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Original Research Article

Anemia and its determinants among adults in central India: a cross-sectional study

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ABSTRACT

Background: Anemia remains a major public health problem in India despite national control programmes. Its multifactorial causes include nutritional deficiencies, chronic illnesses, and sociodemographic factors. Limited data are available on the interplay of anemia with nutritional status and hematological variations in central India.
Methods: A cross-sectional study was conducted among 392 participants. Demographic and anthropometric details were recorded, and BMI was classified using WHO Asian cut-offs. Hematological parameters (Hb, MCV, MCH, MCHC, hematocrit) were measured using an automated analyser. Anemia was defined and graded using WHO criteria and further classified morphologically. Statistical analysis included Chi-square test, Student's t-test, ANOVA, and Pearson's correlation. A p value <0.05 was considered significant.
Results: The mean hemoglobin level was 12.64±1.49 gm/dl. The prevalence of anemia was 36%, with 0.3% severe, 12.8% moderate, and 23% mild cases. Morphologically, microcytic anemia (24%) and hypochromic anemia (53.6%) predominated. Anemia was significantly associated with age (p=0.012), highest among participants <18 years (43.2%). No significant association was found with sex or BMI, though underweight individuals had the highest prevalence (43.8%). Mean hemoglobin was significantly higher in males (13.38 gm/dl) than females (12.22 gm/dl, p<0.001). Hemoglobin correlated positively with both BMI (r=0.159, p=0.002) and age (r=0.202, p<0.001).
Conclusions: Anemia affects more than one-third of the studied population, with microcytic and hypochromic patterns suggesting iron deficiency as a major cause. Younger individuals and those with low BMI are most vulnerable. The findings highlight the dual burden of malnutrition- anemia and undernutrition coexisting with rising overweight, obesity, and elevated blood sugar. Targeted interventions addressing both ends of the nutritional spectrum are urgently needed.

Keywords: Anemia, Body mass index, Hematological parameters, Hemoglobin, Nutritional status, Public health

INTRODUCTION

Anemia, defined as a reduction in hemoglobin concentration below physiological norms for age and sex, is a widespread public health problem, particularly in low- and middle-income countries. It contributes to impaired oxygen transport, reduced work productivity, poor cognitive and physical development, and higher maternal and perinatal morbidity and mortality. Nutritional deficiencies- especially iron, folate, and vitamin B_{12}- are the most common causes, along with chronic infections, parasitic infestations, and genetic disorders.

Despite several national programmes, such as the National Anemia Control Programme, the iron plus initiative, and Anemia Mukt Bharat, anemia remains highly prevalent in India. According to NFHS-5 (2019-21), 57.2% of non-pregnant women aged 15-49 years and 52.2% of pregnant women are anaemic.[1] A recent systematic review estimated that more than half of women of reproductive age and about one-quarter of men are anemic, reflecting both high burden and gender disparity.[2]

Madhya Pradesh (MP), one of the central Indian states, has consistently reported higher anemia prevalence compared

to the national average. NFHS-5 showed that anemia among women aged 15-49 years in MP increased from 52.5% (NFHS-4) to 54.7% (NFHS-5).[3] Among children aged 6-59 months, nearly 73% were anemic, one of the highest proportions in India.[4] Local research also corroborates these findings: a community-based study from the Malwa region reported anemia prevalence of around 45% among apparently healthy adults.[5] Another hospital-based study in central India highlighted the clinical and hematological diversity of anemia and confirmed the persistence of nutritional anemia as a major concern.[6]

Multiple factors influence anemia risk. Age is an important determinant, adolescents have higher requirements due to growth spurts, while older adults may develop anemia due to chronic diseases and nutritional deficiencies.[2] Sex differences are well documented, with women more vulnerable due to menstruation, pregnancy, and lactation.[1,2] Nutritional status, commonly assessed by body mass index (BMI), is also associated with anemia. Underweight individuals are often more prone to micronutrient deficiencies, whereas some studies suggest that overweight/obese individuals may also be anaemic due to chronic inflammation and altered iron metabolism.[2] However, the relationship between BMI and anemia is inconsistent, with some studies showing higher hemoglobin in overweight individuals, while others describe a "double burden" of malnutrition.[2,5]

Although national surveys provide valuable prevalence data, they often focus on limited groups (women of reproductive age, children) and do not detail morphological classifications (microcytic, normocytic, macrocytic; hypochromic vs normochromic). There is a lack of comprehensive, community-based studies from MP that examine anemia prevalence, severity, morphology, and associations with demographic and nutritional factors across all age groups.

This study therefore aimed to assess the prevalence, severity, and morphological classification of anemia in a community-based population in central India, and to examine its association with age, sex, and nutritional status (BMI). By including both sexes across a wide age spectrum and detailed hematological parameters, this study seeks to generate locally relevant evidence to support more effective anemia control strategies in Madhya Pradesh.

METHODS

This community-based cross-sectional study was conducted in rural health camps organised by RDGMC college, central India (Madhya Pradesh), a state with consistently high prevalence of anemia according to national surveys. The study was carried out over a period of six months among 392 participants recruited from the community. Individuals aged above five years, of both sexes, who were permanent residents of the study area and willing to provide informed consent (or parental consent in the case of minors) were eligible. Participants with acute febrile illness at the time of examination, those who had received blood transfusions in the previous three months, and individuals with known hematological malignancies, hemoglobinopathies, or chronic renal disease were excluded. Pregnant women in the third trimester were also excluded to avoid confounding by pregnancy-related physiological anemia. The sample size of 392 was based on feasibility and was adequate to detect an expected anemia prevalence of approximately 40% (based on NFHS-5 for Madhya Pradesh), with 5% absolute precision and 95% confidence level.

Demographic and anthropometric data, including age, sex, height, and weight, were collected using a structured proforma. Height was measured to the nearest 0.1 cm using a stadiometer, and weight was recorded to the nearest 0.1 kg with a calibrated digital weighing scale. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres. BMI was classified according to WHO Asia-Pacific guidelines: underweight (<18.5 kg/m^2), normal (18.5-22.9 kg/m^2), overweight (23.0-24.9 kg/m^2), and obese (≥25.0 kg/m^2).

Venous blood samples (2-3 ml) were collected under aseptic precautions in EDTA vials and analysed using an automated hematology analyser. Hematological parameters measured included hemoglobin concentration, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and differential leucocyte counts (neutrophils, lymphocytes, monocytes, eosinophils, eosinophils, and basophils). Random blood sugar (RBS) was measured using the glucose oxidase-peroxidase method with a semi-automated analyser. Blood group typing was performed by slide agglutination using anti-A, anti-B, and anti-D sera.

Anemia was defined and graded using WHO criteria: mild (10-11.9 gm/dl in women and 10-12.9 gm/dl in men), moderate (7-9.9 gm/dl), and severe (<7 gm/dl). Morphological classification was performed using red cell indices, categorising cases as microcytic (MCV <80 fl), normocytic (MCV 80-100 fl), or macrocytic (MCV >100 fl). Chromic classification was based on MCHC values, with hypochromic anemia defined as MCHC <32 gm/dl and normochromic as ≥32 gm/dl.

Data entry was done using Microsoft Excel, and statistical analyses were carried out in SPSS version. Continuous variables were presented as means with standard deviations, while categorical variables were expressed as frequencies and percentages. Associations between categorical variables (such as anemia and age group, sex, or BMI category) were assessed using the Chi-square test. Mean hemoglobin differences between two groups (e.g., males and females) were tested using the independent t-test, while one-way analysis of variance (ANOVA) was applied for comparisons across multiple groups such as

BMI or age categories. Post-hoc analysis was conducted where applicable. Pearson's correlation coefficient was calculated to examine linear relationships between continuous variables, such as hemoglobin with BMI and hemoglobin with age. A p value of less than 0.05 was considered statistically significant.

RESULTS

The mean age of participants was 37.6 years, with a wide range (SD±21.9). Females were the majority (64.3%), while males comprised 35.7%. The average height and weight (151 cm and 50 kg, respectively) suggest a smaller body build compared to global norms. The mean BMI of 21.5 was within the normal range, though variation indicates the presence of both underweight and overweight individuals. These demographic and anthropometric findings provide important baseline characteristics for understanding subsequent health outcomes.

Table 1: Demographic and anthropometric characteristics of participants (n=392).

Variables	Value mean±SD/N (%)
Age (years)	37.6±21.9
Sex (M/F)	140 (35.7)/252 (64.3)
Height (cm)	151.0±13.9
Weight (kg)	49.9±15.6
BMI (kg/m^2)	21.5±5.6

Mean hemoglobin was 12.6 gm/dl, close to the lower limit of normal, suggesting that a notable portion of the population was anaemic. Red cell indices (MCV, MCH, MCHC) were within reference ranges but with wide variability, indicating mixed types of anemia. Hematocrit levels (40.3%) corresponded with hemoglobin values. Blood sugar levels averaged 128 mg/dl, slightly above normal fasting values, raising concerns for impaired glucose regulation. White cell differentials appeared low but consistent across participants, likely reflecting reference variations. Overall, the hematological profile highlighted a tendency toward mild anemia and possible metabolic issues in some individuals.

Table 2: Hematological parameters (n=392).

Parameter	Mean±SD
Hemoglobin (gm/dl)	12.6±1.5
MCV (fl)	85.1±9.7
MCH (pg)	27.0±6.0
MCHC (gm/dl)	31.2±4.6
Hematocrit (%)	40.3±5.2
Blood sugar (mg/dl)	128±42
Neutrophils (%)	5.8±7.1
Lymphocytes (%)	3.5±5.1
Monocytes (%)	0.8±1.0
Eosinophils (%)	0.3±0.5
Basophils (%)	0.1±0.2

Table 3: Distribution of anemia and morphological classification (n=392).

Category	N (%)
Normal (Hb)	251 (64.0)
Mild anaemia	90 (23.0)
Moderate anaemia	50 (12.8)
Severe anaemia	1 (0.3)
Total anaemic	141 (36.0)
Microcytic	94 (24.0)
Normocytic	258 (65.8)
Macrocytic	40 (10.2)
Hypochromic	210 (53.6)
Normochromic	182 (46.4)

Anemia was found in 36% of participants, with most cases being mild (23%) or moderate (12.8%). Severe anemia was rare (0.3%). Morphologically, normocytic anemia was most common (65.8%), followed by microcytic (24%) and macrocytic (10.2%). Over half of the cases were hypochromic (53.6%), indicating iron deficiency or chronic illness as possible contributors. These findings suggest that anemia is a significant public health issue in this population, primarily of the mild-to-moderate type, warranting nutritional and preventive interventions.

Table 4: Association between age, gender, BMI and anemia (n=392).

Variables	Category	Normal N (%)	Anemic N (%)	Total N (%)	χ^2	df	P value
Age (years)	<18	75 (56.8)	57 (43.2)	132 (100)	10.954	3	0.012
	18-30	23 (59.0)	16 (41.0)	39 (100)			
	31-60	95 (64.2)	53 (35.8)	148 (100)			
	>60	58 (79.5)	15 (20.5)	73 (100)			
Gender	Male	87 (62.1)	53 (37.9)	140 (100)	0.337	1	0.562
	Female	164 (65.1)	88 (34.9)	252 (100)			
BMI (kg/m²)	Underweight <18.5	68 (56.2)	53 (43.8)	121 (100)	5.488	3	0.139
	Normal 18.5-22.9	77 (65.8)	40 (34.2)	117 (100)			
	Overweight 23.0-24.9	33 (64.7)	18 (35.3)	51 (100)			
	Obese ≥25	73 (70.9)	30 (29.1)	103 (100)			

Table 5: Mean hemoglobin and blood sugar by BMI category (n=392).

BMI category	N	Mean±SD Hb (gm/dl)	ANOVA	Mean±SD blood sugar (mg/dl)	ANOVA
Underweight (<18.5)	121	12.29±1.15	F=3.64, p=0.013	116.65±20.45	F=6.74, p<0.001
Normal (18.5-22.9)	117	12.66±1.45		127.75±40.07	
Overweight (23.0-24.9)	51	12.86±1.65		128.88±37.00	
Obese (≥25.0)	103	12.90±1.74		141.45±58.78	
Total	392	12.64±1.49		128.07±42.05	

Table 6: Correlation of hemoglobin with BMI and age (n=392).

Variable 1	Variable 2	Pearson's correlation (r)	P value	N
Hb (gm/dl)	BMI (kg/m^2)	0.159**	0.002	392
Hb (gm/dl)	Age (years)	0.202**	0.000	392

**: Clinically significant

Age was significantly associated with anemia (p=0.012). The prevalence was highest in participants under 18 years (43.2%) and those aged 18-30 years (41%), while those over 60 years had the lowest prevalence (20.5%). This suggests that adolescents and young adults are particularly vulnerable. Gender differences were not statistically significant (p=0.562), although anemia was slightly more common in males (37.9%) than females (34.9%). Underweight individuals had the highest prevalence (43.8%) compared to obese individuals (29.1%), but BMI was not significantly associated (p=0.139). Thus, age emerged as the strongest predictor of anemia in this population.

Hemoglobin levels were lowest in underweight participants and highest in the obese group, showing a significant association with BMI (F=3.64, p=0.013). Blood sugar rose steadily with BMI (F=6.74, p<0.001), indicating greater anemia risk in underweight individuals and higher metabolic risk in overweight/obese participants.

Hemoglobin showed a positive correlation with both BMI (r=0.159, p=0.002) and age (r=0.202, p<0.001), indicating higher levels with better nutritional status and advancing age.

DISCUSSION

In this community-based cross-sectional study from central India (n=392), the overall prevalence of anemia was 36.0%, with most cases being mild or moderate and a morphological predominance of normocytic and hypochromic patterns. The observed prevalence is lower than that reported in national surveys. For example, NFHS-5 documented a prevalence of 57% among women of reproductive age in India.[7]

The morphological pattern in our sample (microcytic and hypochromic features) suggests that iron deficiency remains the leading cause of anemia. Similar findings of microcytic hypochromic predominance have been reported in hospital and community studies from central India.[6,9]

Age was the only sociodemographic factor significantly associated with anemia. The prevalence was highest in participants younger than 18 years (43.2%) and in the 18-30-year age group (41%). This aligns with national analyses showing adolescents and young adults to be highly vulnerable due to increased nutritional demands and suboptimal dietary intake.[4,5]

A modest positive correlation between hemoglobin and BMI was observed, with underweight individuals showing the highest prevalence (43.8%). This relationship has been reported in previous studies, where undernutrition is linked with higher anemia risk, while overweight status often shows higher hemoglobin levels.[10,11] However, the literature also indicates that obesity may impair iron absorption through hepcidin-mediated pathways, leading to functional iron deficiency even among those with higher BMI.[12,13]

The coexistence of borderline anemia and elevated blood sugar in some participants underscores the emerging "double burden" of malnutrition, where both undernutrition and metabolic disorders occur in the same communities. Similar patterns have been reported in recent national-level studies linking overweight and impaired glucose tolerance with iron-related disturbances.[13,14]

Strengths of this study include a community-based design and use of venous blood analysis. However, limitations include its cross-sectional nature, absence of biochemical markers of iron status (ferritin, transferrin saturation, hepcidin), and restriction to a single region. Future studies should incorporate detailed iron biomarkers to differentiate iron-deficiency anemia from anemia of inflammation and to clarify the role of nutritional and metabolic determinants.[8,9]

Our findings emphasize the need for integrated interventions- continued focus on iron supplementation and dietary diversification for undernourished groups, alongside strategies to address rising metabolic risk in overweight populations. Adolescents and young adults should be prioritized for anemia control programmes given their higher vulnerability.[7,8]

There are some limitations of the study. This study was cross-sectional in nature, which limits the ability to establish causality. The findings are based on participants from a single region, which may affect generalizability. Additionally, biochemical markers such as ferritin, transferrin saturation, and hepcidin were not assessed, which could have provided more insight into the underlying causes of anemia.

CONCLUSION

Anemia affected over one-third of adults in this central Indian population, mostly mild to moderate, with patterns suggestive of iron deficiency. Age was the strongest determinant, with adolescents and young adults most affected, while underweight individuals were also at higher risk. The coexistence of anemia and rising metabolic risk highlights a double burden of malnutrition. Interventions should prioritize nutritional supplementation and adolescent-focused programmes while integrating anemia control with broader nutrition and non-communicable disease strategies.

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