

Original article

Association between Red Blood Cell Indices and Hypertension Among Patients Attending Primary Health Care Centers in Libya

Mabrouka Rahoma¹ , Sara Hwisa^{2*} , Munya Rajab¹ 

¹Department of Medical Laboratories, Faculty of Medical Technology, University of Sabratha, Sabratha, Libya

²Department of Medical Science, Faculty of Dentistry, Sabratha University, Zawia, Libya

Corresponding Email. sara.ab.mu.hw@gmail.com

Abstract

Hypertension is a major risk factor for cardiovascular disease, and identifying inexpensive laboratory markers associated with elevated blood pressure may improve early risk assessment in primary healthcare. This study investigated associations between red blood cell (RBC) indices and hypertension among patients attending primary health centers. A cross-sectional analytical study was conducted at the Sabratha and Surman Health Centers between January and July 2024, involving 326 participants (151 hypertensive patients and 175 normotensive patients). Hematological profiles were compared and correlated with blood pressure measurements. Hypertensive patients had significantly higher mean RBC counts (4.50 ± 0.58 vs. $4.38 \pm 0.42 \times 10^{12}/L$; $p = 0.030$), hemoglobin (12.79 ± 1.91 vs. 12.32 ± 1.66 g/dL; $p = 0.019$), hematocrit (38.14 ± 5.14 vs. $36.46 \pm 4.11\%$; $p = 0.001$), mean corpuscular volume (85.12 ± 6.41 vs. 83.50 ± 7.16 fL; $p = 0.033$), and RDW-SD (44.44 ± 5.44 vs. 42.37 ± 5.24 fL; $p = 0.001$). Correlation analysis showed RBC count was positively associated with systolic ($r = 0.205, p = 0.012$) and diastolic blood pressure ($r = 0.172, p = 0.034$). Hemoglobin and hematocrit also correlated significantly with diastolic blood pressure, while RDW-SD showed a negative correlation ($r = -0.160, p = 0.050$). In conclusion, routine RBC parameters are significantly associated with hypertension and correlate with blood pressure levels. These indices may serve as accessible, low-cost biomarkers for hypertension risk assessment in primary healthcare settings.

Keywords. Hypertension, Red Blood Cell Indices, MCHC, Hematocrit.

Introduction

Hypertension is a major global health problem and one of the leading modifiable risk factors for cardiovascular disease, stroke, kidney disease, and premature death [1]. In 2024, approximately 1.4 billion adults aged 30–79 years worldwide were estimated to have hypertension, with a substantial proportion living in low- and middle-income countries [1]. Libya also has a considerable burden of hypertension, with an estimated prevalence of 39% among adults aged 30–79 years in 2024 [2]. Despite advances in prevention and treatment, hypertension remains highly prevalent, particularly in low- and middle-income countries, where early detection and adequate control continue to represent important public health challenges [3]. Therefore, the identification of additional accessible markers associated with hypertension may contribute to improved risk assessment and early detection, particularly in primary healthcare settings.

Red blood cells (RBCs) are the major cellular component of blood and play an essential role in oxygen transport. In addition, RBC characteristics are closely related to blood viscosity and vascular resistance [4,5]. Hematological parameters obtained from the routine complete blood count, including RBC count, hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cell distribution width (RDW), have increasingly attracted attention in cardiovascular research [5,6]. Changes in RBC count, hemoglobin, and hematocrit may influence blood viscosity and consequently affect vascular resistance and blood pressure [4,5].

Previous studies have reported significant relationships between RBC-related parameters and blood pressure. Higher hemoglobin and hematocrit levels have been associated with increased blood pressure, while RBC count has also been linked to the development of hypertension [6-8]. In addition, RDW, which reflects the variation in erythrocyte size, is routinely reported as part of the complete blood count and has been investigated as an inexpensive marker of cardiovascular risk [9,10]. Increased RDW may reflect disturbances in erythropoiesis, inflammation, oxidative stress, and erythrocyte survival, all of which may be relevant to cardiovascular and hypertensive conditions [9,10]. However, the relationships between individual RBC indices and hypertension have not been consistent across different populations [6,8].

Although RBC indices are routinely available in primary healthcare laboratories, limited information is available regarding their association with hypertension among patients in Libya. Evaluating these routinely measured parameters may provide useful evidence on whether simple hematological indices are related to blood pressure levels in the Libyan population. Therefore, this study aimed to investigate the association between RBC indices and hypertension among patients attending primary healthcare centers in Sabratha and Surman, Libya, and to examine the relationships of these indices with systolic and diastolic blood pressure.

Methods

Study Design and Setting

This study employed a cross-sectional analytical design to investigate the association between red blood cell indices and hypertensive status among adult participants. The study was conducted at the Sabratha and Surman Health Centers in Libya during the period extending from January through July 2024.

Study Population and Sampling

The study included 326 adults attending a primary health care center. The inclusion criteria comprised two groups: a hypertensive group consisting of individuals diagnosed with hypertension based on standardized clinical blood pressure criteria or receiving antihypertensive therapy, and a normotensive group consisting of individuals with no history of hypertension.

Participants were excluded if they had hematological disorders, acute or chronic infections, inflammatory or systemic diseases affecting blood indices, malignancy, pregnancy, recent blood transfusion, or incomplete clinical or laboratory data.

Data Collection and Clinical Assessment

Demographic data, including gender, were systematically documented for all participants. Hemodynamic assessment was conducted via manual sphygmomanometry using a calibrated mercury sphygmomanometer and a stethoscope. To ensure diagnostic precision, measurements adhered to standardized clinical protocols, requiring participants to remain in a seated, rested state for a minimum of five minutes prior to evaluation.

Blood Sampling and Laboratory Analysis

Venous blood specimens were obtained through aseptic venipuncture. Samples were collected into K3-EDTA-anticoagulated tubes for hematological analysis and plain vacuum tubes for serum isolation. Quantitative erythrocyte profiling was performed using the Sysmex XN-330 Automated Hematology Analyzer (Sysmex Corporation, Kobe, Japan). This instrumentation enabled the comprehensive assessment of red blood cell (RBC) indices, specifically:

- RBC count and hemoglobin (HGB) concentration;
- Hematocrit (HCT) and Red Cell Distribution Width (RDW-SD and RDW-CV);
- Mean Corpuscular indices, including Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC).

Statistical Analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 21.0. Descriptive statistics were expressed as frequencies and percentages for categorical variables, while continuous variables were presented as mean $\pm$ standard deviation (SD). For inferential analysis, an independent samples *t*-test was employed to compare the mean red blood cell indices between the hypertensive and normotensive groups. Pearson correlation analysis was utilized to assess the relationship between RBC parameters and blood pressure levels (SBP and DBP) within the hypertensive cohort. Results were considered statistically significant at $p < 0.05$, with $p < 0.01$ indicating high significance.

Ethical Considerations

Ethical approval was obtained from the Department of Medical Technology, Faculty of Medical Technology, in collaboration with Surman Hospital and Sabratha Hospital. All participants were informed about the study objectives and their right to voluntary participation and withdrawal at any time, after which written informed consent was obtained. Participant confidentiality was strictly maintained through data anonymization. All clinical procedures and blood sample collection were performed by trained personnel under aseptic conditions in accordance with national biosafety and ethical guidelines.

Results

The study population's demographic characteristics are detailed in Table 1. Among the 326 participants, 46.3% ($n=151$) were hypertensive. The cohort was predominantly female (59.5%), a trend that remained consistent within the hypertensive group (53.6%). Furthermore, the clinical assessment of blood pressure magnitude revealed that 35.1% of hypertensive patients maintained a systolic blood pressure (SBP) ≥ 140 mmHg, while 19.2% presented with a diastolic blood pressure (DBP) ≥ 90 mmHg (Table 1).

The comparison of red blood cell indices between the cohorts revealed significant physiological variations, as demonstrated in Table 2. Hypertensive patients exhibited a significantly higher mean RBC count compared to normotensive controls (4.50 ± 0.58 vs. $4.38 \pm 0.42 \times 10^{12}/L$; $p = 0.030$). Moreover, hemoglobin levels (12.79 ± 1.91 vs. 12.32 ± 1.66 g/dL; $p = 0.019$) and mean corpuscular volume (85.12 ± 6.41 vs. 83.50 ± 7.16 fL; $p = 0.033$) were also significantly elevated in the hypertensive group.

Table 1. Demographic Characteristics Among the Study Participants.

Items		Participants (326)		Hypertension (151)	
		N	%	N	%
Gender	Male	132	40.5%	70	46.4%
	Female	194	59.5%	81	53.6%
SBP (mmHg)	<120	161	49.4%	23	15.2%
	120–139	102	31.3%	75	49.7%
	≥140	63	19.3%	53	35.1%
DBP (mmHg)	<80	208	63.8%	44	29.1%
	80–89	88	27.0%	78	51.7%
	≥90	30	9.2%	29	19.2%

In addition, both hematocrit ($38.14 \pm 5.14\%$ vs. $36.46 \pm 4.11\%$; $p = 0.001$) and RDW-SD (44.44 ± 5.44 vs. 42.37 ± 5.24 fL; $p = 0.001$) demonstrated a high level of statistical significance. Conversely, other parameters, including MCH, MCHC, and RDW-CV, showed no statistically significant differences between the two groups (Table 2), indicating that specific indices are more sensitive to hypertensive status than others.

Table 2 Comparison of Red Blood Cell Indices Between Control and Hypertension Groups

Items	Control Group (175)				Hypertension Group (151)				P – value
	Max	Min	Mean	SD	Max	Min	Mean	SD	
RBC	5.55	3.33	4.38	0.42	6.70	2.49	↑ 4.50	0.58	0.030*
HGB	16.20	5.30	12.32	1.66	17.10	6.80	↑ 12.79	1.91	0.019*
HCT	47.50	19.20	36.46	4.11	52.10	24.00	↑ 38.14	5.14	0.001**
MCV	113.10	54.50	83.50	7.16	104.30	62.20	↑ 85.12	6.41	0.033*
MCH	39.20	14.70	28.23	3.19	35.00	17.60	↑ 28.54	2.74	0.344
MCHC	36.50	26.20	33.73	1.65	38.90	27.20	↓ 33.52	1.51	0.232
RDW-SD	77.00	35.50	42.37	5.24	67.30	32.50	↑ 44.44	5.44	0.001**
RDW-CV	34.00	11.50	13.93	2.24	33.60	4.00	↑ 14.32	3.07	0.185

Independent Samples t- Test. *: Correlation is significant at the 0.05 level. **: highly significant at the 0.01 level.

The relationship between hematological indices and blood pressure levels was further evaluated using Pearson correlation analysis (Table 3). The erythrocyte count showed a significant positive association with both SBP ($r = 0.205$, $p = 0.012$) and DBP ($r = 0.172$, $p = 0.034$). Consequently, hemoglobin ($r = 0.168$, $p = 0.040$) and hematocrit ($r = 0.178$, $p = 0.029$) also demonstrated significant positive correlations, though exclusively with diastolic blood pressure.

On the other hand, RDW-SD exhibited a statistically significant negative correlation with diastolic pressure ($r = -0.160$, $p = 0.050$). Parameters such as MCV and MCHC showed no linear relationship with blood pressure magnitude. Thus, the data suggest that elevated RBC counts, hemoglobin, and hematocrit are intrinsically linked to increased blood pressure, potentially reflecting changes in blood viscosity or compensatory erythropoiesis in hypertensive states.

Table 3. Correlation Between Red Blood Cell Indices and Blood Pressure in Hypertensive Patients

Items	Systolic (r)	P – value	Diastolic	P – value
RBC	0.205	0.012*	0.172	0.034*
HGB	0.123	0.131	0.168	0.040*
HCT	0.139	0.089	0.178	0.029*
MCV	-0.099	0.224	0.019	0.821
MCH	-0.082	0.319	0.025	0.762
MCHC	0.091	0.264	0.049	0.550
RDW-SD	-0.091	0.267	-0.160	0.050*
RDW-CV	-0.110	0.178	-0.138	0.091

Pearson Correlation in hypertensive patients, *. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

Discussion

Our study provides a comparative analysis of haematological parameters between hypertensive and normotensive individuals, with particular emphasis on red blood cell indices and their relationship with blood pressure. Our findings demonstrate that hypertension was highly prevalent (46.3%) and frequently uncontrolled, with 35.1% of hypertensive patients having SBP ≥ 140 mmHg and 19.2% having DBP ≥ 90 mmHg (Table 1); hypertensive patients exhibited significantly higher RBC count, haemoglobin, haematocrit, MCV, and RDW-SD compared with controls, whereas MCH, MCHC, and RDW-CV did not differ significantly (Table 2); and RBC count correlated positively with both SBP and DBP, haemoglobin and haematocrit correlated positively only with DBP, and RDW-SD showed a negative correlation with DBP (Table 3). This

pattern of variation suggests that specific erythrocyte indices may serve as potential biomarkers for hypertension and its associated cardiovascular risk. Recent reviews have similarly highlighted the potential relevance of routine hematological parameters in hypertension because they are inexpensive, readily available, and may reflect inflammatory, vascular, and rheological processes [11,12].

The predominance of females in the overall study population and the slight female predominance persisted among hypertensive patients. This finding is consistent with studies reporting sex differences in hypertension prevalence and control, which may be influenced by biological, hormonal, and lifestyle factors [13,14]. In our hypertensive group, more than one-third of hypertensive participants had SBP ≥ 140 mmHg, whereas approximately one-fifth had DBP ≥ 90 mmHg. This is clinically important because uncontrolled hypertension is a major driver of target organ damage and cardiovascular events [15-17]. Previous studies have shown that elevated blood pressure is linearly associated with increased risk of stroke, myocardial infarction, and mortality [18]. Therefore, the high proportion of uncontrolled hypertension in our cohort highlights the need for intensified therapeutic strategies and regular monitoring.

The significantly higher RBC count in hypertensive patients, together with its positive correlations with SBP and DBP, suggests that increased erythrocyte mass may contribute to elevated blood pressure through increased blood viscosity and peripheral vascular resistance [15,19,20]. In addition, renin-angiotensin system activation may enhance erythropoiesis through angiotensin II-mediated stimulation of erythropoietin, while RBC-derived microparticles and cell-free haemoglobin may impair nitric oxide signalling and vascular function [5,21,22].

Despite these associations, the modest correlation coefficients indicate that RBC count explains only a limited proportion of blood pressure variability and should therefore be considered a complementary marker rather than an independent determinant [11,12]. This finding is consistent with longitudinal evidence linking higher RBC counts with incident hypertension [12,23]. However, comparative studies have reported variable haematological profiles among hypertensive populations [24-26], suggesting that the relationship may be influenced by population characteristics and accompanying clinical factors. Erythrocyte-related mechanisms may also extend beyond cell number, as altered sodium-lithium countertransport has been associated with subsequent hypertension [27]. Although machine-learning models have incorporated haematological variables into hypertension prediction [28], their clinical value remains adjunctive. Given its routine availability through CBC testing, RBC count may therefore provide useful additional information when interpreted alongside established cardiovascular risk factors.

The higher haemoglobin and haematocrit concentrations in hypertensive patients, particularly their associations with DBP, suggest that altered erythrocyte concentration accompanies increased vascular pressure. Erythropoietic activity and plasma volume can influence these parameters [6,21], while haemoglobin and cell-free haemoglobin may reduce nitric oxide availability and modify vascular tone [5,22,29]. Such endothelial dysfunction may contribute to hypertension through impaired vasodilation [30], providing a plausible basis for the observed relationship with DBP.

This interpretation is supported by epidemiological studies linking higher haematocrit and haemoglobin with blood pressure and hypertension [31-33]. More recent evidence demonstrates associations between RBC traits and DBP [34], while long-term haemoglobin variability has been related to incident hypertension [35]. Conversely, lower or different haematological profiles have been reported in other hypertensive populations [24,36], highlighting substantial biological and population heterogeneity. Recent assessments of CBC parameters in hypertension [37], together with evidence that haematological indices may change during antihypertensive treatment [38], further indicate that these measures are influenced by the broader clinical context. Accordingly, haemoglobin and haematocrit should be interpreted as complementary, nonspecific markers associated with hypertension rather than independent determinants.

The significantly higher MCV in hypertensive patients, despite the absence of correlations with SBP or DBP, indicates altered erythrocyte size without a clear relationship to blood pressure magnitude. MCV is influenced by erythrocyte maturation, nutritional status, iron metabolism, inflammation, and oxidative stress [39-42]. Therefore, the observed difference may reflect accompanying systemic or haematological factors rather than hypertension severity.

Evidence from hypertensive populations remains heterogeneous, with variable MCV findings across studies [12,36,43]. Recent comparative data likewise indicate inconsistent changes in erythrocyte indices among hypertensive patients [25], suggesting that these parameters may be population and context dependent. Beyond hypertension, MCV has been associated with major adverse cardiovascular events in acute coronary syndrome and with peripheral arterial disease severity [44,45]. Moreover, recent cohort evidence demonstrates nonlinear associations between MCV and all-cause and cardiovascular mortality [46]. Thus, MCV may represent a broader marker of erythrocyte or cardiovascular abnormalities, although its specific role in hypertension remains uncertain.

The absence of significant differences in MCH and MCHC between hypertensive and normotensive participants suggests relatively preserved erythrocyte haemoglobinisation. Although MCHC has been associated with prognosis in heart failure, acute pulmonary embolism, and hypertensive populations [47-50], its stability in the present cohort suggests limited utility for distinguishing hypertension status. These findings further illustrate that individual CBC indices should be interpreted within the broader clinical and haematological context.

In contrast, the selective elevation of RDW-SD indicates greater erythrocyte size heterogeneity. RDW-SD represents the absolute width of the erythrocyte volume distribution, whereas RDW-CV expresses variability relative to MCV [51]. RDW is influenced by inflammation, oxidative stress, and altered erythropoiesis [52-56], and these processes are also implicated in hypertension-related vascular dysfunction [55]. Thus, the increased RDW-SD observed here may reflect systemic

erythrocyte disturbance rather than a hypertension-specific abnormality.

This interpretation is supported by reports of higher RDW in prehypertension and hypertension [57], abnormal blood-pressure patterns [58,59], and incident hypertension [60]. RDW has additionally been associated with endothelial dysfunction and hypertensive target-organ damage [54,61], while its broader cardiovascular relevance includes associations with cardiovascular disease [53,62,63], coronary artery disease severity [64], and adverse outcomes in acute coronary syndrome [65]. Evidence from critically ill populations further links RDW with mortality [66,67]. Collectively, these findings indicate that RDW reflects broader systemic and cardiovascular disturbances and is not specific to hypertension.

Notably, the weak negative correlation between RDW-SD and DBP in the present study contrasts with several previous observations [57-59,34,61]. This discrepancy may reflect differences in population characteristics, comorbidities, treatment, or RDW methodology. The association of RDW with multiple disease outcomes in large cohorts further supports its nonspecific nature [68]. Accordingly, RDW-SD may be most appropriately regarded as a complementary indicator of erythrocyte heterogeneity and systemic vascular disturbance rather than a specific marker of hypertension.

Conclusion

In conclusion, this study establishes that specific erythrocyte indices are significantly associated with systemic hypertension and correlate with blood pressure magnitude. Hypertensive patients exhibited significantly elevated mean values for RBC count, hemoglobin, hematocrit, MCV, and RDW-SD compared to normotensive controls. Furthermore, correlation analysis revealed that RBC count was positively associated with both systolic and diastolic blood pressure; likewise, hemoglobin and hematocrit demonstrated significant positive correlations with diastolic pressure. Conversely, parameters such as MCH, MCHC, and RDW-CV did not show significant variations between the study groups, suggesting that only specific indices are sensitive markers of hypertensive status. Consequently, routine hematological profiling represents a simple and highly accessible method for evaluating hemodynamic risk. Therefore, these inexpensive laboratory parameters should be integrated as supplementary biomarkers in primary healthcare settings to enhance early hypertension risk stratification and improve overall patient management.

Conflicts of Interest Nil

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