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# What works for anemia reduction among women of reproductive age? Synthesized findings from the exemplars in anemia project

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## ABSTRACT

**Background:** Few countries have succeeded to decrease the prevalence of anemia in women of reproductive age (WRA), and where improvements have been observed, contributing factors are not well understood.

**Objectives:** To synthesize cross-cutting findings from specific exemplar studies in Uganda, Senegal, the Philippines, and Pakistan by reviewing anemia trends, policies, and programs, comparing drivers of change, and proposing strategies to achieve further reductions in WRA anemia.

**Methods:** A mixed-methods approach was used for exemplar case studies: *1*) descriptive analyses of Demographic and Health Surveys and national survey data; *2*) review of relevant policies/programs; *3*) stakeholder in-depth interviews and focus group discussions with WRA and community members; and *4*) Oaxaca–Blinder decomposition to identify determinants of hemoglobin change over time. This cross-country analysis performs triangulation of qualitative and quantitative analyses.

**Results:** Compound annual change rates for anemia from the ~2005–2018 period were –0.7% in Senegal, –2.4% in Uganda, –3.4% in Pakistan, and –6.2% in the Philippines. Despite these reductions, WRA anemia burden in Senegal and Pakistan continues to be a severe public health problem. Direct and indirect health sector strategies, such as iron–folic acid supplementation in pregnancy, vitamin A supplementation during lactation, malaria control (Uganda and Senegal), investments in family planning, and better access to health services through community-based approaches, contributed to a median of 36.5% (range: 30%–66%) change in hemoglobin. Nonhealth sector strategies, including social protection and poverty alleviation schemes, empowering of girls and women, and improving household conditions, contributed to a 21% (18%–58%) change in hemoglobin. Large-scale food fortification (for example, wheat flour with iron) could have also contributed to improved micronutrient intakes and reduction in iron deficiency anemia.

**Conclusions:** A context-specific, multisectoral approach is needed to decrease WRA anemia, incorporating direct nutritional interventions and indirect strategies within the health and nonhealth sectors. Lessons from the successes and challenges from exemplar countries could help accelerate global anemia reduction.

*Keywords:* women of reproductive age, anemia, family planning, malaria control, poverty alleviation, exemplars

## Introduction

Anemia [hemoglobin (Hb) < 120 g/L] is a persistent global health challenge, affecting one-third of all women of reproductive age (WRA; 15–49 y) [1]. Between 1990 and 2019, WRA had a prevalence of anemia between 20,000 and 32,000 per 100,000 population compared with 15,000 to 24,000 per 100,000 population in male counterparts [2], explained by physiological changes such as menstruation (increased blood loss), pregnancy (increased nutritional requirements) and delivery blood losses [3], and potential differences in dietary patterns/consumption of bioavailable iron-rich foods. In low- and middle-income countries (LMICs) in particular, many WRA experience anemia; for example, prevalence of anemia among WRA was higher than 50% in Yemen, India, Maldives, and 7 countries in west and central Africa in 2019 [4]. Despite global commitments at the World Health Assembly (WHA) to halve the 2012 estimated prevalence of anemia in women by 2025 [5] (since revised to 2030), declines in anemia have at best stagnated over the last decade. Millions of women today continue to experience the negative short- and long-term effects of anemia, including fatigue, reduced productivity, poor birth outcomes, and increased morbidity and mortality. In addition, substantial human capital gains are never realized among communities and nations that experience a high burden of anemia [6].

Exemplars in Global Health (EGH) is a multidisciplinary community of experts that includes academic researchers, philanthropic funders, and program implementers who are working toward a common goal of better understanding country-level public health successes such that they can be replicated [7]. EGH topics are diverse, spanning from nutrition to women's health to the COVID-19 response, but each follows a similar mixed-methods approach to determine drivers of change in "exemplar" countries (that is, those that have outperformed peer countries and achieved better progress than what would be expected based on sociodemographic improvements; Supplemental Figure 1).

Importantly, not all countries have maintained a persistently high burden of anemia without improvement, and EGH set out to better understand the drivers of improvements of WRA anemia among a set of exemplar countries. This article will synthesize the cross-cutting findings from the global review and specific exemplar studies. The specific objectives are to: *1)* review the current burden, trends, and distribution of WRA anemia among exemplars; *2)* compare and contrast the drivers of change over time; *3)* review common policies and programs for anemia reduction implemented across WRA anemia exemplars; and *4)* propose a general way forward to achieve further reductions in anemia among WRA.

## Methods

The cross-country analysis presented in this article is derived from exemplar country case studies of the Philippines, Pakistan, Uganda, and Senegal that were undertaken between June 2020 and December 2022, using a mixed-methods approach, as described in detail in the methodology article of this series [8] and in the Supplemental Material. Briefly, we used modeled data from the Institute for Health Metrics and Evaluation (IHME) [9] and WHO's Global Health Observatory [10], to identify a shortlist of countries, which observed a decline in WRA anemia prevalence between 2000 and 2018 [8]. Final country selection was based on not only improvements in anemia burden, but also geography (1 county each from Southeast Asia, South Asia, East Africa, West Africa, and Latin America), etiological diversity of anemia (for

example, malaria endemicity), and feasibility of conducting the study in country. Mexico, although studied using a similar approach alongside these 4 countries, is not considered an exemplar given the increase in WRA anemia prevalence that has occurred over the last decade. As such, results from Mexico will not be included in the cross-country analysis. In brief, these methods included: *1)* a series of descriptive analyses of cross-sectional Demographic and Health Survey (DHS) and other nationally representative, population-based survey data; *2)* a review of policies, programs, and other initiatives over the study time frame, with a focus on those relevant to anemia and grouped according to those that affect the proximal determinants of anemia ("direct" strategies) and more distal determinants ("indirect" strategies), and by sector (whether delivered inside or outside of the health sector); *3)* in-country stakeholder in-depth interviews and focus group discussions with WRA and influential family members; *4)* advanced quantitative analyses to determine the drivers of improvement in WRA Hb over time; and *5)* an integrative analysis across methods 1–4. The advanced quantitative analyses included hierarchical linear multivariate regression analysis to identify determinants of Hb improvement/anemia decline in each exemplar country, followed by Oaxaca–Blinder decomposition analysis to quantify estimate the proportion percentage in of Hb improvement attributable to each determinant (Supplemental Material). This cross-country integrative analysis was further triangulated against findings from our systematic review that examined the determinants and drivers of anemia progress among WRA in LMICs [11] and further learnings from in-country consultations.

Each case study component was informed by a conceptual framework, modified from the Lancet Nutrition Series framework for undernutrition [12] that outlines the distal, intermediate, proximal, and biological causes of anemia among WRA (Figure 1). Importantly, this framework emphasizes the need to consider nutritional anemia, alongside anemia caused by other etiologies, such as genetic disorders, blood loss, infectious diseases, and noninfectious inflammatory conditions that may not necessarily respond to iron supplementation alone.

Ethical approval for the broader WRA Anemia Exemplars study was obtained from the Research Ethics Board of the Hospital for Sick Children (REB File #1000073344, approved 1 December, 2020). We also obtained country-specific ethical approvals, details of which are presented their respective manuscripts included in this Supplement. All participants provided informed consent.

## Results

### Descriptive trends

Among our exemplar countries, WRA anemia prevalence at baseline varied considerably, ranging from 23% in the Philippines in 2008 to 58.2% in Senegal in 2005 (Figure 2). According to the WHO anemia classification as a mild (5%–19% prevalence), moderate (20%–39% prevalence), or severe (≥40% prevalence) public health problem [13], at baseline, Senegal (in 2005) and Pakistan (in 2011) were classified as having a severe public health problem, whereas Uganda (in 2006) and the Philippines (in 2008) had a moderate problem. WRA anemia prevalence in Mexico remained a mild public health problem throughout the time period studied. However, the burden fluctuated, with an observed anemia prevalence of 12.5% in 2006, which decreased to 8.5% in 2012, but then worsened to 19.8% in 2018, and was the reason why we did not consider Mexico an exemplar. All other countries showed improvements over time, although only the Philippines reached a level by study endline (2018) that could be
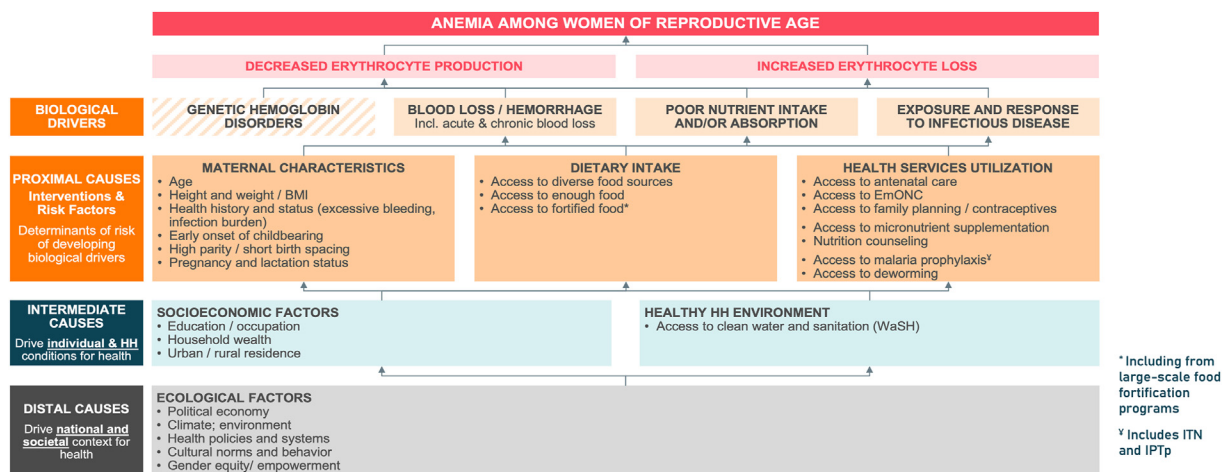
**FIGURE 1.** Conceptual framework for analyzing determinants of anemia among WRA. HH, household; IPTp, intermittent preventative treatment for malaria in pregnancy; ITN, insecticide-treated nets; WASH, water, sanitation, and hygiene; WRA, women of reproductive age.
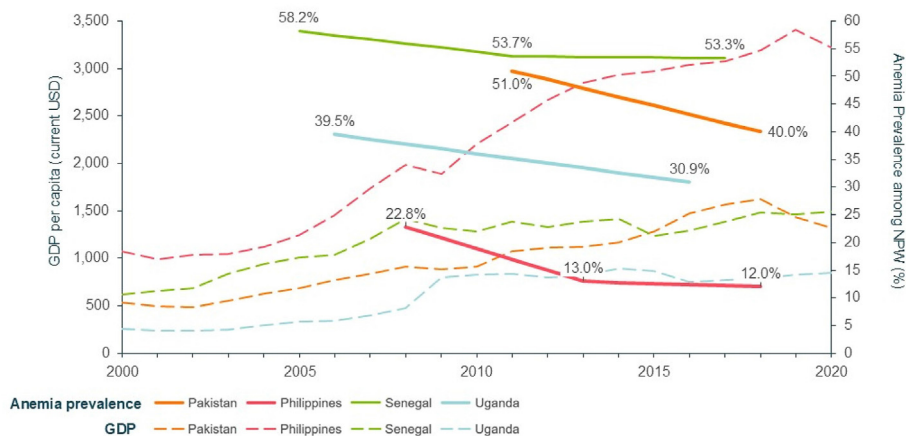


**FIGURE 2.** Anemia prevalence among nonpregnant women and GDP per capita (current USD) from 2000 to 2020. GDP, gross domestic product; NPW, nonpregnant women; USD, United States Dollar.

classified as a mild public health problem. Compound annual growth rates for anemia from the ~2005–2018 period, calculated as described in the methodology article of this series [8], corresponded to –0.7% in Senegal, –2.4% in Uganda, –3.4% in Pakistan, and –6.2% in the Philippines. Across all countries, these improvements trended in the same direction as the gross domestic product (GDP) per capita growth; in Senegal, where GDP growth was slower post-2007, relative to GDP growth in other countries, anemia prevalence decline was slower than in other exemplars (Figure 2). In the Philippines, GDP growth was double that of Pakistan, which was the second best GDP performer of the group, underscoring the positive role of country-level economic status on anemia reduction, at least among our exemplar countries.

Contextual factors differed considerably across selected exemplars. For example, the population of Pakistan in 2018 was 212 million, compared to the 16 million residents of Senegal (Table 1) [14–19]. The urban population in the Philippines and Senegal was almost double that of Uganda (47% compared with 24%, respectively). Extreme poverty in 2018 was <5% in the Philippines and Pakistan, 9% in Senegal, and 42% in Uganda, and only two-thirds of young females (15–24 y) were considered literate in Pakistan and Senegal compared with >90% in the Philippines and Uganda. Despite these baseline differences, improvements across many health and development indicators were realized across all countries. With the exception of piped water access in

Pakistan, water, sanitation, and hygiene (WASH) indicators improved over time in all locations. As shown in articles 2–5 of this series [20–23], the exemplars also saw gains in women's education, access to health services (for example, antenatal care) through improved density of healthcare professionals, malaria control, fertility and family planning indicators, and lower levels of poverty, over the study period (Table 1).

Equity analyses revealed differing patterns across countries. In Uganda and Pakistan, inequalities by wealth worsened over time, with the gap in anemia prevalence between the wealthiest and poorest women widening over the study period (Figure 3). Although there was an apparent stagnation in progress between 2011 and 2017 in Senegal, wealth inequalities improved slightly overall (2005–2017). The Philippines, however, stands out as eliminating wealth inequalities over time; substantial reductions in inequalities by urban/rural residence were also observed.

## Policy and programmatic investments

Although emphasis differed depending on the country, anemia reduction across exemplars was probably driven by investments in several common strategies and programs that align with the quantitative results (discussed below). Table 2 summarizes some of the key

**TABLE 1**
Trends in key economic, demographic, and other contextual factors across exemplar countries.

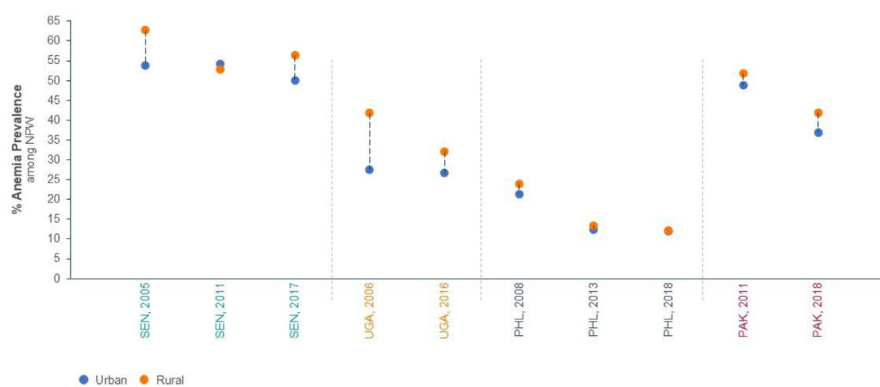| | Philippines | | | Pakistan | | | Uganda | | | Senegal | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | 2018 | Change | 2000 | 2018 | Change | 2000 | 2018 | Change | 2000 | 2018 | Change |
| Total pop.[1] (millions) | 78.0 | 106.7 | +28.7 | 142.3 | 212.2 | +69.9 | 23.7 | 41.5 | +17.8 | 9.7 | 15.6 | +5.9 |
| Pop. growth[1] (annual %) | 2.2 | 1.4 | −0.8 | 2.6 | 2.1 | −0.5 | 3.0 | 3.4 | +0.4 | 2.4 | 2.7 | +0.3 |
| Urban pop.[1] (% of total) | 46.0 | 47.0 | +1.0 | 33.0 | 36.7 | +3.7 | 14.8 | 24.0 | +9.2 | 40.0 | 47.0 | +7.0 |
| Human Development Index[2] | 0.632 | 0.711 | +0.079 | 0.441 | 0.545 | +0.104 | 0.404 | 0.528 | +0.124 | 0.388 | 0.512 | +0.124 |
| Piped water access[3] (%) | 42.3 | 63.2 | +20.9 | 37.5 | 35.7 | −1.8 | 11.5 | 21.7 | +10.2 | 53.5 | 73.1 | +19.6 |
| Open defecation[3] (%) | 11.0 | 5.0 | −6.0 | 38.0 | 10.0 | −28.0 | 14.0 | 6.0 | −8.0 | 24.0 | 12.0 | −12.0 |
| GDP per capita, PPP[1] (current intl $) | 3437.1 | 8565.6 | +5128.5 | 2721.5 | 5235.6 | +2514.1 | 1123.1 | 2239.2 | +1116.1 | 2016.4 | 3449.3 | +1432.9 |
| Poverty headcount ratio at $2.15/d, 2017 PPP[1] (%) | 14.5 | 3.0 | −11.5 | 33.3 (2001) | 4.9 | −28.4 | 68.7 (1999) | 42.2 (2019) | −26.5 | 52.4 (2001) | 9.3 | −43.1 |
| Total unemployment[1] (%) | 11.2 | 2.3 | −8.9 | 7.2 | 4.1 | −3.1 | 3.5 (2002) | 3.6 (2017) | +0.1 | 5.7 (2002) | 3.6 | −2.1 |
| Total health expenditure[1] (% of GDP) | 3.1 | 4.0 | +0.9 | 2.9 | 3.2 | +0.3 | 5.1 | 4.0 | −1.1 | 3.5 | 4.2 | +0.7 |
| Out of pocket expenditure[1] (% of total health expenditure) | 41.2 | 50.4 | +9.2 | 61.5 | 56.2 | −5.3 | 43.1 | 35.6 | −7.5 | 55.6 | 49.8 | −5.8 |
| Net ODA received[1] (current US$ in millions) | 553.0 | 547.4 | −5.6 | 549.6 | 1400 | +850.4 | 855.9 | 1950 | +1094.1 | 432.1 | 999.0 | +566.9 |
| Age at first marriage[1,4] (mean, women 15-49) | 22.0 (2003)[4] | 22.5 (2017)[4] | +0.5 | 19.1 (2006)[4] | 20.4[4] | +1.3 | 17.8[4] | 18.7 (2016)[4] | +0.9 | 18.3 (2005)[4] | 20.4[4] | +2.1 |
| Total fertility rate[1] (births per woman 15-49) | 3.7 | 2.8 | −0.9 | 5.0 | 3.5 | −1.5 | 6.8 | 4.9 | −1.9 | 5.5 | 4.6 | −0.9 |
| Adolescent fertility rate[1] (births per 1000 girls aged 15–19 y) | 52.0 | 55.0 | +3.0 | 75.0 | 45.0 | −30.0 | 167.0 | 113.0 | −54.0 | 100.0 | 69.0 | −31.0 |
| Contraceptive prevalence, any methods[1] (among WRA 15–49) (%) | 47.0 | 54.0 (2017) | +7.0 | 28.0 | 34.0 | +6.0 | 23.0 (2001) | 43.0 | +20.0 | 11.8 (2005) | 27.8 (2017) | +16.0 |
| Malaria burden among WRA[5] (% of total prevalent cases) | 0.07 | 0.01 | −0.06 | 0.56 | 0.31 | −0.25 | 35.8 | 28.8 | −7.0 | 9.2 | 2.0 | −7.2 |
| SBA[1] (%) | 58.0 | 84.0 (2017) | +26.0 | 23.0 (2001) | 69.0 | +46.0 | 36.0 | 74.0 (2016) | +38.0 | 58.0 | 74.0 | +16.0 |
| ANC 4+ visits[4,6] (%) | 70.4 (2003)[4] | 86.5 (2017)[4] | +16.1 | 28.4[4] | 51.4[4] | +23.0 | 41.9[4] | 59.9 (2016)[4] | +18.0 | 39.8 (2005)[4] | 57.0 (2017)[4] | +17.2 |
| Female adult literacy rate[1] (% of females 15+ y) | 93.0 | 97.0 | +4.0 | 35.4 | 45.0 | +9.6 | 59.0 (2002) | 71.0 | +12.0 | 29.0 (2002) | 40.0 (2017) | +11.0 |
| Female youth literacy rate[1] (% of females 15–24 y) | 96.0 | 99.0 | +3.0 | 53.0 (2005) | 64.0 | +11.0 | 76.2 (2002) | 90.0 | +13.8 | 41.0 | 64.0 (2017) | +23.0 |
| Gender Inequality Index[2] | 0.493 | 0.429 | −0.064 | 0.764 | 0.542 | −0.222 | 0.640 | 0.533 | −0.107 | 0.659 | 0.532 | −0.127 |
| Density of physicians[1] (per 1000) | 1.2 | 0.6 (2017) | −0.6 | 0.6 | 1.0 | +0.4 | 0.047 (2002) | 0.095 (2017) | +0.048 | 0.1 (2004) | 0.1 (2017) | 0.0 |
| Density of nurses and midwives[1] (per 1000) | 4.3 | 4.9 | +0.6 | 0.4 | 0.6 (2017) | +0.2 | 0.7 (2004) | 1.2 | +0.5 | 0.3 (2004) | 0.3 (2017) | 0.0 |
| Child stunting (%) | 33.8 (2003) | 30.3 | −3.5 | 41.4 (2001) | 37.6 | −3.8 | 44.9 | 23.9 | −21.0 | 26.0 | 18.8 | −7.2 |

Abbreviations: ANC, antenatal care; GDP, gross domestic product; ODA, official development assistance; SBA, skilled birth attendance; WRA, women of reproductive age.
[1] World Bank Open Data [14].
[2] UNDP Human Development Reports [15].
[3] WHO/UNICEF Joint Monitoring Program (JMP) for Water Supply, Sanitation, and Hygiene [16].
[4] Demographic and Health Surveys [17].
[5] IHME/GBD [18].
[6] UNICEF [19].

**A**
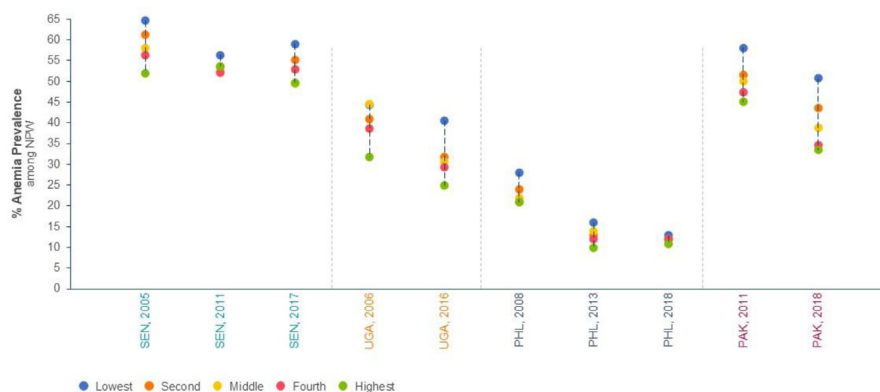


**B**



**FIGURE 3.** Anemia prevalence by wealth quintile, 2005-2018 (A), and anemia prevalence by urban and rural residence, 2005–2018 (B), in WRA anemia exemplar countries. NPW, nonpregnant women; PAK, Pakistan; PHIL, Philippines; SEN, Senegal; UGA, Uganda.

policies and implemented programs in exemplar countries, with a visual depiction of a country's investment, throughout the study period, across sectors and strategies relevant to anemia reduction illustrated in Figure 4. The degree of investment reported (Figure 4) is based on the triangulation of data across case study components and expert opinions of in-country partners.

Direct health sector nutrition strategies implemented in the exemplar countries included micronutrient supplementation initiatives, such as iron–folic acid (IFA) supplementation in pregnancy, vitamin A capsules for lactating women (which may enhance iron utilization and erythropoiesis), as well as programs to improve the supply and uptake/adherence of IFA. The control of infectious diseases and specifically malaria alleviation strategies in Uganda and Senegal were also important for anemia reduction. Key indirect strategies delivered within the health sector included investments in family planning measures, which led to improved contraceptive uptake and reduced unwanted and closely spaced pregnancies among adolescents and older WRA in exemplars, which may have promoted better recovery of iron stores. Better access to health services generally, but especially during pregnancy, through community-based approaches (for example,

community health workers (CHWs) platforms) and improved health system functioning were commonly noted through qualitative research. Strategies delivered outside of the health sector that may have indirectly impacted anemia prevalence included social protection and poverty alleviation schemes (for example, conditional cash transfers) that likely improved food security; empowering of girls and women through minimizing gender disparities and increasing educational attainment; and improving household conditions, including WASH services. Large-scale food fortification (LSFF) efforts, including the fortification of wheat flour with iron in Uganda, Senegal, and the Philippines, may have been highly effective in improving micronutrient intakes, among women with nutrient gaps especially [24]. Finally, we found that for all exemplar countries, moderate to high political and financial support for anemia reduction and the utilization of nutrition and other data for decision making were important contributors to reduction in anemia burden over the study period.

## Drivers of WRA Hb improvements

We utilized Oaxaca–Blinder decomposition [8] to examine the drivers of mean Hb improvement among WRA (Figure 5). Across all

**TABLE 2**

Key policy, strategy, and programmatic investments for anemia reduction in WRA Anemia Exemplar countries.

| Classification of actions | Country | Interventions for anemia reduction | Key strategies |
|---|---|---|---|
| Direct nutrition, health sector | Philippines | • Micronutrient supplementation[1]<br>• ANC[1] | • Universal Micronutrient Supplementation—provision of vitamin A for lactating mothers, and iron for pregnant women<br>• Micronutrient Supplementation Guideline Updates—updates to supplementation guidance in 2003, 2010, and 2017<br>• National ANC Guidelines for Health Facilities—provision of quality ANC including IFA, deworming, and malaria treatment in all birthing centers and health facilities |
| | Uganda | • Malaria control[1]<br>• Micronutrient supplementation | • National Malaria Control Policy and Program –focus on prevention and treatment, including universal community-level distribution of bed nets and improved coverage of IPTp and ACTs<br>• IFA Supplementation Policy—established program to improve IFA supply and adherence among mothers during ANC<br>• VHTs—community health platform improved access to healthcare in underserved communities, enabling greater malaria control, FP and micronutrient supplementation utilization |
| | Senegal | • Micronutrient supplementation[1]<br>• Malaria control[1]<br>• ANC | • Local Micronutrient Supplement Programs—provision of IFA for pregnant and postpartum women in Kolda and Kédougou<br>• National Malaria Control Program—promotion of ITNs, IPTp, and rapid diagnostic testing<br>• Community Health Workers—intermediary between communities and health centers; provide health education on FP, malaria case management, and ANC |
| | Pakistan | • Access to healthcare[1]<br>• Micronutrient supplementation[1]<br>• Access to healthcare/ ANC[1] | • IFA Supplementation—concurrent efforts led by groups like NI and UNICEF with the Government of Pakistan that worked to increase supply and adherence among mothers during ANC<br>• LHWs—community health workers who provide a range of services including door-to-door healthcare provision, IFA, nutrition education, and counseling for FP<br>• Increases in Healthcare Utilization—particularly ANC, driven by the expansion of healthcare access through LHWs and the National MNCH Program |
| Indirect nutrition, health sector | Philippines | • Family planning[1] | • Responsible Parenthood and Reproductive Health Act—universal and free access to modern contraceptives at government health centers |
| | Uganda | • Family planning[1] | • Reproductive Health Commodity Security Program—improved access and counseling for FP at facility and community levels for women and adolescents<br>• VHTs—community health platform improved access to healthcare in underserved communities, enabling greater malaria control, FP, and supplementation utilization<br>• Donor and NGO Support—supported scale-up and implementation of FP and malaria interventions, especially in remote communities |
| | Senegal | • Family planning[1] | • UN and USAID Health Programming—trained healthcare workers on FP interventions<br>• Community Health Workers—intermediary between communities and health centers; provide health education on FP, malaria case management, and ANC |
| | Pakistan | • Counseling on family planning | • Integration of FP and MNCH Services - improved access and counseling for FP as a result of integration of the National MNCH Program with the LHW platform<br>• LHWs—community health workers who provide a range of services including door-to-door healthcare provision, IFA, nutrition education, and counseling for FP |
| Nonhealth sectors (direct and indirect nutrition interventions) | Philippines | • Dietary diversity (direct)<br>• LSFF (direct)<br>• Poverty alleviation (indirect)<br>• WASH improvements (indirect) | • National LSFF Program - fortification of sugar and cooking oil with vitamin A, rice with iron, and wheat flour with vitamin A and iron<br>• CCTs—cash transfers conditional on adherence to health check-ups and family development sessions that improve nutrition<br>• National and Local WASH Programming—construction of sanitary toilets and improved access to safe drinking water |
| | Uganda | • Agricultural improvements (indirect)<br>• LSFF (direct)<br>• WASH improvements (indirect) | • National Agriculture Advisory Services—provide high-yield pest-resistant seedling to enable communities to grow a broader range of nutritious food crops<br>• National LSFF Program—fortification of vegetable oil with vitamin A, wheat and maize flour with zinc, iron, and folic acid<br>• National and Cross-Sectoral WASH Programs—collaboration between the Ministry of Water and Environment and Ministry of Health to improve rural access to safe water and sanitation services |
| | Senegal | • LSFF (direct)<br>• Dietary diversity (direct)<br>• WASH improvements (indirect) | • National LSFF Programs—fortification of wheat flour with iron and folic acid and edible oils with vitamin A<br>• Market Gardens—introduction of diverse foods to rural areas, including certain vegetables<br>• National and Local WASH Programming—improved drinking water supply, especially in rural areas |
| | Pakistan | • Poverty alleviation via social protection programs (indirect)[1]<br>• LSFF (direct)[1] | • BISP—social protection program that targets the poorest/most vulnerable populations; highest coverage rates in Sindh, which also experienced the largest decline in anemia<br>• National LSFF Program—fortification of vegetable oil and ghee with vitamin A steadily improved over time through oversight by the National Fortification Alliance and technical assistance and support from GAIN |

Abbreviations: ACT, artemisinin-based combination therapy; ANC, antenatal care; BISP, Benazir Income Support Program; CCT, conditional cash transfer; FP, family planning; GAIN, Global Alliance for Improved Nutrition; IFA, iron and folic acid; IPTp, intermittent preventive treatment in pregnancy; ITN, insecticide-treated bed net; LHW, Lady Health Worker; LSFF, large-scale food fortification; MNCH, maternal, newborn, and child health; NI, Nutrition International; UN, United Nations; VHT, Village Health Team; WASH, water, sanitation, and hygiene; WRA, women of reproductive age.

[1] Interventions indicate those that were most important for anemia reduction in a given country.

| Category | Area | Philippines | Pakistan | Uganda | Senegal |
|---|---|---|---|---|---|
| Country context | High-level political & donor support for anemia reduction | 🟢 | 🟡 | 🟢 | 🟡 |
|  | Investing in granular data for decision making | 🟢 | 🟢 | 🟡 | 🟡 |
| Other sectoral categories | Addressing food insecurity, especially among marginalized households | 🟢 | 🟢 | 🟡 | 🟢 |
|  | Large-scale food fortification | 🟢 | 🟢 | 🟡 | 🟡 |
|  | Investing in girls' education | 🟢 | 🟡 | 🟡 | 🟡 |
|  | Addressing gender disparities and empowering girls & women | 🟢 | 🔴 | 🟡 | 🟢 |
|  | Improving living conditions | 🟡 | 🟡 | 🔴 | 🟡 |
| Indirect, health sector nutrition strategies | Reducing unwanted pregnancies through family planning initiatives | 🟢 | 🟡 | 🔴 | 🟢 |
|  | Improving access to health services, particularly in pregnancy | 🟢 | 🟢 | 🟡 | 🟢 |
| Direct, health sector nutrition strategy | Addressing infectious diseases, including malaria | 🟢 | 🟢 | 🟡 | 🟢 |
|  | Macro- and micronutrient supplementation initiatives | 🟢 | 🟡 | 🟡 | 🟡 |

⚪ No significant investments made

🔴 Low investments and/or number of initiatives

🟡 Moderate investments and/or number of initiatives

🟢 High investments and/or number of initiatives

**FIGURE 4.** Degree of investments in policy, strategy, and programmatic interventions related to anemia reduction in selected countries.
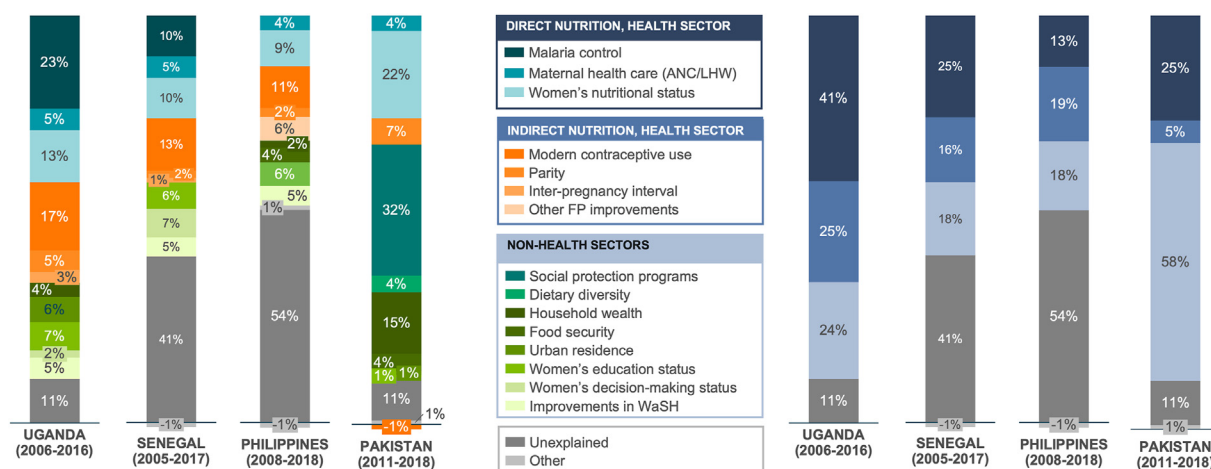


**FIGURE 5.** Decomposition of hemoglobin (Hb) change among nonpregnant women and aggregation of factors into those that are direct and indirect and delivered within and outside of the health sector. [Women's nutritional status: BMI (Philippines, Pakistan, Uganda), use of iron–folic acid supplements (Pakistan, Senegal), serum retinol (Pakistan)]. ANC, antenatal care; FP, family planning; Hb, hemoglobin; LHW, Lady Health Workers; WASH, water, sanitation, and hygiene.

WRA anemia exemplars, the multivariable models explained 46%–89% of the change in mean Hb. Supplemental Table 1 summarizes key drivers of improved Hb across the 4 countries. Several key themes emerged, which also reflect the findings from the qualitative analyses and global systematic review. Of particular note is the split between the contribution of direct/indirect interventions and those delivered within/outside of health, which was similar to findings from the stunting exemplars cross-country analyses [26] and outlines the importance of multisectoral collaboration for anemia reduction among WRA. Contribution of nonhealth sector strategies ranged from 18% to 58% (median 21%) compared with the health sector strategies, which contributed to 30%–66% (median 36.5%) of change (Figure 5). When comparing indirect and direct health sector strategies, contributions were similar (indirect range: 5%–25%, median 17.5%; direct range: 13%–41%, median 25%). It should be noted that there were differences in data availability across countries, so results are not always directly comparable. For example, social protection scheme data and dietary diversity data were available only for Pakistan. Some of these missing data, particularly those that are diet-related (for example, food fortification coverage or intake), are likely contributing to the portion of unexplained change.

From triangulation across quantitative and qualitative research findings, the following key themes emerged across countries: 1) Improved access to and knowledge of family planning methods—across contexts, improved access, knowledge, and utilization of family planning methods, particularly modern contraceptives, proved to be a critical driver for the reduction of unwanted, closely spaced, and high-risk pregnancies that introduce increased blood and nutrient requirements for women and thus increase their risk of anemia. Long-acting injectable contraceptives were particularly important for more rural and remote communities. 2) Micronutrient supplementation through high-quality antenatal care (ANC) platforms—exemplar

countries with micronutrient supplementation programs, including vitamin A for lactating mothers and IFA supplementation in pregnancy, were found to be highly effective for anemia reduction among WRA through improved micronutrient status. National ANC guidelines that ensured quality of care and provision of micronutrient supplementation were critical enablers. *3*) Malaria control programs—in malaria-endemic regions, including Uganda and Senegal, a focus on both prevention (that is, insecticide-treated bed nets, intermittent preventive treatment in pregnancy) and treatment (that is, artemisinin-based combination therapies) via community-level access and integrated community case management of malaria were critical to reduce malaria burden and the associated risk of anemia. *4*) Social protection programs for vulnerable populations—conditional cash transfer (CCT) and other social protection programs proved to be associated with improved anemia outcomes. Our qualitative research suggests that these programs improve access to basic needs, including healthcare and better quality diets for the poor. Particularly effective were CCTs that were conditional on adherence to health check-ups and nutrition education sessions.

In addition, we have identified several cross-cutting themes that enabled success through supporting the delivery of interventions: *1*) Political support for nutrition and multisectoral coordination—political commitment to nutrition, and anemia specifically, with a platform for multisectoral coordination to deliver nutrition interventions and access to critical data for policy advocacy toward nutrition was a recurring theme for success. For example, in Uganda, the Nutrition Action Plan established a platform for coordination across Ministries of Health and Agriculture, and Food and Nutrition stakeholders including for malaria control, family planning, and agricultural improvement programs. *2*) Program quality, effective targeting, and implementation—particularly in the Philippines, high-quality tailored programming targeted at vulnerable and historically underserved populations was critical in equitably improving anemia outcomes across wealth quintiles, education levels, and rural populations. *3*) Health systems strengthening and community health platforms—improved healthcare access at the community level via local facilities and community health platforms proved critical in enabling success for both direct and indirect health sector interventions (that is, malaria control, family planning, ANC, and micronutrient supplementation). Community platforms include the village health teams (VHTs) in Uganda, the Lady Health Workers Program (LHWP) in Pakistan, and community health workers in Senegal. *4*) Women's education and empowerment—across all exemplars, initiatives to improve women's access to education led to greater empowerment and probably increased access to economic resources and opportunities, in addition to improved knowledge of nutritious foods, healthy diets, and anemia outcomes.

## Discussion

The 4 countries highlighted in this study have demonstrated some significant progress in anemia reduction among WRA, achieved through multisectoral action and political commitment. The findings illustrate that investments in health and indirect nutrition-relevant sectors are hugely important in countries where these programs are linked to health and well-being at a population level. Across exemplar countries that we studied, we found that key themes emerged, but with varying importance, including improvements in family planning, malaria control, ANC, LSFF, and women's nutrition. These themes overlapped with the findings of the global systematic review [11], which also highlighted the importance of healthcare utilization during

pregnancy, family planning, women's nutrition, access to fortified foods, household wealth, educational attainment, and WASH. The review also pointed to the importance of context, and the variations in strength of association between drivers and WRA anemia reduction depending on setting. Mexico, although not an exemplar, also provided lessons in the importance of program continuity and effective implementation to ensure an ongoing reduction in WRA anemia [26]. This requires strong government support, sustained financing, and monitoring and evaluation to ensure that anemia-related programs are reaching those who need them most.

The findings of this study also underscored challenges associated with achieving low levels, or complete elimination of disease burden. This is reflected in the fact that WRA anemia burden in some exemplars (Senegal and Pakistan) continues to be classified as a severe public health problem ($\geq$40% prevalence) at study endline, despite demonstrable significant reductions over time. To achieve the 2030 WHA anemia targets, average annual rates of reduction should reach 3.8% in Pakistan and 7.3% in Uganda, with the Philippines (5.0%) and Senegal (5.3%) falling in the middle. Global analyses of anemia reduction have also demonstrated greater positive shifts among populations with severe and moderate anemia, and less progress within the mildly anemic groups [4]. It is possible that, because of the outsized reductions in moderate and severe anemia, respectively, overall anemia prevalence reductions may actually not capture the full degree of improvement [1].

These challenges are partly due to the complex etiology of anemia, given that only ~50%–60% is potentially related to iron deficiency and is, therefore, amenable to change through improving nutrient intake/absorption or response to infectious disease [27]. Recent individual-level analyses have revealed that iron deficiency among nonpregnant WRA was 20% or more in half (10/20) of all country-level datasets examined [28]. It has also been shown that 65% and 71% of anemia is attributable to iron deficiency in countries with moderate and low infection rates, respectively, whereas iron deficiency tends to be much lower in countries with higher infection rates [29]. This highlights the need for a multisectoral approach to decrease anemia that adapts not only to nutrition and infections, but also to the sociodemographic characteristics of populations.

Several limitations should be recognized in considering these findings and their implications. Similar to other exemplars studies [25], poor data availability was an issue, especially for the quantitative study components. This is particularly true for food security, dietary intake and quality data, and potential impact of climate change. However, these data availability limitations also relate to a lack of information on key micronutrient and inflammation-related indicators [30], which makes it difficult to assess trends related to iron deficiency anemia or iron status. Limited literature has not been able to consistently demonstrate a high sensitivity and specificity of point-of-care methods for measuring Hb, which is necessary for the accurate determination of anemia prevalence in populations [31]. Results from a WHO review are forthcoming that will help guide decision making for sample collection and analysis when assessing Hb at the population level [32]. Disentangling nutritional anemia from other etiologies (that is, infection, pregnancy, and genetic) is also challenging given the paucity of information at national and subnational levels, especially in countries where anemia remains a severe public health issue. The lack of information on multiple micronutrient deficiencies also limits our understanding of other drivers of anemia, especially those related to optimizing hematopoiesis in populations with widespread nutritional deficiencies. We had limited programmatic information on nutrition financing and multicomponent nutrition programs, which posed

challenges in interpreting relative effectiveness and subnational trends. For example, quality-of-care assessment for nutritional components of ANC, like IFA, remained a challenge, making it difficult to assess effective coverage and its impact on anemia identification and reduction. This study examined anemia among WRA, with the quantitative study focused on nonpregnant women (NPW), so it should be noted that findings are not necessarily generalizable to anemia during pregnancy. However, across all 4 countries, ANC receipt during last pregnancy emerged as an important driver of Hb/anemia improvements among NPW, underscoring how crucial quality obstetric care is for women's continued health and well-being, with its effects lasting well beyond the antenatal and postnatal period. Finally, the results of this cross-country analysis are not necessarily generalizable to every country context, given the varying anemia etiologies (and, relatedly, successful strategies for reduction) that we have discussed above. However, given the regional representation across these exemplars, we believe that we have likely captured the major drivers of positive change that are widely applicable.

The anemia exemplars studies underscore the importance of the range of direct/indirect and health/other sectoral interventions of multisectoral investments in addressing the social determinants of health and well-being across the life course. These also include investments in the WASH sector and, where the disease burden is substantial, strategies to reduce exposure to and treatment for soil-transmitted helminth infestation. Although we have noted many common themes, the wide variation in the proportion of change in Hb explained is likely attributable to country-specific anemia etiology, data availability, and policies and programs instituted by country governments in the previous 2 decades. There were insufficient data across countries to assess the prevalence of anemia in subsets, such as adolescent girls, which could provide insight into background rates and progression of anemia from childhood to adulthood. However, other studies have underscored the importance of improving adolescent nutrition to improve nutrition during pregnancy, birth outcomes, and early childhood [33, 34].

## Way forward for accelerating country-level anemia reduction

Key investments needed to ensure country-level progress to reduce the anemia burden among WRA globally will require accelerated implementation of strategies in populations with WRA anemia classified as a moderate to severe public health problem.

- First, there is the necessary ongoing implementation of context-specific anemia reduction interventions at scale (for example, LSFF) that are based on country-level assessments of data and multisectoral national plans for anemia reduction. Countries should double-down on these no-regrets actions, in addition to investing in additional strategies, as outlined below.
- Investing in indirect nutrition interventions and strategies within the health and nonhealth sectors—investments are needed that target across social determinants of health, particularly for family planning access and education, poverty reduction via social protection programs, and malaria control in endemic regions.
- Ensuring effective program targeting for underserved populations to reduce disparities—in designing programs for women's health and nutrition, including anemia, program targeting for vulnerable populations will be critical to ensure access, coverage, and utilization of interventions across populations and drives equitable reduction in anemia burden; interventions with higher accessibility and ease of use (for example, injectable contraceptives for remote communities) can help support program targeting and effectiveness for underserved populations.

- Urgent efforts are needed to improved data quality and relevant information gathering at lower administrative units such as districts. Currently, the relationship between dietary intake, micronutrient status, and anemia is difficult to disentangle due to the lack of data. Efforts and investments are required to improve systems to capture dietary intake and micronutrient status, and this will require an investment in linking nutrition information with health information systems datasets like DHS and data quality control measures.
- The nutrition community needs to better understand the "limiting factors" that are impeding progress toward anemia reduction. This includes a more detailed and context-specific understanding of anemia etiology, but also the role of infection and inflammation in relation to Hb improvements and potential interventions, both of which require enhanced country-level data collection and analysis to determine causes of anemia and appropriate solutions.
- Finally, anemia control measures must move away from lamenting the lack of progress every few years to a much more concerted and real-time strategy to assess national and subnational trends and program quality and for effective and timely course correction. This strategy can be largely informed by the findings from these exemplar countries and will be key to improve the health and well-being of WRA.

## Author contributions

The authors' responsibilities were as follows – ZAB: conceived the project; EU, LMN, RI, NK, SFT, FB, PC, WF: assisted with the research design; AO, EK: conducted research; ZB, AO, EK, DGF: analyzed data; ZB, EK, DGF, NK, FB, SFT: contextualized and interpreted results; ZAB, EK, DGF: wrote the paper; ZAB: had primary responsibility for final content and is the guarantor; and all authors: read and approved the final manuscript.

## Conflict of interest

ZAB is the principal investigator for the Global Exemplars in Maternal Anemia project funded by the Gates Foundation. RI is the Director of the Maternal, Newborn, Child Nutrition & Health portfolio at the Gates Foundation and a member of the Technical Advisory Group for the Global Exemplar in Maternal Anemia project. The other authors report no conflicts of interest. The views expressed in this publication are those of the author(s) and do not necessarily reflect the views of FAO.

## Data availability

Data on economic, demographic, and other contextual factors across exemplar countries are publicly available at the World Bank,

UNDP, WHO/UNICEF JMP, DHS, IHME/GBD and UNICEF websites. Data used for the cross-country analyses derive from individual country case studies and are subject to restrictions depending on each context.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajcnut.2024.11.031.

## References

[1] GBD 2021 Anaemia Collaborators, Prevalence, years lived with disability, and trends in anaemia burden by severity and cause, 1990–2021: findings from the Global Burden of Disease Study 2021, Lancet Haematol 10 (2023) e713–e734, https://doi.org/10.1016/S2352-3026(23)00160-6.

[2] S. Safiri, A.A. Kolahi, M. Noori, S.A. Nejadghaderi, N. Karamzad, N.L. Bragazzi, et al., Burden of anemia and its underlying causes in 204 countries and territories, 1990-2019: results from the Global Burden of Disease Study 2019, J. Hematol. Oncol. 14 (1) (2021) 185.

[3] D. Kinyoki, A.E. Osgood-Zimmerman, N.V. Bhattacharjee, Local Burden of Disease Anaemia Collaborators, N.J. Kassebaum, S.I. Hay, Anemia prevalence in women of reproductive age in low- and middle-income countries between 2000 and 2018, Nat. Med. 27 (10) (2021) 1761–1782.

[4] G.A. Stevens, C.J. Paciorek, M.C. Flores-Urrutia, E. Borghi, S. Namaste, J.P. Wirth, et al., National, regional, and global estimates of anaemia by severity in women and children for 2000-19: a pooled analysis of population-representative data, Lancet Glob. Health 10 (5) (2022) e627–e639.

[5] Sixty-fifth World Health Assembly, Resolutions and Decisions [Internet] (2012) [cited 4 July, 2023], https://apps.who.int/gb/DGNP/pdf_files/A65_REC1-en.pdf.

[6] P. Christian, Anemia in women–an intractable problem that requires innovative solutions, Nat. Med. 27 (10) (2021) 1675–1677.

[7] Exemplars in Global Health, Making better decisions in global health: understand positive outliers to inform policy and practice [Internet] (2023) [cited 23 June, 2023], https://www.exemplars.health.

[8] A. Owais, M. Islam, A. Ataullahjan, Z.A. Bhutta, Understanding the determinants of anemia reduction among women of reproductive age: exemplar country case studies' methodology, Am. J. Clin. Nutr. 122 (S1) (2025) S1–S7.

[9] IHME, Global Burden of Disease Study 2019 (GBD 2019) data resources [Internet]. 2019. Available from: https://ghdx.healthdata.org/gbd-2019.

[10] WHO, The Global Health Observatory: Prevalence of anaemia in women of reproductive age (aged 15-49) [Internet] (2021). https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-anaemia-in-women-of-reproductive-age-(-).

[11] A. Owais, C. Merritt, C. Lee, Z.A. Bhutta, Anemia among women of reproductive age: an overview of global burden, trends, determinants, and drivers of progress in low- and middle-income countries, Nutrients 13 (8) (2021) 2745.

[12] R.E. Black, C.G. Victora, S.P. Walker, Z.A. Bhutta, P. Christian, M. de Onis, et al., Maternal and child undernutrition and overweight in low-income and middle-income countries, Lancet 382 (9890) (2013) 427–451.

[13] WHO, Anaemia, Nutrition Landscape Information System (NLiS) [Internet] (2023). https://www.who.int/data/nutrition/nlis/info/anaemia.

[14] WHO, World bank open data [Internet] (2023). https://data.worldbank.org/.

[15] UNDP, Human development summary capturing achievements in the HDI and complementary metrics that estimate gender gaps, inequality, planetary pressures and poverty [Internet] (2023). https://hdr.undp.org/data-center/specific-country-data#/countries/.

[16] WHO/UNICEF JMP, The WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene (JMP) has reported country, regional and global estimates of progress on drinking water, sanitation and hygiene (WASH) since 1990 [Internet] (2023). https://washdata.org/data/household#!/dashboard/new.

[17] DHS Program, Demographic and Health Surveys [Internet] (2023). https://dhsprogram.com/search/index.cfm?bydoctype=publication&bypubtype=5.

[18] The Institute for Health Metrics and Evaluation (IHME), GBD compare [Internet] (2023). https://vizhub.healthdata.org/gbd-compare/.

[19] UNICEF, UNICEF Data Warehouse [Internet] (2023) [cited 24 July, 2023], https://data.unicef.org/resources/data_explorer/unicef_f/?ag=UNICEF&df=GLOBAL_DATAFLOW&ver=1.0&dq=MEX.MNCH_ANC4.&startPeriod=1970&endPeriod=2023.

[20] I. Angeles-Agdeppa, A. Owais, E.A. Goyena, C.E. Merritt, C. Lee, P. Rattan, et al., Drivers of anemia reduction among women of reproductive age in the Philippines: a country case study, Am. J. Clin. Nutr. 19 (24) (2024) S0002–9165, https://doi.org/10.1016/j.ajcnut.2024.06.005, 00529-X.

[21] R.B. Kajjura, A. Owais, C. Lee, H. Ahsan, C.E. Merritt, P. Rattan, et al., Drivers of anemia reduction among women of reproductive age in Uganda: a country case study, Am. J. Clin. Nutr. 122 (S1) (2025) S36–S45.

[22] N.F. Ndiaye, A. Owais, H. Diop, C. Lee, C.E. Merritt, D. González-Fernández, et al., Drivers of anemia reduction among women of reproductive age in Senegal: a country case study, Am. J. Clin. Nutr. 20 (24) (2024) S0002–9165, https://doi.org/10.1016/j.ajcnut.2024.05.031, 00530-6.

[23] A. Owais, et al., Drivers of anemia reduction among women of reproductive age in Pakistan: a mixed-methods country case study, Am. J. Clin. Nutr. 122 (S1) (2025) S46–S56.

[24] E.C. Keats, L.M. Neufeld, G.S. Garrett, M.N.N. Mbuya, Z.A. Bhutta, Improved micronutrient status and health outcomes in low- and middle-income countries following large-scale fortification: evidence from a systematic review and meta-analysis, Am. J. Clin. Nutr. 109 (6) (2019) 1696–1708.

[25] Z.A. Bhutta, N. Akseer, E.C. Keats, T. Vaivada, S. Baker, S.E. Horton, et al., How countries can reduce child stunting at scale: lessons from exemplar countries, Am. J. Clin. Nutr. 112 (Suppl 2) (2020) 894S–904S.

[26] S. Pacheco Miranda, A. Owais, M.V. Lopez, E.K. Herrera, M. Unar-Munguía, F.M. Rodriguez, et al., Factors affecting anemia among women of reproductive age in Mexico: a country case study, Am. J. Clin. Nutr. 122 (S1) (2025) S22–S35.

[27] N.J. Kassebaum, GBD 2013 Anemia Collaborators, The global burden of anemia, Hematol. Oncol. Clin. North Am. 30 (2) (2016) 247–308.

[28] G.A. Stevens, T. Beal, M.N.N. Mbuya, H. Luo, L.M. Neufeld, Micronutrient deficiencies among preschool-aged children and women of reproductive age worldwide: a pooled analysis of individual-level data from population-representative surveys, Lancet. Glob. Health 10 (11) (2022) e1590–e1599.

[29] J.P. Wirth, B.A. Woodruff, R. Engle-Stone, S.M. Namaste, V.J. Temple, N. Petry, et al., Predictors of anemia in women of reproductive age: Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project, Am. J. Clin. Nutr. 106 (Suppl 1) (2017) 416s–427s.

[30] S.M. Namaste, G.J. Aaron, R. Varadhan, J.M. Peerson, P.S. Suchdev, Methodologic approach for the Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) project, Am. J. Clin. Nutr. 106 (Suppl 1) (2017) 333s–347s.

[31] R.D. Whitehead Jr., Z. Mei, C. Mapango, M.E.D. Jefferds, Methods and analyzers for hemoglobin measurement in clinical laboratories and field settings, Ann. N. Y. Acad. Sci. 1450 (1) (2019) 147–171.

[32] WHO, Developing a systematic review on accuracy and precision of data collection and analytical methods for haemoglobin assessment in populations, Call for authors [Internet] (2023) [cited 20 July, 2023], https://www.who.int/news-room/articles-detail/call-for-authors-developing-a-systematic-review-on-accuracy-and-precision-of-data-collection-and-analytical-methods-for-haemoglobin-assessment-in-populations.

[33] N. Akseer, E.C. Keats, P. Thurairajah, S. Cousens, A.P. Bétran, B.M. Oaks, et al., Characteristics and birth outcomes of pregnant adolescents compared to older women: an analysis of individual level data from 140,000 mothers from 20 RCTs, EClinicalmedicine 45 (2022) 101309.

[34] E.C. Keats, N. Akseer, P. Thurairajah, S. Cousens, Z.A. Bhutta, Multiple-micronutrient supplementation in pregnant adolescents in low- and middle-income countries: a systematic review and a meta-analysis of individual participant data, Nutr. Rev. 80 (2) (2022) 141–156.