Research Article

Routine Haematological Profile and its interrelationship with Leukocyte Profile: A community-based cross-sectional study from Central India

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Background: Community-based haematological profiling in rural populations remains poorly characterised, particularly with respect to the interrelationships among haematological parameters. This study evaluated the relationships between routine haematological and leukocyte parameters in a rural Indian population.

Methods: A community-based cross-sectional haematological survey was conducted among adults from four villages in the rural field practice area of R.D. Gardi Medical College, Ujjain, during FAP and CAPP activities. Sociodemographic, anthropometric, and complete blood count data were analysed using the chi-square test or Fisher's exact test, binary and multivariable logistic regression.

Results: Among the 421 participants, the overall prevalence of anaemia was 33.5% (n=141), with a highly significant predominance among individuals aged 18 to 40 years (p=0.008) and in females (p=0.008). Anaemia was significantly associated with a normal neutrophil count (p=0.019) and lymphocytosis (p=0.006). In terms of erythrocyte morphology, normocytosis was the most common profile, observed in 67.7% (n=285). Microcytic anaemia was twice as common among participants with lymphocytosis (41.5%, n=22; p=0.013). Multivariable logistic regression identified 18 to 40 years of age (AOR=2.44, 95% CI: 1.38–4.32), female sex (AOR=1.83, 95% CI: 1.18–2.82), and lymphocytosis (AOR=2.39, 95% CI: 1.22–2.79) as independent predictors of anaemia. Participants with lymphocytosis also had higher odds of microcytic morphology (AOR=1.97, 95% CI: 1.07–3.65).

Conclusion: Anaemia was found to be prevalent in the economically productive population, and more so, especially in females. The association between microcytic anaemia and lymphocytosis may be due to a high burden of chronic infections, which warrants further investigation.

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Introduction

Routine haematological investigations, particularly the complete blood count (CBC), are vital tools for evaluating the health status of individuals and communities.[1] By measuring haemoglobin concentration, red blood cell indices, and leukocyte (white blood cell) counts, a CBC can effectively identify nutritional deficiencies, infections, and inflammatory conditions.[2] Because it is simple, cost-effective, and widely accessible, the CBC is ideally suited for community-based health screening programmes.[3]

Anaemia remains a critical global public health challenge, affecting nearly 30% of the world's population according to the World Health Organization (WHO).[4] In India, the burden remains high despite long-standing national control programmes. The National Family Health Survey-5 (NFHS-5) highlighted that anaemia affects 57.0% of women and 25.0% of men aged 15 to 49 years nationwide.[5] In Madhya Pradesh, the prevalence among women in this age group is 54.7%.[6] This burden is particularly pronounced in rural areas, driven by poor nutrition, recurrent infections, parasitic infestations, inadequate sanitation, and limited healthcare access.[5-7]

While anaemia is primarily diagnosed by low haemoglobin levels, evaluating red blood cell indices such as mean corpuscular volume (MCV), mean

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corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) is essential for classifying its morphological types and understanding its underlying causes.[8] Concurrently, leukocyte profiles reflect the body's immune status and frequently fluctuate in response to nutritional deficiencies and chronic infections.[9] Examining erythrocyte and leukocyte parameters together offers valuable insights into the complex relationship between nutrition, haematopoiesis, and immune function.[10,11]

Most existing literature on these haematological variations relies on hospital-based studies involving symptomatic patients. These findings may not accurately reflect the general rural population, where individuals with mild infections or nutritional deficiencies often remain undiagnosed.[9] Community-based research is therefore essential to capture the true baseline distribution of these parameters in apparently healthy adults.

To improve community outreach, the National Medical Commission (NMC) introduced the Family Adoption Programme (FAP).[12] Complementing this macro-framework, institutional initiatives like the "Community Adoption Program for Postgraduates" (CAPP) actively engage postgraduate medical students to assist local communities in addressing their health issues. These programs work toward achieving the vision of a "Healthy Village" and fulfilling relevant Sustainable Development Goals (SDGs) while providing an ideal platform to screen rural populations using simple diagnostic tools like the CBC.[13]

However, community-based data regarding routine haematological profiles and their relationship with leukocyte parameters remain scarce, particularly in rural Central India.[14] Addressing this gap could enhance early detection strategies for nutritional deficiencies and subclinical illnesses at the community level. Therefore, this study was conducted to characterise the routine haematological profile of adults in a rural community of Central India and to evaluate the relationships between anaemia status, erythrocyte morphology, and leukocyte profiles.

We hypothesised that erythrocyte morphology would be significantly associated with differential leukocyte profiles among rural adults.

Objectives

- To estimate the prevalence of anaemia and morphological anaemia among adults in a rural community.
- To assess the distribution and leukocyte profile among study participants.
- To study the as sociation of socio-demographic factors, anthropometric measurements, anaemia status and morphological anaemia with leukocyte profile.

Materials And Methods

Study Design and Setting

While conducting activities under the Family Adoption Programme (FAP) and the Community Adoption Programme for Postgraduates (CAPP) in the rural field practice area of R.D. Gardi Medical College, Ujjain, we undertook a community-based cross-sectional haematological survey across four villages. Individuals who participated underwent sociodemographic, anthropometric, clinical, and haematological assessments. Eligible and consenting individuals were enrolled sequentially from the four villages until the required sample size was achieved.

Sample Size Calculation

The minimum sample size required for the study was estimated based on the reported prevalence of anaemia. Assumptions:

Prevalence of anaemia (p) = 54.7% or 0.547, based on NFHS-5 data in Madhya Pradesh;[5]

$q = 1 - p = 0.453$;
$Z = 1.96$ at a 95% confidence level; and
absolute precision (d) = 5% or 0.05.
Formula: $n = Z^2pq/d^2$
Substitution: $n = (1.96^2 \times 0.547 \times 0.453)/(0.05^2)$

Calculated sample size: $n = 380.77 \approx 381$ participants
After adding 10% for possible non-response or incomplete data: $380.77 + 38.08 = 418.85 \approx 419$ participants.

The minimum required sample size was calculated as 419 participants. A total of 421 eligible participants were finally included.

Study Participants

Adults aged 18 years and above residing in the four selected villages who participated in the FAP and CAPP survey activities and provided informed consent were considered for inclusion. Pregnant women and those unwilling to participate were excluded. Eligible participants were enrolled sequentially until the required sample size was achieved; ultimately, 421 participants were included in the final analysis.

Data Collection

Data were collected using a predesigned and pretested structured proforma during the FAP and CAPP survey activities. Sociodemographic characteristics, anthropometric measurements, clinical findings, and laboratory investigation reports were recorded systematically. All participants underwent measurement of height, weight, blood pressure, and random blood sugar. Blood grouping, complete blood count, and urine analysis were performed using standard laboratory procedures.

Definition and Morphological Classification of Anaemia

Participants were categorised as anaemic or non-anaemic according to the World Health Organisation (WHO) haemoglobin criteria adopted by the Indian Council of Medical Research (ICMR). Anaemia was defined as haemoglobin levels <13 g/dL in males and <12 g/dL in females.[14] Morphological classification of anaemia was performed using the mean corpuscular volume (MCV) obtained from the complete blood count. Participants were classified as microcytic (MCV <80 fL), normocytic (MCV 80–100 fL), or macrocytic (MCV >100 fL).[15]

Categorisation of Leukocyte Counts

Leukocyte counts (neutrophils, lymphocytes, monocytes, eosinophils, and basophils) were categorised as low, normal, or high based on standard haematological laboratory reference ranges and established guidelines.[16]

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 16.0. Continuous variables were assessed for normality. Normally distributed variables were summarised as mean ± standard deviation (SD), whereas non-normally distributed variables were expressed as median with interquartile range (IQR). Categorical variables were presented as frequencies and percentages. Associations between categorical variables were analysed using the chi-square test or Fisher's exact test, as appropriate. Multivariable logistic regression was performed to identify independent predictors of anaemia and factors independently associated with microcytic erythrocyte morphology. Receiver operating characteristic (ROC) curve analysis was used to evaluate the discriminatory ability of absolute neutrophil and lymphocyte counts for microcytic morphology; areas under the curve (AUCs) with 95% confidence intervals were calculated. A *p-value* <0.05 was considered statistically significant.

Results

Table 1 shows the sociodemographic and anthropometric profile of the study participants. Among the 421 participants, the majority belonged to the 18 to 40 years age group, 175 (41.6%), followed by 40 to 60 years, 148 (35.2%) and >60 years, 98 (23.3%). Females constituted a higher proportion of the study population, 260 (61.8%), compared to males, 161 (38.2%). Nearly half of the participants were overweight, 209 (49.6%), while 171 (40.6%) had normal BMI and 41 (9.7%) were underweight.

Table 2 shows that 421 participants were enrolled from four villages: 106 (25.18%) from Ghosla and 105 (24.94%) each from Lambikhedi, Tukral, and Samanera. Overall, 260 (61.76%) participants were female, and 161 (38.24%) were male. The distribution across villages was nearly equal.

Table 3 summarises the routine haematological profile of the study participants. The mean haemoglobin concentration was 12.75 ± 1.55 g/dL, and the mean MCV was 85.57 ± 8.59 fL, both falling within normal reference ranges. Likewise, the median absolute neutrophil count was 4.67 (3.55–6.10) × 10^3/μL and the median lymphocyte count was 2.84 (2.16–3.63) ×10^3/μL, indicating that the overall erythrocyte indices and differential leukocyte parameters were largely within expected physiological limits.[15] Platelet parameters were not included in the present analysis and are therefore not reported.

Table 4 shows that anaemia was present in 33.5% (n=141) of the participants. Among the 141 anaemic individuals, the majority had mild anaemia (51.8%, n=73), followed closely by moderate anaemia (47.5%, n=67), while severe anaemia was rare (0.7%, n=1). With

Table 1: Sociodemographic and anthropometric profile of study participants

Variable	*Category*	*Frequency (N)*	*Percentage (%)*
Age group (years)	18–40	175	41.60
	40–60	148	35.20
	≥60	98	23.30
	Total	421	100
Sex	Male	161	38.20
	Female	260	61.80
	Total	421	100
Body mass index (BMI)	Underweight	41	9.70
	Normal	171	40.60
	Overweight	209	49.60
	Total	421	100

Table 2: Distribution of study participants by village and gender (N = 421)

Village	*Male, n (%)*	*Female, n (%)*	*Total, n (%)*
Lambikhedi	40 (9.50)	65 (15.44)	105 (24.94)
Tukral	40 (9.50)	65 (15.44)	105 (24.94)
Samanera	40 (9.50)	65 (15.44)	105 (24.94)
Ghosla	41 (9.74)	65 (15.44)	106 (25.18)
Total	161 (38.24)	260 (61.76)	421 (100.00)

Table 3: Routine haematological profile of the study participants

Parameter	
Erythrocyte Parameters	*Mean ± SD*
Haemoglobin (g/dL)	12.75 ± 1.55
Haematocrit (%)	40.62 ± 5.04
Mean corpuscular volume (MCV, fL)	85.57 ± 8.59
Mean corpuscular haemoglobin (MCH, pg)	27.14 ± 5.65
Mean corpuscular haemoglobin concentration (MCHC, g/dL)	31.21 ± 1.76
Leukocyte parameters	Median (IQR)
Absolute neutrophil count (×10³/μL)	4.67 (3.55–6.10)
Absolute lymphocyte count (×10³/μL)	2.84 (2.16–3.63)
Absolute monocyte count (×10³/μL)	0.62 (0.51–0.80)
Absolute eosinophil count (×10³/μL)	0.19 (0.11–0.36)
Absolute basophil count (×10³/μL)	0.05 (0.03–0.08)

Table 4: Prevalence of anaemia and morphological grade of anaemia among study participants

Condition	*Category*	*Frequency (N)*	*Percentage (%)*
Anaemia category	Normal	280	66.51
	Mild	73	17.34
	Moderate	67	15.91
	Severe	1	0.24
	Total	421	100
Erythrocytic classification	Macrocytic	40	9.50
	Microcytic	96	22.80
	Normocytic	285	67.70
	Total	421	100

respect to erythrocyte morphology, the normocytic pattern was predominant, observed in 67.7% (n=285) of the total population, whereas microcytic and macrocytic patterns were present in 22.8% (n=96) and 9.5% (n=40) of participants, respectively.

Table 5 presents the distribution of differential leukocyte profiles among the study participants. The majority of participants had normal leukocyte counts across all parameters, including neutrophils (382, 90.7%), lymphocytes (365, 86.7%), monocytes (407, 96.7%), eosinophils (367, 87.2%), and basophils (404, 96.0%). Among the abnormal leukocyte categories, lymphocytosis (53, 12.6%) and eosinophilia (51, 12.1%) were the most frequently observed, whereas neutropenia (8, 1.9%), lymphopenia (3, 0.7%), monocytopenia (2, 0.5%), eosinopenia (3, 0.7%), and basopenia (0%) were uncommon.

As shown in Table 6, anaemia was significantly associated with both age and sex. The highest prevalence was observed among participants aged 18 to 40 years (70, 40.0%; p = 0.008) and among female participants (100, 38.50%; p = 0.008). Conversely, anthropometric status showed no relationship with the condition, as no significant association was found between BMI category and anaemia (p = 0.775).

Table 5: Frequency distribution of leukocyte profile in the study population

Leukocyte parameter	*Category*	*Frequency (N)*	*Percentage (%)*
Neutrophils	Neutropenia	8	1.90
	Normal	382	90.7
	Neutrophilia	31	7.40
	Total	421	100
Lymphocytes	Lymphopenia	3	0.70
	Normal	365	86.7
	Lymphocytosis	53	12.6
	Total	421	100
Monocytes	Monocytopenia	2	0.5
	Normal	407	96.7
	Monocytosis	12	2.9
	Total	421	100
Eosinophils	Eosinopenia	3	0.70
	Normal	367	87.20
	Eosinophilia	51	12.10
	Total	421	100
Basophils	Basopenia	0	0.00
	Normal	405	96.00
	Basophilia	16	4.00
	Total	421	100

Table 6: Association of anaemia with sociodemographic and anthropometric profile of study participants

Variable	*Category*	*Non-anaemic N (%)*	*Anaemic N (%)*	*Chi-square*	*p-value*
Age group (years)	18–40	105 (60.0)	70 (40.0)	9.736	0.008
	40–60	98 (66.2)	50 (33.8)		
	≥60	77 (78.6)	21 (21.4)		
Gender	Male	120 (74.5)	41 (25.5)	6.967	0.008
	Female	160 (61.5)	100 (38.5)		
BMI category	Underweight	27 (62.8)	16 (37.2)	0.511	0.775
	Normal	109 (65.7)	57 (34.3)		
	Overweight	144 (67.9)	68 (32.1)		

Table 7 shows the association between leukocyte profile and anaemia among the study participants. A statistically significant association was observed between anaemia status and neutrophil count (p=0.019) as well as lymphocyte count (p=0.006). Participants with lymphocytosis had a higher prevalence of anaemia (27, 50.9%) compared with those having normal lymphocyte counts (114, 31.2%). In contrast, participants with neutrophilia had a lower prevalence of anaemia (6, 19.4%) than those with normal neutrophil counts (135, 35.3%). No significant associations were observed between anaemia and monocyte, eosinophil, or basophil categories ($p > 0.05$).

Table 8 shows the association between leukocyte parameters and the morphological classification of anaemia. Normocytic morphology was the most common type across all leukocyte categories. A statistically significant association was observed for neutrophil ($p = 0.046$) and lymphocyte counts ($p = 0.013$), indicating that the distribution of anaemia morphology varied according to these parameters. Although normocytic anaemia remained the predominant morphology, microcytic anaemia was relatively more frequent among participants with lymphocytosis (22, 41.5%) than among those with normal lymphocyte counts (74, 20.3%). No significant association was observed between anaemia morphology and monocyte ($p = 0.908$), eosinophil ($p = 0.540$), or basophil counts ($p = 0.777$).

Table 9 presents the results of the binary logistic regression analysis for identifying independent

Table 7: Association of leukocyte profile with anaemia among study participants using Fisher's exact test

Leukocyte parameter	*Category*	*Non-anaemic N (%)*	*Anaemic N (%)*	*p-value*
Neutrophils	Neutropenia	8 (100.0)	0 (0.0)	0.019
	Normal	247 (64.7)	135 (35.3)	
	Neutrophilia	25 (80.6)	6 (19.4)	
Lymphocytes	Lymphopenia	3 (100.0)	0 (0.0)	0.006
	Normal	251 (68.8)	114 (31.2)	
	Lymphocytosis	26 (49.1)	27 (50.9)	
Monocytes	Monocytopenia	2 (100.0)	0 (0.0)	0.604
	Normal	271 (66.6)	136 (33.4)	
	Monocytosis	7 (58.3)	5 (41.7)	
Eosinophils	Eosinopenia	2 (66.7)	1 (33.3)	0.891
	Normal	243 (66.2)	124 (33.8)	
	Eosinophilia	35 (68.6)	16 (31.4)	
Basophils	Normal	272 (67.2)	133 (32.8)	0.154
	Basophilia	8 (50.0)	8 (50.0)	

Fisher's exact test was used because more than 20% of cells had expected frequencies <5. Exact two-sided p-values are reported.

Table 8: Association between leukocyte profile with morphological classification of anaemia among study participants using Fisher's exact test

Leukocyte parameter	*Category*	*Macrocytic N (%)*	*Microcytic N (%)*	*Normocytic N (%)*	*p-value*
Neutrophils	Neutropenia	1 (12.50)	2 (25.00)	5 (62.50)	0.046
	Normal	38 (9.90)	92 (24.10)	252 (66.00)	
	Neutrophilia	1 (3.20)	2 (06.50)	28 (90.30)	
Lymphocytes	Lymphopenia	0 (00.00)	0 (00.00)	3 (100.00)	0.013
	Normal	37 (10.10)	74 (20.30)	254 (69.60)	
	Lymphocytosis	3 (05.70)	22 (41.50)	28 (52.80)	
Monocytes	Monocytopenia	0 (00.00)	0 (00.00)	2 (100.0)	0.908
	Normal	40 (09.80)	93 (22.90)	274 (67.30)	
	Monocytosis	0 (00.00)	3 (25.00)	9 (75.00)	
Eosinophils	Eosinopenia	0 (00.00)	2 (66.70)	1 (33.30)	0.540
	Normal	36 (09.80)	82 (22.30)	249 (67.80)	
	Eosinophilia	4 (07.80)	12 (23.50)	35 (68.60)	
Basophils	Normal	38 (9.40)	92 (22.70)	275 (67.90)	0.777
	Basophilia	2 (12.50)	4 (25.00)	10 (62.50)	

Fisher's Exact Test was used for all parameters because more than 20% of cells had expected frequencies less than 5.

predictors of anaemia. The positive β coefficients for the 18 to 40 years (β = 0.894), 40 to 60 years (β = 0.626), female sex (β = 0.604), and lymphocytosis (β = 0.873) indicate a positive association with anaemia, suggesting that these factors increase the likelihood of being anaemic. Compared with participants aged >60 years, those aged 18 to 40 years had 2.44 times higher odds (AOR = 2.44, 95% CI: 1.38–4.32; $p = 0.002$) and those aged 40 to 60 years had 1.87 times higher odds (AOR = 1.87, 95% CI: 1.04–3.38; $p = 0.038$) of anaemia. Females had 1.83 times higher odds of anaemia than males (AOR = 1.83, 95% CI: 1.18–2.82; $p = 0.006$). Similarly, participants with lymphocytosis had 2.39 times higher odds of anaemia compared with those with normal lymphocyte counts (AOR = 2.39, 95% CI: 1.22–2.79; $p = 0.007$). In contrast, the negative β coefficient for normal neutrophil count (β = –0.772) indicates an inverse association with anaemia, corresponding to 54% lower odds of anaemia than participants with neutrophilia; however, this association was not statistically significant (AOR = 0.46, 95% CI: 0.18–1.16; $p = 0.101$).

Table 10 presents the multivariable logistic regression analysis for factors associated with microcytic morphology. The negative β coefficient for normal neutrophil count (β = −1.582) indicates a reduced likelihood of microcytic morphology compared with neutrophilia, corresponding to 79% lower odds (AOR = 0.21, 95% CI: 0.06–0.69; p = 0.010). In contrast, the positive β coefficient for lymphocytosis (β = 0.680) indicates an

Table 9: Binary logistic regression analysis for independent predictors of anaemia

Variable	*Category*	*B*	*Adjusted OR (95% CI)*	*p-value*
Age	>60 years	Ref	Ref	Ref
	40–60 years	0.626	1.87 (1.04–3.38)	0.038
	18–40 years	0.894	2.44 (1.38–4.32)	0.002
Gender	Male	Ref	Ref	Ref
	Female	0.604	1.83 (1.18–2.82)	0.006
Neutrophil	Neutrophilia	Ref	Ref	Ref
	Normal	-0.772	0.46 (0.18–1.16)	0.101
Lymphocyte	Normal	Ref	Ref	Ref
	Lymphocytosis	0.873	2.39 (1.22–2.79)	0.007

Table 10: Multivariable logistic regression analysis for factors associated with microcytic morphology of anaemia

Variable	*Category*	*B*	*Adjusted OR (95% CI)*	*p-value*
Neutrophil count	Increased	Ref	Ref	Ref
	Normal	−1.582	0.21 (0.06–0.69)	0.010
Lymphocyte count	Normal	Ref	Ref	Ref
	Increased	0.680	1.97 (1.07–3.65)	0.031

Table 11: Receiver operating characteristic (ROC) analysis of absolute neutrophil and lymphocyte counts for predicting microcytic morphology

Leukocyte parameter	*AUC (95% CI)*	*SE*	*p-value*
Neutrophil count	0.413 (0.355–0.470)	0.029	0.004
Lymphocyte count	0.566 (0.507–0.625)	0.030	0.029

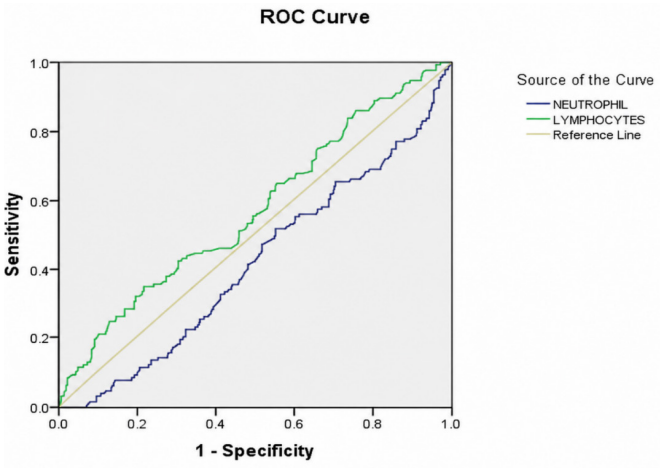

Figure 1: Receiver operating characteristic (ROC) curves of absolute neutrophil and lymphocyte counts for predicting microcytic morphology among study participants

increased likelihood of microcytic morphology, with participants having 1.97-fold higher odds than those with normal lymphocyte counts (AOR = 1.97, 95% CI: 1.07–3.65; $p = 0.031$).

Table 11 shows ROC analysis showed the discriminatory ability of absolute lymphocyte count for microcytic morphology (AUC=0.566, 95% CI: 0.507–0.625; $p = 0.029$). The absolute neutrophil count had an AUC below 0.50 (AUC=0.413, 95% CI: 0.355–0.470; $p = 0.004$), indicating poor discrimination and an inverse classification pattern (Figure 1).

Discussion

The present community-based cross-sectional study evaluated the interrelationship between routine haematological parameters and differential leukocyte profiles among 421 rural adults from Central India. To our knowledge, community-based evidence exploring these relationships in apparently healthy rural populations is scarce. Although the overall haematological profile was largely within normal limits, 141 (33.5%) participants were anaemic, highlighting the continued burden of anaemia in rural communities. These findings demonstrate that routine complete blood count assessment can provide valuable baseline information on both nutritional status and immune-related haematological changes at the community level.

Despite an overall normal haematological profile, 141 (33.5%) participants were anaemic. This prevalence is lower than that reported in the National Family Health Survey-5, where anaemia affects 57.0% of women and 25.0% of men aged 15 to 49 years, but it still represents a moderate public health burden.[5] The lower prevalence observed in the present study is likely due to the inclusion of both sexes across a broader adult age range rather than only women of reproductive age. Similarly, Let *et al*. reported that anaemia among women residing in India's Aspirational Districts increased from 58.7% during NFHS-4 to 61.1% during NFHS-5, highlighting that anaemia remains a persistent challenge despite ongoing nutritional interventions.[17]

Anaemia was significantly more common among 100 (38.5%) females than 41 (25.5%) males ($p = 0.008$). Likewise, the highest prevalence was observed among participants aged 18 to 39 years, where 70 (40.0%) individuals were anaemic. These findings are consistent with the review by Givens *et al*., who concluded that women of reproductive age remain the population most affected by anaemia in India because of menstrual blood loss, pregnancy, poor dietary intake and deficiencies of iron, vitamin B12 and folate. The authors further emphasized that anaemia in India has a multifactorial aetiology and that iron deficiency alone cannot explain the high prevalence observed in the population.[18]

An important observation of the present study was the predominance of normocytic erythrocyte morphology, which was observed in 285 (67.7%) participants, while microcytic and macrocytic morphology accounted for 96 (22.8%) and 40 (9.5%) participants, respectively. The predominance of normocytic morphology suggests that anaemia in the community may not be solely attributable to iron deficiency but may also reflect chronic inflammation, infections, mixed nutritional deficiencies, or early stages of nutritional anaemia. Similar observations have been described by Weiss, Ganz and Goodnough, who explained that anaemia of

inflammation is one of the commonest forms of anaemia worldwide and results from impaired iron utilisation mediated by inflammatory cytokines and hepcidin rather than absolute iron deficiency alone.[3]

Although the majority of participants demonstrated normal leukocyte counts, significant associations were observed between anaemia and neutrophil ($p = 0.019$) and lymphocyte ($p = 0.006$) categories. Among participants with lymphocytosis, 27 (50.9%) were anaemic compared with 114 (31.2%) among those with normal lymphocyte counts. Similarly, Samanta and Senapati reported significant alterations in differential leukocyte counts among patients with nutritional anaemia, including increased neutrophil counts, reduced lymphocyte counts and a higher neutrophil-to-lymphocyte ratio, suggesting that nutritional deficiencies may influence immune function and inflammatory responses.[9]

A novel finding of the present study was the significant association between erythrocyte morphology and lymphocyte profile. Among participants with lymphocytosis, 22 (41.5%) demonstrated microcytic morphology compared with 74 (20.3%) among those with normal lymphocyte counts ($p = 0.013$). Comparable community-based evidence describing this relationship is limited. However, Chen *et al*. demonstrated that increasing systemic inflammatory activity was associated with both the presence and severity of anaemia in a large population-based study, suggesting that immune activation and haematological alterations frequently coexist.[19] Likewise, Givens *et al*. emphasized that nutritional deficiencies, chronic infections and inflammatory disorders collectively contribute to anaemia in India, supporting the multifactorial nature of the present findings.[18]

After adjustment, participants aged 18-40 and 40-60 years had 2.44-fold and 1.87-fold higher odds of anaemia, respectively, than those aged >60 years, while females had 1.83-fold higher odds than males. These findings are consistent with Jones *et al*. and Little *et al*., who also reported a higher prevalence of anaemia among women than men in rural India, although Little *et al*. observed a greater burden among older men, unlike the higher odds among younger adults in the present study.[21,22] Such differences may reflect variations in demographic characteristics, nutritional status, and healthcare access. Givens *et al*. attributed the high burden of anaemia in India to multiple factors, including nutritional deficiencies, chronic inflammation, and recurrent infections.[20] Similarly, Mare *et al*. identified younger reproductive age, undernutrition, poor socioeconomic status, inadequate antenatal care, and poor sanitation as independent determinants of anaemia.[23] Furthermore, lymphocytosis independently increased the odds of anaemia by 2.39-fold in our study, comparable to the 1.51-fold higher odds associated with an elevated systemic immune-inflammation index reported by Chen *et al*., supporting the role of immune activation in anaemia.[19]

A particularly important finding of the present study was that lymphocytosis remained an independent predictor of both anaemia (AOR = 2.39, 95% CI: 1.22–2.79) and microcytic erythrocyte morphology (AOR = 1.97, 95% CI: 1.07–3.65) after adjustment for potential confounders. In contrast, participants with normal neutrophil counts had significantly lower odds of microcytic morphology than those with neutrophilia (AOR = 0.21, 95% CI: 0.06–0.69). Although studies evaluating absolute lymphocyte count as an independent predictor are scarce, Chen *et al*. reported that a higher systemic immune-inflammation index was independently associated with anaemia (OR = 1.51, 95% CI: 1.36–1.68), supporting the role of immune activation in the development of anaemia.[19] Likewise, Samanta and Senapati observed significant alterations in leukocyte profiles among patients with nutritional anaemia, suggesting that immune cell disturbances frequently coexist with abnormalities in erythropoiesis.[9] González-Fernández *et al*. further demonstrated that chronic inflammation, nutritional deficiencies, and persistent infections collectively contribute to anaemia, supporting the hypothesis that the associations observed in the present study may reflect the combined effects of inflammation and impaired erythropoiesis in rural populations.[24]

Receiver operating characteristic (ROC) analysis demonstrated that absolute lymphocyte count had a statistically significant discriminatory ability for identifying microcytic erythrocyte morphology (AUC = 0.566, $p = 0.029$). In contrast, absolute neutrophil count showed an AUC of 0.413 ($p = 0.004$), indicating an inverse discriminatory pattern. These findings complement the regression analysis, in which lymphocytosis emerged as an independent predictor of microcytic erythrocyte morphology, suggesting that leukocyte parameters may provide supportive information when interpreted alongside erythrocyte indices and other laboratory investigations. Future studies with larger and more representative samples may provide more precise AUC estimates and help determine the true discriminatory value of these leukocyte parameters. In addition,

incorporating other haematological, biochemical, and inflammatory biomarkers in predictive models may improve their diagnostic performance and provide a better understanding of the relationship between immune cell profiles and erythrocyte morphology. Validation of these findings in diverse community and clinical populations would further strengthen their potential application in community-based screening programmes.

The present study provides one of the few community-based assessments of the interrelationship between the routine haematological profile and the differential leukocyte profile in rural adults in Central India. While most haematological parameters remained within normal physiological ranges, 141 (33.5%) participants were anaemic, and significant associations between anaemia, erythrocyte morphology, and leukocyte profiles indicate that routine complete blood count assessment may serve as a useful community screening tool for identifying nutritional and immune-related disorders.

Conclusion

In this community-based study, anaemia affected 141 (33.5%) of 421 participants and was more prevalent among females (100/260; 38.5%) and adults aged 18 to 40 years (70/175; 40.0%). Normocytic morphology predominated (285/421; 67.7%), while microcytic morphology was more frequent among participants with lymphocytosis than among those with normal lymphocyte counts (22/53; 41.5 *vs*. 74/365; 20.3%; $p = 0.013$). Younger age, female sex, and lymphocytosis were independent predictors of anaemia, and lymphocytosis was also associated with microcytic morphology. The ROC findings demonstrated limited discriminatory performance, highlighting the need for validation in larger prospective studies. Larger prospective studies incorporating iron indices, nutritional biomarkers, inflammatory markers, and assessment of infection are needed to confirm these associations and clarify their underlying mechanisms.

Strengths & Limitations of The Study

The major strength of this study is its community-based design, which provides real-world evidence from apparently healthy rural adults rather than hospital-based patients. Additionally, the study simultaneously evaluated routine haematological parameters, erythrocyte morphology, and differential leukocyte profiles, an area that remains inadequately explored in rural Indian populations.

The cross-sectional design limits causal inference between anaemia and leukocyte alterations. Iron studies, serum ferritin, vitamin B12, folate, inflammatory markers, and detailed assessment of infection were not available; therefore, the causes of anaemia could not be determined. In addition, small numbers in some abnormal leukocyte and morphology subgroups may have reduced the precision and stability of the regression and ROC estimates.

Recommendations

- Future prospective and longitudinal studies should test the hypothesis that lymphocytosis is an independent predictor of anaemia in community populations, as participants with lymphocytosis had significantly higher odds of anaemia in the present study (AOR = 2.39, 95% CI: 1.22–2.79).
- Future prospective studies should evaluate the hypothesis that lymphocytosis and neutrophil count are independent predictors of microcytic erythrocyte morphology, as lymphocytosis was associated with higher odds of microcytic morphology (AOR = 1.97, 95% CI: 1.07–3.65), whereas normal neutrophil counts were associated with significantly lower odds compared with neutrophilia (AOR = 0.21, 95% CI: 0.06–0.69).
- Further research incorporating iron studies, serum ferritin, vitamin B12, folate, inflammatory markers, and infection screening is recommended to elucidate the biological mechanisms underlying the observed association between lymphocytosis, anaemia, and microcytic morphology.

Conflict of Interest

None.

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Ethical Approval

The study was approved by the Institutional Ethics Committee of R.D. Gardi Medical College, Ujjain (Reference No. 01/2025). Written informed consent was obtained from all study participants before enrolment.

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Author Contributions

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