Factors associated with anaemia in a nationally representative sample of nonpregnant women of reproductive age in Nepal

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Abstract
We used cross-sectional data from the 2016 Nepal National Micronutrient Status Survey to evaluate factors associated with anaemia among a nationally representative sample of nonpregnant women 15–49 years (n = 1, 918). Haemoglobin, biomarkers of iron status and other micronutrients, infection, inflammation, and blood disorders were assessed from venous blood. Soil-transmitted helminth and Helicobacter pylori infections were assessed from stool. Sociodemographic, household, and health characteristics and diet were ascertained by interview. We conducted bivariate analyses between candidate predictors and anaemia (haemoglobin < 12.0 g/dL, altitude- and smoking-adjusted). Candidate predictors that were significant in bivariate models (P < 0.05) were included in the multivariable logistic regression model, accounting for complex sampling design. Anaemia prevalence was 20.2% (95% confidence interval [CI] [17.6, 22.8]). Associated with reduced anaemia odds were living in the Mountain and Hill ecological zones relative to the Terai (adjusted odds ratio [AOR] 0.35, 95% CI [0.21, 0.60] and AOR 0.41, 95% CI [0.29, 0.59], respectively), recent cough (AOR 0.56, 95% CI [0.38, 0.82]), hormonal contraceptive use (AOR 0.58; 95% CI [0.38, 0.88]), ln ferritin (micrograms per litre; AOR 0.43, 95% CI [0.35, 0.54]), and ln retinol binding protein (micrograms per litre; AOR 0.20, 95% CI [0.11, 0.37]). Residing in a house with an earth floor (AOR 1.74, 95% CI [1.18, 2.56]), glucose-6-phosphate dehydrogenase deficiency (AOR 2.44, 95% CI [1.66, 3.60]), and haemoglobinopathies (AOR 6.15, 95% CI [3.09, 12.26]) were associated with increased anaemia odds. Interventions that improve micronutrient status, ensure access to hormonal birth control, and address common infections in Nepal could reduce anaemia prevalence.

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INTRODUCTION

Worldwide, anaemia affects an estimated 29% of nonpregnant women of reproductive age (Stevens et al., 2013) and is thought to contribute to 115,000 maternal deaths annually (Ezzati, Lopez, Rodgers, & Murray, 2004). In South, East, and South-East Asia, approximately a quarter of the anaemia burden is thought to be due to iron deficiency (Petry et al., 2016); however, additional factors contribute to anaemia through underproduction or excessive loss of red blood cells. Deficiency in micronutrients other than iron, infection, inflammation, blood disorders, and blood loss from worm infection, menses, or other causes directly contribute to anaemia (WHO, 2017a) whereas intermediate causes, such as dietary intake, are influenced by food security, access to health services, and sociodemographic characteristics.

Understanding the context-specific factors associated with anaemia is key to developing effective, evidence-based public health programmes and policies. Despite national-level initiatives to reduce iron deficiency and anaemia, anaemia prevalence in Nepal has increased. According to the Demographic and Health Surveys (DHS), anaemia prevalence among women 15–49 years increased from 35% in 2011 to 41% in 2016 (Ministry of Health and Population [Nepal], 2012; Ministry of Health and Population [Nepal], 2017). The physiology of anaemia is relatively well understood globally; however, less is known about context-specific determinants of anaemia among women in Nepal. Previous studies of the risk factors for anaemia among nonpregnant women of reproductive age in Nepal have evaluated iron status, reproductive history, and sociodemographic characteristics (Chandyo et al., 2007; Chandyo et al., 2016; Gautam, Min, Kim, & Jeong, 2019) but have not evaluated many known potential causes, including deficiencies in micronutrients other than iron, infection, inflammation, and blood disorders.

To address this important knowledge gap, the Nepal National Micronutrient Status Survey (NNMSS) collected data on potential causes of anaemia to inform programmatic decision-making (Ministry of Health and Population [Nepal], 2018). The NNMSS is comprehensive, nationally representative survey that collected data on potential causes of anaemia—including multiple biomarkers which are rarely included in large-scale surveys due to logistical complications and cost.

The objective of these analyses was to identify factors associated with anaemia among nonpregnant women of reproductive age 15–49 years in Nepal.

METHODS

2.1 Study population

New ERA implemented the 2016 NNMSS with support from the Ministry of Health and Population of Nepal, United States Agency for International Development, UNICEF Nepal, and the United States Centers for Disease Control and Prevention. The survey used stratified multistage cluster sampling without replacement. In total, 180 clusters were selected from 15 strata using probability proportional to size. In each cluster, twenty-four households were selected by systematic sampling (n = 4,320). After enumerating all nonpregnant women 15–49 years (henceforth referred to as WRA) in the selected households, 12 were selected from each cluster at random (n = 2,160). Sample size was calculated assuming an anaemia prevalence of 35% based on prevalence among WRA in the 2011 DHS, a precision of ±3.5% nationally, a design effect of 2.25, a household response rate of 95%, and an individual response rate of 90% (8). The NNMSS Report has complete details about the study area, study population, and sampling strategy (Ministry of Health and Population [Nepal], 2018).
Of the 2, 160 WRA sampled, 2, 144 consented to participate (99.2%). We excluded participants with missing or invalid values for haemoglobin (n = 8), blood-based indicators (n = 13), anthropometry (n = 5), stool-based indicators (n = 197), and questionnaire data (n = 3), for a final analytic sample of 1, 918 women (89.4%). With the exception of marital/cohabitation status and ecological zone, WRA who were excluded from the analytic sample did not differ with respect to other major sociodemographic characteristics from those included (Table S1).

Ethical approval for the study was granted by the Nepal Health Research Council. Women aged 15–17 years provided oral assent for interview and biological data collection, and their legal guardians/parents provided signed informed consent. Women aged 18 years and older provided signed informed consent.

2.2 | Data collection

2.2.1 | Anthropometry

Using an electronic seca scale, weight with light clothing was measured to the nearest 100 g. Standing height was measured without shoes to the nearest 0.1 cm using a standard height-measuring board (ShorrBoard).

2.2.2 | Biological specimens

Blood and stool samples were collected to assess micronutrient, infection, and inflammation status and blood disorders. Nonfasted blood was collected at the time of interview at the household, and stool samples were retrieved from households within 24 hr.

Following standard procedures, trained phlebotomists collected venous blood samples. A mobile lab station was set up in each cluster where laboratory technicians and pathologists processed and read specimens. In the households, survey staff analysed haemoglobin (HemoCue® Hb 301 analyzer), malaria (CareStart™ malaria antigen combo rapid test kit for Plasmodium falciparum and Plasmodium vivax), and visceral leishmaniosis (IT LEISH rk39 antigen rapid test kit). For blood disorder analysis, whole blood samples were transported to the pathology laboratory in Kathmandu, Nepal within 7 days of sample collection, maintaining the cold chain. Plasma, serum, and stool samples were transported to the National Public Health Laboratory and stored in −86°C freezers until analysis.

Blood disorders including α- and β-thalassemia, sickle cell, haemoglobin E, and glucose-6- phosphate dehydrogenase deficiency (G6PD) were analysed using complete blood count, high performance liquid chromatography, DNA analysis, and PCR (Access Bio Korea Inc. CareStart™ G6PD Biosensor). Red blood cell (RBC) folate was analysed using a microbiological assay (Pfeiffer et al., 2011). Serum zinc was analysed using atomic absorption spectrometry. C-reactive protein (CRP), α-1- acid glycoprotein (AGP), serum ferritin, transferrin receptor (sTfR), and retinol binding protein (RBP) were assessed using a sandwich enzyme-linked immunosorbent assay (Erhardt, Estes, Pfeiffer, Biesalski, & Craft, 2004). Using microscopy examination and the Kato Katz method, pathologists examined stool samples for soil-transmitted helminths (STH; hookworm, Ascaris, and Trichuris) (WHO, 1994). Stool samples were analyzed for H. pylori using an immunoassay (EDI TM Fecal H. pylori antigen enzyme-linked immunosorbent assay kit).

2.2.3 | Sociodemographic, health, and other questionnaire data

Housing, water, and sanitation characteristics; sociodemographic characteristics; marital status; schooling; reproductive history; hormonal contraceptive use; consumption of Food and Agriculture Organization (FAO) food groups and tea; micronutrient supplement intake; pica; morbidity recall; receipt of deworming tablets; and smoking status were collected by an interview-administered questionnaire. Household food security was assessed using a 9-item questionnaire about access to adequate and preferred foods (Ballard, Coates, Swindale, & Deitchler, 2011). GPS coordinates taken at the household and were used to estimate altitude.

2.3 | Variable specification

2.3.1 | Anaemia

Haemoglobin was adjusted for altitude and smoking using standard procedures (WHO, 2017a). We defined anaemia as altitude- and smoking-adjusted Hb <12.0 g/ dL (WHO, 2017a). Anaemia severity was classified as mild (adjusted Hb 11.0–11.9 g/ dL), moderate (adjusted Hb 8.0–10.9 g/ dL), and severe (adjusted Hb < 8.0 g/ dL; WHO, 2017a).

2.3.2 | Anthropometry

We calculated a body mass index (BMI) as weight (kilogrammes) divided by height (metres) squared. BMI categories were defined as underweight (BMI <18.5 kg/ m²), normal weight (BMI 18.5–24.9 kg/ m²), and overweight/obesity (BMI ≥25.0 kg/ m²; WHO, 2004).

2.3.3 | Biomarkers of nutritional status

To correct for the role of inflammation on biomarkers of iron status, we regression-adjusted ferritin and sTfR to a pooled country reference using CRP and AGP (ferritin) or AGP only (sTfR; Namaste et al., 2017). Iron deficiency was defined as adjusted ferritin <15.0 μg/ L (WHO, 2017a) and iron deficiency anaemia as adjusted Hb <12.0 g/ dL and adjusted ferritin <15.0 μg/ L. Vitamin A deficiency
was defined as RBP <0.64 μmol/ L. The population-specific RBP cut-point equivalent to serum retinol <0.70 μmol/ L was calculated by regressing RBP on retinol in a subsample of 100 WRA for whom serum retinol was assessed using high performance liquid chromatography from the same blood draw as RBP (WHO, 1996). Risk of folate deficiency was classified as RBC folate <305.0 nmol/ L based on risk of macrocytic anaemia (Institute of Medicine, 1998). We classified zinc deficiency as zinc <66.0 μg/ dL for nonfasted, morning samples (i.e. before 12pm) and < 59.0 μg/ dL for nonfasted, afternoon samples (i.e. after 12pm) (IZINC, 2012).

2.3.4 | Infection and inflammation

We categorized blood disorders into two groups: (a) haemoglobinopathies (thalassemias, hemoglobin E, and sickle cell) and (b) G6PD. We included malaria, H. pylori, visceral leishmaniosis, recent fever, diarrhoea, and cough as binary variables (yes/no). STH infection was defined as presence of any eggs in stools versus no eggs. CRP and AGP were included as continuous variables. Inflammation was defined as elevated CRP (>5 mg/ L) or elevated AGP (>1 g/ L; Namaste et al., 2017).

2.3.5 | Dietary intake

We included consumption of flesh, organ, or blood-based foods, legumes, green leafy vegetables, vitamin A-rich fruits and vegetables, and tea (an iron inhibitor) the day preceding the survey as binary variables (yes/no). Minimum dietary diversity was defined as intake from five or more of 10 main FAO food groups the day preceding the survey (FAO and FHI 360, 2016). Pica was defined as any consumption of clay, earth, termite mounds, ice, uncooked rice, or starch during the 7 days preceding the survey.

2.3.6 | Reproductive and other health variables

We included lactation status, giving birth during the 5 years preceding the survey, hormonal contraceptive use, intake of any micronutrient supplements (multivitamin, iron, iron-folic acid, vitamin A, and/or zinc) the week preceding the survey, and receipt of deworming tablets during the 6 months preceding the survey as binary variables (yes/no).

2.3.7 | Sociodemographic variables

Age groups were categorized as 15–29 years and 30–49 years. We classified marital status as married or cohabitating vs. other. Grades of schooling completed was categorized as zero grades, 1–8 grades, and ≥9 grades. We categorized ethnicity as Brahmin/ Chettri, Dalit, Janajati, other Terai ethnicities (including Terai/ Madhesi ethnicities but not including Terai or Madhesi Brahmin or Chettri), Newar, and Muslim, according to government classifications (Government of Nepal Central Bureau of Statistics, 2014). We defined household location in accordance with Nepal administrative classifications for rurality (rural vs. urban) and ecological zone (Mountain, Hill, or Terai [Plains]). We created a household wealth score using principal components analysis of housing characteristics and assets. We then divided wealth into tertiles. Improved water source was defined as piped water, tube well borehole, protected well or spring, stone tap, rainwater, or bottled water (WHO and UNICEF, 2017). We defined severe household food insecurity as households who often cut back on meal size or number of meals and/or ever experienced any of the three most severe conditions (there no food to eat of any kind in the household because of lack of resources to get food; any household member goes to sleep at night hungry because there was not enough food; and any household member goes a whole day and night without eating anything because there was not enough food; Ballard et al., 2011). Improved water source, open defecation, earth floor, and severe household food insecurity were included as binary variables (yes/no).

2.4 | Statistical methods

We evaluated differences in sociodemographic and health characteristics by anaemia status using Rao–Scott chi square tests and linear contrast tests for categorical and continuous variables, respectively. We used Rao–Scott chi square tests rather than Pearson to allow for complex sample design correction.

We conducted bivariate analyses between candidate predictors and anaemia status. We tested variables with multiple categories as a group. Non-normally distributed variables were log transformed. Where candidate predictors had $P < 0.05$ in bivariate models, we included them in the multivariable logistic regression model. To identify collinearity, we used eigenvalues <0.01 and conditionality index >30.

We conducted all analyses in SAS v.9.4 (SAS Institute Inc., Cary, North Carolina). All analyses were weighted and accounted for complex sample design. We set statistical significance a priori at two-sided $P < .05$.

3 | RESULTS

In total, 20.2% (95% confidence interval [CI] [17.6, 22.8]) of WRA had anaemia, of which 62.7% (95% CI [57.0, 68.5]) were mild cases and 35.3% (95% CI [29.1, 41.4]) were moderate cases (Table 1). Thirty-eight percent (38.8%, 95% CI [32.1, 45.6]) of WRA with anaemia had iron deficiency.

Candidate predictors ($P < 0.05$ in bivariate analyses) in the initial model included both nonmodifiable (ecological zone, ethnicity, G6PD and haemoglobinopathies) and potentially modifiable factors (open defecation, earth floor, having consumed tea the day preceding the survey, micronutrient status [ferritin; stTfR; RBP], BMI category, cough, and hormonal contraceptive use). Because we identified potential collinearity between ferritin and stTfR, we removed stTfR.
TABLE 1  Selected sociodemographic and health characteristics of nonpregnant women 15–49 years, by anaemia status Nepal National Micronutrient Status Survey, Nepal, 2016 (n = 1, 918)

|               | Anaemia* (n = 355, 20.2%; 95% CI [17.6, 22.8]) | No anaemia* (n = 1, 563, 79.8%; 95% CI [77.1, 82.4]) | Total (n = 1, 918) |
|---------------|--------------------------------------------------|--------------------------------------------------------|-------------------|
|               | n | 95% CI | n | 95% CI | p<br> | n | 95% CI |
| **Sociodemographic characteristics** | | | | | | | |
| Age group, % | 0.4 | | | | | | |
| 15–29 years | 169 | 47.8 (41.8, 53.7) | 801 | 50.9 (47.6, 54.1) | 970 | 50.2 (47.6, 52.8) | | |
| 30–49 years | 186 | 52.2 (46.3, 58.2) | 762 | 49.1 (45.9, 52.4) | 948 | 49.8 (47.2, 52.4) | | |
| Lactating, % | 0.4 | | | | | | |
| Rural | 314 | 88.0 (80.8, 95.2) | 1,338 | 86.1 (80.0, 92.2) | 1,652 | 86.5 (80.5, 92.5) | | |
| Urban | 41 | 12.0 (4.8, 19.2) | 225 | 13.9 (7.8, 20.0) | 266 | 13.5 (7.5, 19.5) | | |
| **Ecological zone, %** | <0.0001 | | | | | | |
| Mountain | 33 | 3.5 (2.1, 4.9) | 288 | 7.1 (6.3, 7.9) | 321 | 6.4 (5.6, 7.1) | | |
| Hill | 109 | 26.8 (20.8, 32.7) | 711 | 48.7 (45.5, 51.9) | 820 | 44.3 (41.5, 47.1) | | |
| Terai | 213 | 69.7 (63.6, 75.8) | 564 | 44.2 (41.1, 47.3) | 777 | 49.3 (46.6, 52.0) | | |
| **Household wealth quintile** | 0.06 | | | | | | |
| Poorest | 96 | 20.1 (14.6, 25.6) | 495 | 22.9 (18.8, 27.1) | 591 | 22.4 (18.4, 26.3) | | |
| Middle | 142 | 41.2 (34.4, 48.0) | 516 | 33.1 (28.2, 38.0) | 658 | 34.8 (30.3, 39.2) | | |
| Wealthiest | 117 | 38.6 (31.0, 46.3) | 552 | 44.0 (37.0, 50.9) | 669 | 42.9 (36.4, 49.4) | | |
| **Ethnicity, %** | 0.03 | | | | | | |
| Brahmin or Chettri | 120 | 32.7 (25.1, 40.2) | 655 | 38.8 (33.3, 44.3) | 775 | 37.5 (32.2, 42.9) | | |
| Dalit | 54 | 14.2 (8.5, 19.9) | 255 | 15.3 (11.6, 19.0) | 309 | 15.1 (11.4, 18.8) | | |
| Janajati | 131 | 35.3 (26.4, 44.2) | 498 | 30.8 (25.3, 36.3) | 629 | 31.7 (26.4, 37.0) | | |
| Other Terai ethnicities<sup>c</sup> | 37 | 13.4 (6.2, 20.7) | 69 | 7.9 (4.1, 11.7) | 106 | 9.0 (5.0, 13.0) | | |
| Newar | 4 | 2.1 (0.1, 4.1)<sup>d</sup> | 60 | 5.5 (2.9, 8.0) | 64 | 4.8 (2.7, 6.9) | | |
| Muslim | 9 | 2.3 (0.2, 4.5)<sup>d</sup> | 26 | 1.8 (0.5, 3.1) | 35 | 1.9 (0.6, 3.2) | | |
| **Schooling (grades completed), %** | 0.5 | | | | | | |
| No grades | 134 | 34.5 (28.0, 41.1) | 518 | 31.1 (27.1, 35.2) | 652 | 31.8 (28.0, 35.6) | | |
| 1–8 grades | 107 | 33.1 (26.6, 39.7) | 505 | 32.3 (29.3, 35.4) | 612 | 32.5 (29.7, 35.3) | | |
| ≥9 grades | 114 | 32.3 (25.5, 39.1) | 540 | 36.6 (32.4, 40.7) | 654 | 35.7 (32.0, 39.4) | | |
| **Improved water source<sup>e</sup>, %** | 0.2 | | | | | | |
| Rural | 344 | 96.7 (94.3, 99.1) | 1,497 | 95.2 (91.9, 98.5) | 1,841 | 95.5 (92.5, 98.5) | | |
| Urban | 55 | 20.3 (12.3, 28.3) | 111 | 10.0 (5.8, 14.1) | 166 | 12.0 (7.6, 16.5) | | |
| **Severe household food insecurity, %** | 0.03 | | | | | | |
| Rural | 31 | 7.1 (3.8, 10.3) | 96 | 5.3 (3.6, 6.9) | 127 | 5.6 (4.1, 7.1) | | |
| Urban | 2 | 0.2 (0.1, 0.4)<sup>d</sup> | 8 | 0.5 (0.1, 0.9)<sup>d</sup> | 10 | 0.5 (0.1, 0.9)<sup>d</sup> | | |
| **Health characteristics** | | | | | | | |
| Hemoglobin<sup>f</sup>, g/ dL | <0.0001 | | | | | | |
| Anaemia severity<sup>g</sup> | | | | | | | |
| No anaemia | 0 | - | 1,563 | - | 1,563 | 79.8 (77.1, 82.4) | | |
| Mild | 224 | 62.7 (57.0, 68.5) | 0 | - | 224 | 12.7 (10.6, 14.7) | | |
| Moderate | 125 | 35.3 (29.1, 41.4) | 0 | - | 125 | 7.1 (5.6, 8.7) | | |
| Severe | 6 | 2.0 (0.0, 4.0)<sup>d</sup> | 0 | - | 6 | 0.4 (0.0, 0.8)<sup>d</sup> | | |
| Anthropometry<sup>h</sup>, % | 0.01 | | | | | | |
| Underweight | 74 | 18.8 (13.4, 24.1) | 223 | 14.1 (11.8, 16.4) | 297 | 15.0 (12.9, 17.2) | | |
| Normal weight | 233 | 64.7 (59.3, 70.2) | 976 | 60.3 (56.8, 63.8) | 1,209 | 61.2 (58.1, 64.2) | | |

(Continues)
TABLE 1 (Continued)

| Anemiaa (n = 355, 20.2%; 95% CI [17.6, 22.8]) | No anaemiaa (n = 1, 563, 79.8%; 95% CI [77.1, 82.4]) | Total (n = 1, 918) |
|---|---|---|
| n | n | P | n |
| Overweight/ obesity | 48 | 16.5 (11.0, 22.0) | 364 | 25.6 (22.3, 28.9) | 412 | 23.8 (20.6, 27.0) |
| Fever | 43 | 10.8 (7.0, 14.6) | 257 | 14.7 (12.2, 17.2) | 300 | 13.9 (11.7, 16.1) |
| Cough | 42 | 10.9 (7.3, 14.6) | 276 | 16.2 (13.7, 18.6) | 318 | 15.1 (12.9, 17.3) |
| Diarrhoea | 29 | 9.4 (5.2, 13.6) | 155 | 9.7 (7.7, 11.6) | 184 | 9.6 (7.8, 11.4) |
| CRP, mg/ L | 355 | 0.44 (0.36, 0.53) | 1,563 | 0.52 (0.47, 0.57) | 1,918 | 0.50 (0.46, 0.55) |
| AGP, g/ L | 355 | 0.56 (0.54, 0.59) | 1,563 | 0.56 (0.55, 0.58) | 1,918 | 0.56 (0.55, 0.58) |
| Inflammationi, % | 36 | 9.0 (5.5, 12.6) | 125 | 8.5 (6.7, 10.4) | 161 | 8.6 (7.1, 10.2) |
| Malaria, % | - | - | - | - | - | - |
| Helicobacter pylori, % | 153 | 44.2 (36.3, 52.0) | 639 | 38.8 (35.3, 42.4) | 792 | 39.9 (36.2, 43.6) |
| Visceral leishmaniasis, % | 2 | 0.6 (0.0, 1.5) | 5 | 0.4 (0.0, 0.8) | 7 | 0.4 (0.1, 0.8) |
| Soil-transmitted helminth infectionj, % | 49 | 14.2 (9.3, 19.1) | 285 | 19.3 (16.1, 22.6) | 334 | 18.3 (15.2, 21.4) |
| G6PD, % | 89 | 25.5 (18.6, 32.3) | 145 | 10.6 (8.4, 12.7) | 234 | 13.6 (11.2, 15.9) |
| Hemoglobinopathiesk % | 36 | 9.0 (5.5, 12.6) | 125 | 8.5 (6.7, 10.4) | 161 | 8.6 (7.1, 10.2) |
| Malaria, % | 0 | - | 0 | - | 0 | - |
| Helicobacter pylori, % | 153 | 44.2 (36.3, 52.0) | 639 | 38.8 (35.3, 42.4) | 792 | 39.9 (36.2, 43.6) |
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Note. Ns are unweighted. Values presented are geometric mean (95% CI) or percent (95% CI). All estimates account for weighting and complex sampling design.

Abbreviations: AGP, α-1 acid glycoprotein; CI, confidence interval; CRP, C-reactive protein; G6PD, glucose-6-phosphate dehydrogenase deficiency; RBC, red blood cell; RBP, retinol binding protein; sTfR, transferrin receptor.

aAnaemia defined as altitude-and smoking-adjusted Hb <12.0 g/ dL (WHO, 2017a).
bP values calculated for Rao–Scott chi square tests for categorical variables and linear contrast tests for continuous variables.
cOther Terai cases include Terai/ Madhesi ethnicities not including Terai/ Madhesi Brahmin/ Chettri.
dInterpret with caution. Estimates may be unstable due to small n.
eWater source based on self-report. Improved water source defined as piped water, tube well borehole, protected well or spring, stone tap, rainwater, or bottle water (WHO and UNICEF, 2017).
fHaemoglobin adjusted for altitude and smoking (WHO, 2017a).
from the final multivariable model. Ferritin is the recommended indicator to assess iron status in populations (WHO, 2017a).

In the final multivariable model, few modifiable factors were associated with anaemia (Table 2). Iron status (in ferritin in micrograms per litre) and vitamin A status (in RBP in micrograms per litre) were both associated with reduced odds of anaemia (adjusted odds ratio [AOR] 0.43, 95% CI [0.35, 0.54] and AOR 0.20, 95% CI [0.11, 0.37], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively). Hormonal contraceptive use was associated with 42% reduced odds of anaemia (adjusted odds ratio [AOR] 0.58, 95% CI [0.47, 0.72], respectively).

Our study also identified several nonmodifiable factors associated with anaemia. G6PD and haemoglobinopathies were associated with 2.44 (95% CI [1.66, 3.60]) and 6.15 (95% CI [3.09, 12.26]) times increased odds of anaemia, respectively. Compared with living in the Terai ecological zone, women living in the Mountain and Hill ecological zones had lower odds of anaemia (AOR 0.35, 95% CI [0.21, 0.60] and AOR 0.41, 95% CI [0.29, 0.59], respectively).

4 | DISCUSSION

Using a nationally representative sample of nonpregnant women 15–49 years, we identified both potentially modifiable and nonmodifiable factors associated with anaemia in Nepal. One in five women had anaemia—a prevalence level of moderate public health significance, according to the World Health Organization (WHO, 2017a). We identified potentially modifiable factors including serum ferritin, serum RBP, hormonal contraceptive use, residing in a house with an earth floor, and recent cough. Nonmodifiable factors included residing in the mountain or hill ecological zones relative to the Terai ecological zone, G6PD, and haemoglobinopathies. Evidence from this analysis suggests that some but not all of the burden of anaemia among WRA in Nepal might be addressed through improved public health programming targeting micronutrient status, access to family planning, and replacing dirt flooring.

Micronutrient status was among the potentially modifiable factors in this population. Iron status was inversely associated with anaemia odds. High birth rates, short birth intervals, diets poor in bioavailable iron and other key micronutrients, and low access to iron supplementation exacerbate women's physiological vulnerabilities to iron deficiency and anaemia (Balarajan, Ramakrishnan, Özaltin, Shankar, & Subramanian, 2011). A 2006 study of nonpregnant WRA in Nepal found that 54% consumed less than the recommended daily intake of iron (Chandyo et al., 2007). We were unable to estimate total iron intake; however, 69.7% of women reported consuming organ, flesh, or blood-based foods the day preceding the survey, suggesting that the majority of women consume iron-rich food sources. Reported intake of micronutrient supplements, however, including iron tablets/syrups and multiple micronutrient supplements, was low (6.5%).

Despite <1% of WRA having vitamin A deficiency, vitamin A status was associated with anaemia in our study. Vitamin A is essential to mobilize of iron stores for erythropoiesis, and for immune function (WHO, 2017a). Although we were unable to estimate total vitamin A intake, reported consumption of food sources high in vitamin A during the day preceding the survey did not vary by anaemia status. Policies or programmes to support frequent physiological intakes of vitamin A or pro-retinol carotenoids through low-dose supplements, fortification, or improved diets could improve vitamin A status and potentially reduce anaemia (Mason et al., 2011).

Although Nepal has national policies aimed at reducing anaemia among pregnant women, mandatory food fortification is the main policy currently in place designed to prevent micronutrient deficiencies
in all populations—including nonpregnant women. Since 2011, Nepal has mandated that all industrially produced wheat flour be fortified with iron (60 mg of elemental iron per kilogramme), vitamin A (1 mg/ kg), and folic acid (1.5 mg/ kg). However, the iron compound in the fortification premix used by industrial roller mills does not conform to World Health Organization recommendations (WHO, 2009). Additionally, 58.7% of households in Nepal grow their own wheat and only purchase it seasonally (Ministry of Health and Population [Nepal], 2018). Other commonly consumed processed foods made from industrially produced wheat flour, such as noodles, could increase the reach. Household purchasing data for fortifiable staples could help inform fortification policy to improve iron and vitamin A status, as well as promote nutrient-rich diets, and enhance the bioavailability of micronutrients through food processing and preparation.

Hormonal contraceptive use was associated with 42% lower odds of anaemia in our study. Contraception in general can reduce anaemia through fewer pregnancies and increased birth intervals whereas hormonal contraception specifically may help prevent anaemia by reducing menstrual blood loss (UNDP, 1998). A study of 201,720 women in 12 countries found that continued hormonal contraceptive use of at least 1 year was associated with 44% lower odds of anaemia (95% CI [0.52, 0.61]; Bellizzi & Ali, 2018). Chandyo et al. reported that Depo-Provera injections were positively associated with haemoglobin concentrations (β = 0.45; 95% CI [0.17, 0.73]) among WRA in Nepal (Chandyo et al., 2007), and a study using data from the 2016 DHS reported that women 15- 49 years who were currently using hormonal contraception had 37% lower odds of anaemia (Gautam et al., 2019).

Residing in a house with a dirt floor was associated with 1.74 times higher odds of anaemia relative to residing in a house with another floor type. An evaluation of the Mexican government program Piso Firme found that replacing dirt floors with concrete cement floors was associated with an 81% reduction in anaemia prevalence.

### TABLE 2

Multivariable binomial logistic regression predicting anaemia among nonpregnant women 15–49 Years, Nepal National Micronutrient Status Survey, Nepal, 2016 (n = 1,918)

|                          | Unadjusted odds ratio (95% CI) | Adjusted odds ratio (95% CI) | P  |
|--------------------------|--------------------------------|------------------------------|----|
| **Potentially modifiable factors** |                                |                              |    |
| Open defecation           | 2.30 [1.45, 3.63]              | 1.53 [0.81, 2.89]            | 0.2 |
| Dirt, earth, or dung floor| 1.41 [1.04, 1.90]              | 1.74 [1.18, 2.56]            | 0.005 |
| **BMI category (ref. normal weight)** |                                |                              |    |
| Underweight (BMI <18.5 kg/ m²) | 1.24 [0.84, 1.83]              | 1.10 [0.68, 1.80]            | 0.5 |
| Overweight/ obesity (BMI ≥25.0 kg/ m²) | 0.60 [0.41, 0.88]              | 0.85 [0.51, 1.40]            | 0.4 |
| Recent cough*             | 0.64 [0.43, 0.94]              | 0.56 [0.38, 0.82]            | 0.003 |
| Hormonal contraceptive use | 0.38 [0.27, 0.55]              | 0.58 [0.38, 0.88]            | 0.01 |
| Consumed tea              | 0.76 [0.60, 0.96]              | 0.95 [0.72, 1.25]            | 0.7 |
| Ln ferritin in μg/ Lb      | 0.44 [0.35, 0.56]              | 0.43 [0.35, 0.54]            | <0.0001 |
| Ln RBP in μmol/ L         | 0.10 [0.05, 0.18]              | 0.20 [0.11, 0.37]            | <0.0001 |
| **Nonmodifiable factors** |                                |                              |    |
| Ecological zone (ref. Plains) |                                    |                              |    |
| Mountain                  | 0.31 [0.20, 0.49]              | 0.35 [0.21, 0.60]            | 0.0002 |
| Hill                      | 0.35 [0.25, 0.49]              | 0.41 [0.29, 0.59]            | <0.0001 |
| **Ethnicity (ref. Brahmín or Chettri)** |                                        |                              |    |
| Dalit                     | 1.10 [0.72, 1.68]              | 0.79 [0.48, 1.29]            | 0.3 |
| Janajati                  | 1.36 [0.93, 1.99]              | 1.20 [0.80, 1.78]            | 0.4 |
| Other Terai ethnicities*   | 2.02 [1.09, 3.75]              | 0.69 [0.33, 1.44]            | 0.3 |
| Newar                     | 0.45 [0.16, 1.24]              | 0.50 [0.21, 1.21]            | 0.1 |
| Muslim                    | 1.67 [0.64, 4.36]              | 0.76 [0.40, 1.47]            | 0.4 |
| G6PD                      | 2.89 [1.92, 4.35]              | 2.44 [1.66, 3.60]            | <0.0001 |
| Hemoglobinopathies*        | 5.32 [2.86, 9.89]              | 6.15 [3.09, 12.26]           | <0.0001 |

Note. Estimates are unadjusted odds ratios and adjusted odds ratios with 95% confidence intervals from logistic regression models, accounting for weighting and complex sampling design. Anaemia was defined as altitude- and smoking- adjusted Hb <12.0 g/ dL (WHO 2017). Abbreviations: AGP, α- 1- acid glycoprotein; BMI, body mass index; CI, confidence interval; CRP, C- reactive protein; G6PD, glucose- 6- phosphate dehydrogenase deficiency; RBP, retinol binding protein.

*Recent cough defined as self- report of cough during the 2 weeks preceding the survey.

*Biomarker was regression- adjusted to a pooled country reference to adjust for inflammation, using CRP and AGP (Namaste et al., 2017).

*Other Terai ethnicities include Teraí/ Madhési ethnicities not including Terai/ Madhési Brahmín/ Chettri.

*Other blood disorders α- and β- thalassemia, haemoglobin E, sickle cell, and other blood disorders not including G6PD.
among children (Cattaneo, Galiani, Gertler, Martinez, & Titunik, 2009). Dirt floors can expose household members to faecal matter, worms, protozoa, and other parasites (WHO, 2017a), increasing prevalence of infection (Benjamin-Chung et al., 2015). Infection and inflammation can cause both micronutrient malnutrition and anaemia (Balarajan et al., 2011). Although we directly measured STH infection and biomarkers of inflammation, these indicators were not associated with anaemia in bivariate models. However, dirt floors may represent an infection not otherwise captured. It is also possible that dirt floors represent overall living conditions; however, household socioeconomic status was not associated with anaemia in bivariate models.

Although infection is a known risk factor for anaemia, recent cough was inversely associated with anaemia. Recent cough might be a proxy for household air pollution. Smoke exposure is associated with increased haemoglobin because RBC production increases to compensate for chronically low blood oxygen concentrations (Nordenberg, Yip, & Blinkin, 1990). Exposure to biomass smoke was associated with higher prevalence of respiratory symptoms in Nepal (Kurmli et al., 2014). In our study, women who reported recent cough had a higher prevalence of cooking with biomass fuel relative to women without recent cough (Table S2). Thus, recent cough may be a proxy for exposure to smoke from burning biomass for cooking fuel.

We identified nonmodifiable factors associated with anaemia among women. WRA residing in the Mountain or Hill ecological zones had lower odds of anaemia relative to women residing in the Terai ecological zone. Chronic exposure to arsenic via contaminated groundwater due to the geology of the Terai might explain persistently high burden of anaemia in this zone. Populations in the Terai are exposed to arsenic concentrations above the upper limit of drinking water per the World Health Organization (>10 μg/L; Pokharel, Bhandari, and Viraraghavan, 2009; WHO, 2017b). Arsenic can depress haemopoiesis (Hernandez-Zavala et al., 1996) and increase erythrocyte haemolysis (Mahmud, Foller, & Lang, 2008). A study among women in Bangladesh reported a positive association between arsenic exposure and anaemia (Heck et al., 2008). Because vitamin B12 and folate are required to metabolize inorganic arsenic, deficiencies in these micronutrients could further contribute to anaemia (Gamble et al., 2005). Future research might explore arsenic exposure and anaemia in the Terai. Because ethnicity and blood disorders were included in multivariable models, regional differences in anaemia are unlikely due to these factors; however, other cultural, dietary, or other factors might also help explain anaemia in the Terai.

G6PD and haemoglobinopathies had the strongest associations with anaemia in this population. WRA with G6PD had more than double the odds of anaemia, and WRA with haemoglobinopathies had more than 6.1 times higher odds of anaemia relative to women without these conditions. While inherited disorders are nonmodifiable, our findings have may implications for frontline health workers and program planning. Because exposure to some foods and commonly prescribed antibiotics, antimalarials, and anthelmintics can induce acute haemolysis among people with G6PD (Beutler, 2008), frontline health workers could be trained about the prevalence among the population and contraindications for these drugs (WHO, 1989). Identifying the patterning of blood disorders is key to understanding monitoring and evaluation data. Blood disorders might explain gaps in reducing anaemia prevalence despite well-designed and implemented anaemia control programmes.

Our findings of 20.2% anaemia prevalence stand in contrast to those of the 2016 DHS, which reported 46% prevalence among non-pregnant WRA (Ministry of Health and Population [Nepal], 2017). The NNMSS collected data from April–June whereas the DHS collected data from July-January; thus, seasonal differences in dietary practices, infection, and other factors might contribute to differing anaemia prevalence. No diet, infection, or morbidity data are available among WRA in the DHS to explore potential seasonal differences. The two surveys used different methods and equipment to measure haemoglobin. Venous blood, used in the NNMSS, is the reference blood for haemoglobin assessment (Whitehead 2019). The DHS used single drops of blood from capillary blood samples. Artificially low haemoglobin concentrations can arise from capillary samples when the finger is squeezed too hard during blood collection, introducing interstitial fluid (Whitehead 2019). Finally, the NNMSS used the HemoCue® Hb 301, and DHS used the HemoCue® Hb 201 analyzer—neither of which is the gold standard method to measure haemoglobin. The HemoCue® Hb 201 is sensitive to both temperature and humidity; the manufacturer-recommended operating temperature is 15°–30°C. Although further analysis is needed to better understand the differences in anaemia prevalence in Nepal, the discrepancies between DHS and national micronutrient surveys conducted close in time have been documented in other countries (SPRING, 2018).

4.1 | Strengths and Limitations

To our knowledge, this analysis is the first to examine causes of anaemia among WRA in Nepal using comprehensive, nationally representative data on multiple potential causes of anaemia—many of which are rarely included in large-scale surveys in low-income and middle-income countries. Due to the cross-sectional study design, we were unable to establish causality between candidate predictors and anaemia status. The NNMSS did not collect data on all micronutrients for which deficiency could lead to anaemia. Although plasma vitamin B12 was measured, we excluded it from these analyses due to data quality. Dietary recall questions were limited in scope, which might explain the lack of findings for any diet-related indicators and anaemia.

5 | CONCLUSION

Our analysis suggests a combination of effectively implemented strategies might potentially reduce anaemia among nonpregnant women 15–49 years in Nepal by addressing micronutrient status, access to hormonal contraception, and improved flooring. Although nonmodifiable, understanding the patterning of factors like blood
disorders among WRA in Nepal might help inform public health policies and programmes and provide context to program monitoring and evaluation data.

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CONFLICTS OF INTEREST

The authors do not report any conflicts of interest.

CONTRIBUTIONS

MEJ, RDW, ZM, RFA, NP, SC, SR, KRP, RPB, and NJ designed the research. NJ, NP, SC, DA, SR, KRP, and RPB conducted the research. NJ performed the initial database cleaning. NDF performed the statistical analyses and wrote the paper. NDF, NP, NJ, RPB, KRP, RDW, SC, SR, ZM, RFA, DA, and MEJ edited subsequent drafts. NDF had primary responsibility for the final content. All authors have read and approved the manuscript.

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REFERENCES

Balarajan, Y., Ramakrishnan, U., Özaltin, E., Shankar, A. H., & Subramanian, S. V. (2011). Anaemia in low-income and middle-income countries. Lancet, 378, 2123–2135.

Ballard, T. J., Coates, J., Swindale, A., & Deitchler, M. (2011). Demographic and Health Survey 2016—Nepal. Kathmandu, Nepal: Ministry of Health, Nepal.

Benjamin-Chung, J., Nazneen, A., Halder, A. K., Haque, R., Siddique, A., Bellizzi, S., & Ali, M. M. (2018). Effect of oral contraception on anemia in reproductive age women: Evidence from recent national survey data. PLoS ONE, 14(6), e0218288.

Balarajan, Y., Ramakrishnan, U., Özaltin, E., Shankar, A. H., & Subramanian, S. V. (2011). Anaemia in low-income and middle-income countries. Lancet, 378, 2123–2135.

Bellizzi, S., & Ali, M. M. (2018). Effect of oral contraception on anemia in 12 low- and middle-income countries. Contraception, 97(3), 236–242.

Benjamin-Chung, J., Nazneen, A., Halder, A. K., Haque, R., Siddique, A., Uddin, M. S., … Luby, S. P. (2015). The interaction of deworming, improved sanitation, and household flooring with soil-transmitted helminthes in rural Bangladesh. PLoS Neglected Tropical Diseases, 9(12), e0004256.

Beutler, E. (2008). Glucose-6- phosphate dehydrogenase deficiency: A historical perspective. Blood, 111(1), 16–24.

Cattaneo, M. D., Galani, S., Gertler, P. J., Martinez, S., & Titunik, R. (2009). Housing, health, and happiness. American Economic Review: Economic Policy, 1(1), 75–105.

Chandyo, R. K., Henjum, S., Ulak, A., Thorne-Lyman, A. L., Ulvik, R. J., Shrestha, P. S., … Strand, T. A. (2016). The prevalence of anaemia and iron deficiency is more common in breastfed infants than their mothers in Bhaktapur, Nepal. European Journal of Clinical Nutrition, 70, 456–462.

Chandyo, R. K., Strand, T. A., Ulvik, R. J., Adhikari, R. K., Ulak, M., Dixit, H., & Sommerfelt, H. (2007). Prevalence of iron deficiency and anaemia among healthy women of reproductive age in Bhaktapur, Nepal. European Journal of Clinical Nutrition, 61(2), 262–269.

Erhardt, J. G., Estes, J. E., Pfieffer, C. M., Biesalski, H. K., & Craft, N. E. (2004 Nov). Combined measurement of ferritin, soluble transferrin receptor, retinol binding protein, and C-reactive protein by an inexpensive, sensitive, and simple sandwich enzyme-linked immunosorbent assay technique. The Journal of Nutrition, 134(11), 3127–3132.

Ezzati, M., Lopez, A. D., Rodgers, A. A., & Murray, C. J. L. (2004). Comparative quantification of health risks: Global and regional burden of disease attributable to selected major risk factors. Geneva, Switzerland: WHO.

FAO and FHI 360 (2016). Minimum dietary diversity for women: A guide to measurement. Rome, Italy: Food and Agriculture Organization of the United Nations.

Gamble, M. V., Liu, X., Ahsan, H., Plisner, J. R., Illievski, V., Slavkovic, V., … Graziano, J. H. (2005 Dec). Folate, homocysteine, and arsenic metabolism in arsenic-exposed individuals in Bangladesh. Environmental Health Perspectives, 113(12), 1683–1688.

Gautam, S., Min, H., Kim, H., & Jeong, H. S. (2019 Jun 12). Determining factors for the prevalence of anemia in women of reproductive age in Nepal: Evidence from recent national survey data. PLoS ONE, 14(6), e0218288.

Government of Nepal Central Bureau of Statistics (2014). Statistical pocketbook of Nepal 2014. Katmandhu, Nepal: Government of Nepal.

Heck, J. E., Chen, Y., Grann, V. R., Slavkovich, V., Parvez, F., & Ahsan, H. (2008 Jan). Arsenic exposure and anaemia in Bangladesh: A population-based study. Journal of Occupational and Environmental Medicine, 50(1), 80–87.

Hernandez-Zavala, A., Del Razo, L. M., Garcia-Vargas, G. G., Aguilar, C., Borja, V. H., Albores, A., & Cebrán, M. E. (1996 Jun). Altered activity of heme biosynthesis pathway enzymes in individuals chronically exposed to arsenic in Mexico. Archives of Toxicology, 27(3), 90–95.

Institute of Medicine, Food and Nutrition Board (1998). Dietary reference intakes: Thiamin, riboflavin, niacin, vitamin B6, folate, vitamin B12, pantothenic acid, biotin, and choline. Washington (DC): National Academy Press.

I2ZNCG Technical brief. No. 2. 2012. Assessing population zinc status with serum zinc concentration. Accessed at: https://static1.squarespace.com/static/56424f6ce4b0552eb7dc4eb/t/5774378f144bf54105168748/1467234199261/I2ZNCG_TechBrief2_2012-3.pdf.

Kurni, O. P., Semple, S., Devereux, G. S., Gaire, S., Lam, K. B., Sadhra, S., … Ayres, J. G. (2014). The effect of exposure to biomass smoke on respiratory symptoms in adult rural and urban Nepalese populations. Environmental Health, 13, 92.

Mahmud, H., Foller, M., & Lang, F. (2008 Jul). Arsenic-induced suicidal erythrocyte death. Archives of Toxicology, 83(2), 107–113.

Mason, J. B., Ramirez, M. A., Fernandez, C. M., Pedro, R., Lloren, T., Luby, S. P. (2015). The interaction of deworming, improved sanitation, and household flooring with soil-transmitted helminth infection in rural Bangladesh. PLoS Neglected Tropical Diseases, 9(12), e0004256.

Ministry of Health and Population - MOHP/ Nepal, New ERA/ Nepal, and ICF International (2012). Nepal Demographic and Health Survey 2011. Kathmandu, Nepal: MOHP/ Nepal, New ERA/ Nepal, and ICF International.

Ministry of Health and Population Nepal, New ERA, ICF (2017). Nepal Demographic and Health Survey 2016. Kathmandu, Nepal: Ministry of Health Nepal.

Ministry of Health and Population Nepal, New ERA, ICF International. (2012). Nepal Demographic and Health Survey 2011. Kathmandu, Nepal: Ministry of Health Nepal.

Nordengberg, D., Yip, R., & Binkin, N. J. (1999). The effect of cigarette smoking on hemoglobin levels and anemia screening. Journal of the American Medical Association, 284(12), 1556–1559.
The proportion of anemia associated with iron deficiency in low, medium, and high human development index countries: A systematic analysis of national surveys. 

**Petry, N., Olofin, I., Hurrell, R. F., Boy, E., Wirth, J. P., Moursi, M., ... Rohner, F.** (2016 Nov). Nutrients, 8(11), 693.

Comparison of serum and red blood cell folate microbiologic assays for national population surveys.

**Pfeiffer, C. M., Zhang, M., Lacher, D. A., Molloy, A. M., Tamura, T., Yetley, E. A., ... Johnson, C. L.** (2011). The Journal of Nutrition, 141(7), 1402–1409.

Arsenic contamination in the Terai region of Nepal: An overview of health concerns and treatment options.

**Pokharel, D., Bhandari, B. S., & Viraraghavan, T.** (2009). Environment International, 35(1), 157–161.

**SPRING** (2018). Anemia assessment in micronutrient and demographic and health surveys: Comparisons in Malawi and Guatemala. Arlington, VA: Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project.

**Stevens, G. A., Finucane, M. M., De-Regil, L. M., Paciorek, C. J., Flaxman, S. R., Branca, F., ...** Nutrition Impact Model Study Group (2013 Jul). Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: A systematic analysis of population-representative data. The Lancet Global Health, 1(1), e16–e25.

**UNDP/ UNFPA/ WHO/ WB Task Force for Epidemiological Research on Reproductive Health** (1998). Effects of contraceptives on hemoglobin and ferritin. Contraception, 58, 261–273.

**Whitehead, R. D. Jr, Mei, Z., Mapango, C., & Jefferds, M. E.** (2019) Methods and analyzers for hemoglobin measurement in clinical laboratories and field settings. Annals of the New York Academy of Sciences, 1450(1), 147.

**WHO** (1994). Bench aids for the diagnosis of intestinal parasites. Geneva, Switzerland: World Health Organization.

**WHO** (1996). Indicators for assessing vitamin A deficiency and their application in monitoring and evaluating intervention programmes. Geneva, Switzerland: World Health Organization.

**WHO** (2009). Recommendations on wheat and maize flour fortification meeting report: Interim consensus statement. WHO/ NMH/ NHD/ MNM/ 09.1. Geneva, Switzerland: World Health Organization.

**WHO** (2017a). Nutritional anemias: Tools for effective prevention and control. Geneva: World Health Organization. License: CC BY-NC-SA 3.0 IGO

**WHO** (2017b). Guidelines for drinking-water quality: fourth edition incorporating the first addendum. Geneva, Switzerland: World Health Organization. License CC BY-NC-SA 3.0 IGO

**WHO and UNICEF** (2017). Progress on drinking water, sanitation and hygiene: 2017 Update and SDG Baselines. Geneva, Switzerland: World Health Organization and the United Nations Children’s Fund.

**WHO Consultation on Obesity** (1999; Geneva, Switzerland) (2004). Obesity: Preventing and managing the global epidemic: Report of a WHO Consultation. Geneva, Switzerland: World Health Organization, 2000 (reprint).

**WHO Working Group** (1989). Glucose-6- phosphate dehydrogenase deficiency. Bulletin of the World Health Organization, 87(6), 601–611.

**SUPPORTING INFORMATION**

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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