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Original Research

Predictors of Incidence and Remission of Anemia among Never-Married Adolescents Aged 10–19 Years: A Population-Based Prospective Longitudinal Study in India

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A B S T R A C T

Background: Dynamics of the anemia burden among Indian adolescents are poorly understood because of a lack of population-based longitudinal data.

Objectives: To examine the burden of anemia among never-married adolescents aged 10–19 y from the states of Bihar and Uttar Pradesh, India, and a wide range of predictors of its incidence and remission.

Methods: A sample of 3279 adolescents (male: 1787 and female: 1492) aged 10–19 y were included from baseline (2015–2016) and follow-up (2018–2019) surveys of the UDAYA (Understanding the Lives of Adolescents and Young Adults) project in India. In 2018–2019, all new cases of anemia were considered as incidence, whereas a return to the nonanemic status from being anemic in 2015–2016 was considered remission. Univariate and multivariable modified Poisson regression models with robust error variance were deployed to attain the study objective.

Results: The crude prevalence of anemia among males decreased from 33.9% (95% CI: 30.7%–37.3%) in 2015–2016 to 31.6% (95% CI: 28.6%–34.7%) in 2018–2019 but increased among females from 57.7% (95% CI: 53.5%–61.7%) in 2015–2016 to 63.8% (95% CI: 59.9%–67.5%) in 2018–2019. Anemia incidence was estimated to be 33.7% (95% CI: 30.3%–37.2%), whereas nearly 38.5% (95% CI: 35.1%–42.1%) of adolescents experienced remission of anemia. Older adolescents (aged 15–19 y) were less likely to experience anemia incidence. Consumption of eggs daily or weekly was negatively associated with anemia incidence compared with occasional or never consumption. Females had a higher risk of experiencing an incidence of anemia and decreased risk of experiencing anemia remission. The likelihood of adolescents experiencing anemia increased with an increased patient health questionnaire score. Household size was also associated with an increased risk of anemia incidence.

Conclusions: Interventions that are sensitive to socio-demographic factors and encouraging access to mental health services and nutritious food consumption could be helpful in further anemia mitigation.

Keywords: anemia, iron-deficiency anemia, micronutrients, nutrition, adolescent

Abbreviations: ASHA, accredited social health activist; AWC, anganwadi center; AWW, anganwadi worker; Hb, hemoglobin; IFA, iron–folic-acid; PHQ-9, patient health questionnaire 9; UDAYA, Understanding the Lives of Adolescents and Young Adults; USHA, urban social health activist; VIF, variance inflation factor; WIFS, Weekly Iron-and-Folic-Acid Supplementation Program.

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Introduction

Adolescents (aged 10–19 y) have a relatively high burden of anemia as compared with adults in South Asia, including India [1,2], and anemia remains the most studied sign of micronutrient deficiency among adolescents in South Asia [3]. The causes of anemia are multifactorial and complex [4–6]. Adolescent girls are disproportionately affected by anemia, as they have higher iron requirements to make up for iron lost during menstruation. In addition, poor diet quality, high rate of infection, and worm infestation, primarily because of poor living conditions and suboptimal health care, adversely affect the hemoglobin concentration among all adolescents, and the social norm of early marriage of girls and adolescent pregnancy could also cause anemia [7,8]. Anemia could lead to major adverse consequences among adolescents, including irreversible cognitive and developmental delays (such as a deficit in intelligence and poor academic performance), decreased physical capacity and loss of productivity, impaired immune function, increased infection risks, and poor reproductive health outcomes among teenage girls [5,9–14].

India is home to 253 million adolescents, accounting for 21% of its population [2]. The 2016–2018 Comprehensive National Nutrition Survey of India found a high burden of anemia (28.1%) and iron deficiency (41.5%) among 10–19-y-old adolescents [15]. To tackle the burden of anemia, the Government of India introduced the Weekly Iron-and-Folic-Acid Supplementation (WIFS) Program in 2012. Through this initiative, adolescent boys and girls are provided with weekly iron–folic-acid (IFA) tablet/syrup supplementation consisting of 100 mg elemental iron and 500 μg of folic acid [16]. Under WIFS, school-going adolescent boys and girls (aged 10–19 y) of grades 6 through 12, enrolled in government, government-aided or municipal schools, and out-of-school girls aged 10–19 y are entitled to receive IFA tablet/syrup. Additionally, the WIFS screens adolescents at risk for anemia and provides counseling and health care, including referral services. However, the program was criticized for its limited coverage and approach to executing the IFA supplementation strategy [7,8,17,18], primarily for its insufficient efforts in increasing the IFA uptake. A recent study [7] estimated that only 3.6% of male and 4.8% of female adolescents received IFA supplements in the preceding year of the survey conducted during 2015–2016.

Although a few studies have explored the burden of anemia among adolescents in India [19], those studies are either outdated or have used cross-sectional data. A recent study on WIFS among adolescents [8] used cross-sectional data from a smaller region, which limited the generalizability of the results. Another cross-sectional study [20] used 2016–2018 Comprehensive National Nutrition Survey data and analyzed the prevalence and associated factors of anemia among adolescents aged 10–19 y. A similar type of analysis was conducted using the cross-sectional District Level Household and Facility Survey data [21]. The lack of longitudinal studies examining the incidence and remission of anemia in adolescents has resulted in the shortage of empirical evidence for state and national anemia reduction programs.

To fill this knowledge gap, we analyzed prospective longitudinal survey data of the Understanding the lives of Adolescents and Young Adults (UDAYA) project in Bihar and Uttar Pradesh, India (https://www.projectudaya.in/), collected in 2015–2016 [22] and 2018–2019 [23]. To our knowledge, to date, only two studies [24,25] used UDAYA data and examined the burden and factors associated with anemia among adolescents; however, these studies did not explore the dynamics of incidence and remission of anemia. Our study serves two aims. First, we determined, for the first time to our knowledge, the incidence and remission of anemia among never-married adolescents aged 10–19 y, leveraging longitudinal data, which is representative of two of India's most under-resourced states–Bihar and Uttar Pradesh. Second, we examined a wide range of individual- and household-level predictors of incidence and remission of anemia among those never-married adolescents.

Methods

Data source

Through the UDAYA project, the Population Council conducted two rounds of surveys among adolescents in the states of Bihar and Uttar Pradesh, India. UDAYA aims to provide robust insights on how and where to invest in adolescents to influence their life course [22,23]. The first round of the survey, or the baseline survey, was conducted in 2015–2016 among unmarried 10–19 y old boys and girls and married girls aged 15–19 y and a follow-up survey was conducted with them in 2018–2019. State-representative 150 primary sampling units 75 each for rural and urban respondents were drawn to derive a sample for each state. The 2011 census list of Indian villages (in rural areas) and wards (in urban areas) was used as the sampling frame. The selection of villages and wards was stratified by using region, village/ward size, the proportion of the population belonging to Scheduled Castes and Scheduled Tribes, and female literacy. In 2015–2016, a total of 10,433 and 10,161 adolescents were recruited and interviewed in Bihar and Uttar Pradesh, respectively (males: 5969; females: 14,625), whereas a total of 8467 and 7825 individuals were followed up in 2018–2019 from Bihar and Uttar Pradesh, respectively. Hemoglobin (Hb) concentration was assessed in a sub-sample of 7882 adolescents in 2015–2016 and 5602 adolescents in 2018–2019. The sub-sample drawn for Hb measurement was representative of a large sample [22,23]. After rigorous training protocol for interviewers, keeping with the ethics of data collection, one-to-one interviews were conducted with survey participants. Further details about the UDAYA project can be obtained from its official webpage https://www.projectudaya.in/.

Study population

As stated above, 5602 individuals were measured for Hb in the follow-up survey, and of which this study included a sample of 3279 individuals (male: 1787, female: 1492) to attain the study objective. It is worth mentioning that this sample of 3279 individuals had the reported age of 10–19 y during both the 2015–2016 and 2018–2019 surveys, excluding 624 individuals whose ages ranged from 20 through 23 y during the follow-up survey in 2018–2019. Furthermore, this sample excluded the ever-married females from the analysis because incidence and remission of anemia are greatly influenced by pregnancy status and outcomes, their gravida number, and other socio-demographic condition likely to change immediately after

marriage [26,27]. In India, girls move to their husband's/in-law's houses after marriage. Studies have empirically demonstrated that compared with adults, female adolescents are more likely to be undernourished if they are married before 18 y of age for various reasons ranging from diminished decision-making power to unfair intra-household food allocation [28]. Thus, including never-married female adolescents would provide a reliable understanding of the incidence and remission of anemia as their living environment remains nearly the same during both rounds of surveys. A detailed derivation of sample size is presented in Figure 1.

Outcome events

The measurement of the anemia threshold was used to construct the primary outcome event. To measure anemia, Hb concentrations were measured from the sampled adolescents using a portable HemoCue Hb 201+ analyzer (HemoCue AB, Sweden), which provides test results using a capillary blood sample in <1 min. HemoCue is one of the best instruments for measuring community-level anemia burden in a resource-poor setting [29]. Using hemoglobin concentrations, two outcome events were assessed: incidence of anemia and remission of anemia. Standard age and sex-specific WHO cut-offs were applied to define the two levels of anemia (that is, normal and anemic) [16,22,23]. WHO defines the person as anemic if the Hb concentration <11.5 g/dl in children 5–11 y of age, <12 g/dl in children 12–14 y of age, <12 g/dl in nonpregnant women aged ≥15 y, and <13 g/dl in men aged ≥15 y [30]. Hb concentrations of all participants were adjusted for smoking status and altitude [31] before applying these cut-offs. We removed extreme values of Hb concentration below 2 g/dL or above 20 g/dL under the assumption that these extreme values are likely because of a measurement error. The new cases of anemia in 2018–2019 were considered as the incidence of anemia, whereas the return to the

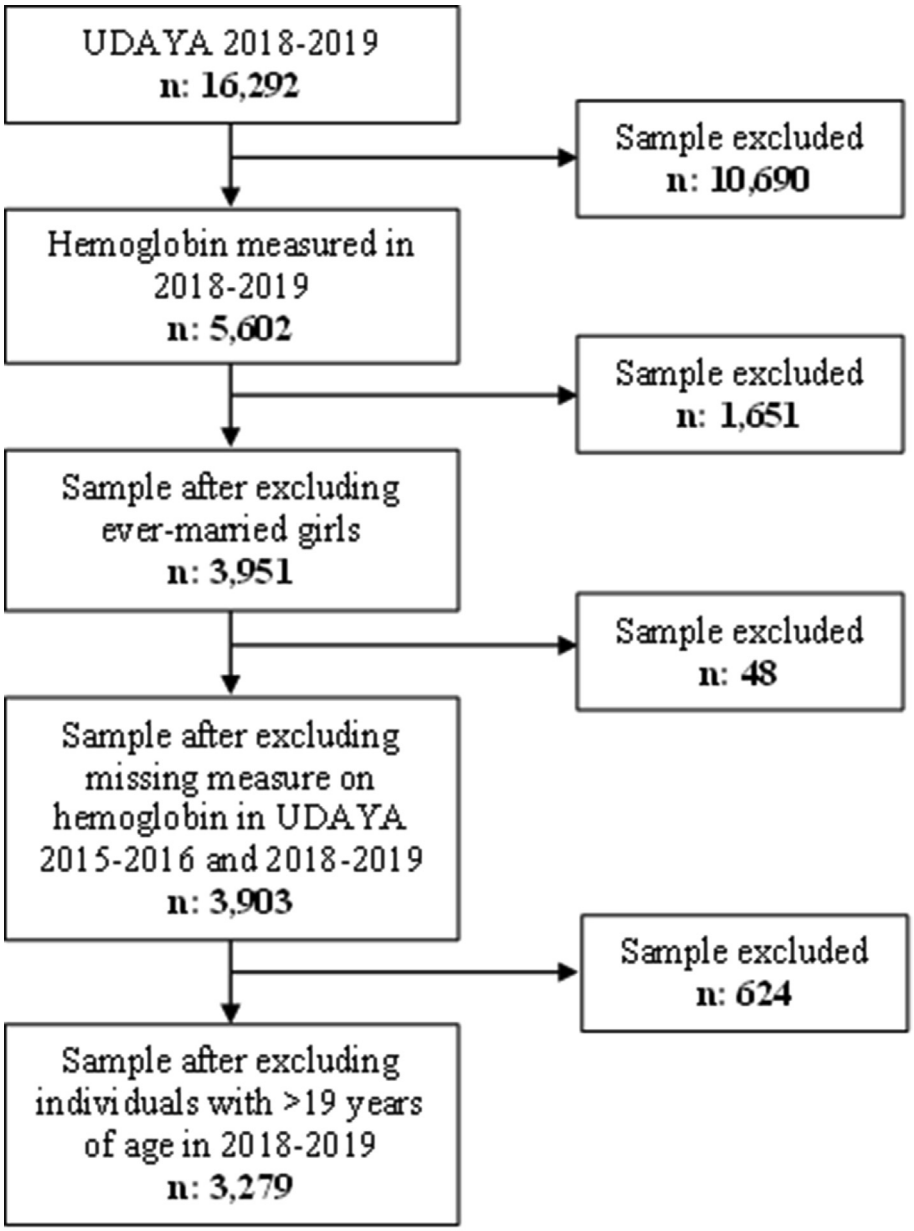

FIGURE 1. Derivation of sample included in the analysis. *n*, sample; UDAYA, Understanding the Lives of Adolescents and Young Adults survey.

nonanemic status in 2018–2019 was considered as a remission of anemia. The denominator for measuring anemia incidence was 1880, whereas 1399 adolescents were included to measure the anemia remission.

Predictors

Guided by the existing literature on the determinants of anemia [2,4–6,19,32], a wide range of potential predictors were included to examine the incidence and remission of anemia. We focused on five major domains of potential predictors, including *1*) socio-demographic characteristics; *2*) exposure to health care information and health care; *3*) history of violence and sexual abuse; *4*) nutrition and physical activity; and *5*) modifiable lifestyle risk behavior. These variables represent potential targets of anemia prevention and treatment efforts among adolescents, which could be recognized by healthcare workers without needing to undertake physical or laboratory measurements. As deemed suitable in earlier studies in India [33–35], all potential predictor variables were selected from the baseline survey (2015–2016) because the changes in the anemia level (incidence or remission) at the population level is a long-term process, except for one predictor variable (education was computed using information from both 2015–2016 and 2018–2019 surveys). One may expect that baseline characteristics of adolescents might remain more or less unchanged during the survey period, which justifies the inclusion of a majority of baseline characteristics as potential predictors.

First, in terms of *socio-demographic characteristics*, we considered the participant's age, religion, social group, place of residence, education in years, and engagement in paid work. Other household-level demographic characteristics included household size, mother's education, household wealth quintile, source of drinking water, and toilet facility. Between 2015–2016 and 2018–2019, a change in the education level could have a significant effect on health status [36,37], thus using both rounds of surveys, we computed this variable into four categories: remained uneducated, remained with the education of 1–9 y, the transition from 1–9 y to ≥10 y of education, and remained with education with ≥10 y. Engagement in paid work was defined if the respondent reported doing paid work since the time they were 10 y of age. The definition of social groups was guided by the Constitution of India, where Scheduled Tribes are considered as the most underserved group, followed by Scheduled Castes and Other Backward Classes, whereas the rest of the people fall into the "Others" category who have historically enjoyed privileges [33,34]. Sources of drinking water were considered as improved sources if the water was fetched from own piped water/hand pump/covered well, other piped water/hand pump/covered well, surface water/spring/river/stream/pond/rainwater, and water from a tanker, whereas open wells and other sources of water were considered as nonimproved sources of drinking water. Available with the dataset, the wealth quintile comprises household asset data on the ownership of selected durable goods, including means of transportation, and data on access to several amenities. A score ranging from 0–57 was allocated to a household's reported assets or amenities, followed by household ranking according to the index score, and ranked samples were divided into five quintiles [22].

Second, variables representing exposure to *healthcare information and healthcare* included if adolescents received health information from accredited social health activist (ASHA)/Urban Social Health Activist (USHA) in the last 1 y (yes, and no/never heard of ASHA or USHA), and if they received health information from *Anganwadi* worker (AWW) in last 1 y (yes, and no/never heard of AWW). Furthermore, if they had heard about adolescent-friendly health clinics (yes and no), if they received IFA and/or de-worming tablet from school or *Anganwadi* center (AWC) or ASHA in the last 1 y (none, IFA tablet only, de-worming tablet only, and both IFA and de-worming tablet), and if they underwent blood testing for anemia at the school or AWC in last 1 y (yes and no) were also considered as potential predictors. In India, AHSAs are village-level community health workers, whereas USHAs are responsible for catering healthcare services in urban areas. In addition, the National Iron Plus Initiative, a guideline devised in 2013 for mitigating anemia among children, adolescents, and adults, advises weekly IFA supplementation and bi-annual administration of de-worming tablets to all adolescents (irrespective of their sex) by AWW, ASHA, or the school authority [16].

Third, *information on violence and sexual abuse* were collected through three closed-ended questions–*1*) if adolescents were ever physically hurt by their parents since they turned 10 y old, *2*) the experience of sexual abuse was assessed through a closed-ended question whether the adolescents were ever deliberately touched on their private parts when they did not want to be touched, and *3*) depressive symptoms were measured using patient health questionnaire (PHQ-9) [22,23]. With a 15-d reference period, respondents were asked, among other questions, about their experience in sleeping patterns, eating patterns, concentration on their studies or whatever they did, and their feelings of tension. Responses were coded into four categories (nearly every day, ≥1 wk, <1 wk, and not at all) to define the frequency of their experience with the above symptoms.

Fourth, in the dietary section of the questionnaire, adolescents provided information on their diet intake, if they received mid-day meals in the school, and cooked meals and/or rations from AWC. Adolescents provided the frequency of consuming foods from the following food groups in the first round of the survey: milk and milk products, pulses and beans, dark green leafy vegetables, other vegetables, fruits, eggs, fish and seafood, poultry and meat, fried food, and aerated drinks (aerated drinks refer to nonalcoholic carbonated beverages). Responses were coded into four categories of frequency: daily, weekly, occasionally (less than once a week), and never. A question recorded if adolescents received mid-day meals from the school during their last school visit, and the responses were coded into yes, no, not provided in the school, and currently not attending school. According to the National Food Security Act, 2013, children (children aged 3–6 y, children of lower- as well as upper primary classes) are expected to receive a morning snack/hot cooked meal from the school [38]. A closed-ended question was asked to collect information on whether adolescents ever received a take-home ration/hot cooked meal from the AWC. Adolescents' experience of discrimination in food distribution at home was assessed through the question of whether their opposite-sex sibling (age difference ± 3 y) was given more or better-quality

food. Responses were coded as no discrimination/unaware of discrimination, more amount of food/quality food to boys/girls, and not co-residing with a same-age sibling. For physical activity, a single close-ended question was asked if they regularly "play any sports or games or engaged in physical activities like walking, skipping, running, yoga, etc.?" and the response (yes and no) was recorded from each respondent.

Finally, adolescents were asked about their modifiable lifestyle risk behaviors. If they ever consumed smoking and/or smokeless tobacco, ate betel nut and/or betel leaf, or consumed alcohol. Their response (yes and no) was recorded against each query of these options. Although data on predictors were available for all 3279 never-married adolescents, other potentially relevant variables were not available in the UDAYA dataset [22, 23].

Statistical analysis

Our analysis proceeded in two steps. First, we calculated descriptive statistics and estimated incidence and remission of anemia, and second, we ran a regression analysis to determine predictors of incidence and remission of anemia. To be specific, for the binary outcome (coded "1" if incidence/remission, otherwise coded "0"), the modified Poisson regression models with robust error variance [39] were developed to understand the predictors (estimated in terms of RR) of incidence and remission of anemia. Using a Poisson model without robust error variances could result in a wide confidence interval (CI). A 2-fold strategy was used to deploy the modified Poisson regression models. At Stage I, labeled as a "univariate" model, RR was estimated for each variable representing socioeconomic characteristics, exposure to healthcare information and healthcare, history of violence, sexual abuse and PHQ score, diet, nutrition, physical activity, and modifiable lifestyle risk behavior. At Stage II, variables with $P < 0.05$ in the univariate regression model were included in one model, which was labeled as a "multivariable" model. This stepwise selection of variables helped narrow down the best possible predictors of outcome events of interest [40,41]. Although running the regressions in the multivariable model, three new variables were introduced: *1*) variables representing the states of Bihar and Uttar Pradesh, *2*) a primary sampling unit, and *3*) an individual-level variable to account for the time difference between baseline and end-line surveys (in completed months). Variance Inflation Factors (VIF) were estimated for the variables included in the multivariable model to assess if the VIFs are <5, which would show a low probability of multicollinearity among predictors [42]. It was found that estimated VIFs were <5, indicating a low chance of multicollinearity. Percentage estimates and RR obtained from the regression model were reported with 95% CI. Appropriate sample weighting devised by the Population Council for analysis of anemia was used for all estimates (except counts). The "svy" suite with statistical software Stata version 14 [43] was used to obtain robust estimates. We clustered standard errors at the primary sampling unit level.

Results

Descriptive statistics

A cohort of 3279 never-married adolescents was used to assess change in the burden of anemia between 2015–2016 and 2018–2019. In addition, the incidence of anemia was analyzed for 1880 adolescents who did not have anemia in the first survey, whereas remission of anemia included a sample of 1399 adolescents that were anemic. Overall, the prevalence of anemia was found to have decreased from 33.9% (95% CI: 30.7%–37.3%) in 2015–2016 to 31.6% (95% CI: 28.6%–34.7%) 2018–2019 among male adolescents, whereas it had increased among females from 57.7% (95% CI: 53.5%–61.7%) in 2015–2016 to 63.8% (95% CI: 59.9%–67.5%) in 2018–2019 (Table 1). In addition, in both baseline and follow-up surveys, the burden of anemia among males living in rural areas was higher than among males residing in urban areas, whereas females residing in urban areas were estimated to have a higher burden of anemia than female adolescents from rural areas.

Incidence and remission of anemia and their predictors

Table 2 lists the predictors of anemia incidence and its burden. Overall, 33.7%, 95% CI: 30.3%–37.2% adolescents experience anemia incidence. The multivariable model suggested that adolescents aged 15–19 y were less likely to experience anemia incidence compared with adolescents aged 10–14 y (RR: 0.71, 95% CI: 0.52–0.96, $P = 0.028$). Females had higher odds of experiencing an incidence of anemia (RR: 2.09, 95% CI: 1.74–2.51, $P < 0.001$). Compared with those living in households with 1–4 members, people living with 5–7 members were more likely to experience an incidence of anemia (RR: 1.48, 95% CI: 1.14–1.94, $P = 0.003$). Increased PHQ score was associated with increased odds of anemia incidence (RR: 1.07, 95% CI: 1.02–1.13, $P = 0.008$). Compared with those who consumed eggs "daily/weekly," those who consumed eggs only "occasionally/never" had increased odds of anemia incidence (RR: 1.30, 95% CI: 1.08–1.56, $P = 0.006$). Nonreceipt of take-home ration/cooked meal from the AWC was negatively associated with the incidence of anemia (RR: 0.69, 95% CI: 0.53–0.91, $P = 0.009$).

Percentage estimates and predictors of remission of anemia are presented in Table 3. Overall, 38.5% (95% CI: 35.1%–42.1%) of adolescents experienced anemia remission. The multivariable model indicates that females were less likely to experience remission of anemia than males (RR: 0.52, 95% CI: 0.43–0.63, $P < 0.001$). Nonreceipt of take-home ration/cooked meal from the AWC positively associated with remission of anemia (RR: 2.42, 95% CI: 1.18–4.96, $P = 0.015$).

Discussion

Using a prospective longitudinal dataset from the UDAYA survey conducted in the states of Bihar and Uttar Pradesh, India, this study assessed the burden, incidence, and remission of anemia among never-married adolescents aged 10–19 y between 2015–2016 and 2018–2019. The burden of anemia increased over time among females, whereas it decreased among males between 2015–2016 and 2018–2019. The incidence of anemia among females was more than double compared with males, whereas their remission from anemia was nearly twice as low. Incidence of anemia was found to be associated with age group, sex, household size, PHQ-9 score, consumption of eggs, and receiving of take-home ration/cooked meal from an AWC. On the other hand, sex and receiving a take-home ration/cooked

TABLE 1
Prevalence of anemia by selected background characteristics among male and female adolescents who participated in the two rounds of UDAYA (Understanding the lives of Adolescents and Young Adults) surveys in Bihar and Uttar Pradesh, India

Background characteristics	Sample		Anemic (Baseline, 2015–2016)		Anemic (Follow-up, 2018–2019)	
	Male, n^1	Female, n^1	Male % (95% CI)	Female % (95% CI)	Male % (95% CI)	Female % (95% CI)
Socioeconomic characteristics						
Age group						
10–14	1397	1136	32.8 (29.1–36.6)	54.7 (50.3–59.0)	35.3 (31.8–38.9)	64.4 (60.0–68.5)
15–19	390	356	37.9 (31.1–45.3)	67.9 (59.6–75.2)	18.5 (13.4–24.9)	61.9 (55.1–68.3)
Education (in y)						
Remained uneducated	31	46	35.5 (18.8–56.7)	60.8 (43.0–76.2)	49.9 (27.8–72.1)	66.7 (44.9–83.1)
Remained with the education of 1–9 y	1240	968	34.2 (30.8–37.9)	55.8 (51.2–60.3)	35.2 (31.7–38.9)	66.6 (61.8–71.0)
Transition from 1–9 y to ≥10 y of education	417	377	32.3 (26.6–38.5)	60.3 (52.6–67.5)	24.1 (18.7–30.6)	59.2 (52.0–66.1)
Remained with education with ≥10 y	99	101	36.5 (24.2–50.8)	64.9 (46.5–79.8)	14.1 (6.9–26.5)	52.0 (36.7–66.9)
Ever done any paid work						
No	1565	1352	32.6 (29.2–36.2)	56.5 (52.1–60.8)	32.1 (28.9–35.5)	63.6 (59.5–67.5)
Yes	222	140	41.5 (33.9–49.6)	66.9 (57.1–75.4)	28.3 (21.0–36.8)	65.7 (55.7–74.5)
Place of residence						
Urban	703	640	27.4 (23.3–32.0)	60.1 (53.0–66.7)	21.3 (17.5–25.5)	64.7 (57.1–71.6)
Rural	1084	852	35.0 (31.3–38.9)	57.2 (52.5–61.8)	33.3 (29.9–36.9)	63.6 (59.2–67.8)
Religion						
Hinduism	1541	1168	34.9 (31.4–38.7)	58.4 (53.7–63.1)	32.0 (28.5–35.6)	63.6 (59.2–67.7)
Islam/others	246	324	27.3 (21.8–33.7)	54.6 (45.3–63.7)	29.1 (22.1–37.1)	64.8 (56.8–72.0)
Social group						
Others	301	301	31.7 (25.1–39.2)	61.6 (53.8–68.9)	34.5 (27.0–42.9)	64.3 (55.3–72.3)
OBC	1046	842	33.5 (29.1–38.2)	55.9 (50.2–61.5)	29.7 (25.6–34.1)	64.1 (58.5–69.4)
SC/ST	440	349	36.2 (30.7–42.0)	58.7 (51.8–65.3)	33.8 (28.0–40.0)	62.7 (55.8–69.2)
Household size						
1–4	340	225	29.1 (22.1–37.1)	59.9 (50.4–68.7)	23.6 (17.7–30.7)	60.7 (52.0–68.8)
5–7	1047	888	35.6 (31.5–39.8)	57.1 (52.3–61.8)	34.6 (30.7–38.7)	64.7 (59.7–69.3)
≥8	400	379	33.4 (27.0–40.5)	57.8 (49.7–65.5)	29.8 (23.1–37.6)	63.5 (56.3–70.2)
Mother's education (in y)						
0	1215	986	34.5 (30.9–38.3)	55.9 (50.9–60.8)	33.1 (29.4–37.1)	63.7 (59.3–67.8)
1–9	355	313	34.1 (27.2–41.7)	63.5 (56.2–70.2)	25.6 (19.4–33.0)	62.8 (54.4–70.5)
≥10	217	193	29.2 (20.6–39.6)	56.1 (46.1–65.7)	30.9 (21.2–42.7)	68.0 (58.9–75.8)
Source of drinking water						
Improved	1743	1468	33.6 (30.4–37.1)	57.9 (53.8–61.9)	32.0 (28.9–35.3)	63.5 (59.5–67.3)
Nonimproved	44	24	42.5 (22.8–64.9)	44.4 (24.5–66.3)	18.7 (8.4–36.8)	83.6 (64.1–93.6)
Toilet facility						
None	1012	754	35.7 (31.6–39.9)	57.6 (52.8–62.3)	34.4 (30.6–38.4)	65.9 (61.5–70.1)
Own flush/pit toilet	620	589	30.3 (25.7–35.4)	57.8 (50.8–64.6)	26.2 (20.7–32.5)	60.2 (52.6–67.3)
Shared flush/pit toilet	155	149	32.6 (21.9–45.4)	57.3 (45.9–68.0)	26.9 (17.8–38.5)	62.5 (50.5–73.2)
Wealth quintile						
Poorest	214	174	40.9 (33.1–49.3)	56.7 (48.3–64.6)	37.2 (29.0–46.2)	62.4 (53.5–70.5)
Poorer	324	241	32.8 (25.1–41.6)	57.9 (50.4–65.1)	35.6 (28.7–43.1)	67.0 (58.3–74.7)
Middle	402	303	31.3 (25.1–38.2)	58.5 (51.1–65.6)	38.7 (32.1–45.7)	71.5 (64.9–77.3)
Richer	432	400	35.9 (29.9–42.4)	52.8 (45.0–60.5)	25.1 (20.4–30.6)	60.4 (52.6–67.7)
Richest	415	374	31.1 (23.8–39.4)	62.5 (53.6–70.6)	22.2 (16.0–29.9)	58.5 (49.3–67.1)
State						
Bihar	909	696	28.6 (23.7–33.9)	59.8 (54.3–65.1)	30.7 (25.9–35.9)	73.8 (68.3–78.6)
Uttar Pradesh	878	796	36.9 (32.7–41.3)	56.5 (50.9–62.0)	32.1 (28.3–36.1)	58.6 (53.6–63.4)

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TABLE 1 (*continued*)

Background characteristics	Sample		Anemic (Baseline, 2015–2016)		Anemic (Follow-up, 2018–2019)	
	Male, n^1	Female, n^1	Male % (95% CI)	Female % (95% CI)	Male % (95% CI)	Female % (95% CI)
Exposure to healthcare information and healthcare						
Received health information from ASHA/USHA						
Yes	50	57	36.5 (22.2–53.6)	60.7 (44.9–74.5)	30.4 (14.5–53.1)	76.5 (62.2–86.6)
No/never heard of ASHA or USHA	1737	1435	33.8 (30.6–37.2)	57.5 (53.2–61.8)	31.6 (28.7–34.7)	63.2 (59.2–67.0)
Received health information from *Anganwadi* workers						
Yes	117	108	31.7 (21.6–43.9)	50.5 (38.2–62.7)	36.8 (26.0–49.2)	69.2 (54.3–80.9)
No/never heard of *Anganwadi* workers	1670	1384	34.1 (30.8–37.5)	58.3 (54.0–62.5)	31.2 (28.1–34.4)	63.4 (59.4–67.1)
Heard about the adolescent-friendly health clinic						
Yes	17	35	20.3 (6.2–49.8)	44.2 (24.8–65.6)	33.1 (8.7–72.1)	51.8 (33.1–70.0)
No	1770	1457	34.2 (30.9–37.6)	58.0 (53.8–62.0)	31.5 (28.5–34.7)	64.1 (60.1–67.8)
Received IFA and/or de-worming tablet from school or *Anganwadi* center or ASHA						
None	1293	1147	35.1 (31.4–39.0)	57.0 (52.2–61.7)	32.5 (29.0–36.3)	63.2 (58.7–67.4)
Yes	494	345	30.6 (25.1–36.6)	59.9 (52.8–66.5)	28.8 (23.6–34.7)	65.9 (58.4–72.7)
Underwent blood testing for anemia at the school or *Anganwadi* center						
Yes	60	46	30.3 (17.9–46.6)	72.3 (54.4–85.1)	38.9 (25.1–54.7)	68.2 (49.8–82.3)
No	1727	1446	34.0 (30.7–37.6)	57.3 (53.0–61.4)	31.3 (28.2–34.6)	63.7 (59.8–67.4)
Violence and sexual abuse						
Ever physically hurt by father or/and mother						
Yes	1161	686	33.4 (29.5–37.6)	56.4 (51.1–61.5)	33.6 (30.1–37.2)	65.0 (59.6–70.0)
No	626	806	34.8 (30.0–40.1)	58.8 (52.6–64.8)	27.7 (23.0–33.0)	62.7 (57.1–68.1)
Sexual abuse						
Yes	31	77	49.7 (28.4–71.0)	46.2 (30.0–63.2)	40.0 (20.3–63.7)	64.3 (50.6–76.0)
No	1756	1415	33.6 (30.3–37.0)	58.1 (54.0–62.2)	31.4 (28.3–34.6)	63.8 (59.8–67.6)
PHQ score	1787	1492	**	**	**	**
Nutrition and physical activity						
Food consumption frequency						
Milk/curd/paneer (cottage cheese)						
Daily/weekly	1267	876	33.3 (29.4–37.5)	56.9 (51.5–62.1)	31.8 (28.3–35.5)	63.4 (58.0–68.4)
Occasionally/never	520	616	35.4 (29.9–41.4)	58.7 (52.8–64.4)	31.0 (26.0–36.4)	64.4 (59.0–69.5)
Pulse/beans						
Daily/weekly	1663	1336	33.7 (30.4–37.0)	57.7 (53.5–61.9)	31.4 (28.2–34.7)	64.4 (60.4–68.3)
Occasionally/never	124	156	36.9 (26.6–48.6)	57.2 (46.0–67.7)	33.9 (23.9–45.6)	59.0 (48.2–69.0)
Dark green leafy vegetable						
Daily/weekly	1147	1134	33.2 (29.4–37.2)	56.2 (51.7–60.7)	31.1 (27.6–34.7)	63.3 (58.9–67.5)
Occasionally/never	640	358	35.2 (29.9–40.9)	62.0 (54.6–68.9)	32.5 (27.5–37.9)	65.4 (58.8–71.5)
Other vegetables						
Daily/weekly	1729	1457	33.9 (30.7–37.2)	58.1 (54.0–62.2)	31.8 (28.7–35.0)	64.2 (60.2–68.0)
Occasionally/never	58	35	35.7 (20.4–54.7)	39.3 (19.7–63.1)	25.1 (13.7–41.3)	50.1 (34.4–65.8)
Fruit						
Daily/weekly	640	593	30.7 (25.5–36.5)	54.8 (49.1–60.4)	26.7 (22.3–31.6)	63.8 (57.2–69.9)
Occasionally/never	1147	899	35.4 (31.5–39.5)	59.3 (54.3–64.1)	33.9 (30.1–37.8)	63.8 (59.5–67.9)
Egg						
Daily/weekly	598	470	31.3 (26.4–36.8)	59.4 (52.4–66.0)	27.0 (22.8–31.6)	60.9 (53.8–67.4)
Occasionally/never	1189	1022	34.9 (31.1–38.9)	57.1 (52.0–62.0)	33.4 (29.6–37.4)	64.8 (60.2–69.2)
Fish/seafood						
Daily/weekly	266	264	30.7 (22.8–40.0)	62.9 (54.5–70.6)	34.3 (26.9–42.6)	68.1 (59.0–75.9)
Occasionally/never	1521	1228	34.4 (31.0–37.9)	56.9 (52.2–61.4)	31.2 (28.0–34.6)	63.2 (59.1–67.0)
Chicken/meat						

(*continued on next page*)

TABLE 1 (*continued*)

Background characteristics	Sample		Anemic (Baseline, 2015–2016)		Anemic (Follow-up, 2018–2019)	
	Male, n^1	Female, n^1	Male % (95% CI)	Female % (95% CI)	Male % (95% CI)	Female % (95% CI)
Daily/weekly	329	325	31.1 (24.0–39.2)	63.8 (55.9–71.0)	29.9 (23.0–37.8)	66.7 (58.5–74.0)
Occasionally/never	1458	1167	34.4 (30.8–38.2)	56.4 (51.8–61.0)	31.9 (28.7–35.3)	63.2 (58.9–67.4)
Fried food						
Daily/weekly	1052	683	30.4 (26.4–34.7)	60.5 (54.7–66.0)	29.5 (25.8–33.5)	65.1 (59.2–70.6)
Occasionally/never	735	809	38.4 (33.9–43.2)	55.5 (50.4–60.6)	34.2 (29.4–39.3)	62.9 (58.0–67.5)
Aerated drinks						
Daily/weekly	218	172	35.1 (26.5–44.8)	53.4 (41.3–65.2)	24.1 (17.5–32.3)	62.1 (48.6–73.9)
Occasionally/never	1569	1320	33.8 (30.3–37.4)	58.2 (54.1–62.2)	32.5 (29.4–35.7)	64.0 (60.1–67.7)
Received mid-day meal						
Yes	559	525	30.1 (24.9–35.9)	53.5 (47.8–59.2)	34.2 (28.7–40.0)	68.1 (61.9–73.8)
No	259	216	45.3 (37.1–53.8)	47.6 (38.5–57.0)	33.6 (25.2–43.2)	59.5 (51.0–67.4)
Not provided in school/college	876	625	32.2 (27.7–37.0)	60.9 (54.6–66.9)	29.0 (24.8–33.7)	59.5 (52.9–65.8)
Currently not attending school/correspondence schooling	93	126	42.0 (28.7–56.6)	74.2 (64.1–82.2)	33.2 (21.7–47.2)	70.9 (61.9–78.6)
Received take-home ration/cooked meal from *Anganwadi* Center						
Yes	66	56	34.2 (21.4–49.7)	40.0 (25.4–56.6)	51.9 (35.7–67.6)	81.6 (61.2–92.6)
No	1721	1436	33.9 (30.6–37.4)	58.5 (54.2–62.6)	30.7 (27.7–33.8)	63.0 (59.2–66.7)
Witnessed discrimination in food distribution at home						
No discrimination/unaware of discrimination	757	643	31.7 (27.0–36.7)	56.4 (50.8–61.9)	33.5 (29.2–38.1)	62.7 (57.4–67.7)
More amount of food/quality food for boys	na	91	na	62.9 (50.3–74.0)	na	69.2 (57.9–78.6)
More amount of food/quality food for girls	45	na	33.2 (16.4–55.6)	na	22.0 (11.5–38.2)	na
No co-residing brother/sister or cousin brother/sister (aged ± 3 y)	985	758	35.5 (31.2–40.1)	58.1 (53.0–63.0)	30.7 (27.0–34.6)	64.1 (59.0–68.9)
Physical activity						
Yes	1654	1092	33.2 (30.0–36.6)	56.0 (51.5–60.4)	31.8 (28.8–35.0)	63.2 (58.4–67.8)
No	133	400	41.5 (30.3–53.7)	61.7 (54.2–68.7)	28.8 (19.8–39.9)	65.2 (58.6–71.2)
Modifiable lifestyle risk behavior						
Ever had smoking and/or smokeless tobacco						
Yes	87	17	23.9 (13.5–38.9)	61.9 (29.8–86.1)	29.8 (18.5–44.4)	56.8 (27.0–82.3)
No	1700	1475	34.5 (31.1–38.0)	57.6 (53.4–61.7)	31.7 (28.7–34.8)	63.9 (59.9–67.6)
Ever had alcohol						
Yes	30	0	17.8 (6.3–41.3)	nc	23.8 (9.4–48.4)	nc
No	1757	1492	34.2 (31.0–37.6)	57.7 (53.5–61.7)	31.7 (28.7–34.9)	63.8 (59.9–67.5)
Overall	1787	1492	33.9 (30.7–37.3)	57.7 (53.5–61.7)	31.6 (28.6–34.7)	63.8 (59.9–67.5)

ASHA, accredited social health activist; IFA, iron and folic acid; nc, no cases; na, not applicable; OBC, other backward classes; PHQ, patient health questionnaire; SC, scheduled caste; ST, scheduled tribe; USHA, urban social health activist. [1]All *n* are unweighted. Sampling weights were used to estimate prevalence. The distribution of observations is for baseline characteristics, except education. **Percentage values were not calculated as the variable is continuous.

TABLE 2
Predictors of anemia incidence among adolescents who participated in the two rounds of UDAYA (Understanding the lives of Adolescents and Young Adults) surveys in Bihar and Uttar Pradesh, India

Predictor	Sample, *n*	Incidence	Univariate model		Multivariable model	
		% (95% CI)	RR (95% CI)	*P*	RR (95% CI)	*P*
Socioeconomic characteristics						
Age group						
10–14	1489	37.1 (33.5–41.0)	1.00 (referent)		1.00 (referent)	
15–19	391	19.5 (14.8–25.2)	0.52 (0.40–0.69)	<0.001	0.71 (0.52–0.96)	0.028
Sex						
Male	1244	23.9 (20.5–27.8)	1.00 (referent)		1.00 (referent)	
Female	636	52.3 (46.4–58.1)	2.18 (1.83–2.60)	<0.001	2.09 (1.74–2.51)	<0.001
Education (in y)						
Remained uneducated	36	46.9 (28.6–66.2)	1.00 (referent)		1.00 (referent)	
Remained with the education of 1–9 y	1288	37.1 (33.2–41.2)	0.79 (0.50–1.26)	0.324	0.81 (0.45–1.45)	0.481
Transition from 1–9 y to ≥10 y of education	450	27.0 (21.5–33.3)	0.58 (0.35–0.96)	0.033	0.66 (0.36–1.19)	0.166
Remained with education with ≥10 y	106	15.1 (8.0–26.6)	0.32 (0.15–0.68)	0.003	0.49 (0.21–1.10)	0.085
Ever done any paid work						
No	1679	34.9 (31.5–38.5)	1.00 (referent)			
Yes	201	24.3 (16.1–35.0)	0.70 (0.48–1.01)	0.054		
Place of residence						
Urban	793	30.7 (26.6–35.2)	1.00 (referent)			
Rural	1087	34.2 (30.4–38.3)	1.11 (0.93–1.33)	0.233		
Religion						
Hinduism	1555	33.7 (29.9–37.8)	1.00 (referent)			
Islam/others	325	33.4 (27.2–40.3)	0.99 (0.78–1.25)	0.941		
Social group						
Others	344	37.4 (31.0–44.4)	1.00 (referent)			
OBC	1107	32.0 (27.5–36.9)	0.85 (0.68–1.07)	0.167		
SC/ST	429	35.0 (28.7–42.0)	0.94 (0.73–1.21)	0.609		
Household size						
1–4	352	22.1 (17.4–27.6)	1.00 (referent)		1.00 (referent)	
5–7	1076	37.2 (32.2–42.5)	1.68 (1.29–2.20)	<0.001	1.48 (1.14–1.94)	0.003
≥8	452	33.5 (27.2–40.4)	1.52 (1.11–2.07)	0.008	1.29 (0.95–1.74)	0.102
Mother's education (in y)						
0	1239	34.4 (30.4–38.6)	1.00 (referent)			
1–9	391	31.5 (26.2–37.3)	0.91 (0.73–1.15)	0.439		
≥10	250	32.8 (24.3–42.5)	0.95 (0.72–1.26)	0.732		
Source of drinking water						
Improved	1842	33.8 (30.3–37.5)	1.00 (referent)			
Nonimproved	38	30.6 (15.8–50.8)	0.91 (0.51–1.60)	0.733		
Toilet facility						
None	995	34.4 (30.3–38.6)	1.00 (referent)			
Own flush/pit toilet	706	32.1 (26.2–38.6)	0.93 (0.76–1.14)	0.504		
Shared flush/pit toilet	179	35.3 (26.2–45.6)	1.03 (0.76–1.40)	0.858		
Wealth quintile						
Poorest	204	37.3 (30.5–44.7)	1.00 (referent)			
Poorer	330	33.3 (26.5–40.8)	0.89 (0.67–1.19)	0.439		
Middle	413	38.4 (32.3–44.8)	1.03 (0.78–1.35)	0.846		
Richer	476	31.8 (25.5–38.8)	0.85 (0.64–1.13)	0.270		
Richest	457	28.7 (22.0–36.5)	0.77 (0.56–1.05)	0.101		

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TABLE 2 (*continued*)

Predictor	Sample, *n*	Incidence	Univariate model		Multivariable model	
		% (95% CI)	RR (95% CI)	*P*	RR (95% CI)	*P*
Exposure of healthcare information and healthcare						
Received health information from ASHA/USHA						
Yes	52	40.5 (23.3–60.4)	1.00 (referent)			
No/never heard of ASHA or USHA	1828	33.4 (30.2–36.8)	0.83 (0.51–1.33)	0.428		
Received health information from *Anganwadi* workers						
Yes	129	42.3 (30.4–55.2)	1.00 (referent)			
No/never heard of *Anganwadi* workers	1751	33.0 (29.6–36.5)	0.78 (0.57–1.05)	0.106		
Heard about adolescent-friendly health clinic						
Yes	29	36.4 (14.5–65.7)	1.00 (referent)			
No	1851	33.6 (30.3–37.1)	0.93 (0.42–2.02)	0.845		
Received IFA and/or de-worming tablet from school or *Anganwadi* center or ASHA						
None	1383	34.5 (30.6–38.6)	1.00 (referent)			
Yes	497	31.4 (25.4–38.0)	0.91 (0.74–1.11)	0.350		
Underwent blood testing for anemia at the school or *Anganwadi* center						
Yes	58	34.8 (21.6–50.7)	1.00 (referent)			
No	1822	33.7 (30.3–37.2)	0.97 (0.60–1.56)	0.893		
Violence and sexual abuse						
Ever physically hurt by father or/and mother						
Yes	1097	33.9 (30.1–37.8)	1.00 (referent)			
No	783	33.4 (28.4–38.9)	0.99 (0.82–1.18)	0.892		
Sexual abuse						
Yes	59	50.4 (33.0–67.7)	1.00 (referent)		1.00 (referent)	
No	1821	33.2 (29.8–36.8)	0.66 (0.47–0.93)	0.019	0.74 (0.51–1.07)	0.111
PHQ score	1880	**	1.08 (1.02–1.14)	0.009	1.07 (1.02–1.13)	0.008
Nutrition and physical activity						
Food consumption frequency						
Milk/curd/paneer (cottage cheese)						
Daily/weekly	1257	32.6 (28.5–37.0)	1.00 (referent)			
Occasionally/never	623	36.1 (31.3–41.2)	1.11 (0.93–1.32)	0.267		
Pulse/beans						
Daily/weekly	1733	33.5 (30.1–37.0)	1.00 (referent)			
Occasionally/never	147	35.9 (26.3–46.9)	1.07 (0.79–1.46)	0.652		
Dark green leafy vegetable						
Daily /weekly	1302	33.9 (30.0–38.1)	1.00 (referent)			
Occasionally/never	578	33.1 (27.6–39.2)	0.98 (0.80–1.19)	0.804		
Other vegetables						
Daily/weekly	1827	34.1 (30.7–37.6)	1.00 (referent)			
Occasionally/never	53	22.8 (10.9–41.6)	0.67 (0.34–1.32)	0.245		
Fruit						
Daily/weekly	710	33.9 (28.8–39.4)	1.00 (referent)			
Occasionally/never	1170	33.6 (29.5–37.9)	0.99 (0.83–1.19)	0.929		
Egg						
Daily/weekly	627	26.1 (21.7–31.1)	1.00 (referent)		1.00 (referent)	
Occasionally/never	1253	36.6 (32.5–40.9)	1.40 (1.14–1.71)	0.001	1.30 (1.08–1.56)	0.006
Fish/seafood						
Daily/weekly	299	36.2 (28.9–44.1)	1.00 (referent)			
Occasionally/never	1581	33.3 (29.7–37.1)	0.92 (0.73–1.16)	0.494		
Chicken/meat						
Daily/weekly	369	31.4 (25.0–38.5)	1.00 (referent)			

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TABLE 2 (*continued*)

Predictor	Sample, *n*	Incidence	Univariate model		Multivariable model	
		% (95% CI)	RR (95% CI)	*P*	RR (95% CI)	*P*
Occasionally/never	1511	34.1 (30.4–38.1)	1.09 (0.87–1.36)	0.463		
Fried food						
Daily/weekly	1024	30.3 (26.4–34.5)	1.00 (referent)		1.00 (referent)	
Occasionally/never	856	37.5 (32.3–42.9)	1.24 (1.04–1.48)	0.018	1.03 (0.87–1.22)	0.755
Aerated drinks						
Daily/weekly	222	29.7 (21.6–39.3)	1.00 (referent)			
Occasionally/never	1658	34.2 (30.8–37.7)	1.15 (0.84–1.57)	0.374		
Received mid-day meal						
Yes	643	37.1 (31.8–42.8)	1.00 (referent)		1.00 (referent)	
No	255	35.6 (27.4–44.9)	0.96 (0.73–1.26)	0.772	1.05 (0.77–1.42)	0.770
Not provided in school/college	883	30.3 (25.7–35.3)	0.82 (0.67–0.99)	0.044	1.11 (0.91–1.35)	0.307
Currently not attending school/correspondence schooling	99	34.1 (23.3–46.9)	0.92 (0.62–1.36)	0.676	1.22 (0.85–1.74)	0.273
Received take-home ration/cooked meal from *Anganwadi* center						
Yes	73	54.4 (38.7–69.3)	1.00 (referent)		1.00 (referent)	
No	1807	32.6 (29.3–36.2)	0.60 (0.45–0.81)	0.001	0.69 (0.53–0.91)	0.009
Witnessed discrimination in food distribution at home						
No discrimination/unaware of discrimination	828	36.2 (31.2–41.6)	1.00 (referent)			
More amount of food/quality food for boys/girls	69	33.8 (21.3–49.1)	0.93 (0.62–1.40)	0.736		
No co-residing brother or cousin brother (aged ± 3 y)	983	31.7 (27.5–36.3)	0.88 (0.73–1.05)	0.146		
Physical activity						
Yes	1640	32.5 (29.1–36.2)	1.00 (referent)		1.00 (referent)	
No	240	41.0 (32.5–50.0)	1.26 (1.01–1.57)	0.041	1.02 (0.83–1.26)	0.844
Modifiable lifestyle risk behavior						
Ever had smoking and/or smokeless tobacco						
Yes	75	19.8 (10.9–33.1)	1.00 (referent)		1.00 (referent)	
No	1805	34.3 (31.0–37.9)	1.74 (1.01–2.98)	0.044	1.14 (0.70–1.88)	0.600
Ever had alcohol						
Yes	24	12.6 (3.0–40.2)	1.00 (referent)			
No	1856	34.0 (30.7–37.5)	2.69 (0.72–10.05)	0.141		
Overall	1880	33.7 (30.3–37.2)				

All *n* are unweighted. All regression models used appropriate sample weighting and were adjusted for the state, PSU, and the time difference between baseline and follow-up surveys (in months). ASHA, accredited social health activist; IFA, iron and folic acid; OBC, other backward classes; *P*, level of significance; PHQ, patient health questionnaire; PSU, primary sampling unit; SC, scheduled caste; ST, scheduled tribe; USHA, urban social health activist. **Percentage values were not calculated as the variable is continuous.

TABLE 3
Predictors of anemia remission among adolescents who participated in the two rounds of UDAYA (Understanding the lives of Adolescents and Young Adults) surveys in Bihar and Uttar Pradesh, India

Predictor	Sample, *n*	Remission	Univariate model		Multivariable model	
		% (95% CI)	RR (95% CI)	*P*	RR (95% CI)	*P*
Socioeconomic characteristics						
Age group						
10–14	1044	36.6 (32.8–40.6)	1.00 (referent)			
15–19	355	44.0 (37.0–51.2)	1.20 (0.99–1.47)	0.070		
Sex						
Male	543	53.6 (48.1–59.0)	1.00 (referent)		1.00 (referent)	
Female	856	27.7 (23.3–32.6)	0.52 (0.43–0.63)	<0.001	0.52 (0.43–0.63)	<0.001
Education (in y)						
Remained uneducated	41	26.0 (12.9–45.6)	1.00 (referent)		1.00 (referent)	
Remained with education of 1–9 y	920	35.8 (32.0–39.8)	1.37 (0.77–2.46)	0.286	1.19 (0.63–2.23)	0.589
Transition from 1–9 y to ≥10 y of education	344	44.3 (36.9–51.9)	1.70 (0.94–3.08)	0.079	1.38 (0.73–2.61)	0.314
Remained with education with ≥10 y	94	49.6 (37.3–62.0)	1.91 (1.01–3.59)	0.046	1.53 (0.77–3.02)	0.223
Ever done any paid work						
No	1238	38.3 (34.2–42.5)	1.00 (referent)			
Yes	161	39.8 (31.3–49.0)	1.04 (0.80–1.35)	0.768		
Place of residence						
Urban	550	43.0 (36.1–50.2)	1.00 (referent)			
Rural	849	37.7 (33.9–41.7)	0.88 (0.73–1.06)	0.179		
Religion						
Hinduism	1154	40.1 (36.1–44.1)	1.00 (referent)		1.00 (referent)	
Islam/others	245	30.3 (21.9–40.3)	0.76 (0.57–1.00)	0.049	0.84 (0.63–1.10)	0.201
Social group						
Others	258	37.7 (28.9–47.2)	1.00 (referent)			
OBC	781	37.7 (33.0–42.7)	1.00 (0.76–1.32)	0.985		
SC/ST	360	40.7 (33.8–47.9)	1.08 (0.81–1.44)	0.599		
Household size						
1–4	213	40.6 (32.2–49.6)	1.00 (referent)			
5–7	859	39.5 (35.3–43.8)	0.97 (0.76–1.24)	0.814		
≥8	327	35.4 (28.6–42.8)	0.87 (0.64–1.17)	0.362		
Mother's education (in y)						
0	962	38.0 (34.1–41.9)	1.00 (referent)			
1–9	277	41.9 (33.0–51.3)	1.10 (0.87–1.40)	0.410		
≥10	160	34.2 (24.2–45.9)	0.90 (0.66–1.23)	0.518		
Source of drinking water						
Improved	1369	38.2 (34.6–41.9)	1.00 (referent)			
Nonimproved	30	50.8 (26.0–75.1)	1.33 (0.82–2.15)	0.249		
Toilet facility						
None	771	35.3 (31.1–39.8)	1.00 (referent)		1.00 (referent)	
Own flush/pit toilet	503	43.8 (37.1–50.7)	1.24 (1.01–1.51)	0.036	1.02 (0.81–1.29)	0.866
Shared flush/pit toilet	125	46.4 (33.5–59.7)	1.31 (0.95–1.81)	0.094	1.24 (0.94–1.65)	0.133
Wealth quintile						
Poorest	184	39.1 (30.6–48.4)	1.00 (referent)		1.00 (referent)	
Poorer	235	31.1 (24.1–39.1)	0.80 (0.57–1.11)	0.178	0.77 (0.56–1.05)	0.095
Middle	292	28.2 (22.1–35.1)	0.72 (0.53–0.98)	0.034	0.67 (0.50–0.89)	0.007
Richer	356	44.9 (37.8–52.3)	1.15 (0.87–1.51)	0.324	1.00 (0.74–1.35)	0.993
Richest	332	48.2 (39.4–57.2)	1.23 (0.93–1.64)	0.150	1.03 (0.74–1.44)	0.857

(*continued on next page*)

TABLE 3 (*continued*)

Predictor	Sample, *n*	Remission	Univariate model		Multivariable model	
		% (95% CI)	RR (95% CI)	*P*	RR (95% CI)	*P*
Exposure of healthcare information and healthcare						
Yes	55	32.6 (19.3–49.5)	1.00 (referent)			
No/never heard of ASHA or USHA	1344	38.8 (35.3–42.5)	1.19 (0.77–1.84)	0.431		
Received health information from *Anganwadi* workers						
Yes	96	32.8 (21.1–47.1)	1.00 (referent)			
No/never heard of *Anganwadi* workers	1303	38.9 (35.4–42.6)	1.19 (0.79–1.79)	0.410		
Heard about the adolescent-friendly health clinic						
Yes	23	44.9 (21.4–71.0)	1.00 (referent)			
No	1376	38.4 (34.9–42.1)	0.86 (0.47–1.57)	0.612		
Received IFA and/or de-worming tablet from school or *Anganwadi* center or ASHA						
None	1057	38.6 (34.4–43.1)	1.00 (referent)			
Yes	342	38.2 (31.3–45.5)	0.99 (0.80–1.22)	0.914		
Underwent blood testing for anemia at the school or *Anganwadi* center						
Yes	48	32.5 (18.2–51.0)	1.00 (referent)			
No	1351	38.7 (35.2–42.4)	1.19 (0.71–2.01)	0.508		
Violence and sexual abuse						
Ever physically hurt by father or/and mother						
Yes	750	39.1 (34.8–43.7)	1.00 (referent)			
No	649	37.8 (32.5–43.4)	0.96 (0.80–1.16)	0.710		
Sexual abuse						
Yes	49	40.2 (21.7–61.9)	1.00 (referent)			
No	1350	38.5 (34.9–42.1)	0.96 (0.55–1.67)	0.877		
PHQ score	1399	**	1.01 (0.97–1.05)	0.673		
Nutrition and physical activity						
Food consumption frequency						
Milk/curd/paneer (cottage cheese)						
Daily/weekly	886	39.8 (35.6–44.1)	1.00 (referent)			
Occasionally/never	513	36.4 (30.9–42.1)	0.91 (0.75–1.11)	0.361		
Pulse/beans						
Daily/weekly	1266	38.4 (34.8–42.1)	1.00 (referent)			
Occasionally/never	133	39.5 (28.0–52.3)	1.03 (0.76–1.39)	0.857		
Dark green leafy vegetable						
Daily/weekly	979	37.3 (33.1–41.6)	1.00 (referent)			
Occasionally/never	420	41.4 (35.2–47.7)	1.11 (0.91–1.35)	0.292		
Other vegetables						
Daily/weekly	1359	38.4 (34.9–42.0)	1.00 (referent)			
Occasionally/never	40	45.0 (25.8–65.8)	1.17 (0.76–1.82)	0.475		
Fruit						
Daily/weekly	523	41.1 (34.7–47.9)	1.00 (referent)			
Occasionally/never	876	37.3 (33.3–41.5)	0.91 (0.75–1.10)	0.315		
Egg						
Daily/weekly	441	38.5 (32.4–45.0)	1.00 (referent)			
Occasionally/never	958	38.5 (34.1–43.2)	1.00 (0.82–1.22)	0.989		
Fish/seafood						
Daily/weekly	231	33.2 (25.3–42.3)	1.00 (referent)			
Occasionally/never	1168	39.3 (35.6–43.2)	1.18 (0.89–1.56)	0.237		
Chicken/meat						
Daily/weekly	285	34.7 (26.1–44.4)	1.00 (referent)			
Occasionally/never	1114	39.3 (35.3–43.4)	1.13 (0.87–1.47)	0.360		

(*continued on next page*)

TABLE 3 (*continued*)

Predictor	Sample, *n*	Remission	Univariate model		Multivariable model	
		% (95% CI)	RR (95% CI)	*P*	RR (95% CI)	*P*
Fried food						
Daily/weekly	711	39.0 (34.2–44.1)	1.00 (referent)			
Occasionally/never	688	38.0 (33.4–42.9)	0.97 (0.81–1.17)	0.781		
Aerated drinks						
Daily/weekly	168	44.2 (33.6–55.3)	1.00 (referent)			
Occasionally/never	1231	37.9 (34.3–41.6)	0.86 (0.66–1.11)	0.237		
Yes	441	30.3 (25.0–36.3)	1.00 (referent)		1.00 (referent)	
No	220	44.0 (34.6–53.8)	1.45 (1.09–1.92)	0.010	1.10 (0.84–1.44)	0.502
Not provided in school/college	618	44.4 (38.3–50.7)	1.46 (1.17–1.83)	0.001	1.09 (0.87–1.38)	0.451
Currently not attending school/correspondence schooling	120	31.4 (22.6–41.8)	1.03 (0.69–1.54)	0.867	1.01 (0.68–1.49)	0.973
Received take-home ration/cooked meal from *Anganwadi* center						
Yes	49	16.1 (7.8–30.3)	1.00 (referent)		1.00 (referent)	
No	1350	39.3 (35.7–43.0)	2.44 (1.24–4.81)	0.010	2.42 (1.18–4.96)	0.015
Witnessed discrimination in food distribution at home						
No discrimination/unaware of discrimination	572	38.8 (33.6–44.3)	1.00 (referent)			
More amount of food/quality food for boys/girls	67	31.0 (17.2–49.4)	0.80 (0.45–1.40)	0.434		
No co-residing brother or cousin brother (aged ± 3 y)	760	39.0 (34.6–43.5)	1.00 (0.83–1.21)	0.966		
Physical activity						
Yes	1106	40.3 (36.5–44.2)	1.00 (referent)			
No	293	32.4 (25.2–40.5)	0.80 (0.62–1.04)	0.098		
Modifiable lifestyle risk behavior						
Ever had smoking and/or smokeless tobacco						
Yes	29	33.9 (16.6–56.8)	1.00 (referent)			
No	1370	38.6 (35.1–42.2)	1.14 (0.63–2.05)	0.661		
Ever had alcohol						
Yes	6	24.7 (3.6–74.1)	1.00 (referent)			
No	1393	38.6 (35.1–42.2)	1.56 (0.31–7.90)	0.592		
Overall	1399	38.5 (35.1–42.1)				

All *n* are unweighted. The multivariable regression model used appropriate sample weighting and was adjusted for the state, PSU, and the time difference between baseline and follow-up surveys (in months). ASHA, accredited social health activist; IFA, iron and folic acid; OBC, other backward classes; *P*, level of significance; PHQ, patient health questionnaire; PSU, primary sampling unit; SC, scheduled caste; ST, scheduled tribe; USHA, urban social health activist. **Percentage values were not calculated as the variable is continuous.

meal from an AWC were associated with the remission of anemia.

Compared with early adolescence (10–14 y), adolescents aged 15–19 y had lower odds of anemia incidence in 2018–2019. This finding is consistent with the fact that adolescents are more likely to be anemic than adults [1]. Findings from the multivariable model also revealed that adolescents residing with 5–7 family members were more likely to experience an incidence of anemia than adolescents who lived in a 1–4-member household. This finding is consistent with a study conducted in India showing that the number of household members was positively associated with the level of anemia among children, pregnant women, and nonpregnant women [44].

Our results indicate that anemia incidence was high, whereas its remission was likely to be lower among females than male adolescents. This finding is consistent with a recent study that used UDAYA data suggesting female adolescents are more likely to be anemic than males [45]. According to the 2019–2021 National Family Health Survey (NFHS), conducted under the Ministry of Health and Family Welfare, the overall burden of anemia in India is estimated to have increased since the 2015–2016 NFHS [46]. The rising burden of anemia among adolescents is an indicative measure of poor intervention coverage and effectiveness of the existing programs [7,8,17]. Adolescent girls have higher requirements of iron to make up for the loss of iron during menstruation, and if India has a poor anemia mitigation policy in place, the girls will be disproportionately affected. These findings are also consistent with the burden of anemia estimated by the Global Burden of Disease study [47] and a study [48] that measured adolescent health during 1990–2016 in 195 countries, in which it was found that the prevalence of anemia among females is likely to be higher than males and remission is likely to be lower. In addition, gender discrimination in food serving also leads to micronutrient deficiency among girls. They also have poor access to healthcare services, whereas the poor bargaining power they can exercise in the family often jeopardizes their health [26,27], and adolescent females are disproportionately affected by it [49]. Furthermore, our analysis reveals that the incidence of anemia is likely to be higher with an increased PHQ-9 score. Studies [50,51] have shown the possible routes through which poor mental health which could lead to adverse health statuses such as anemia.

Our results suggest that the consumption of eggs could protect against the incidence of anemia among adolescents. Hen eggs have a wide range of macronutrients and micronutrients suitable for human consumption. In a whole, raw and freshly laid egg, water, protein, fat, carbohydrates, and ash represents ~76.1%, 12.6%, 9.5%, 0.7%, and 1.1%, respectively. A hen egg has 1.75 mg/100 g of iron, whereas a duck egg contains 3.85 mg/100 g of iron [52]. Although consumption of vegetables, including dark green leafy vegetables, may not be helpful for a reduction in anemia because of the low bioavailability of iron (non-heme iron) in vegetables [4]. A study conducted on women in India documented that daily consumption of eggs was associated with lower odds of being moderately or severely anemic [53]. Also, a cross-sectional study conducted among Colombian children (aged 5–17 y) concluded that eggs were determinants of serum ferritin concentrations in Colombia and, therefore, could be considered for public policy options to reduce anemia and iron deficiency [54]. In light of this finding, a well-designed, randomly assigned controlled trial among the adolescent population is desirable.

The National Institute of Nutrition of the Indian Council of Medical Research, an apex body in India for the formulation, coordination, and promotion of nutrition research, and the National Institute of Nutrition have recommended the consumption of three eggs/wk (nearly 180 eggs/y) for its various nutritional advantages [55]. Egg consumption in India, however, remains unacceptably low for various reasons [56]. For example, in the state of Bihar and Uttar Pradesh, where the UDAYA survey was conducted, the per capita egg availability in 2019–2020 was reported to be 23 and 15, respectively, whereas nationally, the per capita egg availability is 86 [57]. This estimate indicates low consumption of eggs in these two states. The finding of this study reconfirms the possible advantage of egg consumption in the success of national anemia reduction programs.

Our results also suggest that adolescents who did not receive a take-home ration/cooked meal from an AWC were more likely to experience remission of anemia, and the reverse relation was observed in the case of anemia incidence. This finding should be interpreted with caution, however, as this study does not suggest that take-home ration/cooked meal from AWC does not work for anemia remission; rather, it is possible that the people who did not receive food from an AWC probably had better access to food and nutrition, which helped them keeping out of anemia, but this hypothesis requires further investigation.

Limitations of this study should be taken into consideration while interpreting its findings. First, this study did not include an exhaustive list of potential predictors of the incidence or remission of anemia. For instance, information on whether the adolescents were suffering from any illness or disease was not available. Second, most information is self-reported; thus, the responses are likely to be influenced by recall errors or/and social desirability bias. Third, the Hb concentration was measured using the HemoCue device, which may not be comparable with the Hb concentration measured with an automated analyzer, which provides higher accuracy and precision [58]. Finally, these study findings only apply to the states of Bihar and Uttar Pradesh, India, so one should be cautious while extrapolating the results. Despite these limitations, the UDAYA project, which is the first of its kind in India, has provided an opportunity to analyze and understand the burden, incidence, and remission of anemia among adolescents living in two of the most underserved states of India, which house over 72 million of India's adolescents.

In conclusion, this study is the first attempt to analyze the population-based longitudinal data to understand the burden, incidence, and remission of anemia among never-married adolescents. Findings have pointed out that with an unacceptably high burden of anemia among females, and how the socioeconomic indicators, exposure to healthcare use, nutrition behavior, and history of sexual abuse could be relevant in designing an intervention to mitigate anemia among adolescents [59–63], in Bihar and Uttar Pradesh or in a similar setting.

Data Availability

Data described in the manuscript, code book, and analytic code has been made publicly and freely available without restriction at https://dataverse.harvard.edu/.

Ethics Approval

This study used the UDAYA (Understanding the Lives of Adolescents and Young Adults) survey data, which was conducted according to the guidelines laid down in the Declaration of Helsinki. All procedures involving human subjects/patients were approved by the institutional review board of the Population Council. Though written and/or informed consent was obtained from everyone to be interviewed, consent was also sought from a parent or guardian of unmarried adolescents aged 10–17 y. The UDAYA project used cross-sectional and panel survey methods to arrive at a comprehensive picture of young people's lives, their situations, and needs. The participants were informed about the research benefits that could be achieved for the young population using the data from UDAYA surveys, and no compensation was given to the survey participants. Survey participants consented to the future uses of data for research purposes with all identifiers removed. As this study is not part of any clinical trial or intervention study, any health condition that arises during the survey was not subject to attribution to the survey. The primary stakeholder of the UDAYA survey dataset–The Population Council, removed the individual identifier before making the data public for use by researchers. Findings of the UDAYA survey are made available to the public at https://www.projectudaya.in/ for the review of anyone interested.

Author disclosures

The authors report no conflicts of interest.

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The authors' responsibilities were as follows: RKR conceived the study. RKR and SS designed the study. RKR performed the analysis, wrote the first draft, and completed the manuscript for submission. SS, J-WDN, and WWF critically reviewed the results and commented on subsequent manuscript versions. All authors have read and approved the final manuscript.

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