Acta Biologica Szegediensis

Volume 66(2):180-191, 2022
Acta Biologica Szegediensis
http://abs.bibl.u-szeged.hu/index.php/abs

DOI:10.14232/abs.2022.2.180-191

ARTICLE

A longitudinal study on the prevalence of iron deficiency anemia in the multiethnic communities of Jhargram, West Bengal

Moumi Mandal[1], Niladri Prasad Mishra[2], Poulomi Chatterjee[2], Sanchari Bhattacharyya[1], Keshab Chandra Mondal[3], Sagar Acharya[2]*

[1]Centre for Life Sciences, Vidyasagar University, Midnapore, 721102, West Bengal, India
[2]Department of Zoology, Vidyasagar University, Midnapore, 721102, West Bengal, India
[3]Department of Microbiology, Vidyasagar University, Midnapore, 721102, West Bengal, India

ABSTRACT Anemia is a significant public health concern in India, with an estimated prevalence of 38% to 82% in non-pregnant females and 18% to 59% in males. Destitution, poor nutrition, illiteracy, unhealthy practices, obliviousness, and inadequate health service is the significant reasons for the higher rate of IDA in the tribals of India. The objective of the present study was to estimate the disease burden in Binpur-I and II, Jhargram blocks in West Bengal, India. The research was planned as a multiethnic community-based investigation that includes age and sex-specific gradation of anemia with iron status (SF, SI, TIBC). 910 participants (female: 529 and male: 381) were enrolled in the study. Overall, 67.47% of individuals were diagnosed with anemia (female: 42.74% and male: 24.73%). According to severity, 29.12%, 27.14%, and 11.2% of individuals were moderate, mild, and severely anemic. Results also showed that IDA is prevalent among all age groups irrespective of sex, with the highest rates in the 40.1 - 60 age group (female). The higher prevalence of the geriatric population could be due to chronic disease, iron deficiency, and genetic polymorphisms, which require future investigations.
Acta Biol Szeged 66(2):180-191 (2022)

KEY WORDS
anemia prevalence
iron deficiency anemia
iron status
tribal population
Jhargram

ARTICLE INFORMATION
Submitted
28 December 2022
Accepted
3 February 2023
***Corresponding author**
E-mail: sagar.gene@gmail.com

Introduction

Anemia is a global public health burden, with a prevalence of 43% in developing countries and 9% in developed nations (Al-Alimi et al. 2018). Worldwide, anemia affects 47% of preschool children, 12.7% of men (> 15 years), 42% of pregnant women, and 30% of non-pregnant women (15 to 50 years) (WHO 2008). Anemia is a significant public health concern in India, with an estimated prevalence of 38% to 82% in non-pregnant females and 18% to 59% in males (Malhotra et al. 2004; Pratima et al. 2012; Bhattacherjee et al. 2010; Gupta et al. 2014). Severity can vary depending on gender, age, smoking habits, and stage of pregnancy in women, which lowers oxygen-carrying capacity (WHO 2011). Young children and pregnant women are more susceptible to anemia than others due to their high iron requirements during the growth stage (Park 2009).

Iron is a crucial trace element of metabolism and other biochemical activities; long-term negative iron imbalance leads to iron deficiency anemia (IDA), the most prevalent and common micronutrient deficiency in developing nations until today (Hashizume et al. 2003). Usually, iron deficiency grows unhurriedly and does not have clinically noticeable symptoms until anemia becomes severe (Shill et al. 2014). Iron deficiency (ID) is considered the most prevalent cause of anemia worldwide despite other nutritional deficiencies (WHO 2020). IDA is caused by inadequate iron for hemoglobin production because of low dietary iron or improper iron uptake (An et al. 2012). The iron metabolism status is reflected by the levels of serum iron (SI), serum ferritin (SF), and total iron binding capacity (TIBC) (WHO 2004).

According to the 2011 census, 8.6% of all people in India are members of scheduled tribes (Census 2011). The name 'Adivasis' describes a variety of multiethnic and tribal populations in India, and 573 communities are considered scheduled tribes. All of the state districts of West Bengal have tribal communities, although those in Darjeeling, Jalpaiguri, Dakshin Dinajpur, Alipurduar, Paschim Medinipur, Purulia, Bankura, and Jhargram are particularly notable. Factors like poverty, poor nutrition, illiteracy, adverse cultural practices, lack of awareness of the disease, lack of adequate geographic connectivity, and lack of health personnel and services influence the higher prevalence of anemia in these multiethnic populations.

Nevertheless, no data is available on the prevailing occurrence of anemia in the Jhargram district of West Bengal. Estimating the prevalence of anemia in these tribal communities and understanding the socio-demographic factors associated with anemia is essential. Screening the iron status, such as SI, SF, and TIBC will enable us to draw effective public health management systems against IDA.

The objective of the present study was to estimate the disease burden in Binpur-I, Binpur -II, and Jhargram blocks of the Jhargram district due to ID, taking iron consumption into the narrative. Based on dietary surveys and blood iron status for both genders and specific age classes, we have quantified ID risk and the consequent disease burden due to IDA in this multiethnic population.

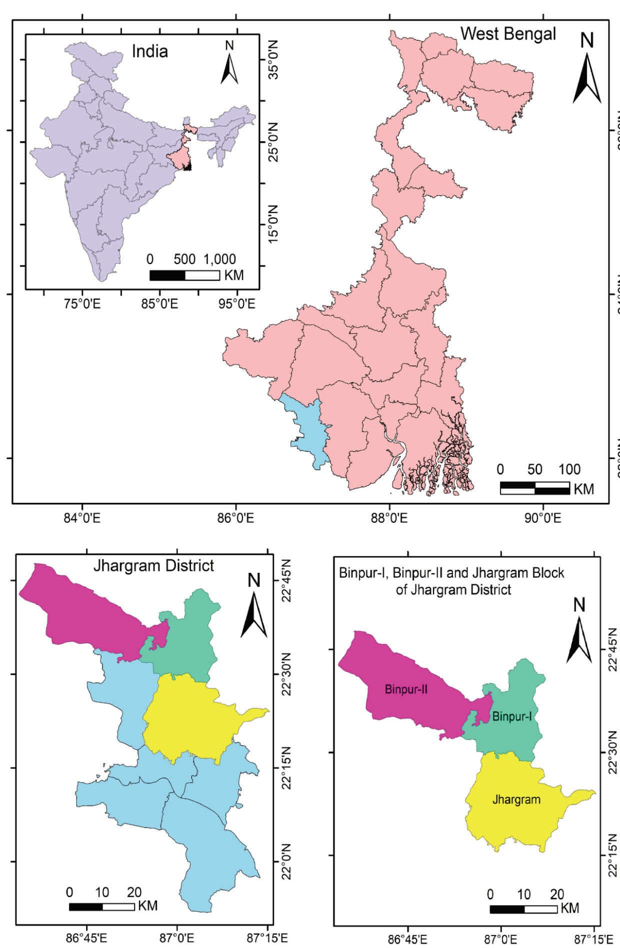

Figure 1. Location map of the study area (Binpur-I, Binpur-II and Jhargram block).

Materials and methods

Study design, area, and populations

The present cross-sectional study was conducted to determine the prevalence of IDA among the multiethnic population from Binpur I, Binpur II, and Jhargram blocks of Jhargram district, West Bengal, which is locally named 'Jungle Mahal'covered with a large belt of green forests and some natural wetland (Fig. 1). The study was conducted from December 2019 to September 2022.

The study population included men and women from 3 randomly selected blocks of Jhargram who agreed to participate and fulfilled the inclusion criteria. Informed consent was obtained in writing from the participants prior to the collection of blood after explaining the purpose of the study.

Total of 910 people (381 men and 529 women) enrolled in a population-based cohort mainly designed to investigate the prevalence of anemia in the Jhargram district. The patient's information was collected from some blocks of Jhargram District.

Inclusion criteria: The study subjects aged 15 to 80 years, male and female, were selected for the study.

Exclusion criteria: Pregnant women and anemic patients other than IDA were excluded from our study group. Participants with ages less than 15 years were not included. Patients with a chronic illness like thalassemia or illness related to blood loss were not considered.

Data collection procedure

Pretested and structured questionnaires were used to collect socio-demographic characteristics, nutritional status, and other factors by interviewing the individual patients of the study populations. The questionnaire was prepared in English, translated into the Ol Chiki language, and then back to English to ensure consistency. Two trained clinical nurses conducted the interview in the Ol Chiki language.

Skilled and trained persons were employed for anthropometric measurements (Lohman et al. 1988). The height and weights were measured using standard procedures. Errors in measurements were computed within acceptable limits (Ulijaszek and Kerr 1999). The Body Mass Index (BMI) of participants was computed using the following standard equations:

BMI (kg/cm^2) = Weight (kg) / Height (cm)^2

Nutritional status was evaluated using internationally accepted BMI guidelines. The following cut-off points were utilized: underweight <18.5, normal weight18.5-24.9, overweight 25-29.9, obese ≥ 30 were estimated by investigators (Cole et al. 2000).

Biochemical analysis

Venous blood samples (4 ml) were collected using blood collection tubes by a trained phlebotomist. Hemocue (HemoCue HB 201 Analyzer) was used to determine the Hb levels instantly. An aliquot of the blood was placed

Table 1. Socio-demographic characteristics of the participated tribal population and nutritional status.

		Variables	Gender	Number of individuals	Percentage
Sex			M	381	41.86
			F	529	58.13
Age group (years)	15-20		M	76	8.35
			F	112	12.30
	20.1-40		M	98	10.76
			F	118	12.96
	40.1-60		M	155	17.03
			F	257	28.24
	60.1 and above		M	52	5.71
			F	42	4.61
Education	Illiterate		M	58	6.37
			F	102	11.20
	Attended primary school		M	144	15.82
			F	215	23.62
	Above primary school		M	95	10.43
			F	115	12.63
	Secondary		M	56	6.15
			F	59	6.48
	Higher secondary		M	18	1.97
			F	21	2.30
	Degree and above		M	10	1.09
			F	17	1.86
Marital status	Unmarried		M	187	20.54
			F	141	15.49
	Married		M	194	21.31
			F	388	42.63
Occupation	household work		M	218	23.95
			F	209	22.96
	Employed		M	79	8.68
			F	127	13.95
	student		M	84	9.23
			F	193	21.20
Habits	Tobacco smoking		M	121	13.29
			F	53	5.82
	Alcohol consumption		M	174	19.12
			F	203	22.30
	No tobacco and alcohol consumption		M	37	4.06
			F	98	10.76
	Pan chewing		M	49	5.38
			F	175	19.23
Nutritional status	Cereals	Once a week	M	183	20.10
			F	194	21.31
		Sometimes in a week	M	104	11.42
			F	228	25.05
		Daily intake	M	94	10.32
			F	107	11.75

immediately in a tube containing Alsever's solution for further analysis. According to World Health Organization standards (2011), the participants were classified as non-anemic, mild, moderate, or severely anemic based on their Hb level. In the case of women, hemoglobin concentrations of less than 8, 8 to 10.9, and 11 to 11.9 g/dl were considered to indicate severe, moderate, and mild anemia, respectively. In the case of men, hemoglobin concentrations of less than 8, 8 to 10.9, and 11 to 12.9 g/dl were considered to indicate severe, moderate, and mild anemia, respectively (WHO 2011).

Measurement of iron status

Serum was extracted from centrifuged blood samples and subsequently stored in a -20 °C freezer before iron status analysis. Blood iron status biomarkers, i.e. SI, TIBC, and SF, were determined in a standard laboratory. SF was measured using an ELISA that was calibrated using WHO standards. SI and TIBC were determined using colorimetric methods (Huebers et al. 1987). SI ranges from 50 to 170 µg/dl for women and 70 to 175 µg/dl for men (Haldeman-Englert et al. 2023). IDA seems to cause low serum iron levels in the blood. SF value ranges from 15-200 µg/l for males and 15-150 µg/l for females (WHO 2020). Low SF levels are a prerequisite for ID without

Table 1. Continued.

		Variables	Gender	Number of individuals	Percentage
Nutritional status	Vegetables	Once a week	M	93	10.21
			F	96	10.54
		Sometimes in a week	M	176	19.34
			F	168	18.46
		Daily intake	M	112	12.30
			F	265	29.12
	Fruits	Once a week	M	132	14.50
			F	196	21.53
		Sometimes in a week	M	195	21.42
			F	236	25.93
		Daily intake	M	54	5.93
			F	97	10.65
	Pulses	Once a week	M	155	17.03
			F	201	22.08
		Sometimes in a week	M	133	14.61
			F	237	26.04
		Daily intake	M	93	10.21
			F	91	10.00
	Milk	Once a week	M	198	21.75
			F	226	24.83
		Sometimes in a week	M	112	12.30
			F	197	21.64
		Daily intake	M	86	9.45
			F	106	11.64
	Egg	Once a week	M	139	15.27
			F	198	21.75
		Sometimes in a week	M	174	19.12
			F	232	25.49
		Daily intake	M	68	7.47
			F	99	10.87
	Fish	Once a week	M	146	16.04
			F	236	25.93
		Sometimes in a week	M	181	19.89
			F	201	22.08
		Daily intake	M	54	5.93
			F	92	10.10
	Meat	Once a week	M	249	27.36
			F	252	27.69
		Sometimes in a week	M	101	11.09
			F	184	20.21
		Daily intake	M	31	3.40
			F	93	10.21

infection because they indicate a reduced iron status. TIBC is increased from the normal range (250-450 µg/dl) due to IDA (Haldeman-Englert et al. 2023).

Ethical statements

Ethical clearance was obtained from the IEC (Institutional Ethical Committee) of Vidyasagar University (VU/IEC-2/1-SA/19 dated 6/12/2019). Patient consent was obtained from all study participants, and additional support was sought from the laboratory management of Vidyasagar University.

Statistical analysis

Statistical analyses were performed using Graph Pad Prism 5 software. Continuous variables are presented by calculating mean ± standard deviation (SD), and frequency percentages are used for categorical variables. ANOVA analyzed the categorical variables, and linear correlation was used to evaluate the correlation between Hb level with SF level, Hb level with SI level, and TIBC level. The confidence interval (CI) was tested at a 95% level. A p-value <0.05 was considered statistically significant.

Results

Socio-demographic characteristics of the study population

Table 1 presents the baseline socio-demographic characteristics of the study sample. Among 910 tribals enrolled in the study, 529 (58.13%) were female, and 381 (41.86%) were male (male:female=1:1.38). The participants were

Table 2a. The grades of anemia in the participating tribal population based on hemoglobin concentration (g/dl).

Age group (years)	G	N	Non-anemic (N)	Anemic N (%)	Mild anemia (N)	Moderate anemia (N)	Severe anemia (N)
15-20	M	76	25	51(5.60%)	18	26	7
	F	112	26	86 (9.45%)	28	47	11
20.1-40	M	98	46	52 (5.71%)	26	17	9
	F	118	44	74 (8.13%)	25	41	8
40.1-60	M	155	68	87 (9.56%)	33	41	13
	F	257	62	195 (21.42%)	87	69	39
60.1 and above	M	52	17	35 (3.84%)	16	13	6
	F	42	8	34 (3.73%)	14	11	9
Total		910	296 (32.53%)	614 (67.47%)	247 (27.14%)	265 (29.12%)	102 (11.2%)

G: Gender; N: Number of individuals; M: Male; F: Female.

divided into four age groups (15-20, 20.1-40, 40.1-60, 60.1 and above years). Most of the study populations have not attended high school education. 23.62% of females had primary education, while 11.20% did not attend primary school. 22.96% of females were involved in household work, and 23.95% of males were unemployed. 13.29% of male individuals had the habit of tobacco smoking, while 19.12% of male individuals indulged in the consumption of country liquor (i.e. Haria & Mahua).

Prevalence of iron deficiency anemia

A total of 910 blood samples were screened for anemia. Among the study population, only 32.53% were non-anemic, and the rest were divided into mild, moderate, and severe anemia categories based on severity. Cross-tabulation was performed to describe the association between IDA, age, and gender. Table 2a shows the overall prevalence of IDA by age and gender; 67.47% of the population was anemic, 42.74% were female (N = 389/910), and 24.73% were male (N = 225/910). According to WHO categorization of anemia, 29.12% (N = 265/910) was found to be moderate anemia, while 27.14% (N = 247/910) were mild anemia, and 11.2% (N = 102/910) were severe anemia in the population (Fig. 2). In this population most of the participants (i.e., M = 97;10.65% and F = 168;18.46%) were moderately anemic.7.36% of female participants (N = 67/910) were severely anemic, while 16.92% (N = 154/910) and 18.46% (N = 168/910) were mild and mod-

Table 2b. Mean, standard deviation (SD), and range of hemoglobin (non-anemic and anemic individuals), specific to age and gender.

Age group (years)	Type	Gender	N	HB (g/dl) Mean±SD	Range
15-20	Non-anemic	M	25	13.48 ± 0.42	13-14.4
		F	26	12.84 ± 0.63	12.1 – 14.5
	Anemic	M	51	10.06 ± 1.75	5.8 -12.9
		F	86	9.92 ± 1.63	5.8 – 11.9
20.1-40	Non-anemic	M	46	13.9 ± 0.6	13 - 15
		F	44	12.93 ± 0.61	12.1 – 14.2
	Anemic	M	52	10.1 ± 2.19	5.6 - 12.9
		F	74	9.85 ± 1.59	5.4 – 11.9
40.1-60	Non-anemic	M	68	13.62 ± 0.43	13 - 14.6
		F	62	12.7 ± 0.61	12 – 14.5
	Anemic	M	87	9.93 ± 2.03	5.6 – 12.9
		F	195	9.65 ± 2.06	5.2 – 11.9
60.1 and above	Non-anemic	M	17	13.53 ± 0.38	13 - 14.2
		F	8	12.51 ± 0.27	12.1 – 12.9
	Anemic	M	35	9.96 ± 1.88	5.8 – 12.3
		F	34	9.45 ± 2.01	5.7 – 11.8

N: Number of individuals; M: Male; F: Female.

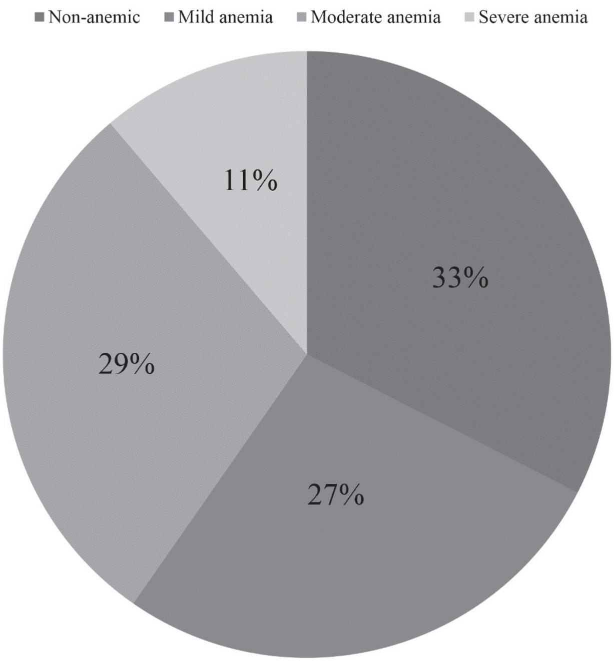

Figure 2. Percentage of different anemic and non-anemic individuals in the studied tribal population.

erately anemic. In the male participants, 10.21% (N = 93), 10.65% (N = 97), and 3.84% (N = 35) were mild, moderate, and severely anemic. The highest(N = 195; 21.43%) and lowest (N = 34; 3.73%) prevalence of IDA was found among female participants 40.1-60 and above 60 years age group. Similarly, in the case of male participants, the 40.1-60 age group was severely anemic (N = 87; 9.56%)with the highest percentage, followed by the other age groups.

The mean hemoglobin level for IDA male and female participants with mean BMI was represented in Table 2b. The lowest mean Hb level was 9.45 ± 2.01, with a range value of 5.7-11.8 observed in females of the 60.1 and above age group. Females of the 40.1-60 age group showed the second lowest Hb, 9.65 ± 2.06, with a range of 5.2-11.9. Anemic females (N = 86) 15-20 years of age were anemic, having a mean Hb value of 9.92 ± 1.63 with a range of 5.8-11.9. Among the females of reproductive age (20.1-40), the Hb level was 9.85±1.59 (range: 5.4-11.9). The males 60.1 and above age group showed the lowest Hb values of 9.96±1.88 (range 5.8-12.3) among males.

One-way Analysis of Variance was performed to compare the mean hemoglobin levels of mild, moderate, and severe with non-anemic individuals in specific age groups. In all age categories, the Hb levels of anemic individuals with mild, moderate, and severe anemia differ significantly (P<0.0001) from those of non-anemic individuals (Table 2c).

The association between BMI and IDA is represented in Table 2d. The lowest BMI (16.86 ± 1.13) was recorded among females of the age group 15-20 years, and most of the participants in this group were found to be anemic. Interestingly female participants from two subsequent age groups show that most individuals with average BMI develop anemia. Among the males, the lowest BMI (16.91 ± 1.23) was documented in the age group 15-20 years. The data shows that most underweight participants are strongly inclined toward being anemic. Overweight participants are, in most cases, found non-anemic. The correlation coefficients (r = 0.3728) (p < 0.0001) between Hb level and BMI in the 40.1-60 age group of females show a positive association between the two variables at a 0.05 significance level (Table 2e). Hemoglobin levels and BMI are significantly correlated in males and females throughout all age categories, except for males between the ages of 15-20.

For each age group, a specific iron status biomarker (SF, SI, TIBC) was used to compare various anemic states using a one-way analysis of variance. The mean Hb levels of anemic people differ considerably (P 0.05) from those of non-anemic people in all age groups (Table 3). Age and

Table 2c: ANOVA between non-anemic and anemic individuals (based on hemoglobin percentage) in specific age groups (years).

Age group (years)		15-20				20.1-40				40.1-60				60.1 and above			
Anemia status		Na	Mi	Mo	Se	Na	Mi	Mo	Se	Na	Mi	Mo	Se	Na	Mi	Mo	Se
Mean ± SD	M	13.49 ± 0.42	11.85 ± 0.61	9.66 ± 0.77	6.97 ± 0.74	13.91 ± 0.60	11.77 ± 0.63	9.67 ± 1.01	6.11 ± 0.34	13.62 ± 0.43	12.08 ± 0.55	9.23 ± 0.87	6.70 ± 0.73	13.54 ± 0.38	11.53 ± 0.48	9.49 ± 1.0	6.78 ± 0.56
	F	12.84 ± 0.63	11.53 ± 0.23	9.72 ± 0.88	6.73 ± 0.70	12.93 ± 0.61	11.47 ± 0.28	9.49 ± 0.81	6.67 ± 0.91	12.71 ± 0.61	11.44 ± 0.23	9.39 ± 0.88	6.14 ± 0.51	12.51 ± 0.26	11.36 ± 0.26	9.28 ± 0.96	6.68 ± 0.72
F-value	M	270.2 ***				405.8***				694.3***				202.9***			
	F	245.3 ***				310.2***				1105***				153.6***			

Na: Non-anemic; Mi: Mild anemic; Mo: Moderate anemic; Se: Severe anemic.
M: Male; F: Female.
SD: Standard Deviation; ***: Statistically highly significant.

Table 2d. Relationship between severity of anemia and BMI according to gender and age groups.

				Male				
Age group (Years)	BMI	BMI Mean±SD	Range	N	Non-anemic	Mild	Moderate	Severe
15-20	Underweight	16.91 ± 1.23	14.3 - 18.4	31	8	5	13	5
	Normal weight	20.37 ± 1.17	18.5 - 22.7	45	17	13	13	2
	Overweight	-	-	-	-	-	-	-
20.1-40	Underweight	17.9 ± 0.52	16.0 - 18.4	35	8	11	10	7
	Normal weight	20.53 ± 1.53	18.5 - 24.5	63	38	15	7	2
	Overweight	-	-	-	-	-	-	-
40.1-60	Underweight	17.61 ± 0.69	15.7 - 18.5	63	10	11	31	11
	Normal weight	21.09 ± 1.42	18.5 - 24.7	88	55	21	10	2
	Overweight	25.34 ± 0.33	25.1 - 25.9	5	4	1	-	-
60.1 and above	Underweight	17.5 ± 0.63	16.4 - 18.4	31	4	8	13	6
	Normal weight	20.06 ± 0.99	18.7 - 23.3	21	13	8	-	-
		-	-	-	-	-	-	-
				Female				
Age group (Years)	BMI	BMI Mean±SD	Range	N	Non-anemic	Mild	Moderate	Severe
15-20	Underweight	16.86 ± 1.13	13.3 - 18.4	60	7	15	29	9
	Normal weight	19.67 ± 1.4	18.5 - 23.8	52	19	13	18	2
	Overweight	-	-	-	-	-	-	-
20.1-40	Underweight	16.69 ± 1.12	13.8 - 18.3	55	13	15	23	4
	Normal weight	20.3 ± 1.51	18.5 – 24.0	63	31	10	18	4
	Overweight	-	-	-	-	-	-	-
40.1-60	Underweight	17.85 ± 0.54	15.2 - 18.4	140	9	49	52	30
	Normal weight	21.21 ± 1.29	18.5 - 24.4	108	53	38	17	9
	Overweight	25.2 ± 0.17	24.9 - 25.5	9	9	-	-	-
60.1 and above	Underweight	17.42 ± 0.65	16.1 - 18.4	29	2	8	10	9
	Normal weight	19.86 ± 1.33	18.7 - 22.7	13	6	6	1	-
		-	-	-	-	-	-	-

BMI: Body mass index; N: Number of Individuals; SD: Standard Deviation

gender-specific iron status (in frequency) of anemic and non-anemic male participants are depicted in table 4.

In all age groups, Hb has a positive association with SF and SI while exhibiting a negative correlation with TIBC level (Table 5).

Discussion

In the present study, we illustrated the burden of ID and anemia using multiple biomarkers in a longitudinal study among the multiethnic groups of Binpur-I, Binpur-II, and Jhargram blocks of the Jhargram district, West Bengal. Our study found that overall anemia was prevalent among

Table 2e. Correlation of hemoglobin (Hb) with BMI in different age groups.

Age groups (years)	**15-20**		**20.1-40**		**40.1-60**		**60.1 and above**	
Gender	Male	Female	Male	Female	Male	Female	Male	Female
N	76	112	98	118	155	257	52	42
Pearson r	0.1130	0.2286	0.3041	0.2046	0.5440	0.3728	0.5064	0.3970
P value (two-tailed)	0.3310	0.0153	0.0023	0.0262	< 0.0001	< 0.0001	0.0001	0.0092
P value summary	ns	*	**	*	***	***	***	**

ns: Statistically not significant; *: Statistically significant (P<0.05); **/***: Statistically highly significant (P<0.01, P<0.001)

Table 3. ANOVA of different grades of anemia with iron status in the specific age group.

		SF				SI				TIBC			
15-20 years													
Anemic status		Na	Mi	Mo	Se	Na	Mi	Mo	Se	Na	Mi	Mo	Se
	Male	73.02 ± 28.29	15.26 ± 3.47	15.78 ± 8.26	9.08 ± 0.84	85.44 ± 9.78	53.56 ± 9.94	59.90 ± 16.66	48.40 ± 0.94	300.1 ± 69.12	447.5 ± 86.86	452.9 ± 80.27	471.3 ± 5.96
	Female	31.97 ± 15.59	24.10 ± 15.83	17.66 ± 11.16	9.864 ± 0.86	59.19 ± 11.68	50.44 ± 4.41	50.15 ± 12.96	42.96 ± 3.61	365.5 ± 33.88	419.4 ± 110.1	431.7 ± 88.94	467.5 ± 5.58
F Value	Male	65.14***				33.78***				23.60 ***			
	Female	10.09 ***				7.497 ***				5.369**			
20.1-40 years													
Anemic status		Na	Mi	Mo	Se	Na	Mi	Mo	Se	Na	Mi	Mo	Se
	Male	50.73 ± 22.64	16.41 ± 6.634	19.91 ± 12.26	9.767 ± 0.8761	79.54 ± 17.37	53.49 ± 9.574	56.17 ± 16.58	41.32 ± 2.115	366.8 ± 55.91	447.3 ± 61.30	457.5 ± 53.41	453.9 ± 3.666
	Female	54.01 ± 27.26	23.85 ± 15.12	15.35 ± 7.709	9.575 ± 0.7186	70.92 ± 26.65	49.35 ± 10.19	39.64 ± 12.01	38.00 ± 1.630	376.9 ± 53.41	435.7 ± 40.07	414.2 ± 99.23	460.6 ± 9.232
F Value	Male	34.62 ***				30.14 ***				19.81 ***			
	Female	36.54 ***				23.08***				5.837 ***			
40.1-60 years													
Anemic status		Na	Mi	Mo	Se	Na	Mi	Mo	Se	Na	Mi	Mo	Se
	Male	70.37 ± 30.49	14.69 ± 1.118	12.10 ± 0.6448	10.02 ± 1.048	80.93 ± 8.319	46.17 ± 17.78	36.81 ± 4.107	37.38 ± 2.925	362.1 ± 58.51	456.8 ± 2.661	460.4 ± 5.034	466.8 ± 1.920
	Female	58.81 ± 19.17	43.72 ± 16.62	13.34 ± 1.433	10.44 ± 1.295	63.52 ± 8.29	37.55 ± 5.472	33.39 ± 4.943	31.18 ± 4.823	318.3 ± 51.19	470.8 ± 14.94	470.8 ± 13.36	481.5 ± 6.878
F Value	Male	102.4 ***				208.4 ***				80.03 ***			
	Female	177.3 ***				363.2 ***				493.1 ***			
60.1 and above years													
Anemic status		Na	Mi	Mo	Se	Na	Mi	Mo	Se	Na	Mi	Mo	Se
	Male	55.42 ± 32.99	21.76 ± 13.67	14.23 ± 3.520	9.400 ± 0.7874	74.86 ± 18.67	57.76 ± 14.14	50.41 ± 14.96	41.72 ± 2.905	349.6 ± 70.86	450.4 ± 30.08	452.4 ± 53.23	468.2 ± 6.941
	Female	45.78 ± 12.58	18.87 ± 10.36	11.95 ± 0.4967	9.444 ± 0.9015	63.26 ± 13.07	44.16 ± 9.391	42.78 ± 8.767	36.20 ± 4.303	384.9 ± 34.49	455.8 ± 36.43	461.4 ± 22.77	471.2 ± 12.14
F Value	Male	14.01 ***				9.947 ***				15.79***			
	Female	35.52 ***				13.24 ***				15.67 ***			

SF: Serum ferritin; SI: Serum iron; TIBC: Total Iron Binding Capacity; Na: Non-anemia; Mi: Mild; Mo: Moderate; Se: Severe; M: Male; F: Female. SD: Standard Deviation; ***: Statistically highly significant (P<0.001)

67.47% of the study population, indicating a problem of severe public health significance, according to World Health Organization (WHO) classification. According to the WHO, the prevalence of IDA is considered a public health problem. The above 5% gives a degree of significance to the respective severity of this prevalence in the present study (WHO 2011). The study also established that the prevalence sequence of anemia is moderate (29.12%) > mild (27.14%) > severe (11.2%). Due to iron deficiency, nutritional anemia is a significant public health problem in India. Our data suggest that anemia is widely prevalent among all age groups and is exceptionally high among females above 40, the most vulnerable groups (Table 2a). Equivalent findings were reported in Ethiopia, where they found an age of more than 34 years to be a risk factor for anemia (Alem et al. 2013). Analogous results were reported from the North Karelian tribal population, where anemia was significantly higher among people aged more than 40 years (Ismail et al. 2016). The present study reported that females are more susceptible to iron deficiency anemia than males, where 42.74% of females and 24.72% of males are anemic. Females aged 40.1–60 are the most predominant group having 21.42% anemic. Likewise, participants above 40 years are the most preva-

Table 4: Age and gender-specific iron status (in frequency) of anemic and non-anemic male participants

Status		Serum indices	15-20 years	20.1-40 years	40.1-60 years	60.1 and above years
Number of Male individuals						
Severe anemia	SF	<15 µg/lt	7	9	13	6
		>15 µg/lt	0	0	0	0
	SI	<70 µg/dl	7	9	13	6
		>70 µg/dl	0	0	0	0
	TIBC	<450 µg/dl	0	0	0	0
		>450 µg/dl	7	9	13	6
Moderate anemia	SF	<15 µg/lt	21	11	41	9
		>15 µg/lt	5	6	0	4
	SI	<70 µg/dl	20	12	41	10
		>70 µg/dl	6	5	0	3
	TIBC	<450 µg/dl	3	3	0	2
		> 450 µg/dl	23	14	41	11
Mild anemia	SF	<15 µg/lt	14	22	23	11
		>15 µg/lt	4	4	10	5
	SI	<70 µg/dl	15	23	25	12
		>70 µg/dl	3	3	8	4
	TIBC	<450 µg/dl	2	5	0	2
		>450 µg/dl	16	21	33	14
Non-anemia	SF	<15 µg/lt	0	9	0	4
		>15 µg/lt	25	37	68	13
	SI	<70 µg/dl	2	7	0	3
		>70 µg/dl	23	39	68	14
	TIBC	<450 µg/dl	22	40	68	14
		> 450 µg/dl	3	6	0	3
Number of Female individuals						
Severe anemia	SF	<15 µg/lt	11	8	39	9
		>15 µg/lt	0	0	0	0
	SI	<50 µg/dl	11	8	39	9
		>50 µg/dl	0	0	0	0
	TIBC	<450 µg/dl	0	0	0	0
		>450 µg/dl	11	8	39	9
Moderate anemia	SF	<15 µg/lt	37	32	59	11
		>15 µg/lt	10	9	10	0
	SI	<50 µg/dl	38	33	60	9
		>50 µg/dl	9	8	9	2
	TIBC	<450 µg/dl	6	10	11	1
		>450 µg/dl	41	31	58	10
Mild anemia	SF	<15 µg/lt	18	16	88	12
		>15 µg/lt	10	9	0	3
	SI	<50 µg/dl	19	15	88	12
		>50 µg/dl	9	10	0	3
	TIBC	<450 µg/dl	7	7	2	2
		>450 µg/dl	21	18	86	13
Non-anemia	SF	<15 µg/lt	8	9	0	0
		>15 µg/lt	18	35	62	8
	SI	<50 µg/dl	5	11	0	1
		>50 µg/dl	21	33	62	7
	TIBC	<450 µg/dl	24	43	62	7
		>450 µg/dl	2	1	0	1

SF: Serum Ferritin, SI: Serum Iron, TIBC: Total Iron Binding Capacity

Table 5. Correlation between HB and iron status biomarkers (SF, SI, and TIBC).

Gender		**Male**			**Female**	
Correlation	Hb & SF	Hb & SI	Hb & TIBC	Hb & SF	Hb & SI	Hb & TIBC
Age groups			15-20 years			
Anemic status		Non-anemia (N = 25)			Non-anemia (N = 26)	
Pearson r	0.9144	0.8033	-0.4213	0.8620	0.7906	-0.6652
P value	< 0.0001	< 0.0001	0.0360	< 0.0001	< 0.0001	0.0002
Anemic status		Mild anemia (N = 18)			Mild anemia (N = 28)	
Pearson r	0.6703	0.6924	-0.5633	0.7713	0.7350	-0.7075
P value	0.0023	0.0015	0.0149	< 0.0001	< 0.0001	< 0.0001
Anemic status		Moderate anemia (N = 26)			Moderate anemia (N = 47)	
Pearson r	0.6867	0.8595	-0.4977	0.6747	0.7638	-0.5833
P value	0.0001	< 0.0001	0.0097	< 0.0001	< 0.0001	< 0.0001
Anemic status		Severe anemia (N = 7)			Severe anemia (N = 11)	
Pearson r	0.8653	0.9394	-0.8399	0.9530	0.9473	-0.8909
P value	0.0119	0.0017	0.0180	< 0.0001	< 0.0001	0.0002
Age groups			20.1-40 years			
Anemic status		Non-anemia (N = 46)			Non-anemia (N = 44)	
Pearson r	0.9412	0.8783	-0.9746	0.9675	0.9592	-0.8639
P value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Anemic status		Mild anemia (N = 26)			Mild anemia (N = 25)	
Pearson r	0.6989	0.8724	-0.8840	0.8358	0.9599	-0.8306
P value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Anemic status		Moderate anemia (N = 17)			Moderate anemia (N = 41)	
Pearson r	0.6725	0.8810	-0.6389	0.7235	0.6073	-0.6979
P value	0.0031	< 0.0001	0.0058	< 0.0001	< 0.0001	< 0.0001
Anemic status		Severe anemia (N = 9)			Severe anemia (N = 8)	
Pearson r	0.8419	0.9134	-0.8459	0.7110	0.9471	-0.9263
P value	0.0044	0.0006	0.0041	0.0480	0.0004	0.0009
Age groups			40.1-60 years			
Anemic status		Non-anemia (N = 68)			Non-anemia (N = 62)	
Pearson r	0.9624	0.6274	-0.9828	0.8319	0.9610	-0.9284
P value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Anemic status		Mild anemia (N = 33)			Mild anemia (N = 87)	
Pearson r	0.8651	0.7133	-0.4569	0.9695	0.9603	-0.9770
P value	< 0.0001	< 0.0001	0.0075	< 0.0001	< 0.0001	< 0.0001
Anemic status		Moderate anemia (N = 41)			Moderate anemia (N = 69)	
Pearson r	0.9744	0.4914	-0.9659	0.9802	0.9221	-0.9814
P value	< 0.0001	0.0011	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Anemic status		Severe anemia (N = 13)			Severe anemia (N = 39)	
Pearson r	0.9030	0.9331	-0.9780	0.9898	0.9188	-0.9850
P value	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Age groups			60.1 and above years			
Anemic status		Non-anemia (N = 17)			Non-anemia (N = 8)	
Pearson r	0.9693	0.8708	-0.8817	0.9286	0.8829	-0.7498
P value	< 0.0001	< 0.0001	< 0.0001	0.0009	0.0037	0.0322
Anemic status		Mild anemia (N = 16)			Mild anemia (N = 14)	
Pearson r	0.8533	0.9416	-0.7369	0.7427	0.8838	-0.8127
P value	< 0.0001	< 0.0001	0.0011	0.0023	< 0.0001	0.0004
Anemic status		Moderate anemia (N = 13)			Moderate anemia (N = 11)	
Pearson r	0.8080	0.8776	-0.6938	0.9781	0.8916	-0.7846
P value	0.0008	< 0.0001	0.0085	< 0.0001	0.0002	0.0042
Anemic status		Severe anemia (N = 6)			Severe anemia(N = 9)	
Pearson r	0.9226	0.9386	-0.9426	0.9053	0.8825	-0.9558
P value	0.0088	0.0055	0.0048	0.0008	0.0016	< 0.0001

Hb: Hemoglobin; SF: Serum ferritin; SI: Serum iron; TIBC: Total Iron Binding Capacity.

lent group among males, with 9.56% severely anemic. The high prevalence of IDA among the study population could be related to destitution, resulting in insufficient nutrition and inadequate health care and education. Our study investigated potential risk factors significantly associated with IDA among the participants: low-income families, infrequent intake of meals, meat, fish, and fruits, and some unhealthy lifestyle habits (drinking country liquor, chewing pans, and smoking). We found illiteracy and lower education levels to contribute to anemia in both males and females, which corroborated with the finding of comparable tribes from India (Balarajan et al. 2011; Shrinivasa et al. 2014). Moreover, the studied tribal population practices early marriage, which may add to the possible risk factors for anemia. However, the current study found that lower socioeconomic status significantly affects anemia among both genders. The present study also demonstrated a significant correlation between BMI with anemia in all age groups. Nevertheless, males below 20 showed no significant association between hemoglobin concentration and BMI.

India is one of the countries with a very high prevalence of anemia. Almost 58% of pregnant women in India are anemic, and anemia is estimated to be the underlying cause of 20-40% of maternal deaths in India. India contributes to about 80% of maternal deaths due to anemia in South Asia (Hashizume et al. 2003). Since independence, the Indian government has made several large-scale measures to contain and treat anemia. The National Nutritional Anemia Prevention Programme has been initiated to provide free iron and vitamin B-12 supplements for children and women via primary healthcare facilities since 1970 (Didzun et al. 2019). From 2013 free iron and folic acid supplements were given to boys aged 10-19 through National Iron Plus Initiative (Anand et al. 2014). In 2018, India launched a massive initiative to dive into anemia called 'Anemia Mukt Bharat,' aiming to reach 450 million participants by 2022. The project aims to enclose male and female participants, including children, pregnant women, women of reproductive age, and male and female adolescents (Kapil and Bhadoria 2013).

The longitudinal design of our study with the assessment of iron status (SF, SI, and TIBC), using multiple iron biomarkers among multiethnic groups of the studied population whose iron status is not routinely assessed, thus adding facts for more reasonable public health management. Iron deficiency is defined as having low serum iron and low serum ferritin levels combined with an elevated TIBC, whereas a low serum ferritin level is practically helpful for diagnosing iron deficiency. The 40.1-60 age group showed the highest TIBC level (481.5 ± 6.87), corresponding to severe anemic males, which indicates low serum iron in the body (Heilmann 1975). The present study recorded a significant partial positive correlation between hemoglobin concentration with serum iron and serum ferritin. However, the data showed a partially negative correlation between hemoglobin concentrations with TIBC. Thus, the study investigates the relationship between serum iron, serum ferritin, total iron binding capacity (TIBC), and iron deficiency among multiethnic populations in the Jhargram district.

The existing evaluations and data of the National Nutritional Anemia Prevention Programme suggest that only iron supplementation is not enough to control anemia in any age group (I-NIPI 2018). Detailed investigation of genetic factors with particular emphasis on genetic polymorphism has to be taken care of before strategizing any anemia prevention program.

In the multiethnic groups of Jangalmahal of West Bengal, ID is prevalent among all the age groups irrespective of sex, with the highest rates seen in the 40.1-60 age group females.

Additionally, anemia remains a significant public health problem during the reproductive age among females in Jhargram. Measures must therefore be put in place for thorough examination of the genetic polymorphism of iron metabolic genes related to anemia, including assessment of iron biomarkers. The study will help determine the cause of anemia before iron supplementation is started, which is especially important in areas like Jangalmahal, where there are many potential threats of anemia. The higher prevalence in the geriatric population could be due to chronic diseases and iron deficiency, but these should be studied further in future investigations.

Acknowledgments

The UGC-Innovative program provided funding and departmental DST-FIST infrastructure was utilized for this study. The authors acknowledge Dr. Kausik Ghosh, Department of Geography, Vidyasagar University, for the preparation of the location map of study area.

References

Al-Alimi AA, Bashanfer S, Morish MA (2018) Prevalence of iron deficiency anemia among university students in Hodeida Province. Anemia 2018:4157876.

Alem M, Enawgaw B, Gelaw A, Kena T, Seid M, Olkeba Y (2013) Prevalence of anemia and associated risk factors among pregnant women attending antenatal care in Azezo Health Center Gondar town. J Interdiscip Histopathol 1:137-144.

Anand T, Rahi M, Sharma P, Ingle GK (2014) Issues in prevention of iron deficiency anemia in India. Nutrition 30(7-8):764-770.

An P, Wu Q, Wang H, Guan Y, Mu M, Liao Y, Wang F (2012) TMPRSS6, but not TF, TFR2 or BMP2 variants are associated with increased risk of iron-deficiency anemia. Hum Mol Genet 21:2124-2131.

Balarajan Y, Ramakrishnan U, Özaltin E, Shankar AH, Subramanian SV (2011) Anaemia in low-income and middle-income countries. Lancet 378:2123-2135.

Bhattacherjee S, Banerjee R, Roy JK, Mandal S, Biswas R, Chakraborty M (2010) Under nutrition and anaemia in rural adults-a cross-sectional study in rural north Bengal. Indian J Prev Soc Med 41:33-36.

Census of India (2011), West Bengal, District Census Handbook, Paschim Medinipur, Series -20, Part-XII -B, Directorate of Census Operations, West Bengal.

Cole TJ, Bellizzi MC, Flegal KM, Dietz WH (2000) Establishing a standard definition for child overweight and obesity worldwide. BMJ 320:1240-1243.

Didzun O, De Neve JW, Awasthi A, Dubey M, Theilmann M, Bärnighausen T, Geldsetzer P (2019) Anaemia among men in India: a nationally representative cross-sectional study. Lancet Glob Health 7:1685-1694.

Gupta SK, Agarwal SS, Kaushal R, Jain A, Gupta VK, Khare N (2014) Prevalence of anemia among rural population living in and around of rural health and training center. Muller J Med Sci Res 5(1):15-18.

Haldeman-Englert C, Turley R, Novick T (2022) Iron and total iron binding capacity. Available:https://www.urmc.rochester.edu/encyclopedia/content.aspx?contenttypeid=167&contentid=iron_total_iron_binding_capacity Accessed 22 August 2022.

Hashizume M, Kunii O, Sasaki S, Shimoda T, Wakai S, Mazhitova Z, Chiba M (2003) Anemia and iron deficiency among school children in the Aral Sea region. J Trop Pediatr 49:172-177.

Heilmann E (1975) The levels of serum iron and total iron-binding capacity in various diseases. Med Welt 26:1629-1630.

Huebers HA, Eng MJ, Josephson BM, Ekpoom N, Rettmer RL, Labbé RF, Pootrakul P, Finch CA (1987) Plasma iron and transferrin iron-binding capacity evaluated by colorimetric and immunoprecipitation methods. Clin Chem 33:273-277.

Ismail IM, Kahkashan A, Antony A, Sobhith V (2017) Role of socio-demographic and cultural factors on anemia in a tribal population of North Kerala. Int J Community Med Public Health 3(5):1183-1188.

Kapil U, Bhadoria AS (2014) National iron-plus initiative guidelines for control of iron deficiency anaemia in India. Natl Med J India 27:27-29.

Killip S, Bennett JM, Chambers MD (2007) Iron deficiency anemia. Am Fam Physician 75:671-678.

Lohman TG, Roche AF, Martorell R (1988) Anthropometric Standardization Reference Manual. Human Kinetics Books, Champaign, IL, USA.

Malhotra P, Kumari S, Kumar R, Varma S (2004) Prevalence of anemia in adult rural population of north India. J Assoc Physicians India 52:18-20.

Park K (2009) Park's Textbook of Preventive and Social Medicine. 20th ed., Banarsidas Bhanot Publishers, Jabalpur, India.

Pratima V, Shraddha S, Ashutosh K, Archna G, Ahilesh K (2012) Prevalence of anemia in adults with respect to socio-demographic status. Blood groups and religion in North Indian population. Int J Biol Med Res 3:2441-2447.

Shill KB, Karmakar P, Kibria MG, Das A, Rahman MA, Hossain MS, Sattar MM (2014) Prevalence of iron-deficiency anaemia among university students in Noakhali region, Bangladesh. J Health Popul Nutr 32:103-110.

Shrinivasa B, Philip R, Krishnapali V, Suraj A, Sreelakshmi P (2014) Prevalence of anemia among tribal women of reproductive age-group in Wayanad district of Kerala. Int J Health Allied Sci. 3:120-120.

Stiller CK, Golembiewski SKE, Golembiewski M, Mondal S, Biesalski HK, Scherbaum V (2020) Prevalence of undernutrition and anemia among santaladivasi children. Int J Environ Res Public Health 17(1):342.

Ulijaszek SJ, Kerr DA (1999) Anthropometric measurement error and the assessment of nutritional status. Br J Nutr 82:165-177.

World Health Organization (2004) Assessing the iron status of populations. 2nd Ed., WHO/CDC Joint Report, Geneva.

World Health Organization (2008) de Benoist B, McLean E, Egli I, Cogswell M. Worldwide prevalence of anaemia 1993-2005: WHO Global Database on Anaemia.

World Health Organization (2011) Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity (No. WHO/NMH/NHD/MNM/11.1). World Health Organization.

World Health Organization (2020) WHO guideline on use of ferritin concentrations to assess iron status in populations.World Health Organization.