American Journal of Laboratory Medicine
2026, Vol. 11, No. 5, pp. 92–103
https://doi.org/10.11648/j.ajlm.20261105.11

Research Article

Sex-Related Differences Predominate Over Donation History in Determining Haematological Indices Among Blood Donors: A Cross-Sectional Study

Bashirudeen Kofi Mensa Essel[1, *], Rebecca Peniel Storph[1], Cephas Adams Kumah[1], Walter Quarm[1], Wisdom Agbotey[2], Evans Duah[1]

[1]Laboratory Department, Cape Coast Teaching Hospital, Cape Coast, Ghana

[2]Department of Microbiology and Immunology, University of Cape Coast, Cape Coast, Ghana

Abstract

Blood donors represent a critical resource for maintaining an adequate and safe blood supply. However, physiological factors such as sex and donation history may influence haematological parameters and donor health. This study assessed haematological indices according to sex and donation history among blood donors. A cross-sectional study was conducted among 237 eligible blood donors. Demographic characteristics and haematological parameters, including white blood cell (WBC) count, red blood cell (RBC) count, haemoglobin concentration, haematocrit, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), and platelet count, were analysed. Comparisons were performed according to sex and donation history, and multivariable regression models were used to identify independent predictors of haematological outcomes. Of the participants, 59.5% were male and 69.6% were first-time donors. Male donors had significantly higher haemoglobin concentrations, haematocrit values, and RBC counts than female donors, while female donors had significantly higher WBC counts. No significant differences in haemoglobin concentration, red-cell indices, WBC count, or platelet count were observed between first-time and repeat donors. Multivariable analysis demonstrated that male sex was independently associated with higher haemoglobin concentration, whereas increasing age was associated with a modest decline in haemoglobin levels. Donation history was not independently associated with haemoglobin concentration or other red-cell indices. Microcytosis and low MCH were identified in 16.0% and 8.9% of donors, respectively, but neither was associated with sex or donation history. These findings indicate that sex is an important determinant of haematological variation among blood donors, whereas donation history has limited influence on routine haematological parameters. Continued monitoring of donor haematological status remains important for maintaining donor health and ensuring a sustainable blood supply.

Keywords

Blood Donors, Haematological Indices, Haemoglobin, Donation History, Sex differences, Microcytosis, Donor Health, Blood Transfusion

*Correspondence: Bashirudeen Kofi Mensa Essel (esseldeen@gmail.com)

Received: 9 August 2026; **Accepted:** 18 August 2026; **Published:** 24 November 2026

Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

1. Introduction

Blood transfusion is an essential component of modern healthcare and plays a vital role in the management of trauma, surgery, obstetric haemorrhage, haematological disorders, and chronic diseases [1]. The availability of safe blood products depends on the recruitment and retention of healthy blood donors. Consequently, donor health assessment remains a fundamental aspect of transfusion medicine and blood-service operations [2].

Haematological evaluation is routinely performed during donor screening to determine donor suitability and identify individuals at risk of anaemia or other haematological abnormalities [3]. Parameters such as haemoglobin (Hb) concentration, haematocrit (HCT), red blood cell (RBC) count, white blood cell (WBC) count, platelet (PLT) count, mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) provide valuable information regarding erythropoietic status and overall donor health. Variations in these parameters may be influenced by age, sex, nutritional status, genetic factors, environmental exposures, and blood donation practices [4, 5].

Sex-related differences in haematological indices are well documented. Male individuals generally exhibit higher haemoglobin concentrations, haematocrit values, and RBC counts than females because of androgen-mediated stimulation of erythropoiesis and greater iron reserves. In contrast, menstrual blood loss and lower iron stores contribute to lower haemoglobin concentrations among women [2, 6]. These physiological differences have important implications for donor eligibility and interpretation of laboratory findings.

Repeated blood donation has also been associated with alterations in haematological and iron-status parameters. Each whole-blood donation removes approximately 200-250 mg of iron, which may contribute to iron depletion and iron-deficient erythropoiesis among frequent donors if iron losses are not adequately replenished [7]. Several studies have demonstrated reduced ferritin concentrations and altered haematological profiles among regular donors compared with first-time donors, although the magnitude of these effects varies across populations [5, 8].

In many low and middle-income countries, blood donors may also be affected by nutritional deficiencies, haemoglobinopathies, and infectious diseases that influence haematological indices [9]. Understanding the effects of sex and donation history on donor haematological status is therefore important for improving donor management strategies, maintaining donor health, and ensuring a sustainable blood supply.

This study aimed to evaluate haematological indices according to sex and donation history among blood donors and to determine the independent effects of sex, age, and repeat donation on haematological outcomes. The findings provide clinically relevant information for donor selection, donor monitoring, and donor-retention programmes. By identifying factors associated with variations in haematological status, this study contributes to efforts aimed at safeguarding donor health, reducing avoidable donor deferrals, and maintaining a safe and sustainable blood supply.

2. Materials and Methods

2.1. Study Site

The Transfusion Medicine Unit at Cape Coast Teaching Hospital (CCTH) in Ghana was the site of this research. As Ghana's principal referral hospital for the Central Region and other areas, CCTH is a 400-bed tertiary facility providing specialized healthcare services.

2.2. Study Design

This study was a hospital-based and was carried out from April to September 2023. Using a random sampling technique, 237 blood donors aged 16-47 years were recruited. Written informed consent was obtained from all participants after they had reviewed and understood the study information. Participants were informed that their involvement was voluntary and that they could withdraw from the study at any time without penalty. They were also assured that all personal and medical information would be treated with strict confidentiality.

2.3. Ethical and Institutional Approvals

Approval for all study processes was granted by the Cape Coast Teaching Hospital Ethical Review Committee (Ethical Review Number: CCTHERC/EC/2023/076). Prior to the study, administrative approval was secured from the Head of the Transfusion Medicine Unit at Cape Coast Teaching Hospital. The research was conducted in accordance with the Declaration of Helsinki (1964).

2.4. Demographics and Sample Collection

Age, sex and donation history were recorded prior to blood sample collection. Four milliliters (4 mL) of whole blood was drawn from each participant with a sterile 5 mL syringe and put into an ethylenediaminetetraacetic acid (EDTA) anticoagulant tube for Full blood count (FBC) analysis.

2.5. Full Blood Count Analysis

A Sysmex XN-350 automated hematology analyser (Sysmex Corporation, Kobe, Japan) was used to determine the haematological profile (full blood count) for all participants, adhering to the manufacturer's guidelines and established standard operating procedures [10].

2.6. Statistical Analysis

Data were analysed using descriptive and inferential statistics. Categorical variables were summarised as frequencies and percentages, while continuous variables were presented as means with standard deviations or medians with interquartile ranges, according to their distributions. Normality was assessed using the Shapiro–Wilk test and graphical inspection. Comparisons of haematological indices by sex and donation history were performed using independent-samples t tests or Mann–Whitney U tests, as appropriate. Effect sizes and 95% confidence intervals were reported, and Holm adjustment was applied to account for multiple comparisons.

Multiple linear regression was used to assess the independent effects of sex, age and donation history on haemoglobin and red-cell indices. Heteroscedasticity-consistent standard errors were applied, and robust regression was used as a sensitivity analysis where residual normality was not satisfied. Logistic regression was used to examine factors associated with microcytosis and low mean corpuscular haemoglobin. Model assumptions, multicollinearity, calibration, influential observations and discrimination were assessed using appropriate diagnostic tests, including the Hosmer–Lemeshow test and area under the receiver operating characteristic curve. A sensitivity analysis was also conducted among donors aged 18 years or older. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Participant Characteristics

Table 1 shows the participant characteristics and the overall haematological profile. The study included 237 donors, of whom 141 (59.5%) were male and 96 (40.5%) were female. There were 165 (69.6%) first-time donors and 72 (30.4%) repeat donors. Median age was 19.0 years (IQR = 18.0-23.0; range = 16-47).

Table 1. *Participant Characteristics and Overall Haematological Profile.*

Characteristic	Category or statistic	Value
Sex	Male	141 (59.5%)
	Female	96 (40.5%)
Donation history	First-time	165 (69.6%)
	Repeat	72 (30.4%)
Age group	16-17 years	51 (21.5%)
	18-24 years	136 (57.4%)
	25-34 years	34 (14.3%)
	35-44 years	13 (5.5%)
	45 years or older	3 (1.3%)
Donation-frequency category	First-time donor	165 (69.6%)
	Second-time donor	36 (15.2%)
	Third-time donor	16 (6.8%)
	Four or more donations	15 (6.3%)
	Repeat donor; frequency unspecified	5 (2.1%)
Age (years)	Mdn [IQR]	19.00 [18.00, 23.00]
WBC (10^9/L)	Mdn [IQR]	6.09 [4.75, 8.66]
RBC (10^12/L)	M (SD)	4.63 (0.44)
Haemoglobin (g/dL)	M (SD)	13.55 (1.09)
Haematocrit (%)	M (SD)	39.39 (3.19)
MCV (fL)	Mdn [IQR]	85.60 [83.20, 87.00]
MCH (pg)	Mdn [IQR]	29.00 [28.40, 29.80]
MCHC (g/dL)	M (SD)	34.42 (1.34)

Characteristic	Category or statistic	Value
Platelets (10^9/L)	M (SD)	208.39 (74.92)

Note: M = mean; Mdn = median; SD = standard deviation; IQR = interquartile range. MCV = mean corpuscular volume; MCH = mean corpuscular haemoglobin; MCHC = mean corpuscular haemoglobin concentration.

3.2. Comparisons by Sex

Table 2 shows the haematological indices by sex. Male donors had higher haemoglobin (median = 13.70 vs. 12.90 g/dL; $p < 0.001$; rank-biserial r = 0.44, 95% CI [0.31, 0.57]), haematocrit (39.50% vs. 37.65%; $p < 0.001$), and RBC count (4.79 vs. 4.38 x 10^{12}/L; $p < 0.001$) than female donors. These differences remained statistically significant after Holm adjustment.

MCV, MCH, and MCHC were similar in male and female donors. Female donors had higher total WBC counts (median = 6.58 vs. 5.65 x 10^9/L; unadjusted p = 0.002; Holm-adjusted p = 0.010). The platelet difference was significant before correction (p = 0.015) but not after Holm adjustment (p = 0.059). Figure 1 shows higher haemoglobin among male donors but substantial overlap in MCV between sexes, consistent with these statistical comparisons.

Table 2. *Haematological Indices by Sex.*

Outcome	Male (n = 141)	Female (n = 96)	Rank-biserial r [95% CI]	p	Holm p
Haemoglobin (g/dL)	13.70 [13.00, 14.60]	12.90 [12.40, 13.60]	0.44 [0.31, 0.57]	< 0.001	< 0.001
Haematocrit (%)	39.50 [37.70, 42.70]	37.65 [36.40, 39.30]	0.44 [0.31, 0.57]	< 0.001	< 0.001
RBC (10^12/L)	4.79 [4.50, 5.05]	4.38 [4.21, 4.59]	0.41 [0.28, 0.55]	< 0.001	< 0.001
MCV (fL)	84.70 [83.20, 87.10]	86.15 [83.60, 86.93]	-0.06 [-0.21, 0.09]	0.414	0.827
MCH (pg)	28.90 [28.30, 29.80]	29.10 [28.58, 29.82]	-0.08 [-0.23, 0.06]	0.271	0.812
MCHC (g/dL)	34.20 [33.70, 35.30]	34.30 [33.58, 35.20]	0.01 [-0.14, 0.16]	0.902	0.902
Platelets (10^9/L)	195.00 [147.00, 236.00]	208.00 [170.75, 271.50]	-0.19 [-0.34, -0.04]	0.015	0.059
WBC (10^9/L)	5.65 [4.55, 7.85]	6.58 [5.46, 9.35]	-0.24 [-0.38, -0.09]	0.002	0.010

Note: Values are medians [IQR]. All comparisons used Mann-Whitney U tests. Positive rank-biserial correlations indicate higher values among male donors. Holm p values adjust the family of eight sex comparisons.

3.3. Comparisons by Donation History

Table 3 shows the haematological indices by first-time and repeat donation history. No haematological outcome differed between first-time and repeat donors after Holm adjustment. Mean haemoglobin was 13.55 g/dL (SD = 1.10) among first-time donors and 13.55 g/dL (SD = 1.08) among repeat donors (mean difference = 0.00 g/dL, 95% CI [-0.31, 0.30]; p = 0.987). WBC and platelet distributions also did not differ by donation history (Holm-adjusted p = 0.807 and p = 0.970, respectively). Figure 1 also shows overlapping haemoglobin and MCV distributions for first-time and repeat donors, consistent with the non-significant donation-history comparisons.

Table 3. *Haematological Indices by First-Time and Repeat Donation History.*

Outcome	First-time (n = 165)	Repeat (n = 72)	Test	Effect size [95% CI]	p	Holm p
Haemoglobin (g/dL)	13.55 (1.10)	13.55 (1.08)	t	0.00 [-0.28, 0.27]	0.987	1.000
Haematocrit (%)	38.50 [36.90, 41.40]	38.75 [36.90, 41.57]	M-W	-0.01 [-0.17, 0.16]	0.937	1.000
RBC (10^12/L)	4.63 (0.46)	4.62 (0.38)	t	0.03 [-0.25, 0.31]	0.825	1.000

Outcome	First-time (n = 165)	Repeat (n = 72)	Test	Effect size [95% CI]	p	Holm p
MCV (fL)	85.40 [83.20, 86.90]	86.00 [83.15, 87.53]	M-W	-0.07 [-0.23, 0.10]	0.412	1.000
MCH (pg)	29.00 [28.40, 29.80]	29.20 [28.35, 29.73]	M-W	-0.05 [-0.21, 0.11]	0.580	1.000
MCHC (g/dL)	34.30 [33.70, 35.20]	34.20 [33.38, 35.30]	M-W	0.02 [-0.15, 0.19]	0.777	1.000
Platelets (10^9/L)	204.00 [166.00, 246.00]	185.50 [128.25, 249.25]	M-W	0.12 [-0.05, 0.29]	0.139	0.970
WBC (10^9/L)	6.25 [4.92, 8.70]	5.54 [4.61, 8.07]	M-W	0.13 [-0.03, 0.30]	0.101	0.807

Note: Values are means (SD) for independent-samples t tests and medians [IQR] for Mann-Whitney U tests. Test: t = independent-samples t test; M-W = Mann-Whitney U test. Effect sizes are Hedges g for t tests and rank-biserial r for Mann-Whitney U tests; positive values indicate higher values among first-time donors.

3.4. Adjusted Linear Regression Models

Table 4 shows the adjusted linear regression models for haemoglobin and red-cell indices. After adjustment for age and donation history, male sex was associated with haemoglobin that was 0.84 g/dL higher than that of female donors (95% CI [0.58, 1.10]; standardised beta = 0.377; p < 0.001). Each additional year of age was associated with 0.03 g/dL lower haemoglobin (95% CI [-0.05, -0.01]; p = 0.001). Repeat donation was not independently associated with haemoglobin (B = -0.05, 95% CI [-0.34, 0.25]; p = 0.751). The adjusted R-squared was 0.143; the model therefore explained approximately 14.3% of the variation in haemoglobin.

Sex, linear age, and repeat donation were not independently associated with MCV, MCH, or MCHC. A quadratic-age diagnostic indicated that the association between age and MCHC was non-linear (joint age p = 0.011); the corresponding sensitivity model had an adjusted R-squared of 0.022. This finding means that the age-MCHC association changed across age and cannot be summarised as one constant effect per year.

Table 4. *Adjusted Linear Regression Models for Haemoglobin and Red-Cell Indices.*

Outcome	Predictor	B	95% CI	Standardised beta	p	Adjusted R-squared
Haemoglobin (g/dL)	Male sex	0.837	[0.58, 1.10]	0.377	< 0.001	0.143
	Age, per year	-0.031	[-0.05, -0.01]	-0.177	0.001	
	Repeat donation	-0.047	[-0.34, 0.25]	-0.020	0.751	
MCV (fL)	Male sex	-0.422	[-2.22, 1.37]	-0.031	0.644	-0.009
	Age, per year	-0.056	[-0.18, 0.07]	-0.053	0.388	
	Repeat donation	0.208	[-1.75, 2.16]	0.014	0.834	
MCH (pg)	Male sex	-0.144	[-0.78, 0.49]	-0.029	0.657	-0.003
	Age, per year	-0.038	[-0.08, 0.01]	-0.099	0.103	
	Repeat donation	0.229	[-0.49, 0.95]	0.044	0.531	
MCHC (g/dL)	Male sex	-0.002	[-0.36, 0.36]	-0.001	0.992	-0.002
	Age, per year	-0.022	[-0.05, 0.01]	-0.103	0.163	
	Repeat donation	0.194	[-0.21, 0.60]	0.067	0.346	

Note: HC3 heteroscedasticity-consistent standard errors and confidence intervals are reported. Female sex and first-time donation are the reference categories. Beta denotes the standardised regression coefficient.

3.5. Prevalence and Categorical Associations

Table 5 shows the prevalence and unadjusted donor-characteristic associations. Microcytosis was present in 38 of 237 donors (16.0%, 95% CI 11.9%-21.2%). Low MCH was present in 21 donors (8.9%, 95% CI 5.9%-13.2%). Neither outcome was associated with sex or repeat donation in the unadjusted analyses.

Table 5. *Prevalence and Unadjusted Donor-Characteristic Associations.*

Outcome	Comparison	Exposed n/N (%)	Reference n/N (%)	OR [95% CI]	p
Microcytosis	Male vs. female	26/141 (18.4%)	12/96 (12.5%)	1.58 [0.76, 3.32]	0.221
Microcytosis	Repeat vs. first-time	11/72 (15.3%)	27/165 (16.4%)	0.92 [0.43, 1.98]	0.834
Low MCH	Male vs. female	14/141 (9.9%)	7/96 (7.3%)	1.40 [0.54, 3.61]	0.483
Low MCH	Repeat vs. first-time	4/72 (5.6%)	17/165 (10.3%)	0.51 [0.17, 1.58]	0.237

Note: Pearson chi-square tests were used because all expected cell counts exceeded five. OR = odds ratio. Odds ratios compare the first named category with the reference category.

3.6. Adjusted Logistic Regression Models

The linear-age microcytosis model failed the Box-Tidwell assessment (p = 0.007) and showed evidence of poor calibration (Hosmer-Lemeshow p = 0.043); it was therefore replaced by the quadratic-age model. In the preferred model, the association between age and microcytosis changed across age; the two age terms were jointly significant, likelihood-ratio chi-square (2) = 7.22, p = 0.027. Male sex (OR = 1.72, 95% CI [0.80, 3.69]; p = 0.166) and repeat donation (OR = 0.90, 95% CI [0.38, 2.13]; p = 0.813) were not independently associated with microcytosis. The overall model was not statistically significant (p = 0.062; Tables 6 and 7).

The low-MCH model was not statistically significant overall (p = 0.477), and neither male sex, linear age, nor repeat donation was independently associated with low MCH. At a 0.50 classification threshold, the model classified all donors as event-negative (sensitivity = 0.0%, specificity = 100.0%, balanced accuracy = 50.0%). Thus, the nominal accuracy of 91.1% reflected outcome imbalance rather than useful event detection. Figure 2 shows that the 95% confidence intervals for the adjusted effects of male sex and repeat donation included 1 for both outcomes, supporting the non-significant findings. Figure 3 shows AUCs of 0.64 for microcytosis and 0.61 for low MCH; both curves were close to the chance line, indicating limited discrimination.

Table 6. *Adjusted Logistic Regression Models for Microcytosis and Low MCH.*

Outcome	Predictor	Adjusted OR	95% CI	Wald chi-square	p
Microcytosis	Male sex	1.716	[0.80, 3.69]	1.92	0.166
	Age centred at 19 years	0.839	[0.72, 0.97]	5.50	0.019
	Centred age squared	1.009	[1.00, 1.02]	6.74	0.009
	Repeat donation	0.902	[0.38, 2.13]	0.06	0.813
Low MCH	Male sex	1.591	[0.61, 4.18]	0.89	0.346
	Age, per year	1.007	[0.93, 1.09]	0.03	0.855
	Repeat donation	0.448	[0.13, 1.50]	1.70	0.192

Note: Microcytosis uses the preferred quadratic-age model because the constant-age-logit assumption failed. The two age terms must be interpreted jointly; a single per-year age odds ratio is not meaningful. Female sex and first-time donation are the reference categories.

Table 7. Logistic Model Fit and Discrimination.

Model	Events/N	LR chi-square (df)	LR p	HL chi-square (df)	HL p	McFadden R-squared	AUC [95% CI]
Microcytosis (quadratic age)	38/237	8.98 (4)	0.062	4.78 (8)	0.781	0.043	0.642 [0.54, 0.74]
Low MCH (linear age)	21/237	2.49 (3)	0.477	8.12 (8)	0.422	0.018	0.606 [0.47, 0.74]

Note: LR = likelihood ratio; HL = Hosmer-Lemeshow; AUC = area under the receiver operating characteristic curve. AUC confidence intervals use the Hanley-McNeil large-sample standard error.

3.7. Model Diagnostics and Sensitivity Analyses

Table 8 shows the linear model diagnostic summary. Residual normality was rejected for all four linear models; therefore, HC3 inference and Huber robust-regression sensitivity analyses were used. Variance inflation factors were low, and there was no indication of important multicollinearity. The quadratic-age diagnostic identified non-linearity only for the MCHC model. Cook's distance, leverage, and studentised residual counts were treated as observations for influence review, not as automatic deletion criteria.

Huber robust regression reproduced the principal haemoglobin findings: male sex was positively associated with haemoglobin (B = 0.85 g/dL, p < 0.001), age was inversely associated with haemoglobin (B = -0.03 g/dL per year, p = 0.006), and repeat donation was not associated with haemoglobin (B = -0.03 g/dL, p = 0.830). No independent sex or donation-history associations with MCV, MCH, or MCHC were identified.

Table 8. Linear Model Diagnostic Summary.

Outcome	SW p	BP p	RESET p	Age-squared p	DW	Cook/leverage n	|Stud. resid.| > 3	VIF range
Haemoglobin (g/dL)	< 0.001	0.219	0.282	0.119	1.78	11 / 12	2	1.05-1.15
MCV (fL)	< 0.001	0.599	0.418	0.632	1.61	15 / 12	6	1.05-1.15
MCH (pg)	< 0.001	0.513	0.543	0.450	1.63	10 / 12	6	1.05-1.15
MCHC (g/dL)	< 0.001	0.238	0.405	0.010	1.81	12 / 12	4	1.05-1.15

Note: SW = Shapiro-Wilk; BP = Breusch-Pagan; RESET = regression specification error test; DW = Durbin-Watson; Stud. resid. = externally studentised residual; VIF = variance inflation factor. Durbin-Watson statistics are descriptive because record order does not define the sampling process.

Table 9 shows the sensitivity analysis restricted to donors aged 18 years or older. The sensitivity analysis restricted to donors aged 18 years or older (n = 186) retained the positive male-haemoglobin and inverse age-haemoglobin associations. The other red-cell outcomes remained unassociated with sex, age, and donation history. The adult-only microcytosis model included 24 events and was not significant overall (p = 0.764); the low-MCH model included 16 events and was also not significant (p = 0.861).

Table 9. Sensitivity Analysis Restricted to Donors Aged 18 Years or Older (n = 186).

Outcome	Male B (p)	Age B (p)	Repeat B (p)	Adjusted R-squared
Haemoglobin (g/dL)	0.76 (< 0.001)	-0.033 (0.002)	-0.10 (0.557)	0.126
MCV (fL)	0.43 (0.684)	-0.072 (0.267)	-0.74 (0.439)	-0.006

Outcome	Male B (p)	Age B (p)	Repeat B (p)	Adjusted R-squared
MCH (pg)	0.20 (0.584)	-0.037 (0.113)	-0.08 (0.825)	-0.004
MCHC (g/dL)	0.06 (0.790)	-0.014 (0.386)	0.21 (0.360)	-0.009

Note: Models used HC3 heteroscedasticity-consistent standard errors. Female sex and first-time donation are the reference categories.

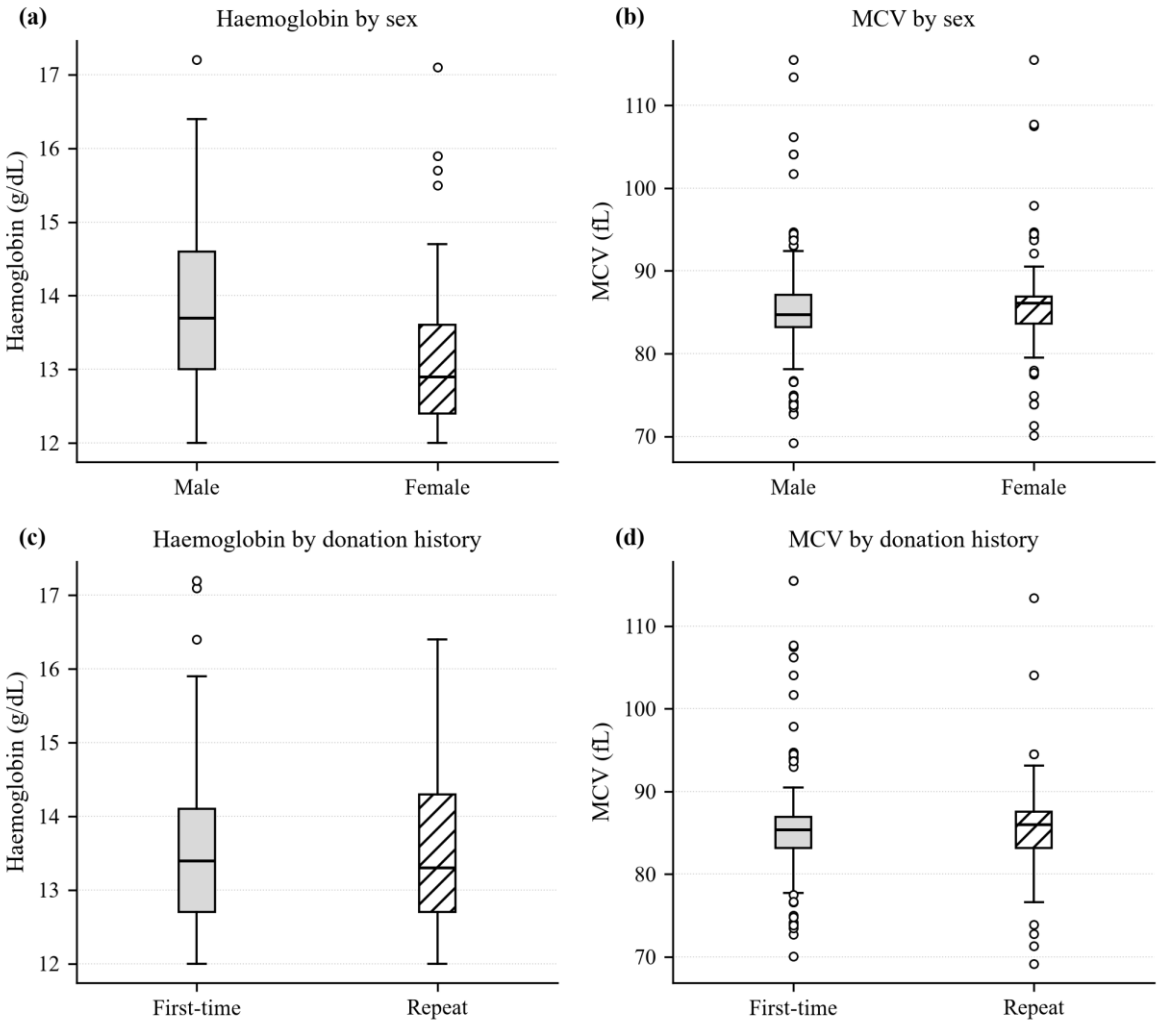

Figure 1. *Distributions of Haemoglobin and MCV by Sex and Donation History.*

Note: Boxes represent interquartile ranges, centre lines represent medians, whiskers extend to 1.5 times the interquartile range, and circles show observations beyond the whiskers. Panels (a) and (b) compare donors by sex, whereas panels (c) and (d) compare donors by donation history. Haemoglobin values were higher among male donors, whereas MCV distributions overlapped between sexes. Both haemoglobin and MCV distributions overlapped considerably between first-time and repeat donors.

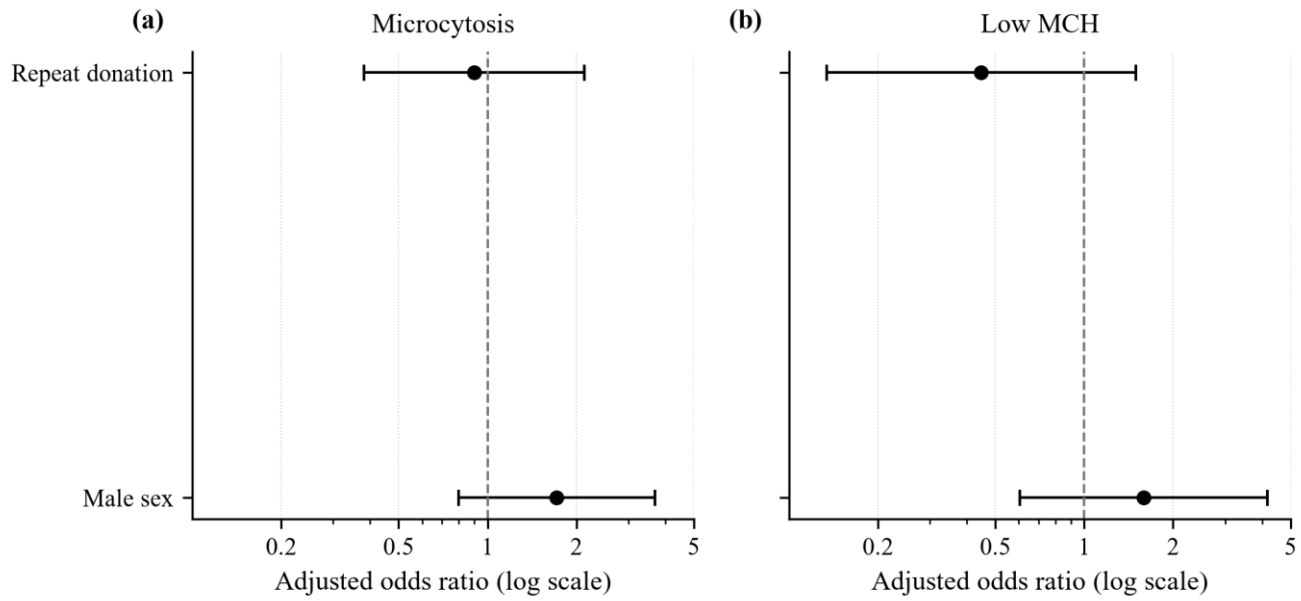

Figure 2. *Adjusted Associations of Sex and Donation History With Morphology Outcomes.*

Note: Points represent adjusted odds ratios and horizontal bars represent 95% confidence intervals; the vertical reference line indicates an odds ratio of 1. Panel (a) presents microcytosis and panel (b) presents low MCH. In both panels, the confidence intervals for male sex and repeat donation included 1, indicating no statistically significant adjusted associations for these predictors. Microcytosis uses the preferred quadratic-age model, whereas low MCH uses the linear-age model.

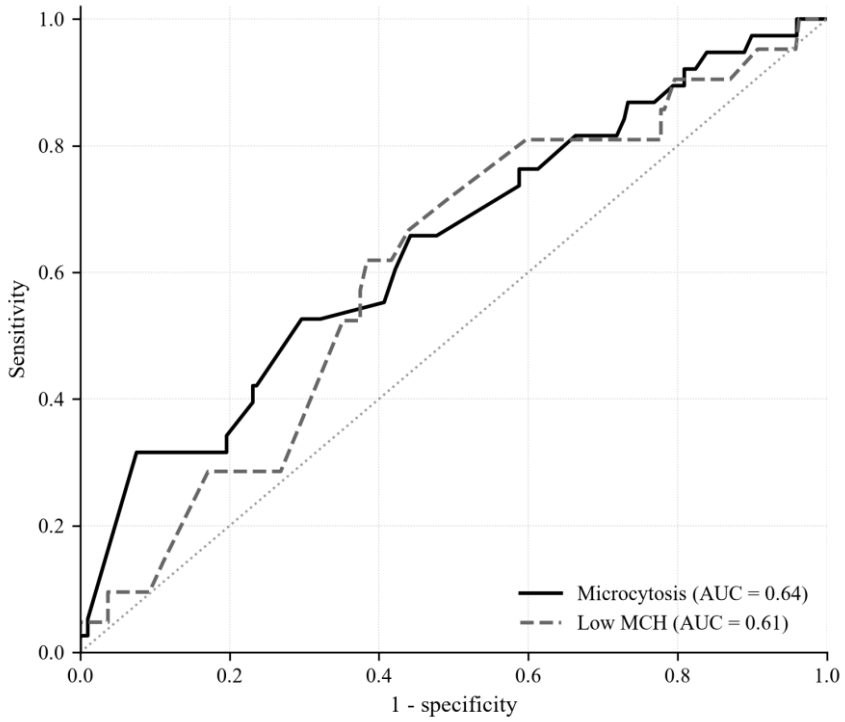

Figure 3. *Receiver Operating Characteristic Curves for the Adjusted Logistic Models.*

Note: The diagonal line represents chance discrimination. The microcytosis curve had an AUC of 0.64 and the low-MCH curve had an AUC of 0.61. Both curves remained relatively close to the chance line, indicating limited ability of the adjusted models to distinguish donors with each outcome from those without it. AUC = area under the receiver operating characteristic curve.

4. Discussion

This study evaluated haematological indices according to sex and donation history among blood donors and demonstrated that sex significantly influenced haemoglobin concentration, haematocrit, and RBC count, whereas donation history showed little effect on routine haematological parameters. These findings contribute to the growing body of evidence on donor haematological characteristics and provide insights relevant to donor management and blood-service practices.

Male donors exhibited significantly higher haemoglobin concentrations, haematocrit values, and RBC counts than female donors. These findings are consistent with previous studies conducted among blood donors in Kenya, Ethiopia, and Nigeria, which similarly reported higher erythrocyte-related parameters among males [4-6]. Njenga et al. reported significant sex differences in haemoglobin concentration, haematocrit, and red-cell count among healthy blood donors, highlighting the influence of biological sex on haematological variation. The observed differences are biologically plausible because testosterone enhances erythropoietin production and erythroid progenitor proliferation [11]. In contrast, menstrual blood loss and lower iron stores contribute to lower haemoglobin concentrations among women [12].

Female donors had significantly higher WBC counts than male donors. Similar findings have been reported in previous donor studies, where females exhibited higher lymphocyte counts and modest elevations in other leukocyte subsets compared with males [6]. Hormonal influences, sex-related differences in immune regulation, and variations in body composition may contribute to these observations. Although the clinical significance of these differences remains uncertain, they emphasize the influence of sex on immune-cell profiles in healthy donor populations.

An important finding of this study was the absence of significant differences in haemoglobin concentration, red-cell indices, and platelet count between first-time and repeat donors. Repeated blood donation is generally associated with cumulative iron loss and may increase the risk of iron deficiency, particularly among frequent donors [7]. Nevertheless, Kebalo et al. observed that most routine haematological parameters remained within normal ranges among regular donors despite evidence of altered iron status [5]. Similarly, Antwi-Baffour et al. emphasized that donor health monitoring should extend beyond haemoglobin screening to include assessments of iron stores [8]. The findings of the present study suggest that repeat donation, at least within this donor population, does not substantially influence routine haematological indices.

The prevalence of microcytosis (16.0%) and low MCH (8.9%) indicates that a considerable proportion of donors exhibited evidence of altered erythropoiesis. However, these abnormalities were not associated with sex or donation history. This finding suggests that factors such as nutritional iron deficiency, haemoglobinopathies, chronic inflammatory conditions, or environmental influences may contribute to microcytosis within the donor population. Similar observations have been reported in African populations, where genetic and environmental factors significantly influence haematological indices and reference values [13, 14].

Multivariable analyses further demonstrated a modest inverse relationship between age and haemoglobin concentration. Although statistically significant, the magnitude of this effect was small and is unlikely to have substantial clinical implications within the age range represented in this study. Nonetheless, age-related physiological changes in erythropoiesis and iron metabolism may partly explain this observation.

The findings have important implications for donor-care programmes. Maintaining donor health is essential for sustaining an adequate blood supply, and routine monitoring of haematological parameters remains an important component of donor management. Although donation history was not associated with significant haematological alterations in this study, periodic assessment of iron status may help identify donors at risk of iron depletion before clinically significant anaemia develops [15, 16].

From a clinical and transfusion-service perspective, the findings of this study have important implications. The significant influence of sex on haemoglobin concentration, haematocrit, and RBC count reinforces the importance of considering sex-specific physiological differences during donor assessment and interpretation of laboratory results. Equally important, the absence of significant haematological differences between first-time and repeat donors suggests that current donor-selection and donation-interval practices may be effective in protecting donor health within this population. The identification of microcytosis and low MCH in a subset of donors further highlights the need for continued haematological surveillance and targeted nutritional counselling [17]. Such measures may facilitate the early detection of iron-related abnormalities, support donor well-being, improve donor retention, and ultimately strengthen the sustainability of the blood supply.

This study has several strengths, including the evaluation of multiple haematological parameters and the use of multivariable analyses to identify independent predictors of haematological outcomes. However, the cross-sectional design limits causal inference, and biomarkers of iron status such as serum ferritin and transferrin saturation were not available. Future longitudinal studies incorporating iron biomarkers and larger cohorts of frequent repeat donors are needed to better characterize the long-term haematological consequences of repeated blood donation.

5. Conclusions

This study demonstrated that sex is a significant determinant of haematological variation among blood donors, with male donors exhibiting higher haemoglobin concentrations,

haematocrit values, and RBC counts than female donors. Female donors, however, had higher WBC counts, reflecting physiological sex-related differences in haematological profiles. In contrast, donation history was not associated with significant differences in haemoglobin concentration, red-cell indices, platelet count, or leukocyte count, suggesting that repeat donation did not adversely affect routine haematological parameters within this donor population.

The detection of microcytosis and low MCH among some donors indicates that haematological abnormalities may still occur despite meeting routine donor eligibility criteria and underscores the importance of ongoing donor monitoring. Clinically, these findings support the need for sex-informed donor assessment, periodic evaluation of donor haematological status, and nutritional education aimed at maintaining adequate iron stores. Collectively, the results provide evidence that can guide donor-care policies, enhance donor safety, improve donor retention, and contribute to the long-term sustainability of blood transfusion services. Future longitudinal studies incorporating iron-status biomarkers are warranted to further clarify the long-term haematological effects of repeated blood donation and optimize donor-management strategies.

Abbreviations

AUC	Area Under the Receiver Operating Characteristic Curve
BP	Breusch-Pagan Test
CCTH	Cape Coast Teaching Hospital
CI	Confidence Interval
DW	Durbin-Watson Statistic
EDTA	Ethylenediaminetetraacetic Acid
FBC	Full Blood Count
Hb	Haemoglobin
HC3	Heteroscedasticity-Consistent Covariance Matrix Estimator, Type 3
HCT	Haematocrit
HL	Hosmer-Lemeshow Test
IQR	Interquartile Range
LR	Likelihood Ratio
MCH	Mean Corpuscular Haemoglobin
MCHC	Mean Corpuscular Haemoglobin Concentration
MCV	Mean Corpuscular Volume
M-W	Mann-Whitney U Test
OR	Odds Ratio
PLT	Platelet
RBC	Red Blood Cell
RESET	Regression Specification Error Test
SD	Standard Deviation
SW	Shapiro-Wilk Test
VIF	Variance Inflation Factor
WBC	White Blood Cell
WHO	World Health Organization

Acknowledgments

The authors gratefully acknowledge the management and laboratory personnel of Cape Coast Teaching Hospital, Cape Coast, for their support and contributions during the study. Special appreciation is extended to the staff of the Transfusion Medicine Unit for their cooperation and assistance throughout the research process.

Author Contributions

Bashirudeen Kofi Mensa Essel: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft

Rebecca Peniel Storph: Formal Analysis, Investigation, Methodology, Writing – original draft

Cephas Adams Kumah: Conceptualization, Investigation, Methodology, Writing – review & editing

Walter Quarm: Conceptualization, Investigation, Methodology, Project administration, Writing – original draft

Wisdom Agbotey: Formal Analysis, Investigation, Methodology, Writing – review & editing

Evans Duah: Investigation, Methodology, Supervision, Writing – review & editing

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. The corresponding author has full access to all the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Essel BKM, Quarm W, Fynn C, Storph RP, Duah E, Adela EM, et al. Silent Risks in the Blood Supply: Co-Inherited Glucose-6-Phosphate Dehydrogenase Deficiency and Sickle Cell Trait Among Donors at the Cape Coast Teaching Hospital, Ghana: A Cross-Sectional Study. Health Science Reports. 2026; 9(7): e72785. https://doi.org/10.1002/hsr2.72785

[2] WHO. Blood safety and availability. World Health Organisation. 2023.

[3] WHO. Blood Donor Selection: Guidelines on Assessing Donor Suitability for Blood Donation: Geneva: World Health Organization; 2012.

[4] Nubila T, Ukaejiofo EO, Nubila NI, Shu EN, Okwuosa CN, Okofu MB, et al. Hematological profile of apparently healthy blood donors at a tertiary hospital in Enugu, south east Nigeria: A pilot study. Nigerian Journal of Experimental and Clinical Biosciences. 2014; 2(1): 33-6. https://doi.org/10.4103/2348-0149.135726

[5] Kebalo AH, Gizaw ST, Gnanasekaran N, Areda BG. Lipid and haematologic profiling of regular blood donors revealed health benefits. Journal of blood medicine. 2022: 385-94. https://doi.org/10.2147/JBM.S367990

[6] Njenga JK, Menza NC, Mathenge SG, Githanga JN. Hematological Profiles of Eligible Blood Donors at Kenyatta National Hospital, Kenya. International Blood Research & Reviews. 2022; 13(2): 24-31.

[7] Cable RG, Glynn SA, Kiss JE, Mast AE, Steele WR, Murphy EL, et al. Iron deficiency in blood donors: the REDS-II Donor Iron Status Evaluation (RISE) study. Transfusion. 2012; 52(4): 702-11. https://doi.org/10.1111/j.1537-2995.2011.03401.x

[8] Antwi-Baffour S, Mensah BT, Armah DNO, Asiedu HNA, Annison L. Evaluation of iron levels and hematological indices among blood donors at the Southern Zonal Blood Center, Accra, Ghana. Transfusion and Apheresis Science. 2025; 64(4): 104201. https://doi.org/10.1016/j.transci.2025.104201

[9] Kassebaum NJ, Jasrasaria R, Naghavi M, Wulf SK, Johns N, Lozano R, et al. A systematic analysis of global anemia burden from 1990 to 2010. Blood. 2014; 123(5): 615-24. https://doi.org/10.1182/blood-2013-06-508325

[10] Sysmex C. Sysmex XN-350 User Training Manual. Ver 5 onwards: Sysmex Corporation; 2020. Available from: www.sysmex.co.uk.

[11] Bachman E, Feng R, Travison T, Li M, Olbina G, Ostland V, et al. Testosterone suppresses hepcidin in men: a potential mechanism for testosterone-induced erythrocytosis. The Journal of Clinical Endocrinology & Metabolism. 2010; 95(10): 4743-7. https://doi.org/10.1210/jc.2010-0864

[12] Sholzberg M, Hillis C, Crowther M, Selby R. Diagnosis and management of iron deficiency in females. Canadian Medical Association Journal. 2025; 197(24): E680-E7. https://doi.org/10.1503/cmaj.240570

[13] Karita E, Ketter N, Price MA, Kayitenkore K, Kaleebu P, Nanvubya A, et al. CLSI-derived hematology and biochemistry reference intervals for healthy adults in eastern and southern Africa. PloS one. 2009; 4(2): e4401. https://doi.org/10.1371/journal.pone.0004401

[14] Kelem A, Engidaye G, Addisu B, Mandefro B, Teketelew BB, Berta DM, et al. Hematological reference intervals for adult population of Debre Berhan town, North East Ethiopia. Scientific Reports. 2025; 15(1): 14121. https://doi.org/10.1038/s41598-025-99405-x

[15] Nkansah C, Appiah SK, Osei-Boakye F, Abbam G, Banyeh M, Andoh G, et al. Determinants of iron deficiency among blood donors: a cross-sectional study in a teaching hospital. Scientific Reports. 2026; 16(1): 10740. https://doi.org/10.1038/s41598-026-44584-4

[16] Dhabangi A, Ssenyonga R, Siu G, Elaborot SA, Kyeyune D, Bates I. Iron deficiency in whole blood donors in a resource-poor setting: a cross-sectional study in Uganda. Transfusion Medicine. 2023; 33(3): 213-20. https://doi.org/10.1111/tme.12953

[17] Segbefia C, Telke S, Olayemi E, Ward C, Asamoah-Akuoko L, Appiah B, et al. Deferrals for low haemoglobin and anaemia among first-time prospective blood donors in Southern Ghana: results from the BLOODSAFE Ghana Iron and Nutritional Counselling Strategy Pilot (BLIS) study. Advances in Hematology. 2025; 2025(1): 9971532. https://doi.org/10.1155/ah/9971532