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Original Research Article

# A Cross-Sectional Study on Association of HbA1c with Red Blood Cell Distribution Width in Patients with Type 2 Diabetes Mellitus

**Elavarasi Sivakumar[1], Ilham Jaleel[2], S. Veerapandian[3]**

[1]Associate Professor, Department of Physiology, Panimalar Medical College Hospital & Research Institute, Chennai, Tamil Nadu, India

[2]Associate Professor, Department of Physiology, Panimalar Medical College Hospital & Research Institute, Chennai, Tamil Nadu, India

[3]Tutor, Department of Physiology, Panimalar Medical College Hospital & Research Institute, Chennai, Tamil Nadu, India

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**Corresponding author: Dr. Elavarasi Sivakumar**

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**Abstract**

**Background:** In Type 2 Diabetes Mellitus, the progressive islets cell disorder has to be properly monitored & treated to avoid future complications. Monitoring is done mainly by a gold standard investigation namely HbA1c, which will reflect the average blood sugar for the past 2-3 months. Red blood cell, the highest count of all the cells in the body, functions to deliver oxygen mainly by hemoglobin present in it. Normal structure of red blood cell being discoid and biconcave, the red blood cell distribution width is considered as one of the blood indices which is calculated by standard deviation (SD) of mean corpuscular volume (MCV) divided by MCV multiplied by 100.

**Objectives:** To determine the association between HbA1c and RDW in patients with T2DM.

**Methods:** Type 2 DM patients attending the OPD were recruited. All demographic details, complete blood count with RDW and blood sugars were all tested along with HbA1c. Statistical analysis was carried out using Pearson correlation to assess the association between HbA1c and RDW.

**Results:** Mean HbA1c is around 9.69 ± 2.2%, and the mean for RDW is around 13.45 ± 1.6%. Pearson correlation analysis demonstrated a strong positive correlation between HbA1c and RDW ($p < 0.001$). Patients who are having higher HbA1c levels prone to manifest higher RDW values, pointing to declining erythrocyte size variability with poorer glycemic control.

**Conclusion:** RDW showed a positive correlation with HbA1c among patients with Type 2 Diabetes Mellitus. As RDW is a regular investigation in the list of complete blood count, it may serve as a latent marker locating patients who are under high risk of diabetic complications.

**Keywords:** Red cell distribution Width, Type 2 Diabetes Mellitus, HbA1c.

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## Introduction

Diabetes is one of the fastest growing public health problems worldwide. According to International Diabetes Federation (IDF) 2019, it is estimated that 463 million people have diabetes and this number is projected to reach 700 million by 2045. India is home to the second largest number (77 million) of adults with diabetes worldwide with 8.8% prevalence [1].

In Type 2 DM, the increasing islets cell disorder has to be properly treated and monitored treated to avoid future complications. Monitoring is done mainly by a gold standard investigation [2] namely HbA1c, which will say the reflection of blood sugar for the past 2-3 months. Red blood cell, a lifesaving, dynamic cell which is having the shape of discoid, biconcave structure functioning mainly to deliver oxygen to all the tissues in the body and to carry away the carbon dioxide from all the cells of the body. It is having a role in governing the viscosity of blood flow by changing their shape and fitting into the capillaries. RBC have the work of clearing the foreign particles, immune complexes, and also regulating the inflammatory responses [3].

Red blood cells metabolism which includes glycolysis, the reductase methemoglobin pathway and pentose monophosphate shunt pathway, helps them in energy production and maintaining the integrity of the cell [3]. It is very much essential in

maintaining overall health of the body. RDW is considered as one of the best and cheapest investigation performed as a part of complete blood count [3]. Red cell width distribution measures the difference in volume and size of the cells present. It is calculated by dividing the standard deviation of red blood cell volume by mean corpuscular volume and multiplying it by 100 to express the result as a percentage. Normal value of RDW is found to be less than or equal to 14.0% [4]. Normal RDW implies the uniformity of circulating red cells and there are no significant anisocytosis. Initially RDW is used to find out the differences in red cell sizes in anemias. Nowadays it is used to find out the inflammation in all the organs in the body and used to find out the oxidative stress also [5,11].

Type 2 DM, when uncontrolled, leads to excessive inflammation in all the systems including cardiovascular system, renal system thereby increases the stress over the circulating RBC, leading to non - enzymatic glycation of red cell membrane proteins, debilitate erythropoiesis, increase the membrane integrity that could possibly elevate the RDW value [6-8]. Many studies proved that high RDW is associated with all-cause mortality, cardiovascular risks & hypertension [9,10,12].

**Aim:** To study the association between HbA1c and RDW in patients with type 2 diabetes mellitus.

**Objectives:**

1. To estimate the mean HbA1c and RDW values among patients with T2DM.
2. To determine the correlation between HbA1c and RDW values.

**Materials and methodology:**

Institutional ethics committee approval obtained. This was a hospital-based, cross-sectional study conducted in the Department of General Medicine, with a known case of type 2 Diabetes mellitus patients, based on inclusion and exclusion criteria. Informed consent was obtained from every individual who participated in the study. Demographic details were collected. Blood sample obtained by venipuncture for Complete blood count, FBS, PPBS, HbA1c.

**Statistical Analysis:** All statistical analysis were performed using Statistical Package for Social Science (SPSS, version 20) for Microsoft windows. The data were not normally distributed. And therefore parametric / non-parametric tests were performed. Descriptive statistics were presented as numbers and percentages. The data were expressed as Mean and SD. Correlation coefficient / spearman's rank correlation was used for relation between two variables. For comparison of two groups, we used independent t test /Mann Whitney U test, A two-sided. p value < 0.05 was considered statistically significant.

**Results**

A total of 300 patients with type 2 diabetes mellitus were included in this cross-sectional study to evaluate the association of glycated hemoglobin (HbA1c) with red cell distribution width (RDW). The mean age of the study population was 58.46 ± 13.156 years. The mean HbA1c was 9.697 ± 2.2599%, and the mean RDW was 13.454 ± 1.6676%. The mean fasting blood sugar (FBS) and post-prandial blood sugar (PPBS) were 209.30 ± 42.931 mg/dl and 289.19 ± 47.194 mg/dl respectively (Table 1).

**Table 1: Descriptive statistics of study variables (N = 300)**

| Variable | Mean | Std. Deviation | N |
|---|---|---|---|
| **HbA1c (%)** | 9.697 | 2.2599 | 300 |
| **RDW (%)** | 13.454 | 1.6676 | 300 |
| **FBS (mg/dl)** | 209.30 | 42.931 | 300 |
| **PPBS (mg/dl)** | 289.19 | 47.194 | 300 |
| **Age (years)** | 58.46 | 13.156 | 300 |

**Correlation of HbA1c with Glycemic and Demographic Parameters:** On Pearson correlation analysis, HbA1c showed a statistically significant positive correlation with RDW ($r = 0.662$, $p < 0.001$), indicating that increasing RDW values were associated with poorer glycemic control. HbA1c also correlated strongly and positively with FBS ($r = 0.919$, $p < 0.001$) and PPBS ($r = 0.786$, $p < 0.001$). A weak but statistically significant negative correlation was observed between HbA1c and age ($r = -0.135$, $p = 0.019$). RDW similarly showed significant positive correlations with FBS ($r = 0.583$, $p < 0.001$) and PPBS ($r = 0.521$, $p < 0.001$), and a weak negative correlation with age ($r = -0.130$, $p = 0.025$) (Table 2).

**Table 2: Pearson correlation matrix between HbA1c, RDW, FBS, PPBS and age (N = 300)**

| Variable | HbA1c | RDW | FBS | PPBS | Age |
|---|---|---|---|---|---|
| **HbA1c** | 1 | 0.662** | 0.919** | 0.786** | -0.135* |
| **RDW** | 0.662** | 1 | 0.583** | 0.521** | -0.130* |
| **FBS** | 0.919** | 0.583** | 1 | 0.850** | -0.097 |
| **PPBS** | 0.786** | 0.521** | 0.850** | 1 | -0.078 |
| **Age** | -0.135* | -0.130* | -0.097 | -0.078 | 1 |

****Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).**

Since some of the study variables were not normally distributed, Spearman's rank correlation was additionally applied as a non-parametric measure of association. The Spearman analysis confirmed the pattern seen with Pearson correlation, with an even stronger correlation between HbA1c and RDW ($\rho = 0.852$, $p < 0.001$) (Table 3).

**Table 3: Spearman's rank correlation matrix between HbA1c, RDW, FBS, PPBS and age (N = 300)**

| Variable | HbA1c | RDW | FBS | PPBS | Age |
|---|---|---|---|---|---|
| **HbA1c** | 1.000 | 0.852** | 0.923** | 0.794** | -0.140* |
| **RDW** | 0.852** | 1.000 | 0.775** | 0.676** | -0.137* |
| **FBS** | 0.923** | 0.775** | 1.000 | 0.855** | -0.098 |
| **PPBS** | 0.794** | 0.676** | 0.855** | 1.000 | -0.071 |
| **Age** | -0.140* | -0.137* | -0.098 | -0.071 | 1.000 |

****Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).**

**Comparison of HbA1c and RDW between Genders:** Of the 300 patients, 148 (49.3%) were male and 152 (50.7%) were female. The mean HbA1c was comparable between male (9.649 ± 2.2423%) and female (9.743 ± 2.2834%) patients, and this difference was not statistically significant on independent samples t-test ($t = -0.363$, $df = 298$, $p = 0.717$). Similarly, the mean RDW did not differ significantly between males (13.515 ± 2.0213%) and females (13.394 ± 1.2337%) ($t = 0.627$, $df = 298$, $p = 0.531$) (Table 4).

The Mann-Whitney U test, applied as a non-parametric alternative, corroborated these findings, showing no significant gender-based difference in either HbA1c ($U = 10973.0$, $Z = -0.366$, $p = 0.714$) or RDW ($U = 11221.5$, $Z = -0.035$, $p = 0.972$) (Table 5).

**Table 4: Gender-wise comparison of HbA1c and RDW (Independent samples t-test)**

| Variable | Gender | Mean ± SD | t (df) | p-value | Sig. |
|---|---|---|---|---|---|
| **HbA1c** | Male (n=148) | 9.649 ± 2.2423 | -0.363 (298) | 0.717 | NS |
| | Female (n=152) | 9.743 ± 2.2834 | | | |
| **RDW** | Male (n=148) | 13.515 ± 2.0213 | 0.627 (298) | 0.531 | NS |
| | Female (n=152) | 13.394 ± 1.2337 | | | |

**NS = Not significant ($p > 0.05$); equal variances assumed (Levene's test $p > 0.05$ for both variables).**

**Table 5: Gender-wise comparison of HbA1c and RDW (Mann-Whitney U test)**

| Variable | Mean Rank (Male) | Mean Rank (Female) | Z | p-value |
|---|---|---|---|---|
| **HbA1c** | 148.64 | 152.31 | -0.366 | 0.714 |
| **RDW** | 150.32 | 150.67 | -0.035 | 0.972 |

**Gender-Stratified Correlation between HbA1c and RDW:** On sub-group analysis, the positive correlation between HbA1c and RDW persisted in both genders and remained highly statistically significant. Among male patients, Pearson correlation showed $r = 0.591$ ($p < 0.001$) and Spearman correlation showed $\rho = 0.875$ ($p < 0.001$). Among female patients, the correlation was stronger, with Pearson $r = 0.831$ ($p < 0.001$) and Spearman $\rho = 0.831$ ($p < 0.001$), suggesting that the association between HbA1c and RDW may be more pronounced in female patients with type 2 diabetes mellitus (Table 6).

**Table 6: Gender-stratified correlation between HbA1c and RDW**

| Gender | N | Pearson r | Spearman ρ | p-value |
|---|---|---|---|---|
| **Male** | 148 | 0.591** | 0.875** | < 0.001 |
| **Female** | 152 | 0.831** | 0.831** | < 0.001 |

****Correlation is significant at the 0.01 level (2-tailed).**

Overall, these results demonstrate a strong, statistically significant positive correlation between HbA1c and RDW in patients with type 2 diabetes mellitus, independent of gender, supporting the use of RDW as a potential adjunct marker of glycemic control.

## Discussion

This cross-sectional study of 300 type 2 diabetic patients says strongly that there is strong association between high RDW and high HbA1c values, evidence from both Pearson ($r = 0.662$, $p < 0.001$) and spearman correlation ($p=0.0852$, $p<0.001$). Previous studies say that there is positive correlation between HbA1C and RDW (2). From the present study findings, we can support RDW is, a test along with other complete blood count, as a best and cheap investigation which assess the glycemic status of an individual with type 2 DM. Comparing with the existing literature, another study also gives significant correlation between HbA1c and RDW along with mean platelet volume and other micro vascular complications in type 2 DM patients [10]

**Correlation with FBS, PPBS, and Age:** The strong correlations of HbA1c with FBS ($r = 0.919$) and PPBS ($r = 0.786$) in this study serve as an internal validation of the dataset, confirming that HbA1c tracked appropriately with concurrent glycemic parameters. The weak but significant inverse correlation between HbA1c and age ($r = -0.135$) may reflect either more aggressive glycemic control efforts or shorter disease duration in older patients in this study.

**Gender-Related Findings:** HbA1c and RDW did not differ significantly by gender on either parametric or non-parametric testing, indicating that glycemic control and red cell size variability were comparable between male and female patients in this study. However, the gender-stratified correlation analysis revealed a more pronounced HbA1c-RDW association in females (Pearson $r = 0.831$) than males ($r = 0.591$), despite similar Spearman correlations in both groups ($\rho = 0.875$ male, 0.831 female). This divergence between Pearson and Spearman coefficients in males suggests a monotonic but non-linear relationship in that subgroup, possibly influenced by outliers or a non-normal distribution of RDW values. The apparent sex difference in the strength of linear association warrants cautious interpretation given the moderate subgroup sizes ($n = 148$ and 152) and merits confirmation in larger, sex-stratified studies; hormonal influences on erythropoiesis and iron metabolism offer one plausible but unproven explanation. Possible pathophysiological mechanisms explain why chronic hyperglycemia changes the normal size of RBC. High glucose content in the blood will elevate non enzymatic glycation of RBC membrane proteins, modifying the membrane properties which is going ultimately end up with anisocytosis. Hyperglycemic driven oxidative stress to the RBC structure will change the shape and size of them. Thereby there will be increased fragility leading to excessive hemolysis reduced defense mechanism, reduces the life span and stimulate compensatory release of new and young reticulocytes into the circulation in excess leading to excess RDW. [11,12]

**Limitations:** Being a single centered study, will limit the generalizability of the finding. Several confounders were not assessed including iron deficiency and other nutritional deficiency, chronic kidney disease, recent blood transfusions can all interfere with red cell size and can widen the RDW, irrespective of glycemic status. Duration of diabetes, other complications of diabetes, reticulocyte count, and iron studies were not performed. Medication usage is not mentioned which can independently influence erythropoiesis.

## Conclusion

This study demonstrates a strong, statistically significant positive correlation between HbA1c and RDW in patients with type 2 diabetes mellitus, a relationship that persisted across both genders and was confirmed by both parametric and non-parametric statistical methods. RDW also correlated significantly with fasting and post-prandial blood glucose, further supporting its relevance as a marker of overall glycemic status. These findings suggest that RDW, an inexpensive and routinely available parameter of the complete blood count, may serve as a useful adjunct to HbA1c in monitoring glycemic control in patients with type 2 diabetes mellitus, particularly in settings where HbA1c testing is costly or not readily accessible. Given the cross-sectional nature of this study, prospective longitudinal studies are warranted to confirm the temporal relationship between glycemic deterioration and RDW elevation and to evaluate the incremental clinical value of incorporating RDW into routine diabetes monitoring protocols.

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