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Macro rheological and micro rheological parameters: Can they be used as early indicators of macro vascular and micro vascular complications in diabetes mellitus type II

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Abstract
Introduction & Background: Diabetes mellitus is one of the most common and complex metabolic disorders and it is characterized by disordered metabolism and abnormally high blood sugar (hyperglycaemia) resulting from either low insulin level or low insulin resistance in many body cells. It is a chronic illness characterized by macro vascular and micro vascular complications.
Aim: The aim of the study is to find out the effects and changes of various haemorrheological parameters in diabetes and the relationship between these parameters and HbA1c in Type II DM.
Materials and Methods: This was a retrospective study conducted on patients with Type II Diabetes Mellitus. The data of these diabetic patients were obtained from our Diabetic and Obesity Research Department, at Sree Balaji Medical College and Hospital, Chennai, Tamil, Nadu. For these included subjects, the various haematological and biochemical values were collected from our Laboratory Database using the Laboratory Information System. All the parameters studied under a complete hemogram namely haemoglobin, RBC count, Packed Cell Volume, Red cell distribution Width, Total WBC count, Differential count, Platelet count, Platelet indices were compared with the HbA1C values in this study subjects. The correlation graphs were designed using SPSS software version ----.
Results: It was observed that there was a significant correlation with Platelet Distribution Width and Mean Platelet Volume with the levels of fasting blood glucose and HbA1c.
None of the other parameters showed significant correlation.
Conclusion: Hence, to conclude, platelet indices could be used as a haemorheological early marker for advancement in the pathology of diabetes and hence its macro vascular complications like atherosclerosis and also micro vascular complications like coronary artery disease.

Keywords: HbA1c, haemorrheological parameters, PDW, MPV, MCHC, RDW

Introduction

Incidence of Diabetes mellitus is steadily on the rise and an estimated population of 300 million in the world will be diagnosed with the condition in 2025 [1].
The prevalence of type 2 diabetes is increasing worldwide and exhibits a challenge on the health care system as well as on the public health and socio-economic development of all nations [2].
Diabetes mellitus is a syndrome caused by deficiency of insulin or insulin resistance with its consequent changes in all tissues of the body. Diabetes patients are at a high risk of cardiovascular, renal and ophthalmic diseases compared to the normal age matched population.
Obesity is another major risk factor for diabetes, which is strongly suspected to develop diabetes. Glucose is an essential nutrient for proper functioning of the body cells.
In response to increase in glucose level in blood, insulin is released by the pancreas, eventually lowering the blood glucose and its transport to cells.
Insulin therefore acts as a regulator of glucose metabolism in the body.
Dysfunction of this auto-regulatory system results in lack of insulin and high blood glucose and thus leading to diabetic conditions.
Physicochemical changes in the red blood cells and platelets are significant in a patient with a diabetes compared to the normal population.
[3]Anaemia in patients with DM might contribute to the pathogenesis and progression of cardiovascular disease and aggravate diabetic nephropathy and retinopathy. [3]DM is the leading cause of end-stage renal disease and significant proportions of patients with DM develop renal complications. [4] Increased differential counts, including counts of eosinophils, neutrophils, and monocytes, also indicate the future incidence of coronary artery disease (CAD) (Majid M *et al*., 2004; Prentice RL *et al*., 1982 & Olivares R *et al*., 1993).
Fu–mei Chung *et al*, in 2005, showed that the white blood cells (WBC) might play a role in the development and progression of diabetic complications. Hyper-reactivity of platelets from T2DM patients is indicated by increased aggregation, greater fibrinogen binding, and thromboxane production [5].
Red cells of patients with type 2 diabetes are known to aggregate more readily than those of normal subjects. Red cell

aggregation is considered to be a primary cause of elevated WBV at low shear rates with respect to higher shear rates. For example, the WBV for a healthy person is approximately 20cP at a low shear rate of 1 s^{-1} and approximately 4 cP at a high shear rate of 300 s^{-1}.The five-fold increase in the WBV observed at the low shear is attributed to the effect of red cell aggregation. The erythrocyte aggregation is an important haemorrheological parameter because it directly affects WBV. [6] Platelets are involved in homeostatic process and have an important role in atherosclerosis and arterial thrombosis.

Aim

The aim of this study is evaluate a possible association between the various basic haematological and biochemical parameters and diabetes mellitus prognosis.

Materials and Methods

The study was done on 200 patients who are diagnosed as Type II DM in the Department of Pathology, Sree Balaji Medical College and Hospital, Tamil Nadu, over a period of 1 year. In all these patients, age, gender, their fasting and postprandial blood glucose values, HbA1c values, haematological parameters like Hemoglobin, RBC count, Hematocrit, MCV, MCH, MCHC, RDW, Total WBC count, Differential WBC count, platelet count, platelet indices like PDW, PCT, MPV were obtained.

In addition to this, their urea, creatinine, cholesterol/LDL ratio and cholesterol/Triglyceride ratio was obtained and compared with the blood glucose values and HbA1c values.

The patients are grouped into three categories based on the blood glucose values into those with isolated impaired fasting glucose IIFG (group I), impaired glucose tolerance IGT (group II) and diabetes mellitus DM (group III) based on the WHO 2006 criteria.

Table 1

Categories	Fasting glucose	2 hr post prandial glucose
diabetes	≥126	≥200
Impaired glucose tolerance	<126	140- 200
Impaired fasting glucose	110-125	<140

Also these parameters are evaluated in comparison with the HbA1c values and divided into two groups as Group I having HbA1C < 7 and Group II having HbA1c >7.

Results

This study was done on 200 patients in which 133 female and 67 male patients were taken. The mean age of study population was 53.7 years. The mean value of HbA1c was 7.11%.The highest value was 12% and lowest value was 4.8%.The mean FBG value was 162.12 mg/dl, the highest value was 495 mg/dl and the lowest value was 84 mg/dl. The mean value of PDW was 15.83, the highest value was 16.6 and the lowest value was 15.2.

The Pearson coefficient correlation was done to calculate the strength of association between the pairs of variables and to find out the correlation significance of HbA1c with all the blood parameters Hb, RBC count, WBC, PCV, MCV, MCHC, MCH, RDW, PDW, MPV etc., and t-tailed student's t-test was done to calculate the level of significance between the means. The P Value was taken highly significant at 0.01 and significant at 0.05.

The HbA1c correlation was found highly significant with Age, FBG, PDW, RDW, Urea and Creatinine and also significant with P-LCR and TLC in overall diabetic patients.

It was also observed that, in female patients, there was a significant correlation with HbA1c values and P-LCR and MPV compared to other parameters. This distinction in the correlation, significance was not observed in the male diabetics. But in male diabetics, it was observed that, MCHC correlated significantly with HbA1c values than other parameters.

Additionally, it was also observed that, HGB and ESR were found highly significant and HCT was found significant in Diabetic males but this significance in correlation with HbA1c values was not observed in female diabetics.

In this study, mild alterations in WBC indices were also observed in correlation with HbA1c values. Among all WBC Parameters, mainly lymphocytes, monocytes and basophils were found significant with HbA1c and there was no significance observed in neutrophils and eosinophils with HbA1c.It was also observed that, in female diabetics, lymphocytes were found highly significant and but there was no significance found with HbA1c in male diabetics. Whereas, in male diabetics, significant correlation was observed in monocytes with HbA1c, but there was no such significance found in female patients.

Discussion

Haemorrheological parameters in diabetes mellitus are often disturbed. The abnormalities associated with much of these parameters have been shown to markedly increase both plasma and whole blood viscosity. As blood viscosity determines blood flow resistance and microcirculation, increases in viscosity can lead to the development of micro vascular complications.

The present study shows significant changes in all erythrocyte indices in diabetic patients although there was no significant correlation with HbA1c was found. The mean values of RBC was 4.358, HCT was 35.76, HGB was 11.359 gm/dl, MCV was 82.295, MCH was 26.334, MCHC was 31.970, ESR was 31.538, RDW was 13.328.

HGB,ESR,RDW were found highly significant and HCT was found significant with HbA1c in diabetes males but not in females and no significant difference was observed in MCH and MCV between male and female diabetics, whereas MCHC was found highly significant with HbA1c in diabetic males and significant in females.

The study also included platelet indices in diabetic patients like MPV, PDW were increased significantly in diabetic patients and this was also found that P-LCR was significant with HbA1c.This is because MPV is an indicator for an increased platelet activity and thus thrombogenic activation, which may play a role in the development of vascular complications in type 2 diabetic patients [1, 2, 6, 12].

However the increase in MPV and P-LCR were highly significant in diabetic females and insignificant in diabetic males while reverse was true with RDW. In this study it was found that MPV and P-LCR were significantly higher in diabetic patients and were stronger in women and PDW was

found highly significant in both male and female diabetic patients and also all these were strongly correlated to fasting and postprandial glucose levels as well as HbA1c values.

Higher levels of HbA1c are found in people with persistently elevated blood sugar in DM. An association was suggested between MPV and increased risk of both myocardial and cerebral infarction [1]. So, as MPV is highly significant in females, they may be at high risk of both myocardial and cerebral infarction. Hence, MPV could be used as an early haemorheological predictor of the risk of cerebrovascular as well as cardiovascular events in DM.

It is established that insulin resistance is seen in the platelets like any other tissue in the body which leads to increase in the platelet volume and platelet hyperactivity with consequent thromboembolic and other vascular events in diabetic patients [1].

During hyperglycaemic states, the platelet size is elevated and consequent hyperactive platelets are produced. This leads to an increase in the mean platelet volume (MPV) which serves as a precursor in the pathogenesis of micro vascular complications in diabetes and atherosclerosis. (Sabiha Ashraf, 2015) [1]

Red cell parameters like PCV, Hb, RDW etc show significant changes in diabetic patients compared with normal persons. One of the studies done by (Subhashree A.R., 2014) [7] shows that RDW could be used as a pro-inflammatory state marker in diabetes.

In another study conducted by (Meisinger C *et al*, 2014) [2] conducted on 2963 patients, they found that significant association between the haematological parameters and blood glucose levels were marked in women compared to men.

(Hanan Mahmoud Fayed *et al*, 2013) [3] In their study on 100 patients of type II diabetes mellitus found that anaemia is significantly seen in these patients due to chronic kidney diseases these patients develop. This study highlighted that there is a significant negative correlation between the severity of the disease and haemoglobin, serum ferritin and uric acid levels. They also found a significant positive correlation between WBC counts and HbA1c values.

(Farah Jabeen *et al*, 2013) [12] in their study on 170 diabetic subjects, concluded that hyperglycaemia produces significant changes in the rheological properties of red blood cells like red cell deformability. Also, they stated that because of the insulin resistance seen in the diabetic subjects, there is an altered concentration of cholesterol and phospholipid in the red cell membranes which leads to amplified membrane lipid peroxidation and hence thrombogenesis with consequent micro vascular complications in diabetes mellitus.

These rheological properties of the RBCs can be studied using the basic haematological parameters like erythrocyte sedimentation rate which serves as a useful marker for prediction of complications earlier in DM.

(Robby kumar, 2012) [14] In his study found th*et al*terations in the lipid profile,

Cholesterol/phospholipid ratio is significant in the diabetic group compared to the normal population. He also stated that this elevation in the cholesterol levels alter the RBC deformability and hence the rheological properties of blood.

Our results and prior studies indicating that elevated MPV and PDW may be involved in development of vascular complications in known diabetic patients.

Table 2: Correlation of Red Cell Indices with HbA1c in Diabetic Patients

		AGE	Fasting Glucose	1#5 HR Post Prandial	HBA1C	urea	Creatinine	HB	RBC	HCT
AGE	Pearson Correlation	1	.281**	.398**	.460**	.146*	.384**	.075	.041	.104
	Sig. (2-tailed)		.000	.000	.000	.040	.000	.294	.562	.141
	N	200	200	200	200	200	200	200	200	200
Fasting Glucose	Pearson Correlation	.281**	1	.703**	.639**	.472**	.356**	.206**	.280**	.211**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.003	.000	.003
	N	200	200	200	200	200	200	200	200	200
1#5 HR Post Prandial	Pearson Correlation	.398**	.703**	1	.757**	.247**	.308**	.200**	.294**	.217**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.005	.000	.002
	N	200	200	200	200	200	200	200	200	200
HBA1C	Pearson Correlation	.460**	.639**	.757**	1	.362**	.379**	.047	.084	.040
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.511	.237	.574
	N	200	200	200	200	200	200	200	200	200
Urea	Pearson Correlation	.146*	.472**	.247**	.362**	1	.571**	.210**	.042	.206**
	Sig. (2-tailed)	.040	.000	.000	.000		.000	.003	.558	.003
	N	200	200	200	200	200	200	200	200	200
creatinine	Pearson Correlation	.384**	.356**	.308**	.379**	.571**	1	.199**	.131	.219**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.005	.064	.002
	N	200	200	200	200	200	200	200	200	200
HB	Pearson Correlation	-.075	.206**	.200**	.047	.210**	.199**	1	.471**	.955**
	Sig. (2-tailed)	.294	.003	.005	.511	.003	.005		.000	.000
	N	200	200	200	200	200	200	200	200	200
RBC	Pearson Correlation	-.041	.280**	.294**	.084	.042	.131	.471**	1	.654**

	Sig. (2-tailed)	.562	.000	.000	.237	.558	.064	.000		.000
	N	200	200	200	200	200	200	200	200	200
HCT	Pearson Correlation	-.104	.211**	.217**	.040	.206**	.219**	.955**	.654**	1
	Sig. (2-tailed)	.141	.003	.002	.574	.003	.002	.000	.000	
	N	200	200	200	200	200	200	200	200	200

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

Table 3: Correlation of Red Cell Indices with HbA1c in Diabetic Patients.

		AGE	Fasting Glucose	HBA1C	MCV	MCH	MCHC	ESR	RDW
age	Pearson Correlation	1	.281**	.460**	.073	.107	.075	.135	.125
	Sig. (2-tailed)		.000	.000	.307	.131	.294	.057	.078
	N	200	200	200	200	200	200	199	199
Fasting Glucose	Pearson Correlation	.281**	1	.639**	.038	.014	.147*	-.095	.295**
	Sig. (2-tailed)	.000		.000	.590	.840	.038	.182	.000
	N	200	200	200	200	200	200	199	199
HBA1C	Pearson Correlation	.460**	.639**	1	.061	.069	.039	.118	.201**
	Sig. (2-tailed)	.000	.000		.390	.331	.582	.096	.004
	N	200	200	200	200	200	200	199	199
MCV	Pearson Correlation	-.073	.038	.061	1	.972**	.654**	.153*	.495**
	Sig. (2-tailed)	.307	.590	.390		.000	.000	.031	.000
	N	200	200	200	200	200	200	199	199
MCH	Pearson Correlation	-.107	.014	.069	.972**	1	.772**	.230**	.588**
	Sig. (2-tailed)	.131	.840	.331	.000		.000	.001	.000
	N	200	200	200	200	200	200	199	199
MCHC	Pearson Correlation	-.075	.147*	.039	.654**	.772**	1	.388**	.622**
	Sig. (2-tailed)	.294	.038	.582	.000	.000		.000	.000
	N	200	200	200	200	200	200	199	199
ESR	Pearson Correlation	-.135	-.095	-.118	.153*	.230**	-.388**	1	.472**
	Sig. (2-tailed)	.057	.182	.096	.031	.001	.000		.000
	N	199	199	199	199	199	199	199	198
RDW	Pearson Correlation	.125	.295**	.201**	.495**	.588**	.622**	.472**	1
	Sig. (2-tailed)	.078	.000	.004	.000	.000	.000	.000	
	N	199	199	199	199	199	199	198	199

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

Table 4: Correlation of WBC Parameters with HbA1c in Diabetic patients

		AGE	Fasting Glucose	HBA1C	TLC	NEUT	LYMP	EOS	MONO	BASO
AGE	Pearson Correlation	1	.281**	.460**	.419**	.237**	.302**	.050	.114	.403**
	Sig. (2-tailed)		.000	.000	.000	.001	.000	.482	.109	.000
	N	200	200	200	200	200	200	200	200	200
Fasting Glucose	Pearson Correlation	.281**	1	.639**	.000	-.022	.212**	.090	.386**	.378**
	Sig. (2-tailed)	.000		.000	.998	.758	.003	.205	.000	.000
	N	200	200	200	200	200	200	200	200	200
HBA1C	Pearson Correlation	.460**	.639**	1	.154*	.098	.247**	.106	.207**	.317**
	Sig. (2-tailed)	.000	.000		.029	.166	.000	.133	.003	.000
	N	200	200	200	200	200	200	200	200	200
TLC	Pearson Correlation	.419**	.000	.154*	1	.548**	.275**	.420**	.355**	.082
	Sig. (2-tailed)	.000	.998	.029		.000	.000	.000	.000	.251
	N	200	200	200	200	200	200	200	200	200
NEUT	Pearson Correlation	.237**	.022	.098	.548**	1	.759**	.528**	.286**	.065
	Sig. (2-tailed)	.001	.758	.166	.000		.000	.000	.000	.364
	N	200	200	200	200	200	200	200	200	200
LYMP	Pearson Correlation	.302**	.212**	.247**	.275**	.759**	1	.110	-.141	.004
	Sig. (2-tailed)	.000	.003	.000	.000	.000		.120	.047	.957
	N	200	200	200	200	200	200	200	200	200
EOS	Pearson Correlation	-.050	-.090	.106	.420**	.528**	.110	1	.403**	.168*
	Sig. (2-tailed)	.482	.205	.133	.000	.000	.120		.000	.017
	N	200	200	200	200	200	200	200	200	200
MONO	Pearson Correlation	.114	.386**	.207**	.355**	.286**	.141*	.403**	1	.142*

	Sig. (2-tailed)	.109	.000	.003	.000	.000	.047	.000		.045
	N	200	200	200	200	200	200	200	200	200
BASO	Pearson Correlation	.403**	.378**	.317**	.082	.065	.004	.168*	.142*	1
	Sig. (2-tailed)	.000	.000	.000	.251	.364	.957	.017	.045	
	N	200	200	200	200	200	200	200	200	200

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

Table 5: Correlation of Platelet Indices with HbA1c in Diabetic Patients.

		AGE	Fasting Glucose	HBA1C	PLT	MPV	PDW	P-LCR
Age	Pearson Correlation	1	.281**	.460**	.402**	.249**	.401**	.229**
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.001
	N	200	200	200	200	200	200	200
Fasting glucose	Pearson Correlation	.281**	1	.639**	.187**	.226**	.332**	.001
	Sig. (2-tailed)	.000		.000	.008	.001	.000	.991
	N	200	200	200	200	200	200	200
HBA1C	Pearson Correlation	.460**	.639**	1	-.322**	.322**	.424**	.182*
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.010
	N	200	200	200	200	200	200	200
PLT	Pearson Correlation	.402**	.187**	.322**	1	.415**	.659**	.710**
	Sig. (2-tailed)	.000	.008	.000		.000	.000	.000
	N	200	200	200	200	200	200	200
MPV	Pearson Correlation	.249**	.226**	.322**	.415**	1	.654**	.195**
	Sig. (2-tailed)	.000	.001	.000	.000		.000	.006
	N	200	200	200	200	200	200	200
PDW	Pearson Correlation	.401**	.332**	.424**	.659**	.654**	1	.658**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000
	N	200	200	200	200	200	200	200
P-LCR	Pearson Correlation	.229**	.001	.182*	.710**	.195**	.658**	1
	Sig. (2-tailed)	.001	.991	.010	.000	.006	.000	
	N	200	200	200	200	200	200	200

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

Comparison of haematological parameters with HbA1c in female diabetics with male diabetics. (Table 5 and Table 6)

Table 6: Haematological parameters with HbA1c in female diabetic patients

		HBA1C	HB	MCHC	RDW	TLC	LYMP	MONO	PLT	MPV	PDW	P-LCR
HBA1C	Pearson Correlation	1	-.108	-.183*	-.011	-.137	.227**	-.139	-.322**	.536**	.474**	-.252**
	Sig. (2-tailed)		.215	.035	.897	.116	.009	.111	.000	.000	.000	.003
	N	133	133	133	132	133	133	133	133	133	133	133
HB	Pearson Correlation	-.108	1	.753**	-.725**	.048	-.156	-.146	-.409**	.106	.364**	-.331**
	Sig. (2-tailed)	.215		.000	.000	.581	.072	.093	.000	.227	.000	.000
	N	133	133	133	132	133	133	133	133	133	133	133
MCHC	Pearson Correlation	-.183*	.753**	1	-.731**	.046	-.269**	-.186*	-.476**	-.047	.211*	-.427**
	Sig. (2-tailed)	.035	.000		.000	.599	.002	.032	.000	.588	.015	.000
	N	133	133	133	132	133	133	133	133	133	133	133
RDW	Pearson Correlation	-.011	-.725**	-.731**	1	.255**	.117	.007	.535**	.094	-.304**	.575**
	Sig. (2-tailed)	.897	.000	.000		.003	.181	.938	.000	.284	.000	.000
	N	132	132	132	132	132	132	132	132	132	132	132
TLC	Pearson Correlation	-.137	.048	.046	.255**	1	-.448**	-.131	.494**	.107	-.326**	.559**
	Sig. (2-tailed)	.116	.581	.599	.003		.000	.132	.000	.221	.000	.000
	N	133	133	133	132	133	133	133	133	133	133	133
LYMP	Pearson Correlation	.227**	-.156	-.269**	.117	-.448**	1	.009	-.272**	.221*	.299**	-.153
	Sig. (2-tailed)	.009	.072	.002	.181	.000		.916	.002	.010	.000	.078
	N	133	133	133	132	133	133	133	133	133	133	133
MONO	Pearson Correlation	-.139	-.146	-.186*	.007	-.131	.009	1	-.045	-.058	-.010	.060
	Sig. (2-tailed)	.111	.093	.032	.938	.132	.916		.608	.504	.908	.493
	N	133	133	133	132	133	133	133	133	133	133	133
PLT	Pearson Correlation	-.322**	-.409**	-.476**	.535**	.494**	-.272**	-.045	1	-.295**	-.623**	.814**

	Sig. (2-tailed)	.000	.000	.000	.000	.000	.002	.608		.001	.000	.000
	N	133	133	133	132	133	133	133	133	133	133	133
MPV	Pearson Correlation	.536**	.106	-.047	.094	.107	.221*	-.058	-.295**	1	.686**	-.071
	Sig. (2-tailed)	.000	.227	.588	.284	.221	.010	.504	.001		.000	.415
	N	133	133	133	132	133	133	133	133	133	133	133
PDW	Pearson Correlation	.474**	.364**	.211*	-.304**	-.326**	.299**	-.010	-.623**	.686**	1	-.591**
	Sig. (2-tailed)	.000	.000	.015	.000	.000	.000	.908	.000	.000		.000
	N	133	133	133	132	133	133	133	133	133	133	133
P-LCR	Pearson Correlation	-.252**	-.331**	-.427**	.575**	.559**	-.153	.060	.814**	-.071	-.591**	1
	Sig. (2-tailed)	.003	.000	.000	.000	.000	.078	.493	.000	.415	.000	
	N	133	133	133	132	133	133	133	133	133	133	133

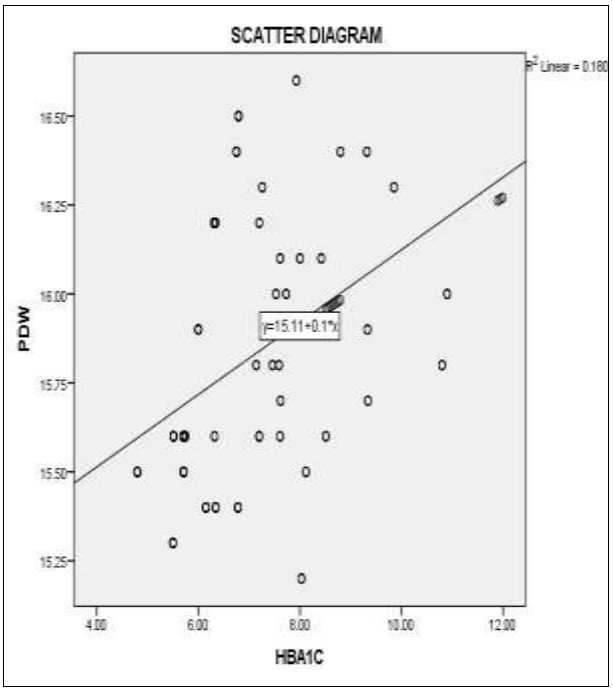
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. GENDER = F

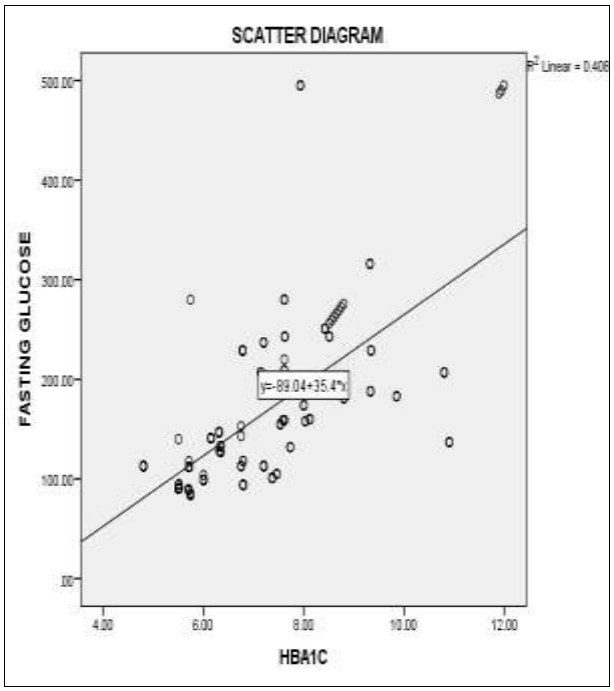
Table 7: Haematological parameters with HbA1c in male diabetic patients.

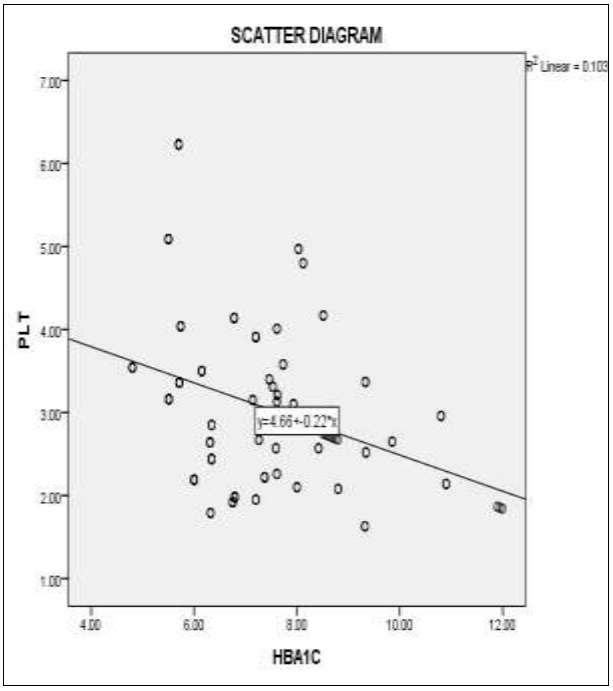
		HBA1C	HB	MCHC	RDW	TLC	LYMP	MONO	PLT	MPV	PDW	P-LCR
HBA1C	Pearson Correlation	1	.352**	.475**	-.357**	-.198	.238	-.272*	-.385**	.131	.525**	-.215
	Sig. (2-tailed)		.003	.000	.003	.108	.052	.026	.001	.289	.000	.080
	N	67	67	67	67	67	67	67	67	67	67	67
HB	Pearson Correlation	.352**	1	.404**	-.653**	-.412**	.052	.156	-.659**	.154	.404**	-.556**
	Sig. (2-tailed)	.003		.001	.000	.001	.679	.207	.000	.214	.001	.000
	N	67	67	67	67	67	67	67	67	67	67	67
MCHC	Pearson Correlation	.475**	.404**	1	-.679**	-.366**	.431**	.255*	-.542**	.019	.327**	-.198
	Sig. (2-tailed)	.000	.001		.000	.002	.000	.037	.000	.881	.007	.109
	N	67	67	67	67	67	67	67	67	67	67	67
RDW	Pearson Correlation	-.357**	-.653**	-.679**	1	.608**	-.156	-.310*	.831**	-.222	-.315**	.181
	Sig. (2-tailed)	.003	.000	.000		.000	.208	.011	.000	.071	.010	.144
	N	67	67	67	67	67	67	67	67	67	67	67
TLC	Pearson Correlation	-.198	-.412**	-.366**	.608**	1	-.095	-.641**	.806**	-.672**	-.605**	.417**
	Sig. (2-tailed)	.108	.001	.002	.000		.442	.000	.000	.000	.000	.000
	N	67	67	67	67	67	67	67	67	67	67	67
LYMP	Pearson Correlation	.238	.052	.431**	-.156	-.095	1	-.167	-.074	-.238	-.092	-.035
	Sig. (2-tailed)	.052	.679	.000	.208	.442		.177	.551	.052	.457	.777
	N	67	67	67	67	67	67	67	67	67	67	67
MONO	Pearson Correlation	-.272*	.156	.255*	-.310*	-.641**	-.167	1	-.506**	.517**	.496**	-.359**
	Sig. (2-tailed)	.026	.207	.037	.011	.000	.177		.000	.000	.000	.003
	N	67	67	67	67	67	67	67	67	67	67	67
PLT	Pearson Correlation	-.385**	-.659**	-.542**	.831**	.806**	-.074	-.506**	1	-.482**	-.690**	.606**
	Sig. (2-tailed)	.001	.000	.000	.000	.000	.551	.000		.000	.000	.000
	N	67	67	67	67	67	67	67	67	67	67	67
MPV	Pearson Correlation	.131	.154	.019	-.222	-.672**	-.238	.517**	-.482**	1	.525**	-.147
	Sig. (2-tailed)	.289	.214	.881	.071	.000	.052	.000	.000		.000	.234
	N	67	67	67	67	67	67	67	67	67	67	67
PDW	Pearson Correlation	.525**	.404**	.327**	-.315**	-.605**	-.092	.496**	-.690**	.525**	1	-.678**
	Sig. (2-tailed)	.000	.001	.007	.010	.000	.457	.000	.000	.000		.000
	N	67	67	67	67	67	67	67	67	67	67	67
P-LCR	Pearson Correlation	-.215	-.556**	-.198	.181	.417**	-.035	-.359**	.606**	-.147	-.678**	1
	Sig. (2-tailed)	.080	.000	.109	.144	.000	.777	.003	.000	.234	.000	
	N	67	67	67	67	67	67	67	67	67	67	67

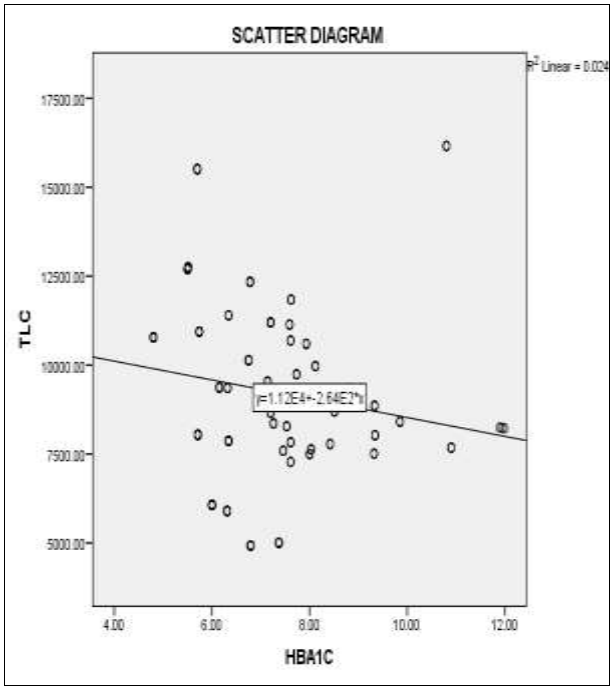
**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Gender = M

Scatter Diagrams of Haematological Parameters in correlation with HbA1c in diabetes patients

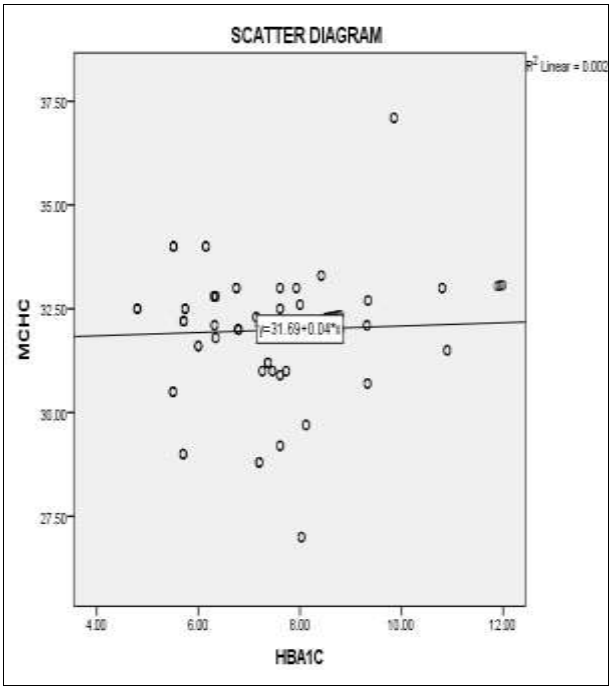


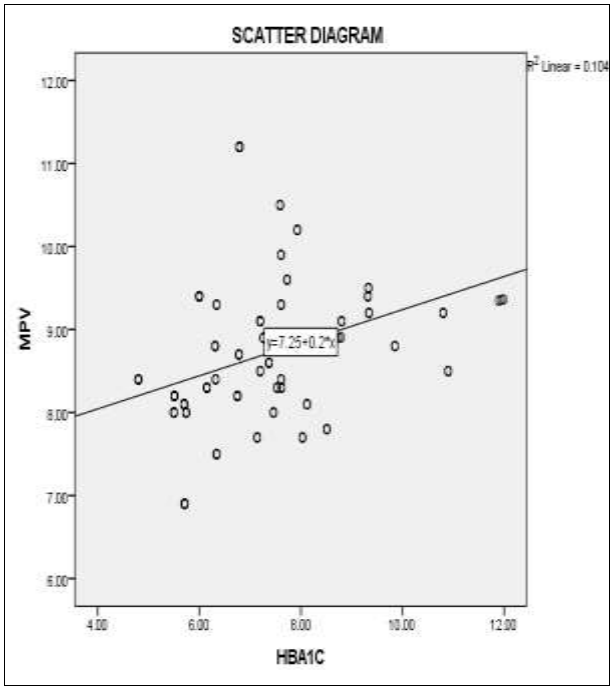


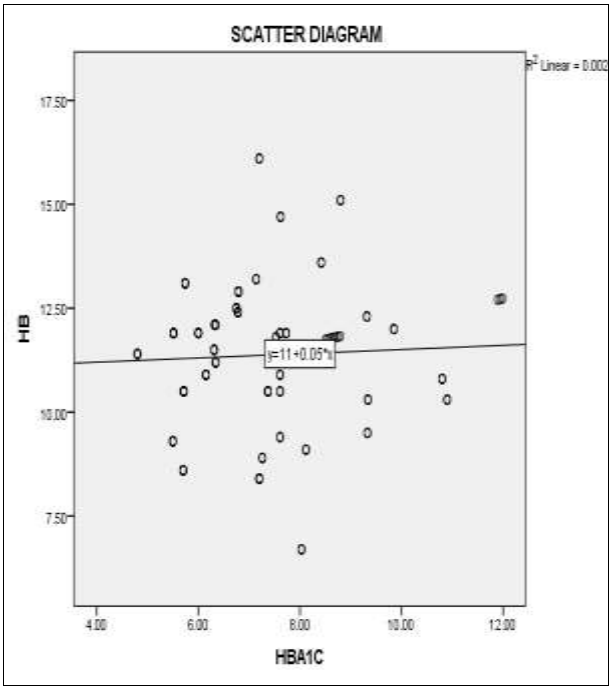


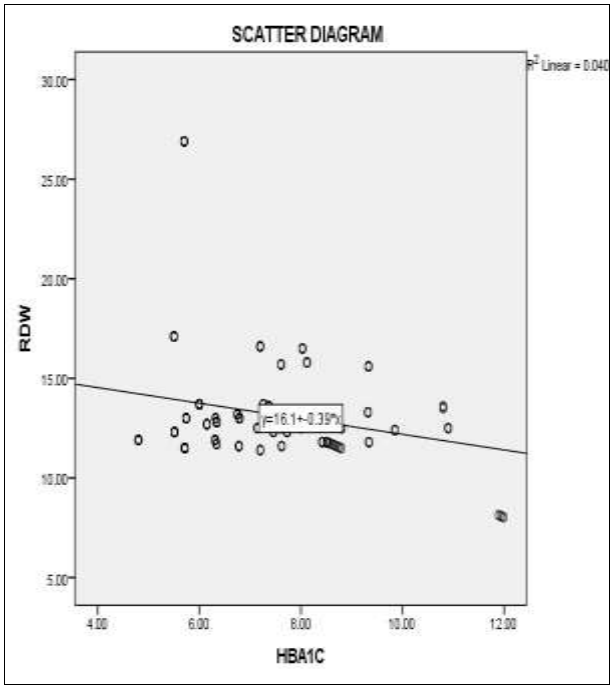


These scattered diagrams show PDW, PLT, FBG show highly significant with HbA1c in both females and male diabetic patients as values shown in Table 1,2,3,4.TLC also shows significant correlation with HbA1c in Overall diabetic patients.









In these scattered diagrams, HB and RDW show highly significant in male diabetics with HbA1c and insignificant in female patients and Reverse is true in MPV. MCHC was found significant in both females and male diabetics as values shown in Table 5 & 6.

Conclusion

This study indicates the usefulness of HbA1c, erythrocyte indices, WBC indices,

Platelet indices mainly PDW and MPV clinically and their values can be used as good haematological diagnostic markers, to predict and assess the risk of diabetes disease burden and possible risk factors that influence pre-diabetes.

By haematological method, we can find out the values of PDW MPV and all other haematological parameters, which is a simple, effortless and cost-effective method and that should be used extensively for predicting microvascular and macro vascular complications and also to predict impending acute cardiovascular attacks, cerebral attacks.

Hence, many indicators for progression of the disease are derived to assess the level of damage of the tissues thereby enabling the patients to have a good glycaemic control and hence preventing the complications.

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