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Original Research Article

APPRAISAL OF PHYSIOLOGICAL AND HAEMATOLOGICAL TRANSFORMATIONS IN MALARIA PATIENTS: A FOCUS ON HAEMOGLOBIN AND WHITE BLOOD CELL COUNT IN KARNATAKA, INDIA

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ABSTRACT

Background: Malaria is associated with a range of haematological alterations that vary with *Plasmodium* species, host factors, and geographic setting. Among these, haemoglobin (Hb) reduction and changes in white blood cell (WBC) count are clinically important indicators of disease severity and host immune response. **Objectives:** The present study aimed to evaluate alterations in haemoglobin and white blood cell count among malaria patients from Karnataka, India, and to assess their association with *Plasmodium* species, gender, age group, and district.

Materials and Methods: A retrospective observational study was conducted using laboratory-confirmed malaria cases reported from Dakshina Kannada and Shivamogga districts between 2019 and 2023. Haemoglobin concentration and total WBC count were analysed in relation to district, gender, age group (≤50 years and >50 years), and parasite species. Data were expressed as mean ± standard deviation, and statistical comparisons were performed using unpaired t-test and one-way ANOVA.

Results: Mean haemoglobin levels were significantly lower in Shivamogga (10.20 ± 1.66 g/dL) compared to Dakshina Kannada (11.15 ± 0.94 g/dL; $p = 0.001$). Female patients showed significantly lower haemoglobin levels than males in both Dakshina Kannada (10.25 ± 0.88 vs 11.26 ± 0.89 g/dL; $p < 0.001$) and Shivamogga (8.41 ± 0.59 vs 10.69 ± 1.52 g/dL; $p < 0.001$). In Dakshina Kannada, patients aged >50 years had significantly lower haemoglobin levels than those aged ≤50 years (10.41 ± 0.76 vs 11.27 ± 0.91 g/dL; $p < 0.001$), whereas no significant age-related difference was observed in Shivamogga. Parasite-wise analysis showed the lowest haemoglobin levels in *Plasmodium falciparum* infections in Dakshina Kannada (9.95 ± 0.87 g/dL), followed by mixed infections (10.35 ± 0.71 g/dL), while *P. vivax* cases showed higher values (11.33 ± 0.83 g/dL; $p < 0.001$). Mean WBC counts did not differ significantly between districts (Dakshina Kannada: 6869 ± 3292 cells/µL; Shivamogga: 7463 ± 1900 cells/µL; $p = 0.243$), but showed significant parasite-wise variation in Dakshina Kannada, with higher values in *P. falciparum* and mixed infections ($p < 0.001$).

Keywords: Malaria; Haemoglobin; White blood cell count; *Plasmodium* species; Haematological alterations; Karnataka, India.

INTRODUCTION

Malaria remains a major parasitic disease of global public health importance, particularly in tropical and subtropical regions. It is caused by protozoan parasites of the genus Plasmodium and transmitted through the bite of infected female Anopheles mosquitoes. Despite a significant reduction in global malaria burden over recent decades, malaria continues to contribute substantially to morbidity and mortality in low- and middle-income countries.[1]

In India, malaria transmission is heterogeneous and influenced by ecological, demographic, and socioeconomic factors. Karnataka has historically been a malaria-endemic state, though recent reports indicate a marked decline in incidence following strengthened control and surveillance measures.[2] Despite this decline, malaria continues to persist in localized endemic pockets, particularly in coastal and forested regions.

Malaria is known to cause a spectrum of haematological and biochemical abnormalities. Anaemia is one of the most common complications, resulting from haemolysis of infected and uninfected erythrocytes, bone marrow suppression, and splenic sequestration.[3,4,5] Alterations in white blood cell counts, including leucocytosis or leukopenia, reflect host immune responses and vary with disease severity and parasite species.[6,7,8]

The degree of haemoglobin reduction and WBC response differs among Plasmodium species. Plasmodium falciparum infections are frequently associated with severe anaemia and thrombocytopenia.[9,10] whereas P. vivax and P. vivax infections generally present with milder haematological changes. Gender- and age-related differences in haematological parameters have also been reported, with females and older individuals often exhibiting lower baseline haemoglobin levels.[11]

While several studies have described epidemiological trends of malaria in Karnataka, comprehensive analyses focusing on physiological and biochemical alterations in relation to parasite species remain limited. Therefore, the present study was undertaken to evaluate haematological and biochemical changes, with special emphasis on haemoglobin and white blood cell counts, among malaria patients from Dakshina Kannada and Shivamogga districts of Karnataka.

MATERIALS AND METHODS

2.1 Study Design and Study Area

The present study was designed as a retrospective observational analysis to evaluate physiological and haematological alterations in malaria patients, with particular emphasis on haemoglobin and white blood cell count. The study was conducted using laboratory-confirmed malaria cases reported from Dakshina Kannada and Shivamogga districts of Karnataka, India, over a five-year period from January 2019 to December 2023. Dakshina Kannada represents a coastal urban malaria setting, while Shivamogga represents an ecologically distinct Malnad region, allowing comparison across two contrasting transmission environments.

2.2 Data Source and Case Selection

Secondary data were collected from government health records and laboratory registers maintained at Primary Health Centres across both districts. Only malaria cases confirmed by peripheral blood smear examination and/or rapid diagnostic tests were included in the analysis. Records lacking complete haematological information were excluded to ensure data reliability.

2.3 Haematological Parameters Considered

The analysis was confined to key haematological indicators reflecting physiological response to malaria infection, namely haemoglobin concentration and total white blood cell count. Haemoglobin values were expressed in grams per decilitre, while white blood cell counts were expressed as cells per microliter of blood. These parameters were selected due to their clinical relevance in assessing anaemia and immune response in malaria patients. The data were analysed in relation to district, gender, age group (≤50 years and >50 years), and *Plasmodium* species.

2.4 Statistical Analysis

The collected data were compiled and analysed using SPSS statistical software. Haemoglobin and white blood cell values were expressed as mean ± standard deviation. Comparisons between two independent groups were performed using the unpaired t-test, while comparisons involving more than two groups were conducted using one-way analysis of variance. A p-value of less than 0.05 was considered statistically significant.

RESULTS

3.1 District-wise Variation in Haemoglobin and White Blood Cell Count

A comparison of haematological parameters between the two districts revealed a statistically significant difference in haemoglobin levels (table 1). Malaria patients from Shivamogga exhibited significantly lower mean haemoglobin values compared to those from Dakshina Kannada ($p = 0.001$). In contrast, although mean white blood cell counts were higher in Shivamogga, the difference between the two districts was not statistically significant.

Table 1: The district-wise comparison of mean haemoglobin and white blood cell counts

Parameter	Dakshina Kannada (Mean ± SD)	Shivamogga (Mean ± SD)	p-value
Haemoglobin (g/dL)	11.15 ± 0.94	10.20 ± 1.66	0.001
White blood cell count (cells/µL)	6,869 ± 3,292	7,463 ± 1,900	0.243

3.2 Gender-wise Distribution of Haemoglobin

Gender-based analysis showed that female malaria patients had significantly lower haemoglobin levels than male patients in both districts (table 2 and figure 2, 3). This difference was statistically significant in Dakshina Kannada as well as Shivamogga ($p < 0.001$). The observed pattern indicates a consistent gender-related disparity in haemoglobin levels among malaria patients.

Table 2: Gender-wise comparison of haemoglobin values across districts

District	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Dakshina Kannada	11.26 ± 0.89	10.25 ± 0.88	<0.001
Shivamogga	10.69 ± 1.52	8.41 ± 0.59	<0.001

The cumulative time-to-rescue profile is summarised in Table 2. The difference was greatest during the first six hours. By 24 hours, all participants in both groups had received rescue analgesia.



Figure 1: Gender-wise comparison of haemoglobin levels in malaria patients in Shivamogga

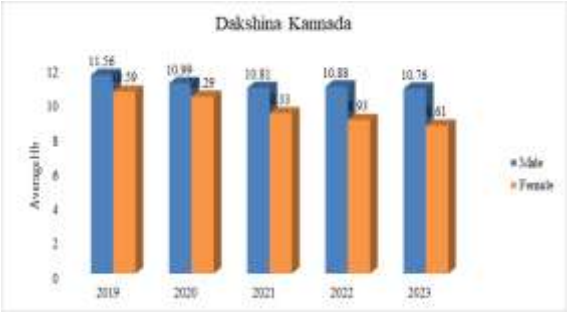


Figure 2: Gender-wise comparison of haemoglobin levels in malaria patients in Dakshina Kannada

3.3 Age-group-wise Variation in Haemoglobin

When stratified by age, a significant reduction in haemoglobin levels was observed among patients aged over 50 years in Dakshina Kannada ($p < 0.001$). However, no statistically significant age-related difference in haemoglobin levels was observed in Shivamogga. This suggests that age-related anaemia was more pronounced in the coastal district. [Table 3]

Table 3: Age-group-wise haemoglobin values in both districts

District	≤50 years (Mean ± SD)	>50 years (Mean ± SD)	p-value
Dakshina Kannada	11.27 ± 0.91	10.41 ± 0.76	<0.001
Shivamogga	10.15 ± 1.78	10.32 ± 1.38	0.767

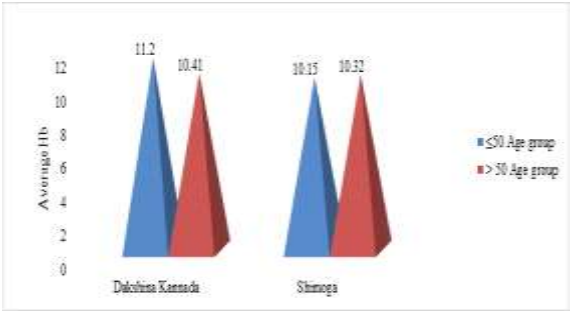


Figure 3: Age-group-wise haemoglobin values in both districts.

3.4 Parasite-wise Variation in Haemoglobin

Analysis based on *Plasmodium* species revealed that *Plasmodium falciparum* infections were associated with the lowest mean haemoglobin values in Dakshina Kannada, followed by mixed infections, while *Plasmodium vivax* infections showed comparatively higher haemoglobin levels. The differences observed among parasite species were statistically significant ($p < 0.001$). In Shivamogga, although *P. falciparum* cases showed lower haemoglobin values than *P. vivax*, the difference was not statistically significant.

Table 4: Parasite-wise comparison of haemoglobin levels in Dakshina Kannada

Plasmodium species	Haemoglobin (Mean ± SD)	p-value
P. vivax	11.33 ± 0.83	<0.001
P. falciparum	9.95 ± 0.87	
Mixed infection	10.35 ± 0.71	

Table 5: Parasite-wise comparison of haemoglobin levels in Shivamogga

Plasmodium species	Haemoglobin (Mean ± SD)	p-value
P. vivax	10.34 ± 1.73	0.179
P. falciparum	9.35 ± 0.87	

3.5 Gender-wise Variation in White Blood Cell Count

Gender-wise analysis of white blood cell count demonstrated a statistically significant difference in Dakshina Kannada, with female patients exhibiting higher mean WBC counts compared to males ($p < 0.001$). In Shivamogga, although females showed slightly higher WBC counts, the difference was not statistically significant.

Table 6: should summarize the gender-wise comparison of white blood cell counts

District	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Dakshina Kannada	6799 ± 3039	7429 ± 4820	<0.001
Shivamogga	7369 ± 1878	7809 ± 2057	0.544

3.6 Parasite-wise Variation in White Blood Cell Count

In Dakshina Kannada, white blood cell counts differed significantly among *Plasmodium* species, with *P. falciparum* and mixed infections showing higher mean WBC values compared to *P. vivax* infections ($p < 0.001$). Conversely, no statistically significant parasite-wise difference in WBC counts was observed in Shivamogga.

Table 7: Parasite-wise comparison of white blood cell count in Dakshina Kannada

Plasmodium species	WBC (cells/µL, Mean ± SD)	p-value
P. falciparum	7625 ± 1618	0.804
P. vivax	7436 ± 1962	

DISCUSSION

The present study evaluated physiological alterations in malaria patients from two ecologically distinct regions of Karnataka, with particular emphasis on haemoglobin concentration and white blood cell count in relation to Plasmodium species. The findings demonstrate that malaria is associated with significant haematological disturbances, and that the magnitude of these alterations varies according to parasite species, gender, age group, and geographic region.

A significant reduction in haemoglobin levels was observed among malaria patients, with patients from Shivamogga exhibiting lower mean haemoglobin values compared to those from Dakshina Kannada. Anaemia is a well-recognized complication of malaria and is primarily attributed to intravascular haemolysis of parasitized and non-parasitized erythrocytes, splenic sequestration, and suppression of erythropoiesis.[12,13] The comparatively lower haemoglobin levels in Shivamogga may reflect differences in baseline nutritional status, delayed diagnosis, or ecological factors influencing disease severity.

Gender-wise analysis revealed significantly lower haemoglobin levels in female patients in both districts. This finding is consistent with previous studies from India, which report higher susceptibility of females to anaemia due to pre-existing iron deficiency and nutritional factors, further exacerbated by malaria infection.[14,15] The persistence of this gender disparity highlights the need for integrated malaria management strategies that also address underlying nutritional anaemia.

Age-related analysis showed that patients aged over 50 years in Dakshina Kannada had significantly lower haemoglobin levels compared to younger individuals. Older age has been associated with increased vulnerability to malaria-induced anaemia due to reduced physiological reserves and co-morbid conditions.[16] However, a similar age-related difference was not observed in Shivamogga, possibly due to the smaller sample size or differences in parasite species distribution.

Parasite-wise analysis demonstrated that Plasmodium falciparum infections were associated with the lowest haemoglobin levels, followed by mixed infections, while P. vivax infections showed comparatively higher haemoglobin values. This observation is in agreement with established literature, which identifies P. falciparum as the species most strongly associated with severe anaemia due to its ability to infect erythrocytes of all ages and cause extensive haemolysis.[17] In contrast, P. vivax typically cause milder anaemia, although severe cases have been reported.[18,19]

Analysis of white blood cell counts revealed parasite- and region-specific variations. In Dakshina Kannada, significant differences in WBC counts were observed among parasite species, with P. falciparum and mixed infections showing higher mean WBC values than P. vivax. Elevated WBC counts in malaria may reflect an enhanced inflammatory and immune response, particularly in more severe infections.[20,21,22] Conversely, no significant parasite-wise variation in WBC counts was observed in Shivamogga, suggesting a more uniform immune response or lower disease severity in this region.

Gender-wise comparison of WBC counts showed significantly higher values among females in

Dakshina Kannada, while no significant difference was observed in Shivamogga. Variations in leukocyte response during malaria have been reported previously and may be influenced by immune status, hormonal factors, and concurrent infections.[23] Overall, the present findings emphasize that haemoglobin is a more sensitive and consistent marker of malaria-associated physiological disturbance than white blood cell count. The observed heterogeneity in haematological response underscores the importance of species-specific diagnosis and region-tailored clinical monitoring, particularly in areas approaching malaria elimination.

CONCLUSION

The present study demonstrates that malaria infection is associated with significant haematological alterations, particularly affecting haemoglobin concentration and, to a variable extent, white blood cell count. A marked reduction in haemoglobin levels was observed among malaria patients, with significantly lower values noted in Plasmodium falciparum infections, female patients, and individuals aged over 50 years. Patients from Shivamogga exhibited lower mean haemoglobin levels compared to those from Dakshina Kannada, highlighting regional variation in the physiological impact of malaria. White blood cell responses showed parasite- and region-specific variation. Although overall WBC counts did not differ significantly between districts, significant parasite-wise differences were observed in Dakshina Kannada, with higher WBC values associated with P. falciparum and mixed infections. These findings suggest that while WBC count reflects host immune response, haemoglobin reduction is a more consistent and sensitive marker of malaria-associated physiological disturbance. Overall, the study underscores the importance of routine haematological assessment, particularly haemoglobin estimation, in the clinical management of malaria patients. Species-specific monitoring and early identification of anaemia are essential for preventing complications and improving patient outcomes. Continued integration of haematological surveillance into malaria control programs will support effective case management and contribute to sustained malaria elimination efforts in Karnataka.

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