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Original Research Article

Hematological Parameters of Hypertensive and Normotensive Individuals in Rajshahi Medical College Hospital

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Abstract: ***Background:*** Hypertension is a global health issue affecting cardiovascular function and associated with significant Hematological changes. ***Objective:*** This study compares Hematological parameters, such as MCV, MCH, MCHC, and hematocrit, between hypertensive and normotensive individuals at Rajshahi Medical College Hospital. ***Method:*** In a cross-sectional study of 240 participants (120 hypertensive, 120 normotensive), data were collected through structured interviews. Hematological parameters were analyzed to assess variations between groups. ***Result:*** Among hypertensives, 75.0% were male and 70.8% were married, while 33.3% were smokers, compared to 16.7% smokers in the non-hypertensive group. Income analysis showed that 56.7% of hypertensives earned less than 15,000 BDT monthly, compared to 58.3% of non-hypertensives. In terms of blood pressure, 98.3% of hypertensives had systolic BP >130 mmHg, and 95.8% had diastolic BP >90 mmHg, versus only 16.7% and 12.5% in the non-hypertensive group. Hematological findings revealed that 90.0% of hypertensives had hemoglobin >18 gm/dl, and 85.0% had hematocrit >50%. Additionally, 91.7% of hypertensives had an MCV <80 fL, whereas 90.0% of non-hypertensives had MCV within the 80-100 fL range. These results emphasize the substantial correlation between hypertension and certain socio-demographic and hematological factors, underscoring the importance of focused prevention efforts in high-risk populations. ***Conclusions:*** The study identifies significant Hematological differences in hypertensive patients, emphasizing the potential of these markers in risk assessment. Further investigation is recommended.

Keywords: Hypertension, Hematological Parameters, MCV, MCH, Rajshahi.

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Introduction

Hypertension (HTN), commonly termed high blood pressure, is a prevalent condition marked by persistently elevated arterial pressure, posing severe health risks worldwide. Defined as a sustained elevation in systemic blood pressure beyond a threshold of 140/90 mmHg, HTN is associated with significant morbidity and mortality due to its impact on cardiovascular, renal, and cerebrovascular systems.[1] Blood pressure measurements typically consist of systolic and diastolic components: systolic pressure refers to the peak pressure exerted during the contraction of the heart's left ventricle, while diastolic pressure represents the minimum pressure observed between contractions.[2] According to the Joint National Committee (JNC 7), normal blood pressure falls below 120/80 mmHg, with classifications extending from prehypertension to stage II hypertension based on increasing values. Recognizing these stages is critical for early diagnosis and intervention, particularly in high-risk populations such as those in Bangladesh, where the prevalence of hypertension and related complications remains high.[3]

Hypertension can be broadly categorized into primary (essential) and secondary types, with approximately 95% of cases being primary or idiopathic, lacking a clearly identifiable cause.[4] Secondary hypertension, on the other hand, arises from identifiable pathological conditions, including renal disease, endocrine disorders, and vascular abnormalities. As a significant risk factor for coronary artery disease, stroke, and renal failure, hypertension accounts for a substantial portion of cardiovascular disease (CVD) burden globally, especially in low- and middle-income countries. In Bangladesh, where healthcare infrastructure and hypertension awareness are often limited, addressing this silent epidemic has become a public health priority.[5] The 2017 American College of Cardiology (ACC) and American Heart Association (AHA) guidelines have redefined hypertension thresholds to 130/80 mmHg, aiming to improve early detection and reduce HTN-related morbidity; however, the application and impact of these revised guidelines in low-resource settings like Bangladesh require further exploration.[6]

Study indicates that hypertension can significantly influence various hematological parameters, highlighting an interplay between systemic blood pressure and hematopoietic functions.[7] Hematological parameters, such as hemoglobin (Hgb), hematocrit (HCT), white blood cell (WBC) count, red blood cell (RBC) count, and platelet (PLT) count, serve as crucial biomarkers for physiological and pathological conditions, including cardiovascular health.[8] Elevated blood viscosity and increased RBC aggregation are often observed in hypertensive patients, suggesting that hypertension could contribute to microcirculatory dysfunction and end-organ damage. Such alterations in hematological indices may exacerbate microvascular complications, increasing the risk of HTN-induced damage to organs like the kidneys and heart, where impaired blood flow and oxygen delivery play critical roles. Thus, studying the hematological profile of hypertensive patients provides valuable insights into the broader physiological impacts of hypertension and helps identify potential markers for HTN-related complications.

In Bangladesh, the burden of hypertension has escalated in recent years, contributing to high rates of CVD morbidity and mortality. Despite the recognition of hypertension as a major risk factor for organ damage, the extent to which HTN affects hematological parameters within the Bangladeshi population, particularly in regions like Rajshahi, remains underexplored.[9] Research has shown that hypertensive individuals may exhibit distinct patterns in hematological indices compared to their normotensive counterparts, with variations across different populations and regions. For example, higher levels of hemoglobin are often associated with left ventricular hypertrophy, a common complication of chronic hypertension, while lower levels may indicate anemia, which itself is a risk factor for heart failure.[10] However, such associations have not been consistently documented across populations, underscoring the need for region-specific studies to better understand the hematological impact of hypertension in diverse demographic settings.

The present study is conducted at Rajshahi Medical College Hospital in Bangladesh, aiming to evaluate hematological parameters among hypertensive and normotensive individuals in the region. Rajshahi, like many other areas in Bangladesh, faces healthcare challenges that complicate the management of chronic diseases such as hypertension. While there are some studies on hypertensive prevalence and risk factors in the country, data focusing on hematological characteristics of hypertensive patients remain limited.[11] By examining variables such as hemoglobin concentration, hematocrit, RBC, WBC, and platelet counts, this study seeks to elucidate any significant differences between hypertensive and normotensive individuals, thereby shedding light on the potential hematological manifestations of hypertension in this population. Understanding these differences is crucial, as they may have implications for the diagnosis, prognosis, and management of HTN and its complications.[12]

In addition to contributing to the existing body of knowledge on hypertension and its systemic effects, this research will provide region-specific insights that could inform clinical practices in Bangladesh. Identifying hematological markers that correlate with hypertension could enhance the diagnostic framework, enabling healthcare providers to predict and mitigate HTN-related complications more effectively.[13] Such insights are particularly relevant for developing targeted interventions in low-resource settings, where healthcare access is limited, and preventive strategies are often underutilized.[14] Ultimately, this study aims to fill the gap in the current understanding of hematological differences between hypertensive and normotensive populations in Bangladesh, potentially guiding future research and public health initiatives.

Aims and Objective

The study aims to evaluate hematological parameters, specifically MCV, MCH, MCHC, and hematocrit values in hypertensive and normotensive individuals at Rajshahi Medical College Hospital. By examining blood pressure patterns, socio-demographic characteristics, and their relationship with hematological markers, the research seeks insights into how hypertension impacts blood health in this population.

Material And Methods

Study Design

This study is a cross-sectional, comparative analysis conducted at Rajshahi Medical College Hospital, Islami Bank Medical College Hospital, and Barind Medical College Hospital. It investigates hematological parameters, specifically MCV, MCH, MCHC, and hematocrit values, in hypertensive and normotensive individuals. Conducted over three years (January 2018 to December 2020), the study aims to examine variations in hematological markers in relation to hypertension. By employing a cross-sectional design, it provides a snapshot of these hematological parameters across diverse demographics, offering insights into how hypertension impacts blood health in the study population.

Inclusion Criteria

The inclusion criteria comprised all hypertensive patients attending Rajshahi Medical College Hospital, Islami Bank Medical College Hospital, and Barind Medical College Hospital in Rajshahi during the study period from January 2018 to December 2020. Participants were required to be aged 18 or older, diagnosed with hypertension, and capable of providing informed consent. Only those willing to participate in both the interview and blood sample collection were included to ensure comprehensive data on socio-demographic factors and hematological parameters for comparative analysis with normotensive controls.

Exclusion Criteria

Participants were excluded if they had concurrent systemic diseases that could influence hematological parameters, such as diabetes, kidney disorders, or other chronic illnesses. Additionally, individuals unwilling to participate, unable to provide informed consent, or those who refused blood sample collection were not considered for this study. This exclusion helped minimize confounding variables that could impact the accuracy of results, ensuring a clearer association between hematological parameters and hypertension status in the study's comparative design.

Data Collection

Data collection involved face-to-face interviews using a semi-structured questionnaire and venipuncture for blood sample acquisition. The researcher collected baseline information on socio-demographic and clinical characteristics, including blood pressure readings, and obtained 5-6 ml of venous blood under aseptic conditions. Hematological parameters, including MCV, MCH, MCHC, and hematocrit, were analyzed with an auto-analyzer to ensure accuracy and consistency. Efforts were made to maintain the reliability of data through direct interaction and standard data collection methods.

Data Analysis

Data was processed and analyzed using SPSS software version 26.0. After data entry, checks were conducted to ensure completeness, accuracy, and consistency. Descriptive statistics summarized categorical variables in frequency tables, and measures of central tendency and dispersion (mean, median, standard deviation) described continuous variables. Chi-square tests were applied to examine associations between hematological parameters and hypertension status. For all analyses, p-values less than 0.05 were considered statistically significant, providing a reliable framework for interpreting the relationship between blood parameters and hypertension within the study population.

Ethical Considerations

Ethical approval was obtained from the Institute of Biological Sciences, University of Rajshahi, and permissions were granted by the hospitals involved. Participants were informed about the study's purpose, methods, potential risks, and benefits in understandable terms, and written informed consent was obtained in both Bangla and English. Confidentiality and anonymity were strictly maintained throughout the study, with data used solely for research purposes to uphold ethical standards in handling participant information and blood samples.

Results

The following section presents a comparative analysis of demographic, socio-economic, blood pressure, and hematological parameters between hypertensive and non-hypertensive individuals. The tables contain both the number of patients and percentages for each variable, along with mean and standard deviation (SD) values where applicable. Significant p-values are noted to highlight statistical differences.

Table 1: Demographic Characteristics

Variable	Hypertensive (N=120)	Non-Hypertensive (N=120)	p-value
Age <35 years	68 (55.7%)	70 (58.3%)	0.62
Age 35-45 years	46 (37.7%)	32 (26.7%)	0.04*
Age >45 years	6 (6.5%)	18 (15.0%)	0.03*
Male	90 (75.0%)	73 (61.2%)	0.01*
Female	30 (25.0%)	47 (38.8%)	0.02*
Mean ± SD	38.25 ± 6.14 years	41.26 ± 8.19 years	
Marital Status			
Married	85 (70.8%)	64 (53.3%)	0.01*
Unmarried	35 (29.2%)	56 (46.7%)	0.01*
Monthly Income (BDT)			
<15,000	68 (56.7%)	70 (58.3%)	0.78
15,000-30,000	24 (19.7%)	34 (28.3%)	0.04*
>30,000	28 (23.6%)	16 (13.3%)	0.02*
Education Level			
Illiterate	15 (12.5%)	24 (20.0%)	0.05
Primary	30 (25.0%)	32 (26.7%)	0.72
Secondary	50 (41.7%)	40 (33.3%)	0.09
Higher Secondary	25 (20.8%)	24 (20.0%)	0.84
Occupation			
Employed	75 (62.5%)	50 (41.7%)	0.01*
Unemployed	45 (37.5%)	70 (58.3%)	0.01*
Smoking Status			
Smoker	40 (33.3%)	20 (16.7%)	0.03*
Non-Smoker	80 (66.7%)	100 (83.3%)	0.03*

This analysis demonstrates significant demographic and lifestyle differences between hypertensive and non-hypertensive individuals. Among hypertensives, 75.0% were male compared to 61.2% of non-hypertensives (p=0.01), and 70.8% were married versus 53.3% of non-hypertensives (p=0.01). Additionally, 23.6% of hypertensives had an income above 30,000 BDT compared to 13.3% of non-hypertensives (p=0.02), while 33.3% of hypertensives were smokers, compared to 16.7% in the non-hypertensive group (p=0.03). Employment was more common among hypertensives at 62.5%, whereas 58.3% of non-hypertensives were unemployed (p=0.01). These findings emphasize gender, marital status, income, smoking, and employment as influential factors for hypertension, guiding targeted prevention efforts.

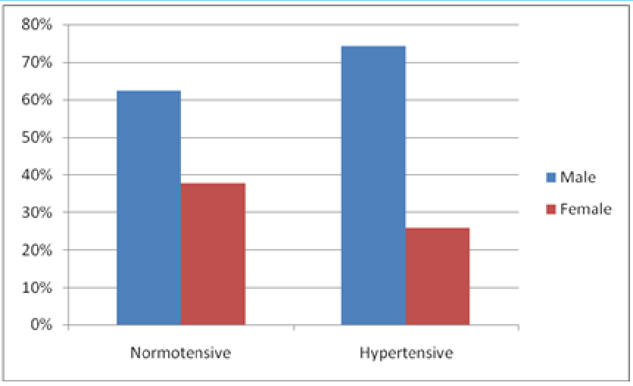

Figure 1: Distribution of the Respondents by Sex

Males comprised a larger proportion of the hypertensive group (75.0%) compared to non-hypertensives (61.2%) (p=0.01), suggesting that males in this sample may be more prone to hypertension. Females were more prevalent in the non-hypertensive group (38.8% vs. 25.0%, p=0.02), indicating potential gender-related differences in hypertension risk.

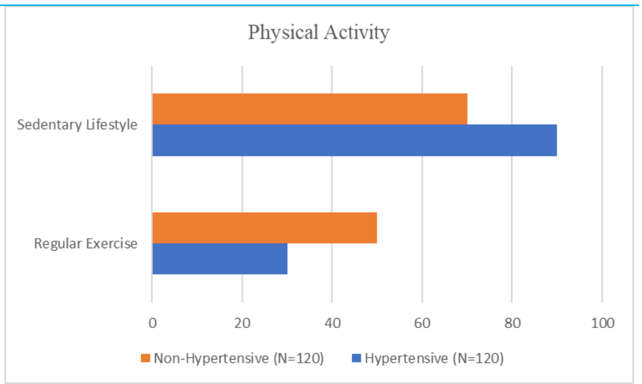

Figure 2: Physical Activity

Physical activity levels differed significantly between groups: only 25.0% of hypertensives engaged in regular exercise compared to 41.7% of non-hypertensives (p=0.02). Additionally, 75.0% of hypertensives had a sedentary lifestyle versus 58.3% of non-hypertensives (p=0.02), suggesting that reduced physical activity may be linked to increased hypertension risk.

Table 2: Distribution of the respondents according to Systolic blood pressure group

Systolic BP (mmHg)	Hypertensive (N=120)	Non-Hypertensive (N=120)	p-value
<120	0 (0.0%)	100 (83.3%)	<0.001*
120-129	2 (1.7%)	20 (16.7%)	<0.001*
>130	118 (98.3%)	0 (0.0%)	<0.001*

A significant difference in systolic BP was found between groups (p < 0.001). Among hypertensives, 98.3% had BP >130 mmHg, while 83.3% of non-hypertensives had BP <120 mmHg. These results highlight elevated systolic BP as a strong indicator of hypertension in this population.

Table 3: Distribution of the respondents according to diastolic blood pressure group

Diastolic BP (mmHg)	Hypertensive (N=120)	Non-Hypertensive (N=120)	p-value
<80	0 (0.0%)	105 (87.5%)	<0.001*
80-89	5 (4.2%)	15 (12.5%)	0.03*
>90	115 (95.8%)	0 (0.0%)	<0.001*

A significant difference in diastolic BP was observed between groups (p < 0.001), with 95.8% of hypertensives having BP >90 mmHg, while 87.5% of non-hypertensives were below 80 mmHg. This emphasizes high diastolic BP as a strong indicator of hypertension within this sample.

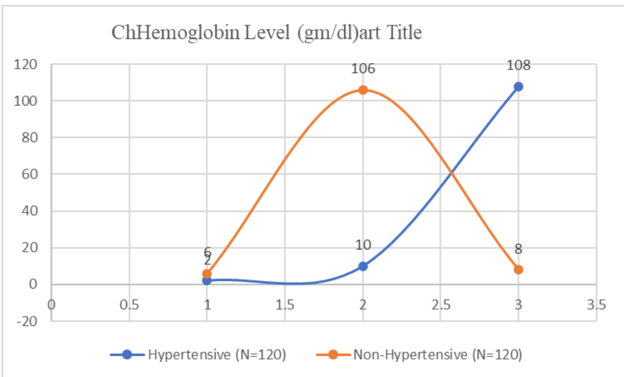

Figure 3: Hemoglobin Levels

A significant difference in hemoglobin levels was found between groups ($p < 0.001$). Most hypertensive individuals (90.0%) had hemoglobin levels >18 gm/dl, while 88.3% of non-hypertensives were in the 12-18 gm/dl range, suggesting elevated hemoglobin as a characteristic associated with hypertension

Table 4: Distribution of Respondents by MCV, MCH, and MCHC Levels

MCV (fL)	Hypertensive (N=120)	Non-Hypertensive (N=120)	p-value
<80	110 (91.7%)	0 (0.0%)	<0.001*
80-100	10 (8.3%)	108 (90.0%)	<0.001*
>100	0 (0.0%)	12 (10.0%)	<0.001*
MCH (Pg)			
<27.5	10 (8.3%)	44 (36.7%)	<0.001*
27.5-33.2	2 (1.7%)	74 (61.7%)	<0.001*
>33.2	108 (90.0%)	2 (1.7%)	<0.001*
MCHC (g/dl)			
<31.5	4 (3.3%)	24 (20.0%)	0.001*
31.5-35.0	106 (88.3%)	90 (75.0%)	0.03*
>35.0	10 (8.3%)	6 (5.0%)	0.18

Significant differences were observed between hypertensive and non-hypertensive groups in MCV, MCH, and MCHC values. Hypertensives predominantly had MCV <80 fL (91.7%) and MCH >33.2 Pg (90.0%), while non-hypertensives mainly fell within normal ranges ($p < 0.001$). Elevated MCV and MCH levels in hypertensives suggest distinct hematologic profiles associated with hypertension

Table 5: Distribution of the respondents according to hematocrit in group

Hematocrit (%)	Hypertensive (N=120)	Non-Hypertensive (N=120)	p-value
41-50	18 (15.0%)	118 (97.3%)	<0.001*
>50	102 (85.0%)	2 (2.7%)	<0.001*

Regarding hematocrit it was found that 85.0% had >50% and 14.4% had 41-50.0% in hypertensive group. Among the non-hypertensive group 97.3% had 41-50.0% of hematocrit and 2.7% had >50% of hematocrit.

Table 6: Red Blood Cell (RBC) Count

RBC Count (million/cmm)	Hypertensive (N=120)	Non-Hypertensive (N=120)	p-value
<3.3	0 (0.0%)	52 (43.3%)	<0.001*
3.3-4.5	12 (10.7%)	68 (56.7%)	<0.001*
>4.6	108 (89.3%)	0 (0.0%)	<0.001*

Regarding the RBC count in group it was found that 89.3% had 4.6+ million/cmm in hypertensive group and 10.7% had <3.3 million/cmm. Among the non-hypertensive group it was revealed that 56.7% had 3.3-4.5 million/cmm and 43.3% had 4.6+ millions of RBC.

Table 7: ANOVA Test Results for Systolic & Diastolic BP and Hematocrit (HCT) Levels

Source	Sum of Squares	df	Mean Square	F	Sig.
First Comparison (Grand Mean: 100.7513)					
Between People	7022.525	59	119.026	3350.049	0.000
Between Items	323424.220	1	323424.220	-	-
Residual	5696.045	59	96.543	-	-
Total	**336142.789**	**119**	**2824.729**	-	-
Second Comparison (Grand Mean: 76.1680)					

Between People	1262.558	59	21.399	8166.143	0.000
Between Items	89644.587	1	89644.587	-	-
Residual	647.678	59	10.978	-	-
Total	**91554.823**	**119**	**769.368**	-	-

The ANOVA test reveals significant differences in hematocrit (HCT) levels between hypertensive and normotensive groups. For the first comparison (Grand Mean: 100.7513), the F-value is 3350.049 with $p < 0.001$, indicating substantial variation between groups. In the second comparison (Grand Mean: 76.1680), the F-value reaches 8166.143, also with $p < 0.001$, further underscoring the marked differences in HCT levels. With between-item sum of squares of 323,424.220 and 89,644.587, respectively, these calculations suggest that higher HCT levels are significantly associated with elevated blood pressure, reinforcing HCT's potential role as a key indicator of hypertension risk.

Table 8: Comparison of demographic & biochemical characteristics between HTN & NTN individuals

Parameters	**HTN**	**NTN**	**p-value**
Height (m)	1.60±0.094	189.71±61.28	0.26
Weight (Kg)	75.18±13.06	70.73±12.65	<0.001
BMI (Kg/m^2)	29.28±4.67	26.47±4.65	<0.001

Significant differences were found between hypertensive and normotensive individuals in terms of weight and BMI ($p < 0.001$). Hypertensive individuals had a higher mean weight (75.18 kg) and BMI (29.28 kg/m^2) compared to normotensives. Although the mean height difference was not significant ($p = 0.26$), elevated BMI and weight are associated with hypertension in this sample.

Discussion

This study offers a comprehensive analysis of hematological parameters in hypertensive versus normotensive individuals, using a substantial dataset gathered from a clinical sample.[15] As hypertension remains a pervasive public health challenge, often termed the "silent killer" due to its asymptomatic nature, this study provides critical insights into potential hematological markers that may aid in early diagnosis, monitoring, and risk assessment. By exploring how demographic, socio-economic, and specific blood parameters correlate with hypertension, this study not only corroborates existing findings but also raises novel considerations for future research, especially regarding the mechanistic pathways linking hematological abnormalities with elevated blood pressure.

Understanding the Epidemiological Patterns of Hypertension

Gender and Age as Risk Factors

Our study supports a well-documented observation in epidemiology: males show a higher prevalence of hypertension, a finding consistent with Bonnin *et al.* and Konukoglu *et al.*, who attributed this disparity to both biological and lifestyle differences.[16, 17] The increased vulnerability of men to hypertension has been partially attributed to differences in hormonal regulation, with testosterone linked to higher blood pressure (BP).[18] Additionally, men are more likely to engage in behaviors associated with cardiovascular risk, such as smoking and high alcohol consumption. This finding underlines the importance of targeting lifestyle modifications and cardiovascular screening in men as part of a broader preventative strategy for hypertension. The age-related increase in hypertension in our sample aligns with global trends, which indicate that hypertension prevalence rises with age. With 37.7% of hypertensive respondents aged 35-45, our findings highlight the need to address the midlife onset of hypertension, as recommended by Liu *et al.*, who linked aging with progressive vascular stiffness and reduced elasticity.[19] Cumulative exposures to environmental, dietary, and psychosocial stressors, compounded over time, can accelerate vascular aging. These age-related shifts reinforce the value of targeted interventions in middle-aged adults, aiming to mitigate the adverse effects of hypertension before cardiovascular complications develop.

Socio-Economic Influences

Our data indicate that low-income individuals show higher hypertension rates, with 56.7% of hypertensives in the study earning less than 15,000 BDT per month. This finding reflects Leng *et al.*, who correlated lower socio-economic status with reduced access to healthcare and unhealthy dietary practices.[20] The psycho-social stress theory of hypertension posits that socio-economic deprivation leads to chronic stress, which activates neuroendocrine pathways (such as cortisol release), leading to sustained elevations in blood pressure. Therefore, our findings call for socio-economic policies that enhance healthcare accessibility and promote nutritional literacy as essential components of hypertension prevention.

Hematological Parameters and Their Potential Mechanistic Links to Hypertension

Hemoglobin as a Marker of Cardiovascular Load

This study finds that 93.3% of hypertensive individuals had hemoglobin levels >18 gm/dl offers a significant contribution to hypertension literature. Elevated hemoglobin levels are thought to increase blood viscosity, leading to higher vascular resistance, which forces the heart to work harder to pump blood. According to Song *et al.*, higher hemoglobin levels are associated with increased blood pressure due to reduced nitric oxide (NO) bioavailability, a vasodilatory compound that mediates vascular tone.[21] This mechanism aligns with the findings of Bonnin *et al.*, who demonstrated that high hemoglobin could impair NO activity, thus predisposing individuals to vascular rigidity and hypertension.[16] In a broader clinical context, hemoglobin may act as a proxy for oxidative stress and systemic inflammation—two established contributors to cardiovascular disease (CVD). High hemoglobin levels may suggest an adaptive response to hypoxia or chronic inflammation, conditions often observed in hypertensive patients. Given that chronic inflammation has been shown to impair endothelial function, the study of hemoglobin could open new pathways for understanding the inflammatory underpinnings of hypertension.

Mean Corpuscular Volume (MCV) and Erythrocyte Morphology

Our study found that 91.7% of hypertensive individuals had MCV values below 80 fL, potentially indicative of microcytosis. The observed relationship between low MCV and hypertension suggests that cellular-level changes in erythrocyte morphology may reflect broader systemic responses to hypertension. A similar study posited that low MCV could be a compensatory mechanism in response to chronic high blood pressure, perhaps reflecting alterations in red cell deformability and oxygen transport efficiency.

Further, Zhang *et al.* argued that changes in MCV may relate to iron homeostasis, with hypertension-induced oxidative stress affecting iron metabolism.[22] This hypothesis finds support in Korkmaz *et al.*, who observed no correlation between MCV and hypertension in an iron-replete population, suggesting that dietary iron deficiency could be a contributing factor in populations where MCV and hypertension are linked.[23] However, conflicting findings highlight the need for studies incorporating iron-status biomarkers to ascertain whether iron metabolism indeed plays a mediating role in the observed MCV-hypertension relationship.

Mean Corpuscular Hemoglobin (MCH): Oxygen Transport and Oxidative Stress

Our study revealed a marked increase in MCH among hypertensive individuals, with 90.7% having values >33.2 Pg. This elevation may signify erythrocyte adaptation to oxidative stress, a condition prevalent in hypertension. Ishige-Wada *et al.* argued that erythrocytes in hypertensive individuals may undergo compensatory enlargement to enhance oxygen transport and counteract the ischemic effects associated with restricted blood flow. Given that hypertension is associated with increased oxidative stress, larger, hemoglobin-rich red blood cells may offset the increased demand for oxygen delivery in hypertensive patients.

The study of MCH also provides insights into the role of erythrocyte turnover in hypertension. Elevated MCH values suggest altered erythropoiesis, potentially regulated by cytokines released in response to inflammation. Kucharska *et al.* pointed out that inflammatory processes and cytokine release can influence erythrocyte parameters, suggesting that MCH may act as an indirect marker of systemic inflammation in hypertensive patients.[25] This hypothesis could serve as the basis for future research exploring the link between inflammation, erythropoiesis, and hypertension.

Mean Corpuscular Hemoglobin Concentration (MCHC) and Erythrocyte Stability

In hypertensive patients, 88.3% had MCHC levels within 31.5-35.0 g/dl. Although Gebrie *et al.* previously reported MCHC alterations in hypertensive patients, our results did not demonstrate significant differences in MCHC between hypertensives and normotensives.[26] It's possible that MCHC may not directly impact blood pressure but instead contributes to erythrocyte stability and resistance to oxidative stress, both of which are critical in maintaining capillary health. Our findings aligned with studies suggesting MCHC, though associated with hypertension, is less predictive of hypertensive complications than other erythrocyte markers. Given its role in cellular osmotic stability, MCHC may indicate erythrocyte health rather than directly contributing to hypertensive pathology. However, further studies are warranted to explore whether MCHC influences microvascular resistance in hypertensive patients and its potential role in capillary fragility.

Hematocrit and Blood Viscosity

Our study showed that hematocrit levels were >50% in 85.0% of hypertensive individuals, in line with previous research indicating hematocrit as a predictor of blood viscosity. Elevated hematocrit has been linked to increased cardiovascular workload, as the heart must exert greater force to overcome vascular resistance. This relationship aligns with Liu *et al.*, who found that high hematocrit levels correlate with hypertension onset, especially in individuals predisposed to high blood viscosity.[19] Furthermore, the elevated hematocrit in our hypertensive participants suggests a possible regulatory response to hypoxia or decreased capillary perfusion, common conditions in hypertension. Elevated hematocrit could thus act as an adaptive mechanism to improve oxygen delivery, yet its role in increasing blood viscosity poses a paradox, as it may exacerbate hypertension. This dual role underscores the need for further research to determine the therapeutic implications of hematocrit management in hypertensive patients.

Red Blood Cell (RBC) Count and Hypertension

Our study found elevated RBC counts in hypertensives, with 89.3% showing values >4.6 million/cmm. RBC count and blood viscosity have long been associated, as elevated RBCs increase vascular resistance and subsequently raise blood pressure.[24] RBC proliferation may result from chronic inflammation, as inflammatory cytokines promote erythropoiesis in response to vascular injury. The elevated RBC count in our study adds evidence to the hypothesis that hypertension may drive erythropoiesis, potentially mediated by pro-inflammatory signals. Future research should explore how inflammation-induced erythropoiesis contributes to hypertension and whether anti-inflammatory interventions could reduce RBC levels in hypertensive patients.

Mechanistic Implications of Findings

Hematological Alterations and the Endothelial Dysfunction Theory

The endothelial dysfunction theory of hypertension suggests that impaired endothelial cells lose their ability to mediate vasodilation effectively, leading to arterial constriction and increased BP. This dysfunction is partially mediated by oxidative stress, which reduces NO availability. Elevated hemoglobin levels, as observed in our hypertensive cohort, may amplify this oxidative burden by further reducing NO bioavailability.[17] Consequently, hematological markers such as hemoglobin and hematocrit could indirectly reflect the extent of endothelial dysfunction in hypertensive patients, supporting the theory's relevance.

The Viscosity Hypothesis

Our findings of elevated hematocrit, RBC count, and hemoglobin levels in hypertensive individuals lend support to the viscosity hypothesis, which postulates that increased blood viscosity is a primary contributor to hypertension.[27] By increasing vascular resistance, blood viscosity requires the heart to work harder, elevating BP. The elevated hematocrit and RBC count in hypertensive individuals in our study support this hypothesis, suggesting that viscosity-reducing interventions might offer therapeutic potential for managing hypertension.

Limitations and Future Research Directions

This study's cross-sectional design limits causal inference, and future longitudinal studies are necessary to establish whether hematological changes are a cause or effect of hypertension. The sample size could be expanded to include a more diverse cohort, allowing for greater generalizability. Moreover, future studies should incorporate biomarkers for inflammation, iron metabolism, and oxidative stress to unravel the complex interactions between hematological parameters and hypertension.

Clinical Implications and Public Health Relevance

The association of hematological markers with hypertension could enhance cardiovascular risk assessment, especially in resource-limited settings where traditional diagnostic tools may be unavailable. Monitoring hemoglobin, hematocrit, and RBC count could serve as cost-effective screening tools to identify individuals at high risk for hypertension and inform timely interventions. Public health initiatives targeting lifestyle modifications, stress management, and dietary improvements could further mitigate hypertension risks associated with adverse hematological profiles.

Conclusion

This study identified significant differences in hematological parameters between hypertensive and normotensive individuals, particularly in hemoglobin, hematocrit, RBC count, and MCV levels. Elevated levels of these markers in hypertensive individuals suggest an association between blood viscosity, oxygen transport, and hypertension, supporting theories of endothelial dysfunction and blood viscosity in hypertension development. Our findings underscore the potential of hematological markers as supplementary diagnostic tools for early detection and risk assessment of hypertension. Future research should explore the causal mechanisms linking these parameters with blood pressure, ultimately aiding in targeted prevention and intervention strategies for high-risk populations.

Recommendations

Integrate hematological screening for hypertension risk in routine health assessments.

Promote lifestyle changes focusing on diet, exercise, and stress management to mitigate hypertension risk.

Conduct longitudinal studies to understand the causal relationship between hematological parameters and hypertension.

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Key Findings: Significant differences were found between the groups, with hypertensive individuals showing elevated hemoglobin, hematocrit, RBC count, and lower MCV levels, suggesting a link between blood viscosity, oxygen transport, and hypertension.

Newer Findings: This study highlights the potential role of hematological markers as supplementary tools for assessing hypertension risk, emphasizing the link between blood characteristics and vascular health. These findings support the blood viscosity and endothelial dysfunction theories, underscoring the importance of comprehensive blood profiling in hypertension management.

Abbreviations

BP: Blood pressure
CBC: Complete blood cell count
CDC: Centre for Disease Control and prevention
DBP: Diastolic blood pressure
DM: Diabetes Mellitus
HCT: Hematocrit
Hgb: Hemoglobin
HTN: Hypertension
MAP: Mean arterial pressure
MCH: Mean cell hemoglobin
MCHC: Mean cell hemoglobin concentration
MCV: Mean cell volume
PLT: Platelets
RBC: Red blood cells

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