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ASSOCIATION OF HAEMATOLOGICAL PARAMETERS WITH GLYCAEMIC CONTROL IN PATIENTS WITH TYPE 2 DIABETES – A STUDY

Sridevi Yerroju[1*], Dr. Pallavi Singh[2]

[1]Research Scholar, Department of Public Health, Poornima University, Jaipur, Rajasthan, Email: ysd174@gmail.com
[2] Associate Professor, Faculty of Public Health, Department of Public Health, Poornima University, Jaipur, Rajasthan, Email: singh.pallavi010@gmail.com
*Corresponding Author: Sridevi Yerroju, Email: ysd174@gmail.com

ABSTRACT
This research explores the intricate relationship between red blood cell indices, haemoglobin, and haematocrit in relation to Type 2 Diabetes (T2DM). The research particularly focuses on understanding how these haematological parameters correlate with glycated haemoglobin (HbA1c), an indicator of long-term glycaemic control. A cohort of 50 T2DM patients, aged 45-72 years, was analyzed to assess various red blood indices, including haemoglobin, haematocrit, MCV, MCH, MCHC, and RDW-CV. The findings revealed a significant negative correlation between HbA1c and key parameters such as haemoglobin (-0.42, p=0.005), haematocrit (-0.40, p=0.008), and MCH (-0.45, p=0.003), indicating that lower levels of these factors are linked with poor glycaemic control. Conversely, RDW-CV displayed a strong positive correlation with HbA1c (0.50, p=0.001), suggesting that increased variability in red blood cell size is linked to higher HbA1c levels. Regression analysis confirmed these findings, with haemoglobin (-0.25, p=0.002) and RDW-CV (0.33, p<0.001) emerging as significant predictors of HbA1c levels. These findings highlight the critical role that haematological factors play in the metabolic profile of T2DM patients. Integrating red blood indices with HbA1c assessments can offer deeper insights into diabetes management, providing a more comprehensive understanding of disease complications like cardiovascular and kidney dysfunction. This study underscores the potential of using these parameters to enhance therapeutic strategies for improved outcomes in T2DM care.

KEYWORDS: Anaemia, Glycaemic control, HbA1c, haematocrit, haemoglobin, Insulin resistance, Kidney dysfunction, Metabolic disturbances, red blood cell indices, T2DM

I. INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a disease whereby hyperglycaemia is characterized by low insulin sensitivity and reduced production of insulin (Rajpathak et al., 2009). There are various comorbidities associated with patients suffering from T2DM. One of these comorbidities is anaemia that could affect glycaemic regulation and increase insulin resistance (Rafaqat & Rafaqat, 2023). The link between anaemia and diabetes is medically relevant because of the role anaemia plays in reducing the supply of oxygen to tissues by lowering the levels of haemoglobin in the body (Rajpathak et al., 2009; Rafaqat & Rafaqat, 2023).

In addition to being a carrier for oxygen in the bloodstream, haemoglobin can be considered an important tool that helps determine whether a person suffers from metabolic abnormalities such as diabetes (Shi et al., 2006; Rajpathak et al., 2009). Specific diabetes medications might affect haemoglobin levels, thus influencing oxygen transport and insulin sensitivity (Rafaqat & Rafaqat, 2023). In addition to this, changes in the level of HbA1c, a well-known parameter indicating the average glycaemic control in a patient during recent months, are usually found among people who suffer from different kinds of anaemia including iron-deficiency anaemia, sickle cell anaemia, thalassemia, and megaloblastic anaemia (Son, 2019; Misra et al., 2016).

Haematocrit and RBC indices have an essential value for revealing the complicated interplay between diabetes and anaemia. Since chronic kidney disease and systemic inflammation are common complications associated with diabetes, they have negative effects on erythropoiesis and functioning of RBCs, which results in anaemia (Rafaqat & Rafaqat, 2023). It has been found that T2DM patients with anaemia, that is with lower haemoglobin concentration, usually have increased triglycerides, lower HDL-C concentration, higher levels of uric acid, and a greater frequency of non-alcoholic fatty liver disease (Yeap et al., 2015). On the contrary, higher haemoglobin concentration leads to a rise in blood viscosity and microcirculation impairment along with increased risks of developing insulin resistance. As with increased levels of haemoglobin, higher haematocrit concentration is related to impaired endothelium-dependent vasodilation and decreased nitric oxide bioavailability, and thus increases risks for heart conditions (Yeap et al., 2015; Huth et al., 2015).

High blood sugar in type 2 diabetes results in oxidative stress that causes premature destruction of erythrocytes leading to a shortened life span of RBCs (Williams et al., 2023). As such, there can be variations in different haematological parameters such as RBC counts, MCV, MCH, and RDW which are useful in determining the condition of the RBCs (Rafaqat & Rafaqat, 2023). Such variances are as a result of the damaging influence of high blood glucose levels and ...may lead to cardiovascular diseases, non-alcoholic fatty liver disease, kidney problems, and other metabolic complications (Huth et al., 2015). While HbA1c has been established as a key indicator for blood sugar level control over

time, assessment of RBC indices is crucial for comprehending the changes caused by T2DM (Son, 2019; Misra et al., 2016).

This study intends to bridge some of the existing research gaps by investigating the associations between RBC parameters, Hb levels, and HCT with regard to T2DM. In this regard, by incorporating these haematological factors, this research is likely to provide greater insight into the relationships among these factors and hyperglycaemia, heart diseases, fatty liver disease, and renal dysfunction (Huth et al., 2015; Yeap et al., 2015). The importance of understanding the associations between the abnormal haematological factors and metabolism cannot be overstated in view of the fact that this will contribute to better management of T2DM. The important causes and complications resulting from RBC abnormalities in DM are outlined in Figure 1 below.

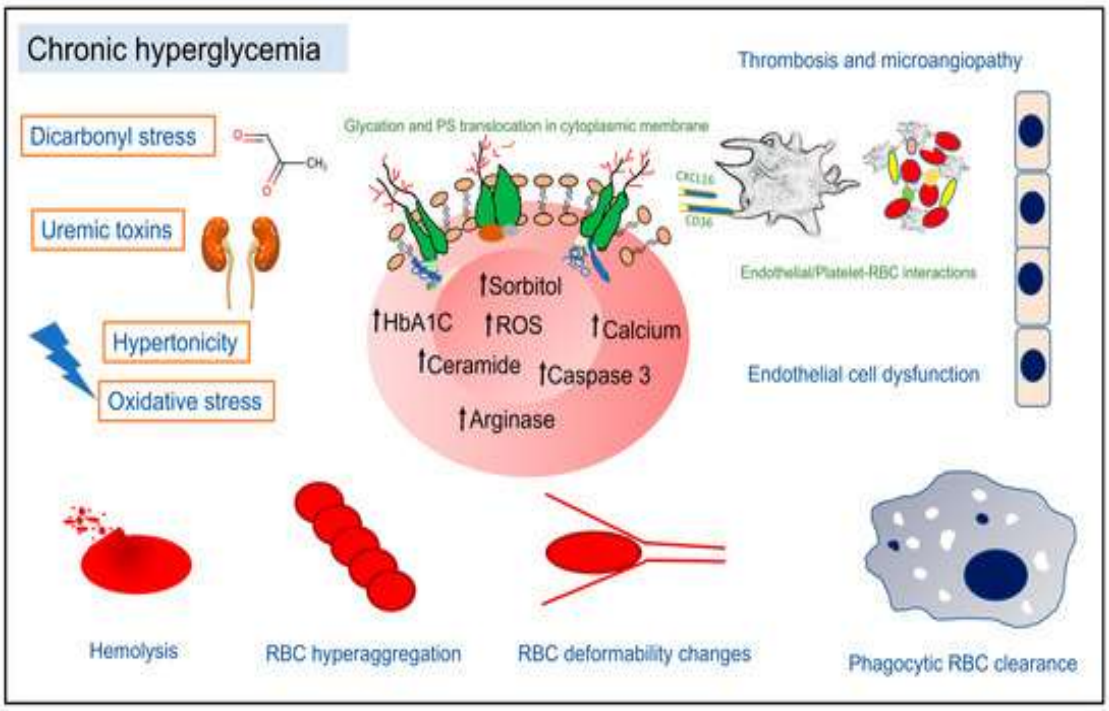

Figure 1. Overview of the Causes and Consequences of Red Blood Cell (RBC) Dysfunction in Type 2 Diabetes (Williams et al, 2023)

Figure 1 shows a summary of some of the most important factors that cause RBC abnormalities and the subsequent results of those abnormalities in patients with diabetes mellitus. One such factor that contributes to the growth of RBC abnormalities in patients with diabetes mellitus is chronic hyperglycaemia. Some of the RBC abnormalities that occur in patients suffering from diabetes include oxidative stress, membrane abnormalities, and cellular abnormalities (Rafaqat & Rafaqat, 2023).

2. LITERATURE REVIEW

Higher levels of ferritin in the blood serum (233.11 ± 43.84 ng/ml) and high sensitivity C-reactive protein (5.29 ± 0.80 mg/L) are believed to be related to insulin resistance and inflammation in cases of type 2 diabetes mellitus (T2DM), suggesting that both elements may contribute to problems with regulating blood sugar levels. These results also show that, regardless of iron excess, ferritin levels could still remain high and affect insulin resistance, which is likely to be increased by inflammation as indicated by the high-sensitivity C-reactive protein (hs-CRP) levels (Alam et al., 2013). Indeed, in support of these findings, one observational study carried out on ARIC participants showed that having plasma ferritin at the top quintile level increases the risk of developing T2DM by 1.74 times when compared to having ferritin at the lowest quintile level (Jehn et al., 2007; Shi et al., 2006). However, although higher levels of ferritin were found to be associated with certain metabolic disturbances that are believed to lead to diabetes, it cannot yet be stated that there is a causal link between them (Jehn et al., 2007; Smotra et al., 2008).

In another study, Canturk et al. (2003) explored the association between serum ferritin levels and glycaemic control status among 329 subjects suffering from T2DM. This study showed that there were significantly higher serum ferritin concentrations in poorly controlled diabetic patients in contrast to well-controlled diabetic patients and normal subjects. Out of 150 poorly controlled patients, 41 patients had hyperferritinaemia. Additionally, the elevated level of ferritin was associated with diabetic retinopathy, indicating that not only impaired glycaemic control but also complications of diabetes can be caused by elevated ferritin concentrations. In a similar vein, it was found that elevated baseline serum ferritin concentrations were significantly predictive of developing T2DM according to the EPIC-Norfolk Study. The baseline ferritin levels were significantly higher in people developing diabetes than in the controls (96.6 ng/ml vs. 67.8 ng/ml; $p<0.001$). Besides, those having clinically elevated ferritin concentrations had 7.4 times the risk of developing diabetes (Forouhi et al., 2007).

In addition to ferritin, serum iron levels have been identified as potential biomarkers of glucose metabolism. Gohel et al. (2013) found a steady rise in free iron serum levels among study participants, with the highest free iron serum levels in individuals with poorly managed diabetic condition (126.4 µg/dL) compared to those with better-controlled glycaemia (95.8 µg/dL) and healthy subjects (85.2 µg/dL). In addition, there were marked positive correlations between serum free iron and fasting blood glucose (r = 0.72) and glycaemic haemoglobin (r = 0.68).

The relationship between iron biomarker levels and glucose metabolism was further illustrated using findings obtained from the KORA F4 study. Huth et al. (2015) found that high levels of serum ferritin (OR = 2.08) and transferrin (OR = 1.89) were major risk factors for poor glucose regulation and type 2 diabetes. On the contrary, high transferrin saturation (OR = 0.55) and serum iron levels (OR = 0.61) had protective effects against the disease development. A negative correlation was also established for the soluble transferrin receptor-ferritin index in relation to abnormal glucose metabolism (OR = 0.67). In addition, data from the Busselton Health Survey revealed that increased serum ferritin levels were independently linked with T2DM in men (OR = 1.29 for each unit increase in log ferritin) and women (OR = 1.31 for each unit increase in log ferritin); on the other hand, serum iron and transferrin levels were not significantly correlated with diabetes risk (Yeap et al., 2015).

In yet another study conducted with 111 T2DM patients, Alam et al. (2014) found that increased serum ferritin and C-reactive protein levels were significantly related to insulin resistance and glycaemic status. The former was positively correlated with fasting blood glucose (r = 0.596) and insulin levels (r = 0.866), thus suggesting its possible use as an indicator of abnormal metabolism. Consistent observations were made in the case of Mongolians with and without T2DM. Batchuluun et al. (2014) reported significantly higher levels of ferritin in diabetic participants, especially female patients, than those without diabetes. Hyperferritinaemia was seen in 43.4% of diabetic patients. Additionally, poorly managed diabetic females had significantly higher levels of ferritin than those with well-managed blood glucose levels. This implies that ferritin levels can be a valuable tool in the identification of patients at serious risk for poor glucose management and complications.

Overall, it is evident from these studies that disruptions in iron metabolism, including an increase in serum ferritin levels, are strongly linked to insulin resistance, hyperglycaemia, and T2DM development. However, there is more to diabetes pathophysiology than just iron metabolism. Other factors such as haemoglobin level, haematocrit levels, red blood cell indices, oxidative stress, and inflammation pathways have also been linked to metabolic problems.

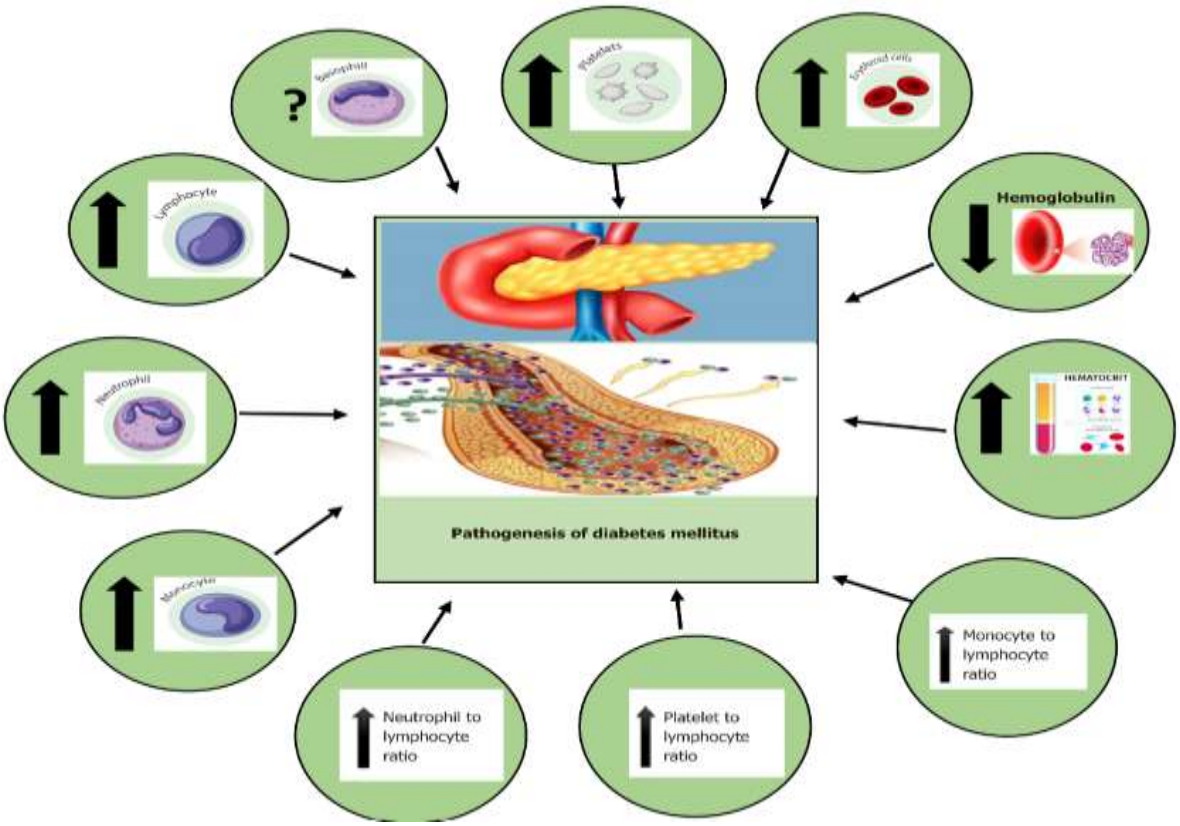

Figure 2. Overview of haematological parameters involved in the pathogenesis of Diabetes mellitus (Rafaqat and Rafaqat, 2023)

According to the findings presented in Fig. 2, chronic hyperglycaemia triggers a series of haematological and biochemical changes, such as oxidative stress, impairment of red blood cells, endothelial damage, membrane glycation, and increased thrombosis. This series of interactions plays a critical role in decreasing tissue perfusion and vascular damage. The figure presents the complex interconnection between different haematological parameters which may affect the disease course and prognosis in individuals diagnosed with T2DM.

Despite the fact that there were numerous studies dedicated to the role of ferritin and haemoglobin-related parameters in insulin resistance and diabetes development, there is limited knowledge about how these parameters interact and how they

affect hyperglycaemia and diabetes-related complications. In most of the existing studies, individual biomarkers were analyzed. As a result, the current study aims at filling in the gap in scientific literature by analyzing the interrelationships between ferritin, haemoglobin, haematocrit, and indices of erythrocytes. In particular, the focus is made on determining whether these factors can be related to cardiovascular disease, fatty liver disease, kidney disease, and other metabolic abnormalities.

3. METHODOLOGY

3.1 Study Design

The current study was carried out at Hyderabad, state of Telangana, India, where a cross-sectional observational study was done in order to determine the relationship between red blood cell (RBC) indices and the levels of glycated haemoglobin (HbA1c) in Type 2 Diabetes Mellitus patients.

3.2 Study Population

The study sample consisted of 50 patients suffering from Type 2 Diabetes Mellitus. Patients' age was 45 – 72 years, while participants were selected by Random Sampling Technique. The blood taken from the participants was analyzed to determine the HbA1c levels and certain haematological parameters.

3.3 Inclusion and Exclusion Criteria

Patients aged 45 – 72 years old with diagnosis of Type 2 Diabetes Mellitus, agreeing to take part in the study and possessing laboratory records for HbA1c and complete blood count parameters were recruited into the study. Patients with Type 1 Diabetes Mellitus, pregnant/lactating women, patients with hematological diseases, malignancy or infection, receiving blood transfusion during the last three months and patients refusing to give informed consent were not included into the study.

3.4 Data Collection Procedure

Blood samples were collected from each individual and subjected to analysis for selected haematological parameters and HbA1c values. Haematological parameters determined include haemoglobin, erythrocytes, packed cell volume (haematocrit), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), and red cell distribution width-coefficient of variation (RDW-CV). Assessment of HbA1c values was done as an indicator of long-term glycaemic control. All laboratory tests were carried out by standard clinical laboratory tests to ensure the reliability and accuracy of the test results.

3.5 Laboratory Analysis

Haematological parameters were analyzed through standard automated haematological analysis techniques usually applied in clinical laboratories. HbA1c estimation was done through standard laboratory procedures usually used for estimating long-term glycaemic control. Quality control measures were applied during the analysis to guarantee accuracy and precision of laboratory results.

3.6 Ethical Considerations

The present research study was carried out as per the ehical guidelines of the Declaration of Helsinki. The Institutional Ethics Committee of **Medipulse Hospital (Jodhpur)** granted an ethical clearance for the present research study (Approval Number ECINEW/19ST/2024/4214). All individuals were given complete information regarding the purpose, process, advantages, and risks associated with the present study prior to taking part in it. Informed written consent was acquired from all subjects before collecting samples and processing data. Confidentiality of the participants was maintained through the entire study and all the data gathered were only used for research purposes.

3.7 Statistical Analysis

Data were recorded on MS Excel and analyzed using appropriate statistical methods. Mean, standard deviation, minimum values, and maximum values were calculated in order to determine the demographic and haematological profile of the study participants. Correlation analysis of HbA1c with selected haematological factors such as haemoglobin, red blood cell count, haematocrit, MCV, MCH, MCHC, and RDW-CV was performed using Pearson correlation analysis. Multiple regression analysis was then carried out to determine the significant haematological variables predicting HbA1c levels. $P<0.05$ was considered statistically significant.

4. RESULTS

This chapter contains the results obtained from the research on the correlation between glycated haemoglobin (HbA1c) and chosen red blood cell indices of individuals with Type 2 Diabetes Mellitus (T2DM). Results have been provided using descriptive statistics, correlation analysis, regression analysis, scatter plots and the correlation heatmap.

4.1. Cumulative Analysis of Data

The descriptive statistics regarding the study variables are included in Table 1. The above-mentioned information provides a summary about demographic details, values of HbA1c and red blood cell indices of the studied individuals. The values of all the parameters mentioned vary because of different levels of glycemia and haematology in T2DM patients.

Table 1. Descriptive Statistics of HbA1c and Red Blood Cell Indices

Parameter	Mean ± SD	Range
Age (years)	58.2 ± 8.7	45 - 72
HbA1c (%)	8.3 ± 1.2	6.2 - 11.5
Haemoglobin (g/dL)	12.1 ± 1.6	9.5 - 14.7
Erythrocyte Count (RBC Count, ×10^6/µL)	4.8 ± 0.6	3.5 - 5.9
Packed Cell Volume - Haematocrit (%)	38.5 ± 4.2	31.0 - 44.0
MCV (fL)	80.5 ± 7.3	72.0 - 90.0
MCH (pg)	25.0 ± 2.8	20.0 - 30.0
MCHC (g/dL)	32.0 ± 1.9	29.0 - 35.0
RDW-CV (%)	14.2 ± 1.6	11.5 - 17.0

To further explore the association between HbA1c and the haematological parameters, correlation analysis was carried out. The outcome is summarized in Table 2. It is noted that some red blood cell indices showed significant correlations with HbA1c, reflecting possible association between the glycaemic state and the haematological condition.

Table 2. Correlation Coefficients Between HbA1c and Haematological Parameters

Parameter	Correlation with HbA1c	p-value
Haemoglobin (g/dL)	-0.42	0.005
Erythrocyte Count (RBC Count, ×10^6/µL)	-0.35	0.020
Packed Cell Volume - Haematocrit (%)	-0.40	0.008
MCV (fL)	0.30	0.040
MCH (pg)	-0.45	0.003
MCHC (g/dL)	-0.37	0.015
RDW-CV (%)	0.50	0.001

Following regression analysis, the relationship between HbA1c and the chosen haematological variables was assessed. As shown in Table 3, a significant number of red blood cell indices were found to be associated with HbA1c.

Table 3. Regression Analysis of HbA1c with Haematological Parameters

Parameter	β-coefficient	Standard Error	p-value
Haemoglobin (g/dL)	-0.25	0.07	0.002
Erythrocyte Count (RBC Count, ×10^6/µL)	-0.20	0.08	0.015
Packed Cell Volume - Haematocrit (%)	-0.22	0.09	0.010
MCV (fL)	0.18	0.07	0.045
MCH (pg)	-0.28	0.06	0.001
MCHC (g/dL)	-0.19	0.08	0.030
RDW-CV (%)	0.33	0.05	<0.001

4.2. Indices-wise Data Analysis

Scatter diagrams showing the relationship between HbA1c and haemoglobin, haematocrit, and RDW-CV were developed to visually represent the findings obtained from the statistical tests. This figure (Figure 3) shows the nature of the relationships discovered.

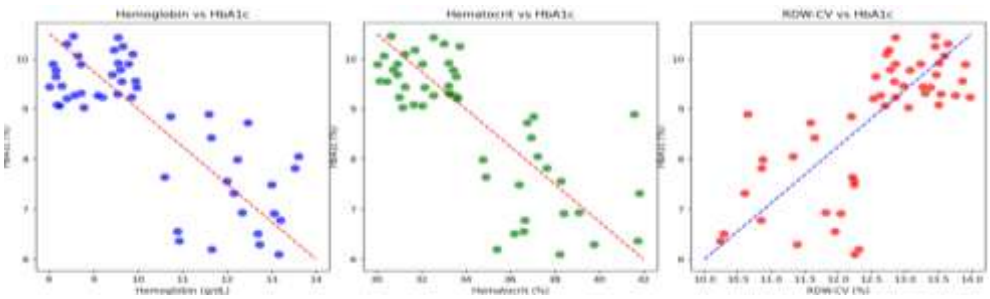

Figure 3. Scatter Plots Showing the Relationship of HbA1c with Haemoglobin, Haematocrit, and RDW-CV

The scatter plots have shown clear patterns of relationship between HbA1c and the haematological indicators chosen, which is in agreement with what was noted during the correlation test.

4.3. Correlation Heatmap

A correlation heatmap was constructed to offer a visual representation of the correlations between HbA1c and the examined red blood cells parameters. The heatmap (see Figure 4) allows one to compare the correlation patterns in all the variables involved in the study.

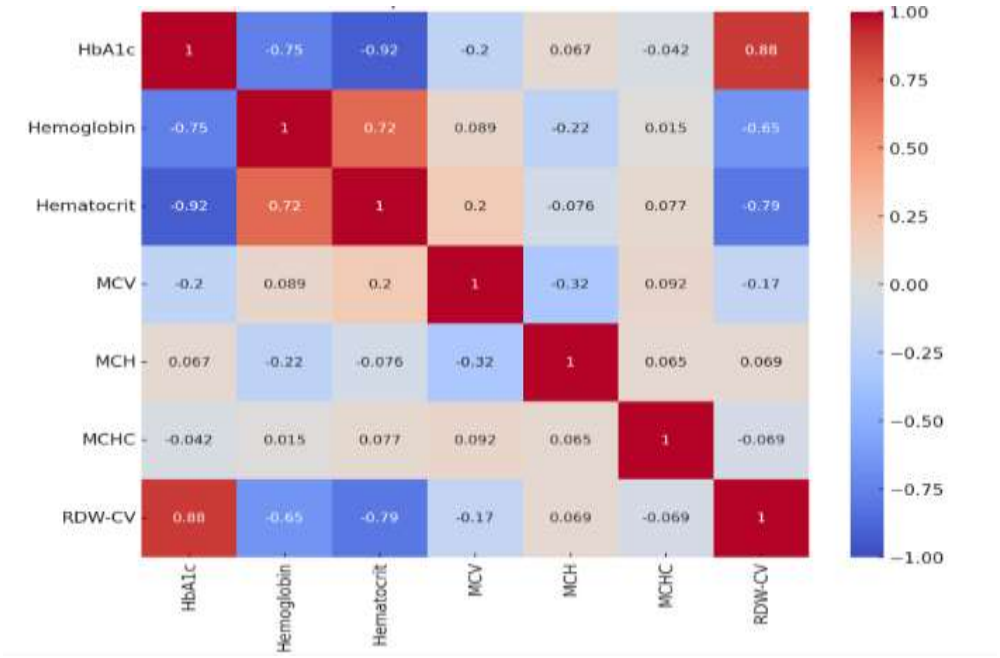

Figure 4. Correlation Heatmap of HbA1c and Red Blood Cell Indices

The above heatmap shows the correlation pattern of the study variables and serves as an aid to the results obtained via correlation and regression analysis.

5. DISCUSSION

This current study analyzed the association between Glycated haemoglobin (HbA1c) and some haematological parameters in patients with Type 2 Diabetes Mellitus (T2DM). Results showed a statistically significant correlation between HbA1c and various indices related to red blood cells. It was observed that there was a significant negative correlation between HbA1c and haemoglobin, erythrocyte count, and haematocrit. In addition, a negative correlation was noted between HbA1c and MCH and MCHC, whereas a positive correlation was observed between HbA1c and RDW-CV. These findings indicate a close relationship between red blood cell indices and glycaemic status in diabetic patients.

Another major result from the study is the existence of the inverse relationship between haemoglobin and HbA1c. According to the scatter plot analysis, patients whose HbA1c level falls within the interval of 9.0%-10.5% usually have higher levels of haemoglobin, which falls within the range of 8.0-10.0 g/dL while patients with lower HbA1c levels (6.0%-9.0%) exhibit variations in haemoglobin concentration. Such findings confirm the claim that lack of glycaemic control is associated with low haemoglobin levels. Similar conclusions were made by Kapoor & Sharma (2015) since they revealed an inverse relationship between the levels of haemoglobin and glycaemic control. In addition, Raj & Rajan (2013) and Rajpathak et al. (2009) have concluded that low levels of haemoglobin-related parameters are associated with poor glycaemic control. It has been proven that anaemia is a common co-morbid condition of T2DM and it is connected with insulin resistance and impaired oxygen-carrying capacity (Yeap et al., 2015). The results concerning the inverse relationship between haemoglobin and HbA1c are confirmed by the findings of Son (2019) and Misra et al. (2016).

The negative correlation between haemoglobin and HbA1c could be attributed to the oxidative stress, inflammation, and decreased erythropoiesis caused by hyperglycemia. Hyperglycemia can affect the erythrocytes' membranes, decrease their life span and cause anemia. In addition, diabetic nephropathy can affect the production of erythropoietin and decrease the amount of hemoglobin formation (Williams et al., 2023; Rafaqat & Rafaqat, 2023).

This trend was similarly observed in the case of haematocrit as well. It has been observed that there is a significant negative correlation between haematocrit and HbA1c, which was evident in the scatter diagram as well, owing to the fact that patients with higher HbA1c values were more likely to exhibit haematocrit values within the range of 30.0% to 34.0%. This finding provided an insight into the link between low glycaemic control and decreased haematocrit values, since low haematocrit levels can interfere with oxygen transport by the blood.

The decrease in haematocrit values of the diabetic patients with high HbA1c values can be attributed to some changes that occur at the level of erythrocytes. The effects of inflammation and other metabolic problems associated with diabetes on the erythrocytes' production and lifespan can lead to low haematocrit values and impaired microcirculation (Huth et al., 2015; Williams et al., 2023).

Moreover, the present study showed significant negative correlations between HbA1c and MCH and MCHC. Regression analysis also validated the results, showing significant negative relationships between the parameters and the level of HbA1c. As such, low content and concentration of haemoglobin in erythrocytes seem to be related to poor glycaemic control (Kapoor & Sharma, 2015; Misra et al., 2016).

It is possible that the state of poor glycaemic control affects negatively the quality of erythrocytes and haemoglobin synthesis in the red blood cells. The changes in MCH and MCHC can act as markers of metabolic dysfunction and erythrocyte malfunction in patients with T2DM. The same phenomenon has been observed in other studies concerning the link between metabolism of iron, haematological abnormalities and glycaemic control (Canturk et al., 2003; Sharifi & Sazandeh, 2004).

However, a high positive correlation was established between RDW-CV and HbA1c. In addition, RDW-CV became one of the strongest predictors in the regression analysis. As can be seen from the results of the scatterplot analysis, a higher percentage of patients had RDW-CV values of 12.5% to 14.0% with HbA1c of 9.0% to 10.5%. It is clear that the higher the HbA1c values were, the higher the RDW-CV values were. It means that the greater the heterogeneity of the erythrocyte size is, the worse the glycaemic control is. The obtained results confirm the assumption about the role of heterogeneous red blood cells in the development of metabolic abnormalities. Several previous studies showed a relationship between impaired glycaemic control, changes in haematology, and complications associated with diabetes (Misra et al., 2016; Son, 2019; Rafaqat & Rafaqat, 2023). Therefore, people with high RDW-CV are more likely to have such problems because of their poor glycaemic control.

The positive correlation between RDW-CV and HbA1c could be due to oxidative stress, inflammation, and changes in the maturation of erythrocytes as a result of poor diabetes control. The higher level of RDW-CV signifies the presence of increased variability in erythrocyte size which is possible due to the faster erythrocyte breakdown and production of immature red blood cells. It explains the use of RDW-CV as a marker for assessing the severity of the disease and metabolic disturbances in diabetic patients (Williams et al., 2023; Rafaqat & Rafaqat, 2023).

The correlation heatmap provided additional support for these conclusions. Haemoglobin and HbA1c had a negative correlation, as well as haematocrit and HbA1c. At the same time, there was a positive correlation between HbA1c and RDW-CV. All these observations correlated with the results of the correlation and regression analysis and scatter plot evaluation.

These results can also be supported by scientific studies examining iron metabolism and ferritin in T2DM patients. Increased ferritin level was always found to be related to worsened glycaemic control and high HbA1c level, proving disturbances of haematological and iron parameters to be related to development of diabetes (Batchuluun et al., 2014; Forouhi et al., 2007; Jehn et al., 2007; Arumugam et al., 2024). Such associations were also confirmed by Smotra and Kudyar (2008) in their paper on relations of iron changes and severity of Type 2 Diabetes Mellitus.

Overall, it can be concluded that there is a significant relation between different haematological parameters and HbA1c level in patients with T2DM. Indeed, haemoglobin, number of erythrocytes and haematocrit were found to correlate negatively with HbA1c level and be lower in T2DM patients with poor glycaemic control. The same thing is true for MCH and MCHC parameters which also prove that low haemoglobin level and poor erythrocytes quality are associated with worsened glycaemic control. On the contrary, RDW-CV showed positive correlation with HbA1c level, implying that increased variability in erythrocytes is associated with metabolic problems (Misra et al., 2016; Son, 2019).

One of the strengths of the current study is the simultaneous assessment of several RBC indices relative to HbA1c levels. Using correlation analysis, regression modeling, scatterplots, and heatmap was an effective way to analyze the association between glycaemic state and haematologic changes in patients with T2DM.

Another advantage of the findings obtained in the current study is their potential clinical significance. Assessment of haematological markers, including haemoglobin, haematocrit, MCH, MCHC, and RDW-CV, can be useful in terms of assessing the risk of developing diabetes-related complications because of their ability to reflect the state of glycaemia. Given the relatively low cost, availability, and frequency of conducting complete blood count tests, these indicators can be used as additional markers in the assessment of the progression of the disease and risk of developing diabetes complications (Misra et al., 2016; Son, 2019).

The results of the current study should be interpreted within the framework of some methodological flaws. Firstly, there was an insufficient number of participants; the study included 50 subjects. Moreover, there were examined only some selected haematological parameters; some other factors that affect glucose metabolism have not been considered. Additionally, due to the cross-sectional design, it is impossible to make any conclusions about cause-and-effect relationships between the parameters of interest. There were no assessed factors such as nutritional status, iron status, inflammation markers, renal function parameters, medications, and the duration of the disease. Further research, which would include these factors, might help to understand the relationship better.

Further research needs to be conducted on the predictiveness of haematological indicators in order to identify complications associated with Type 2 Diabetes Mellitus. More multicenter studies are needed to verify these results and prove that they can be used among other populations. Moreover, other researchers may examine the effect of various approaches of diabetes treatment on red blood cells indicators. In addition, such indicators can be used for the development of diagnostics methods for early detection of complications of T2DM.

6. CONCLUSION

This current study shows considerable evidence for a significant correlation between the red blood cell indices and glycaemic control in patients with T2DM. It was found that several haematological parameters such as haemoglobin, erythrocyte count, haematocrit, mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), and red cell distribution width-coefficient of variation (RDW-CV) correlate with the HbA1c values which are

used as an established measure of glycaemic control. Since there were negative correlations between haemoglobin, erythrocyte count, haematocrit, MCH, MCHC with HbA1c and positive correlations with RDW-CV, poor glycaemic control causes changes in red blood cells. These results underscore the clinical significance of assessing hematological parameters in T2DM patients. As complete blood count tests are affordable and easily obtainable and conducted in clinical practice, they might be valuable for identifying those patients who are at high risk of developing metabolic disorders and complications associated with diabetes mellitus. Their incorporation into the examination protocol will help clinicians to have a broader view of the patient's condition. However, the current results should be taken with reservations considering the limitations of the study. Thus, more research is needed to confirm these results and prove the usefulness of the red blood cell parameters in Type 2 Diabetes Mellitus.

FUNDING SOURCE
No funding was received for conducting this study.

ACKNOWLEDGEMENTS
I would like to express my profound gratitude and sincere appreciation to Dr. Pallavi, whose expert guidance, invaluable suggestions, constant encouragement, and unwavering support have been instrumental throughout the course of my Ph.D. research work. Her scholarly insights, constructive feedback, and mentorship have significantly contributed to the successful completion of this study.
I extend my heartfelt thanks to Amruthaahaar Clinic for granting me permission to conduct this research and for providing access to clients for interaction, assessment, and data collection. The opportunity to engage with participants in a real-world clinical setting greatly enriched the quality and relevance of this research.
Finally, I express my gratitude to all those who have directly or indirectly contributed to the successful completion of this PhD. research work.

Sridevi Yerroju
Ph.D. Research Scholar

CONFLICT OF INTEREST
The authors declared no conflict of interest.

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