the other hand, the decrease of hepcidin (the regulator of iron bioavailability in the body) with the progress of pregnancy [30] might be the result of gradual iron deficiency to maximally absorb iron supplementation to maintain hemoglobin levels. The lower prevalence of anemia among pregnant women during the first trimester compared with that among non-pregnant women might be due to that most of those pregnant women may tend to adhere to iron supplementation [31] prescribed by clinical physician which partly mitigates anemia situation. However, iron supplementation might not meet the increased demands with the progress of pregnancy. Then, there will be a significant increase in anemia prevalence during the second and third trimesters. These findings suggest an urgent need for interventions targeting the cause of anemia in LMICs, particularly for infants and toddlers and pregnant women who have a high demand for iron.

Although there was an overall decline in the prevalence of anemia among women in LMICs, most countries maintained a high prevalence of anemia with the relative decrease of anemia far from the WHO goal of reduction by 50% by 2025 [8,32]. Besides, we found that the prevalence of anemia among children and women increased substantially in Albania (including absolute change and AARR), as well as that among women in Jordan. Albania faced urgent economical challenges that resulted in 57% of children under economic assistance failing to meet fundamental needs such as nutrition and cleaning drinking water [33]. Because of limited funding and ineffective management of supplies in most countries, interventions (e.g., iron-folic acid supplementation) might be not operating at scale [34] and the coverage of nutrition intervention in LMICs was low for women and young children [35]. These findings suggest that a comprehensive implementation plan of interventions should be strengthened and made a key component of a global nutrition framework in multiple sectors according to their specific situation.

Public health interventions that improve bioavailability and infant feeding practices, and increase dietary diversity recommended by the WHO include intake of micronutrients by supplementation or fortification with iron, vitamins, folic acid, and minerals, and delayed cord clamping [1,36]. Despite these recommendations, we observed only a minimal improvement in the prevalence of anemia in these LMICs. In all, co-operative efforts to establish interventions aimed at maintaining sufficient iron levels among women and children are needed to address the issues of basic causes like water, sanitation and hygiene, disease control, reproductive health, gender norms, lack of education, and poverty [1] to ensure effective, safe, and wide delivery to those at high risk.

This is the first study to examine the prevalence, and change in prevalence, of anemia among infants and toddlers and pregnant women across different trimesters in LMICs from 2010 onward. Moreover, the HemoCue blood hemoglobin testing system used in this study includes in-built quality control, ensuring the accuracy of the measurements. However, this study had several limitations. First, the prevalence of anemia was calculated based on 47 LMICs and changes of anemia from 2000-2009 to 2010–2018 were based on 29 LMICs; but further estimation with more LMICs is needed. Second, the information on serum ferritin, soluble transferrin receptor, and transferrin saturation was not available and information on iron status, malaria, inflammation, infection, sickle cell disease, and hemoglobinopathies was limited in the dataset, which may partly have affected the prevalence of anemia. Further surveys will be needed to better acquire the information using uniform questions. Third, results of changes in the prevalence of anemia between 2000-2009 and

2010−2018 in upper-middle-income countries should be interpreted with caution because of limited numbers of countries in these two periods (only 1 country in 2000−2009 and 2 countries in 2010−2018). Fourth, there might be heterogeneity between the two time periods when comparing the prevalence of anemia between 2000-2009 and 2010−2018. However, to ensure comparability and standardization across periods and countries, interviewers were well-trained and standardized measurement tools and questionnaires were applied to collect data [37]. Besides, we have used modified Poisson regression models to estimate changes in the prevalence at the national level with the adjustment for age and survey time to eliminate the effect. Fifth, the prevalence of anemia varied significantly across the WHO regions and the World Bank income levels; therefore, the comparisons across different levels should be interpreted with caution. Sixth, the information on iron supplementation was limited, which impeded us to explore the possible reasons for a higher prevalence of anemia among non-pregnant women than pregnant women in some countries. Further studies are needed to verify this issue.

The current prevalence of anemia in both young children and women among LMICs remains high, particularly for infants and toddlers and pregnant women in their second and third trimesters. Despite a decline in the prevalence of anemia among children and women in most LMICs, the relative decrease of anemia among women of reproductive age was well behind meeting the WHO goal. More effective intervention policies and programs in maintaining sufficient iron, especially targeting high-risk populations, are needed to improve the general health of the population.

Contributors

BX contributed to study design, interpretation of the data analysis and revised the manuscript. JS drafted the manuscript. HW analyzed the data and contributed to the interpretation of the data. CGM contributed to the interpretation of the data and revised the manuscript. MZ contributed to study design, the interpretation of the data and revised the manuscript. HW and JS accessed and verified the data. BX had full access to all the data in the study and had final responsibility for the decision to submit it for publication. The corresponding author BX has access to and responsibility for the raw data associated with the study.

Data sharing statement

Data from the Demographic and Health Surveys are publicly available online (https://dhsprogram.com/).

Declaration of Competing Interest

We declare no competing interests.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.eclinm.2021.101136.

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