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Assessment Of Hematological Parameters Between Hypertensive And Normotensive Individuals In Guwahati, Assam

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Abstract
This study highlights the association between hematological parameters and blood pressure status, as well as gender-based differences and the influence of other factors such as age, BMI, dietary habits, family type, and chronic illness of individuals with normal and high blood pressure in Guwahati, Assam. Anthropometric and hematological assessments revealed wide variability in BMI, Hemoglobin, Red blood Cell count, Packed Cell Volume and Mean Corpuscular Volume, with evidence of both underweight and obese individuals.Additionally, gender-based differences were evident with males showing significantly higher values in most red cell-related parameters like hemoglobin, RBC, MCV, MCH, MCHC and PCV which aligns with known physiological differences such as absence of menstruation, hormonal and hematologic variations.This findings sheds light on the relationship between hypertension and red blood cell-related hematological parameters, underlining the significance of adopting a well-rounded approach to health. Key strategies such as sustaining a healthy weight and routinely checking blood pressure and general health are crucial for preserving blood health and lowering the chances of hypertension-related issues.

Keywords: *Hematological parameters, Hypertension, BMI, Red blood cell indices, Dietary habits*

1. INTRODUCTION

Hypertension is an increasingly prevalent health issue worldwide and is recognized as one of the major risk factors contributing to cardiovascular diseases (CVDs) [Candrawati *et al.,* 2024], which remain the leading cause of mortality and morbidity around the globe [Di Cesare *et al.,* 2024].The World Health Organization [WHO., 2024], defines hypertension as a condition where blood pressure is consistently high, systolic blood pressure (SPB) ≥ 140 millimeters of mercury (mmHg) and diastolic pressure (DPB) ≥ 90 mmHg.According to the WHO 2024 global report on hypertension, nearly 1 in 3 adults worldwide is affected by hypertension, with men showing a slightly higher prevalence than women in the under-50 age group. After the age of 50, the prevalence rises to approximately 49%, or about 1 in 2 individuals, with similar rates observed in both sexes [WHO., 2024]. In India, approximately 22.6% of the population is affected by hypertension, with a higher prevalence among men (24.1%) than women (21.2%)[Mohammad *et al.,* 2024]. Urban areas show a greater prevalence (25%) than rural areas (21.4%) [Raza Mohammad and Dhananjay W. Bansod,2024]. In the Kamrup district of Guwahati, Assam, the prevalence among adults is notably high at 71.7% [Devi A *et al.,* 2024]. Additionally, an overwhelming majority—around 85–95%—of adolescents are reported to suffer from primary hypertension [Bansal *et al.,* 2024].

Hypertension is often referred to as a "silent killer" because it can progress without noticeable symptoms while gradually causing silent damage to vital organs [Fatima S *et al.,* 2021; Jonathan P Kalehoff and Suzanne Oparil, 2020]. As a result, early detection and intervention are crucial, particularly in younger individuals who are usually unaware of their condition and tend to be diagnosed and treated later than the elder population [Hinton *et al.,* 2020; Wang *et al.,* 2020].Hypertension can alter the body's hematological parameters, leading to disruptions in the function of multiple organ systems. It is strongly associated with both structural and functional abnormalities in organs involved in hematopoiesis, and most individuals with hypertension exhibit increased blood viscosity [Kumar A *et al.,* 2020]. Additionally,

changes in hematological markers can reflect the presence of hypertensive end-organ damage [Kumar A *et al.,* 2020].

1.1 Risk factors for the development of hypertension

The following section provide context on the major risk factors for the development of hypertension.

1.1.1 Sex

The way sex affects blood pressure is complex and not easily defined. There are notable and significant physiological, psychological, and hormonal differences between how male and female bodies function [Meher M *et al.,* 2023].Studies have reported a higher prevalence of hypertension in males compared to females [Liu *et al.,* 2017; AlWabel *et al.,* 2018], suggesting that sex differences may play a role as a risk factor in the development of hypertension.

1.1.2 Diet and physical fitness

Unhealthy dietary habits and the increasing preference for fast food are key contributors to the rise in high blood pressure [NB Van *et al.,* 2020]. In addition, the rising consumption of oily and fatty foods in recent years could be associated with the increasing prevalence of obesity. Many individuals with hypertension tend to follow diets that are high in saturated fats but low in protein and carbohydrates. Furthermore, insufficient consumption of fruits and vegetables has also been associated with elevated blood pressure. Unhealthy lifestyle behaviors and physical inactivity are other significant factors in the development of hypertension [X Liu *et al.,* 2017].

1.1.3 Body Mass Index (BMI)

Body mass index (BMI) is a reliable measure for assessing an individual's health and nutritional status.Obesity, being overweight, having an elevated body mass index (BMI), and a high waist-to-hip ratio are all risk factors for hypertension and other noncommunicable diseases[Meher M, *et al.,* 2023].

1.1.4 Alcohol consumption and smoking

The most prominent and significant risk factors of hypertension for adults are smoking and consumption of alcohol. Studies by [Singh *et al.,* 2017], [Tymejczyk *et al.,* 2019], and [Paul *et al.,* 2020] indicate that these factors play a major role in the development of hypertension.

1.1.5 Family history

Hypertension is known to have a hereditary component [AlWabel *et al.,* 2018]. Genetic influences, such as a family history of high blood pressure, play a significant role in its development, as individuals often inherit genes from their parents that elevate their risk [Deborah *et al.,* 2023]. Children with hypertensive parents are more likely to develop the condition themselves. The risk becomes even greater when both parents have hypertension and the child is also exposed to additional risk factors like smoking, alcohol consumption, a high-fat diet, and a lack of physical activity [L Hu *et al.,* 2017]. Research by [DO Ondimu *et al.,* 2019] further supports a strong connection between genetics and hypertension, with obesity and family history emerging as the most significant risk factors.

1.1.6 Excessive salt intake

High salt intake is a significant factor contributing to elevated blood pressure in adults and other individuals.Research conducted across various regions has shown that individuals who consume more than 10 grams of salt per day have an increased risk of developing hypertension [GK Paul *et al.,* 2020].A study by [Singh *et al.,* 2017] found that the typical Asian diet has a higher salt content compared to the average Western diet.In India, where high salt intake has rapidly become a significant risk factor, implementing measures, initiatives, and awareness campaigns aimed at lowering salt consumption would greatly benefit the population.

1.2 Role of hematological parameters in hypertension

1.2.1 Hemoglobin

Some studies have indicated a link between hemoglobin levels and hypertension. An increase in hemoglobin may lead to higher systolic and diastolic blood pressure. Elevated hemoglobin levels can cause blood vessel constriction, which in turn raises blood pressure [G Bazmandegan *et al.*, 2023]. In another study, Xuan et al. found a positive correlation between hemoglobin levels and both systolic and diastolic blood pressure [Y Xuan *et al.*, 2019]. Although the exact mechanism behind the rise in blood pressure among individuals with elevated hemoglobin levels remains unclear, several biological explanations have been suggested to account for this association [Y Xuan *et al.*, 2019].

1.2.2 Red blood cells

Hypertension is associated with significant changes in the rheological, mechanical, and biochemical properties of red blood cells, as well as alterations or disruptions in blood flow[Rafaqat S *et al.,* 2023]. In

individuals with hypertension, red blood cells show reduced deformability, which is influenced more by the level of blood pressure control than by organ damage [Odashiro K *et al.,* 2015]. Key observations include the formation of red blood cell aggregates and 'rouleaux,' increased blood viscosity, and decreased red blood cell flexibility.These hemorheological changes can raise peripheral resistance and arterial pressure, potentially contributing to the development or worsening of hypertension.Furthermore, they may decrease peripheral blood flow, hinder the supply of oxygen to tissues, and decrease the microvasculature's effective exchange surface area—especially in cases of severe or complex hypertension.[Rafaqat S *et al.,* 2023].

1.2.3 Hematocrit

Hematocrit (HCT), a key factor influencing blood viscosity, has been linked to an increased risk of high blood pressure and is recognized as a contributing risk factor for hypertension [X Liu *et al.,* 2015].The length of the packed red blood cell layer is divided by the length of the blood sample, which includes both cells and plasma, to determine HCT [S Rafaqat *et al.,* 2023]. In individuals aged 10 to 18, studies have found a positive relationship between hemoglobin levels and HCT with both systolic and diastolic blood pressure [HR Jeong *et al.,* 2021]. Additionally, research has shown that hematocrit may independently influence the likelihood of developing hypertension [M Emamian *et al.,* 2017].

1.2.4 Red cell indices

High blood pressure influences red cell indices such as MCV, MCH, and MCHC and these parameters may play a role in the development or progression of hypertension. Studies have found significant positive correlation of MCV, MCH and MCHC with high blood pressure [N Rahman *et al*., 2024].

1.2.5 White blood cells

An elevated white blood cell (WBC) count is considered an independent predictor of cardiovascular complications in individuals with hypertension. Both observational studies and genetic analyses have demonstrated a consistent positive correlation between lymphocyte levels and systolic as well as diastolic blood pressure, suggesting a possible causal relationship [Siedlinski M *et al.,* 2020]. In a study involving a Japanese population, a general link was observed between higher WBC counts and the onset of hypertension. Therefore, implementing a high-risk screening strategy based on WBC levels could potentially improve future hypertension prevention efforts [Ishida S *et al.,* 2021].

1.2.6 Platelet count

Platelet activity is believed to play a role in the development of hypertension [Li Gang *et al.,* 2017]. Research has shown that individuals with lower platelet counts exhibit a stronger association between homocysteine levels and blood pressure compared to those with higher platelet counts, suggesting that platelet levels may partially influence this relationship [Zhang, J., *et al.,* 2020]. A study by [K Yang *et al.,* 2016] also indicated that individuals exposed to abnormal platelet indices over a prolonged period could benefit from using these indices for the early detection of hypertension. Essential hypertension has been associated with an increased risk of arterial thrombosis. Since platelet activation significantly contributes to thrombotic events, antiplatelet therapy has been shown to improve outcomes in hypertensive patients with existing atherosclerosis or elevated cardiovascular risk [S Rafaqat *et al.,* 2023].

2. METHOD

Study Population

A prospective study was conducted in the campus of Assam downtown University, Guwahati, Assam.

Study subjects : A total number of 100 cases were studied among individuals above 18 years of age.A questionnaire was used to collect the data and information about the subjects, which includes name, age, gender, educational qualification, lifestyle, weight, blood pressure, etc.

Statistical measurements were applied SPSS software as per requirement of the analysis of the data.

Inclusion criteria: Normotensive and hypertensive individuals above 18 years of age.

Exclusion criteria: Hypotensive individuals and below 18 years of age.

Method of Sample Collection: 2ml of blood is collected intravenously in EDTA vial for different hematological tests.

- Hemoglobin estimation (Cyanmethemoglobin method)
- Red blood cell count (Hemocytometer)
- Packed cell volume (Wintrobe method)
- White blood cell count (Hemocytometer)
- Platelet count (Hemocytometer)

3. RESULT

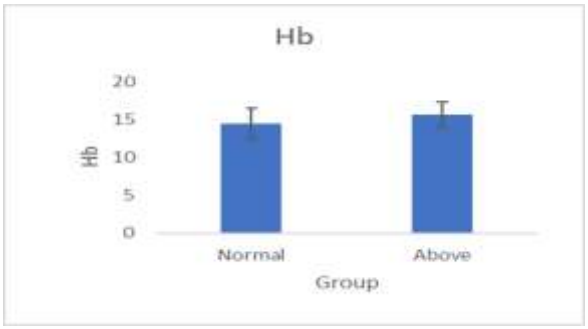

Fig 1: Hemoglobin Levels Between individuals with normal and high blood pressure.

In **Fig 1**, the analysis showed that hemoglobin levels were significantly higher in individuals with high blood pressure (15.61 ± 1.66) than in those with normal blood pressure (14.42 ± 2.02), possibly reflecting a physiological response to hypertension, such as increased oxygen transport or blood viscosity.

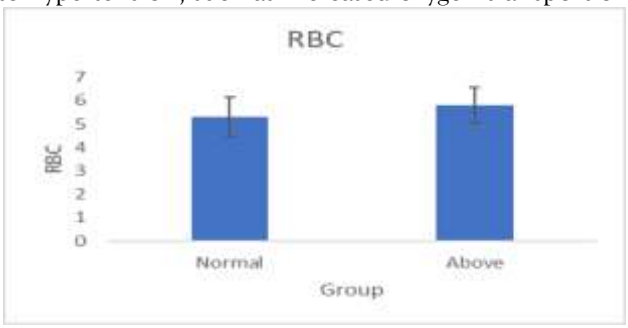

Fig 2: Red blood cell count between individuals with normal and high blood pressure.

In **Fig 2**, the analysis showedthatred blood cell count were significantly higher in individuals with high blood pressure (5.8069 ± 0.7672) compared to those with normal blood pressure (5.3031 ± 0.84384). This significant increase may be due to several physiological and pathological mechanisms such as increased blood viscosity and vascular resistance.

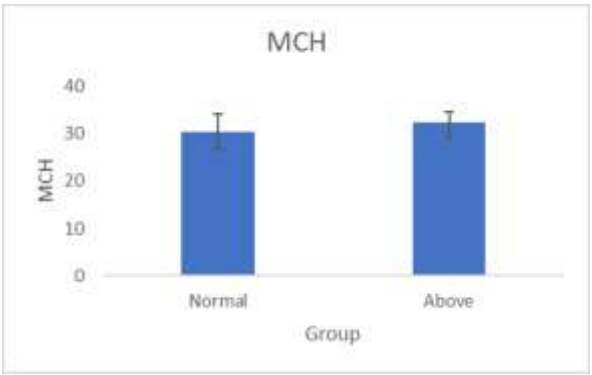

Fig 3: Mean Corpuscular Hemoglobin (MCH) between individuals with normal and high blood pressure.

In **Fig 3**, the statistical analysis of Mean corpuscular hemoglobin (MCH) was significantly higher in individuals with elevated blood pressure (32.26 ± 3.18) compared to those with normal pressure (30.34 ± 3.63), indicating a positive association between MCH and blood pressure.

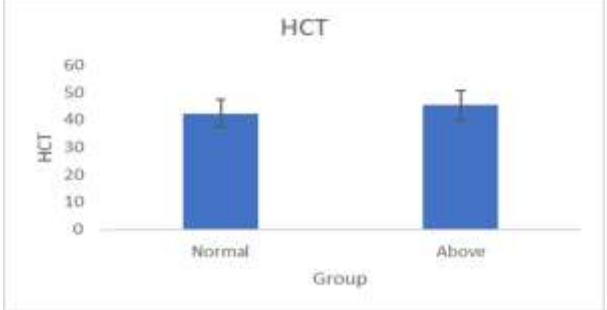

Fig 4: Hematocrit (HCT) levels between individuals with normal and high blood pressure.

In **Fig 4**, the statistical analysis of packed cell volume (PCV), also referred to as hematocrit (HCT), between individuals with normal and elevated blood pressure revealed a positive statistically significant

difference.Packed cell volume (PCV) was significantly higher in individuals with elevated blood pressure (45.28 ± 5.39) compared to those with normal pressure (42.20 ± 5.04), suggesting increased red cell volume may be linked to blood viscosity or oxygen transport in hypertension.

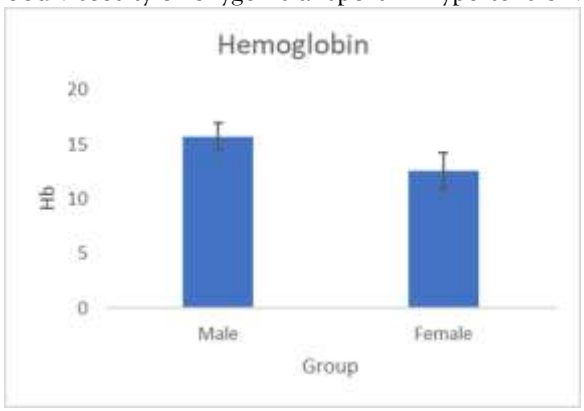

Fig 5: Comparison of hemoglobin levels between male and female

In **Fig 5**, the statistical comparison of hemoglobin (Hb) levels between males and females revealed a positive statistically significant difference. Hemoglobin levels were significantly higher in males (15.74 ± 1.17) than in females (12.58 ± 1.66), reflecting known physiological differences such as greater muscle mass, higher erythropoietin levels, and menstrual blood loss in females.

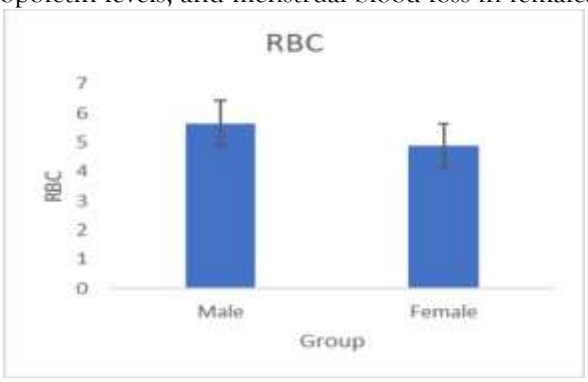

Fig 6: Comparison of red blood cell count between male and female

In **Fig 6**, the statistical analysis of red blood cell (RBC) count between males and females revealed a positive statistically significant difference. Red blood cell count was significantly higher in males (5.66 ± 0.78) than in females (4.90 ± 0.74), reflecting physiological differences like greater muscle mass and higher oxygen demand that promote increased erythropoiesis.

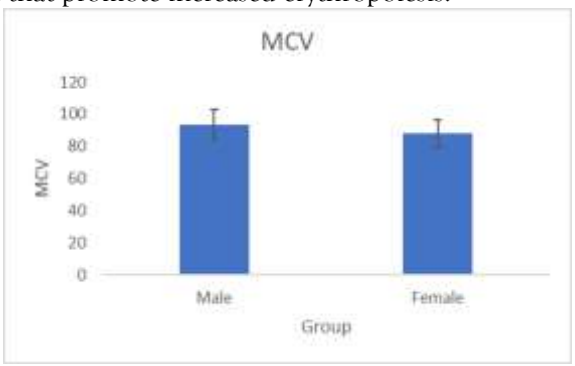

Fig 7: Comparison of Mean Corpuscular Volume (MCV) between male and female

In **Fig 7**,Mean corpuscular volume (MCV) was higher in males (93.40 ± 9.61 fL) than in females (87.85 ± 8.77 fL), indicating larger red blood cells in males. The bar chart illustrates this difference, with slightly greater variability observed in males.

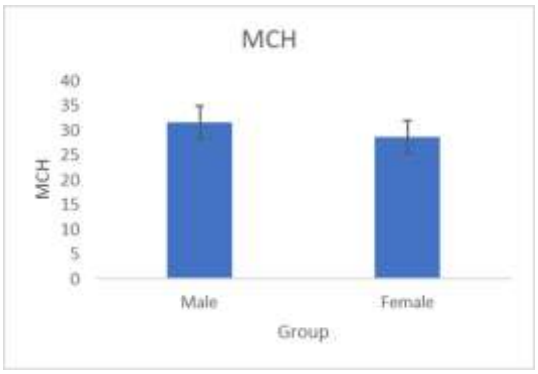

Fig 8: Comparison of Mean Corpuscular Hemoglobin (MCH) between male and female

In **Fig 8**,males had more hemoglobin per red blood cell, as seen by their higher mean corpuscular hemoglobin (MCH) of (31.69 ± 3.33 pg) compared to (28.68 ± 3.40 pg) for females. The bar chart highlights this difference, with similar variation in both groups.

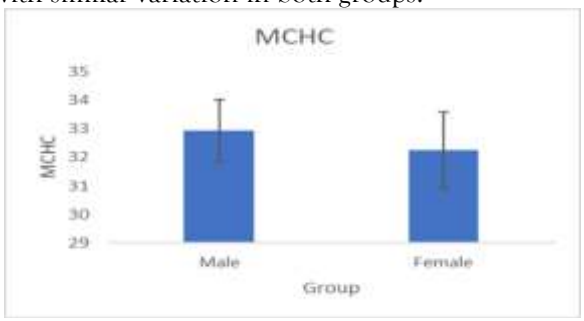

Fig 9: Comparison of Mean Corpuscular Hemoglobin Concentration (MCHC) between male and female

In **Fig 9**, Mean corpuscular hemoglobin concentration (MCHC) was slightly higher in males (32.93 ± 1.07 g/dL) than in females (32.24 ± 1.34 g/dL), indicating slightly more concentrated hemoglobin in male red blood cells. The bar chart reflects this small difference, with greater variation in females.

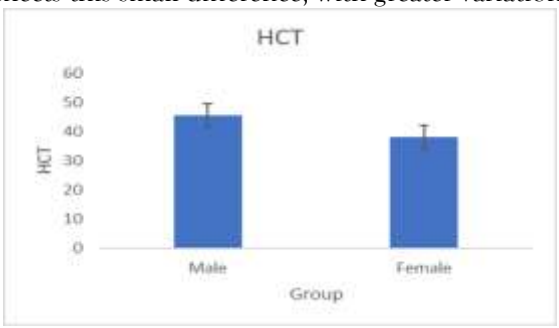

Fig 10: Comparison of Hematocrit (HCT) between male and female

In **Fig 10**, the Packed Cell Volume (PCV), also known as hematocrit (HCT), was higher in males compared to females.The average PCV for males was 45.41 ± 3.97%, whereas the average for females was 38.07 ± 3.91%. This shows that males have a higher proportion of red blood cells in their blood. The amount of variation was similar in both groups.

Our study also showed no significant correlation between dietary habits, family type, or the presence of chronic illness and any of the hematological parameters (Hb, RBC, WBC, platelets, MCV, MCH, MCHC, PCV). Correlation coefficients were near zero and all p-values exceeded 0.05, indicating no measurable impact of these factors on blood indices in this dataset. In addition, the analysis of age in relation to various hematological parameters showed no statistically significant correlations, as all p-values were above 0.05. These results suggest that age does not significantly influence the measured hematological indices in this population.

4. DISCUSSION

This study investigates the assessment of hematological parameters between hypertensive and normotensive individuals in Guwahati, Assam, as well as gender-based differences and the influence of other factors such as age, BMI, dietary habits, family type, and chronic illness. The comparative analysis between individuals with normal and elevated blood pressure revealed statistically significant increases in hemoglobin (Hb), red blood cell (RBC) count, mean corpuscular hemoglobin (MCH), and packed cell volume (PCV) among those with high blood pressure. The findings suggest that hypertension may induce

or be associated with hematological changes that reflect increased erythropoiesis or altered blood rheology.

Blood pressure and certain hematological parameters are significantly positively correlated, as shown in Table 1. Elevated hemoglobin (Mean ± SD = 15.6085 ± 1.65955) and PCV (Mean ± SD = 45.2831 ± 5.39117) may be contributing factors to increased blood viscosity, which may increase peripheral resistance and worsen hypertension.The elevated RBC count (Mean ± SD = 5.8069 ± 0.76720) observed in hypertensive individuals may also be a compensatory response to increased oxygen demand in hypertensive states. Additionally, MCH (Mean ± SD = 32.2597 ± 3.18048), which reflects the average hemoglobin concentration in individual red blood cells, was significantly higher in individuals with hypertension. This elevation could indicate modifications in red blood cell formation triggered by systemic stress or inflammation associated with elevated blood pressure.

Interestingly, other hematological parameters such as white blood cell (WBC) count, platelet count, mean corpuscular volume (MCV), and mean corpuscular hemoglobin concentration (MCHC) did not differ significantly between the normotensive and hypertensive groups. This suggests that while red cell-related parameters are more responsive to changes in blood pressure, other components like WBCs and platelets may remain relatively unaffected.

Table 2, highlighting the gender-based analysis showed significant differences in hematological values between males and females. Males demonstrated significantly higher levels of hemoglobin levels (Mean ± SD = 15.7432 ± 1.17399), RBC (5.6568 ± 0.77718), MCV (93.4022 ± 9.61443), MCH (31.6850 ± 3.32786), MCHC (32.9279 ± 1.07131), and PCV (45.4169 ± 3.97016), which aligns with well-established physiological norms. These differences are primarily attributed to higher androgen levels in males, which stimulate erythropoietin production and red blood cell synthesis, as well as the absence of menstrual blood loss, which often contributes to lower hemoglobin and iron stores in female.

Additionally, BMI showed significant positive correlations with RBC ($p = 0.002$) and WBC counts ($p = 0.048$) and a near-significant correlation with MCH ($p = 0.052$). This implies that individuals with higher BMI may have mild elevations in erythropoiesis and leukocyte counts, possibly reflecting the low-grade inflammation and metabolic changes commonly associated with increased adiposity.

Based on the findings of this study, no significant correlations were observed between hematological parameters and age, dietary habits, family type, or the presence of chronic illness. These results suggest that, in this study population, lifestyle and sociodemographic variables may have a limited impact on basic hematological indices compared to physiological and clinical factors such as gender, BMI, and blood pressure status.

5. CONCLUSION

This study highlights a significant association between hematological parameters and blood pressure status, as well as gender-based differences and the influence of other factors such as age, BMI, dietary habits, family type, and chronic illness of individuals with normal and high blood pressure in Guwahati, Assam. The study concludes that hypertension may influence erythropoiesis or blood viscosity, increased red cell mass and oxygen-carrying capacity potentially contributing to a cycle that further aggravates blood pressure levels. However, dietary habits, family type, chronic illness, and age did not show any major effect on blood parameters. This means that blood pressure, gender, and BMI have a stronger influence on blood health than lifestyle or background factor in this study. However, studies with a larger sample size may be needed to better clarify the effects of lifestyle factors like diet and family type. The findings underscores the importance of understanding these associations to aid in better clinical monitoring and management of hypertension.

Additionally, gender-based differences were evident with males showing significantly higher values in most red cell-related parameters like hemoglobin, RBC, MCV, MCH, MCHC and PCV which aligns with known physiological differences such as absence of menstruation, hormonal and hematologic variations. The findings emphasize the importance of incorporating sex-specific reference ranges in hematological assessments to improve diagnostic accuracy and patient care.

Overall, the study provides valuable insights into the interplay between hypertension and red-blood cell related hematological parameters, emphasizing the need for holistic health management strategies that include maintaining a healthy weight, regular blood pressure and health monitoring, which remain key measures to support optimal blood health and reduce the risk of hypertension-related complications. These findings can help guide future research and public health strategies related to hypertension and improving blood health.

Ethics approval: Ethical approval for this study was obtained from the ethical clearance committee of Assam down town University (Memo no.:AdtU/Ethics/stdnt-lett/2025/142).
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Table 1:Comparison of hematological parameters between individuals with normal blood pressure and high blood pressure.

Sl.no	Parameters	Normal blood pressure(n=50)	Above blood pressure(n=50))	P Value	Remark
1	Hemoglobin	14.4203 ± 2.01685	15.6085 ± 1.65955	0.01	Sig
2	RBC	5.3031 ± 0.84384	5.8069 ± 0.76720	0.01	Sig
3	WBC	6606.8226 ± 1919.43864	7265.1538 ± 1887.15845	0.144	No Sig
4	Platelet	202365.3065 ± 60095.90322	187743.0000 ± 55381.38743	0.29	No Sig
5	MCV	91.2700 ± 10.15850	93.4162 ± 8.57196	0.348	No Sig
6	MCH	30.3444 ± 3.63487	32.2597 ± 3.18048	0.022	Sig
7	MCHC	32.7613 ± 1.19072	32.4654 ± 1.24706	0.297	Not Sig
8	PCV	42.2015 ± 5.04361	45.2831 ± 5.39117	0.012	Sig

Table 1 shows a comparison of hematological parameters between individuals with normal and high blood pressure and revealed that Hemoglobin, RBC, MCH, and PCV levels were significantly higher in the high blood pressure group ($p < 0.05$), indicating potential hematological changes associated with hypertension. Conversely, parameters such as WBC, Platelet count, MCV, and MCHC showed no statistically significant differences between the two groups ($p > 0.05$).

Table 2: Comparison of Hematological parameters between male and female

Sl.No	Parameters	Male (Mean ± SD)	Female (Mean ± SD)	P Value	Remark
1	Hemoglobin	15.7432 ± 1.17399	12.5825 ± 1.65562	0	Sig
2	RBC	5.6568 ± 0.77718	4.8953 ± 0.73576	0	Sig
3	WBC	6893.7059±2001.01792	6552.0938±1700.82178	0.406	No sig
4	Platelet	195477.0735±55097.22795	206141.5313±66585.83653	0.401	No sig
5	MCV	93.4022 ± 9.61443	87.8500 ± 8.76993	0.007	Sig
6	MCH	31.6850 ± 3.32786	28.6756 ± 3.39685	0	Sig
7	MCHC	32.9279 ± 1.07131	32.2438 ± 1.34259	0.007	Sig

8	PCV	45.4169 ± 3.97016	38.0750 ± 3.91061	0	Sig

Table 2 shows the analysis of hematological parameters between males and females and showed several notable differences. Males had significantly higher levels of hemoglobin, RBC, MCH, and PCV compared to females, with all corresponding p-values being 0.000, indicating strong statistical significance. While MCV and MCHC values were also higher in males, their p-values (0.007) suggest these differences were not considered statistically significant based on the study's criteria. In contrast, no significant differences were observed in WBC and platelet counts between the two groups, as indicated by p-values of 0.406 and 0.401. Overall, the results indicate that red blood cell–related parameters vary by gender, other parameters like WBC and platelets are relatively similar between males and females in this study.

Table 3: Correlation of BMI with Hematological Parameters

Sl.no	Variable	Correlation Value	P Value	Remark
1	BMI vs Hb%	0.186	0.064	No Correlation
2	BMI vs RBC	0.304	0.002	Significant positive correlation
3	BMI vs WBC	0.198	0.048	Significant positive correlation
4	BMI vs Platelet	-0.124	0.219	No Correlation
5	BMI vs MCV	0.089	0.38	No Correlation
6	BMI vs MCH	0.195	0.052	Significant positive correlation
7	BMI vs MCHC	-0.165	0.101	No Correlation
8	BMI vs PCV	0.142	0.158	No Correlation

In Table 3, The analysis showed that BMI had a significant positive correlation with RBC ($r = 0.304$, $p = 0.002$) and WBC ($r = 0.198$, $p = 0.048$), and a near-significant correlation with MCH ($r = 0.195$, $p = 0.052$), suggesting these values increase with higher BMI. No significant correlations were found with Hb, platelets, MCV, MCHC, or PCV, indicating BMI mainly affects RBC, WBC, and possibly MCH.

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