International Journal of Academic Health and Medical Research (IJAHMR)
ISSN: 2643-9824
Vol. 8 Issue 6 June - 2024, Pages: 14-24

Hematological Parameters Alterations and Its Relationship with Cardiovascular Diseases Risk Factors among Type II Diabetes Mellitus Patients in Western Libya

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Abstract: Background: *Diabetes is a metabolic disorder characterized by hyperglycemia with impaired insulin secretion or a variable degree of insulin resistance. its complications are a major and growing public health problem around the world, involvement in a developing country like Libya. Dyslipidemia and derangement in various hematological parameters were observed among diabetes mellitus patients.* ***Objectives:*** *The study aimed to evaluate the alterations of haematological parameters, and find the correlation between fasting blood sugar (FBS), and Hemoglobin A1c (HbA1c) with body mass index (BMI), lipid profile, and haematological parameters among type 2 diabetes mellitus patients.* ***Methods:*** *The present study was conducted on 2**2**0 type 2 DM patients, attending Sabratha Teaching Hospital and Surman General Hospital for a routine health check-up and 110 normal healthy subjects without diabetes or any other diseases. All the participants were aged between 30–70 years**.** A blood sample of 5 ml was drawn by venous puncture from each participant. Blood samples were used for determination of CBC, HbA1c, levels of FBS, serum cholesterol, TG, HDL-C, LDL-C, and VLDL-C. Data were analyzed by independent t-test, chi-square Fisher exact test using the Statistical Package for the Social Sciences (SPSS) program for Windows, Version 25**.** **Results:** The results showed RBCs, and Platelets counts, Hb, and Hct were decreased significantly (P<0.01), while WBCs count, PDW and MPV were increased in diabetic patients compared with the healthy individual group. The mean FBS level and HbA1C value, the serum levels of cholesterol, triglycerides, LDL-C, VLDL-C, and LDL/HDL ratio were significantly (P<0.01) increased, whereas the serum levels of HDL-C was significantly (P<0.01) decreased in diabetic patients when compared with the controls.* ***Conclusion:*** *The results showed the diabetic patients had hyperglycemia, increased of HbA1C, dyslipidemia, and disturbance in haematological parameters. Further studies are needed to confirm these results.*

Keywords: Type II diabetic mellitus, HbA1C**,** Lipids profile, haematological parameters, Correlation.

1. Introduction

Diabetes mellitus (DM) has been defined as a metabolic disorder that interferes with a body's ability to efficiently turn food into energy (Alawaini, and Abugila, 2020). It causes hyperglycemia due to impaired insulin secretion by pancreatic beta cells and peripheral insulin resistance, which is accompanied by disturbed metabolism of fats, carbohydrates, and proteins and leads to serious complications (WHO, 2006, Kim *et al.*,2021). Diabetes mellitus and its complications are a major and growing public health problem around the world, involvement in a developing country like Libya (Ahmida *et al.*, 2015).

Kumar and Clark, 2002 reported that impaired glucose tolerance and impaired fasting glycemia are intermediate conditions between normality and diabetes. People with impaired fasting glycemia or impaired glucose tolerance are at high risk of developing type 2 diabetes.

Dyslipidemia is a common metabolic abnormality in diabetes mellitus. Diabetic dyslipidemia was characterized by a high level of plasma triglyceride, and low-density lipoprotein concentrations with a low level of high-density cholesterol due to reduced action of insulin at the tissue level or due to insulin resistance (Lberti *et al.*, 1997, Zafar *et al.*, 2016).

A significant derangement in various hematological parameters were observed among diabetes mellitus patients (Gkrania-Klotsas *et al.*, 2010, Mirza *et al.*, 2012, Mbata *et al.*, 2015, Biadgo *et al.*, 2016, Adane *et al.*, 2020). Ahad *et al.*, 2020 recorded that the hemoglobin levels in underweight and overweight groups were lower as compared to the normal BMI group. There is a negative correlation between hemoglobin concentration with BMI among individuals with abnormal BMI. Several studies indicated a controversial and contradictory relationship between RBC indices and anemia with lipid profile and BMI (Kohsari *et al.*, 2021).

2. Objectives

The evidence reporting the relationship between cardiovascular risk factors and haematological parameters among type 2 diabetes mellitus patients is hardly found. So, the study aimed to evaluate the alterations of haematological parameters, find the correlation between fasting blood sugar (FBS), and Hemoglobin A1c (HbA1c) with body mass index (BMI), lipid profile, and

haematological parameters among type 2 diabetes mellitus patients, and find the association between BMI, and lipid profile with hematological parameters among type 2 diabetes mellitus patients

3. Materials and Methods

3.1. Study design and population:

The present study was conducted on 220 type 2 DM patients, attending Sabratha Teaching Hospital and Surman General Hospital for a routine health check-up and 110 normal healthy subjects. To eliminate the effects of age and gender on the comparison between cases and control groups, age and gender were selected in each pair of groups as similar as possible. All the participants were residents of the surrounding areas in Sabratha and Surman and aged between 30–70 years.

Personal informations regarding DM were collected through interviews, using a structured questionnaire. All patients and normal participants were free from chronic degenerative diseases such as cancer or peritonitis.

3.2. Blood sampling

A blood sample of 5 ml was drawn by venous puncture from each normal healthy individual and DM patient. 2 ml of blood sample was collected in K, EDTA tubes for the haematological examinations. The haematological parameters (RBCs count, Hb, Hct, MCV, MCH, MCHC, WBCs count, differential count of WBCs, and Platelets count) were determined using an automated hematology analyzer Sysmex (K- 4500) machine and Hemoglobin A1c (HbA1c) using Cobas b 101 system. 3 ml of blood sample was collected in plain vials for biochemical tests. After clotting of blood in the plain vials, the serum was separated, within an hour; by centrifugation at 3000 - 5000 g for 5 min. The serum was used for measurements of the levels of serum glucose, total cholesterol, TG, HDL-C, LDL-C, and VLDL-C. Biochemical studies were measured by the ARCHITECTc 4000 apparatus.

3.3. Ethical approvals

Ethical approvals were obtained from Sabratha Teaching Hospital and Surman General Hospital as a point for sample collection and analysis. Informed consent was taken from all the participants before their inclusion in this study (Appendex.2).

3.4. Data analysis

Data analysis of blood parameters and lipid profiles of both healthy and DM patients had performed on a computer Excel sheath. Results were expressed as mean ± SD. Data were analyzed by independent t-test, chi-square Fisher exact test, Person and sperman correlation using the SPSS (Statistical Package for the Social Sciences) program for Windows, version 25. The differences between means ± SD were tested at $P<0.05$ and $P<0.01$. In all statistical tests, the probability level of P<0.05 was considered significant

4. Results

4.1. Mean RBCs count and its indices of healthy individuals and diabetic patients.

Data presented in table (4.1) shows that red blood corpuscles (RBCs) count and hemoglobin concentration, and hematocrit value were decreased significantly ($P<0.01$), 4.37 ± 0.03, 12.33 ± 0.07 & 37.38 ± 0.20 in diabetic patients compared to the healthy individual group (4.89 ± 0.04, 14.42 ± 0.10& 42.56 ± 0.42), respectively. But, MCV, MCH, and MCHC were non significantly changed in diabetic patients group compared with the healthy individual group.

Table . 1: Mean RBCs count and its indices of healthy individuals and diabetic patients.

Parameters \ Groups	Healthy Individuals Mean±SE	Diabetic Patients Mean±SE	*P-Value*
RBC ($x10^6$/µl)	4.89 ± 0.04	4.37 ± 0.03	0.000
Hb (g/dl)	14.07 ± 0.13	12.33 ± 0.07	0.000
Hct (%)	42.56 ± 0.42	37.38 ± 0.20	0.000
MCV (μm^3)	86.53 ± 0.91	85.89 ± 0.32	0.415
MCH (pg)	28.75 ± 0.23	28.39 ± 0.18	0.246
MCHC (g/dl)	33.42 ± 0.55	32.97 ± 0.08	0.252

4.2: Mean WBCs count and differential of healthy individuals and diabetic patients.

The results presented in table (2) showing white blood cell count, lymphocytes%, neutrophils%, and mixed% in healthy individuals and diabetic patients. White blood cells count in diabetic patients was significantly ($P<0.01$) increased, 7.80 ± 0.13 as compared with the healthy individual group (6.03 ± 0.09). But, lymphocytes%, neutrophils%, and mixed% in diabetic patients were in significantly ($P>0.05$) changed compared to the healthy individual group.

4.3: Mean platelets count, PDW, and MPV of healthy individuals and diabetic patients.

Data presents in table (3) shows platelets count, PDW, and MPV in healthy individuals and diabetic patients. Platelets count in diabetic patients was significantly ($P<0.05$) decreased, 252.30 ± 4.76, when compared to the healthy individual group (269.20 ± 6.77). On the other hand, PDW and MPV were significantly ($P<0.01$) increased (14.38 ± 0.17, 11.00 ± 0.08) in diabetic patients as compared with the healthy individual group (13.31 ± 0.21, 10.61 ± 0.10), respectively.

Table .2: Mean WBCs count and differential of healthy individuals and diabetic patients.

Groups / Parameters	Healthy Individuals Mean±SE	Diabetic Patients Mean±SE	*P-Value*
WBC ($x10^3$/µl)	6.03 ± 0.09	7.80 ± 0.13	0.000
LYM (%)	34.00 ± 0.70	33.97 ± 0.60	0.971
NEUT (%)	57.91 ± 0.85	57.59 ± 0.65	0.770
Mixed (%)	8.09 ± 0.39	8.44 ± 0.25	0.424

Table .3: Mean platelets count, PDW, and MPV of healthy individuals and diabetic patients.

Groups / Parameters	Healthy Individuals Mean±SE	Diabetic Patients Mean±SE	*P-Value*
PLT ($x10^3$/µl)	**269.20 ± 6.77**	**252.30 ± 4.76**	**0.042**
Platelet Distribution Width (PDW, fL)	**13.31 ± 0.21**	**14.38 ± 0.17**	**0.000**
MPV (fl)	**10.61 ± 0.10**	**11.00 ± 0.08**	**0.003**

4.4. Mean fasting blood sugar level and haemoglobin A1C value of healthy individuals and diabetic patients.

The results obtained in table (4) showed that the mean fasting blood sugar level and haemoglobin A1C value in diabetic patients group were significantly increased ($P<0.01$) (176.56 ± 5.5 g/dl& 8.48 ± 0.13%) when compared with the healthy individuals group recoding (86.78 ± 0.82 g/dl& 5.46 ± 0.03%) , respectively.

Table .4: Mean fasting blood sugar level and haemoglobin A1C value of healthy individuals and diabetic patients.

Groups / Parameters	Healthy Individuals Mean±SE	Diabetic Patients Mean±SE	P-Value
F.B.S (g/dl)	86.78 ± 0.82	176.56 ± 5.54	0.000
HbA1C (%)	5.46 ± 0.03	8.48 ± 0.13	0.000

4.5. Mean serum levels of cholesterol, triglycerides, HDL-C, LDL-C, VLDL -C and LDL/HDL of healthy individuals and diabetic patients.

Data in table (5) showed a significant ($P<0.01$) increase in the serum levels of cholesterol, triglycerides, LDL-C, VLDL-C and LDL/HDL ratio in diabetic patients, (218.71 ± 2.22, 253.97 ± 7.16, 137.00 ± 1.80, 3.49 ± 0.06 & 51.16 ± 1.46) compared with the healthy individuals (151.73 ± 2.08, 84.78 ± 4.22, 84.34 ± 1.74, 1.90 ± 0.05& 20.56 ± 1.27), respectively. Conversely, the serum levels of HDL-C was significantly ($P<0.01$) decreased in diabetic patients as compared with the healthy individuals.

Table .5: Mean serum levels of cholesterol, triglycerides, HDL-C, LDL-C, VLDL-C and LDL/HDL of healthy individuals and diabetic patients.

Groups / Parameters	Healthy Individuals Mean±SE	Diabetic Patients Mean±SE	P-Value

Cholesterol (mg/dl)	151.73 ± 2.08	218.71 ± 2.22	0.000
TG (mg/dl)	84.78 ± 4.22	253.97 ± 7.16	0.000
HDL-C (mg/dl)	45.71 ± 0.76	39.85 ± 0.45	0.000
LDL-C (mg/dl)	84.34 ± 1.74	137.00 ± 1.80	0.000
VLDL-C (mg/dl)	1.90 ± 0.05	3.49 ± 0.06	0.000
LDL/HDL	20.56 ± 1.27	51.16 ± 1.46	0.000

4.6. Correlation between fasting blood sugar and hemoglobin A1C with hematological parameters

Table (6) illustrated that a significant positive correlation was observed between fasting blood sugar with WBCs count, neutrophils %, lymphocytes %, and MPV at (*P<0.01*), and with PDW at (*P<0.05*) (r=0.297, 0.266, 0.215, 0.180 & 0.169, respectively). While, a significant negative correlation was observed between fasting blood sugar with platelets count and RDW at (*P<0.01*), and with RBCs count, Hb concentration, and Hct value at (*P<0.05*) (r= -0.232,-0.239, -0.213, -0.207& -0.126, respectively).

Also, the same table showed that a significant positive correlation was observed between hemoglobin A1C with WBCs count, neutrophils %, lymphocytes %, and PDW at (*P<0.01*), and with MCHC and MPV at (*P<0.05*) (r= 0.331, 0.319, 0.236, 0.174, 0.205& 0.150, respectively). In contrast, a significant negative correlation was observed between fasting blood sugar with Hb concentration, platelets count and RDW at (*P<0.01*), and with RBCs count, and Hct value at (*P<0.05*) (r = -0.174, -0.252, -0.260, -0.168 & -0.146, respectively) (Table .6).

Table . 6: Correlation between fasting blood sugar and hemoglobin A1C with hematological parameters in diabetic patients.

Correlation with Parameters	Fasting Blood Sugar		HbA1C	
	Correlation Coefficient	P Value	Correlation Coefficient	P Value
RBCs	-0.213*	0.025	-0.168*	0.011
Hb	-0.207*	0.030	-0.174**	0.008
Hct	-0.126*	0.029	-0.146*	0.027
MCV	-0.070	0.466	-0.156	0.103
MCH	0.019	0.841	0.007	0.942
MCHC	0.127	0.185	0.205*	0.031
WBCs	0.297**	0.000	0.331**	0.000
NEUT	0.266**	0.000	0.319**	0.000
LYM	0.215**	0.001	0.236**	0.000
PLT	-0.232**	0.004	-0.252**	0.000
RDW	-0.239**	0.000	-0.260**	0.000
PDW	0.169*	0.012	0.174**	0.010
MPV	0.180**	0.007	0.150*	0.026

*: Significant correlation at *P<0.05*; **: Significant correlation at *P<0.01*

4.7. Correlation between fasting blood sugar and hemoglobin A1C with lipids profile, hemoglobin A1C, and BMI

Data in table (7) showed that a significant positive correlation was observed between fasting blood sugar with the serum levels of triglycerides, LDL-C, VLDL-C, HbA1C, and BMI at (*P<0.01*), and with the serum cholesterol level at (*P<0.05*) (r= 0.289, 0.233,0.567, 0.216 & 0.233, respectively). Conversely, a significant negative correlation was observed between fasting blood sugar with HDL-C at (*P<0.05*) (r=-0.228).

Also, the data obtained in table (7) showed that a significant positive correlation was observed between hemoglobin A1C with the serum levels of triglycerides, LDL-C and BMI at (*P<0.01*), and with the serum levels of cholesterol and VLDL-C at (*P<0.05*) (r= 0.254, 0.314, 0.224, 0.217& 0.236, respectively) . Whereas, a significant negative correlation was observed between hemoglobin A1C with HDL-C at (*P<0.05*) (r=-0.232).

Table.7: Correlation between fasting blood sugar and hemoglobin A1C with lipids profile, hemoglobin A1C, and BMI in diabetic patients.

Correlation with	Fasting Blood Sugar		HbA1C	
Parameters	Correlation Coefficient	P Value	Correlation Coefficient	P Value
Cholestrol	0.233*	0.013	0.217*	0.021
TG	0.238**	0.002	0.254**	0.000
HDL -C	-0.228*	0.017	-0.232*	0.011
LDL-C	0.289**	0.000	0.314**	0.000
VLDL-C	0.233*	0.016	0.236*	0.01
HbA1C	0.567**	0.000	-	-
BMI	0.216**	0.003	0.224**	0.002

*: Significant correlation at *P<0.05*; **: Significant correlation at *P<0.01*

4.8. Correlation between fasting blood sugar and hemoglobin A1C with health problems, period of DM, and family history

A significant positive correlation was recorded between fasting blood sugar and hemoglobin A1C with the duration periods of diabetes, and types of treatment at (*P<0.01*) and family history of diabetes and health problems at (*P<0.05*) (Table. 8).

Table. 4.8. Correlation between fasting blood sugar and hemoglobin A1C with health problems, period of DM, and family history in diabetic patients.

Correlation with	Fasting Blood Sugar		HbA1C	
Parameters	Correlation Coefficient	*P- Value*	Correlation Coefficient	*P- Value*
Health Problems	0.137*	0.042	0.166*	0.014
Period of DM	0.194**	0.004	0.320**	0.000
Family History	0.148*	0.029	0.155*	0.022
Type of Treatment	0.202**	0.003	0.371**	0.000

*: Significant correlation at *P<0.05*; **: Significant correlation at *P<0.01*

4. 9. Correlation between lipids profile with haematological parameters

Data in table (9) showed that a significant positive correlation was observed between the serum cholesterol concentration with Hct value and Lymphocyes % at (P < 0.01), and hemoglobin concentration at (P < 0.05) (r = 0.204, 0.222 & 0.140, respectively). On the other hand, a significant negative correlation was observed between the serum cholesterol concentration with MCV, WBCs, and platelets count at (*P<0.01*), and with neutrophils % at (*P<0.05*) (r = -0.501, -0.522, -0.471 & -0.161, respectively)

A significant positive correlation was observed between the serum triglycerides concentration with WBCs count at (*P<0.01*), and with lymphocytes % at (*P<0.05*) (r = 0.514 & 0.168, respectively). Conversely, a significant negative correlation was observed between the serum triglycerides concentration with, MCV at (*P<0.01*), and with Hb concentration at (*P<0.05*) (r = -0.589 & -0.134, respectively) (Table .9).

Table.9: Correlation between lipids profile with haematological parameters in diabetic patients.

	Cholestrol		TG		HDL-C		LDL -C		VLDL -C	
	Correlation Coefficient	*P-Value*	Correlation Coefficient	*P-Value*	Correlation Coefficient	*P-Value*	Correlation Coefficient	*P-Value*	Correlation Coefficient	*P-Value*
RBCs	-0.119	0.079	0.086	0.206	0.206**	0.002	-0.180**	0.007	0.084	0.222
Hb	0.140*	0.039	-0.134*	0.019	0.321**	0.000	-0.183**	0.007	-0.015	0.828
HCT	0.204**	0.002	-0.015	0.825	0.226**	0.001	-0.225**	0.001	-0.010	0.888
MCV	-0.501**	0.000	-0.589**	0.000	-0.226**	0.001	-0.062	0.362	-0.108	0.115

MCH	0.017	0.797	-0.589	0.00	0.066	0.329	0.030	0.656	-0.094	0.170
MCHC	-0.100	0.138	0.034	0.613	-0.169*	0.012	-0.047	0.490	0.027	0.693
WBCs	-0.522**	0.002	0.514**	0.003	-0.533**	0.002	-0.790**	0.000	0.724**	0.000
LYM %	0.222**	0.001	0.168*	0.013	-0.554**	0.001	0.216**	0.001	0.174*	0.011
NEUT %	-0.161*	0.017	0.102	0.133	0.481**	0.004	-0.164*	0.015	-0.115	0.093
PLT	-0.471**	0.001	-0.064	0.347	-0.442**	0.002	-0.083	0.219	-0.054	0.430
RDW	0.061	0.368	-0.105	0.120	0.286**	0.000	-0.016	0.818	-0.067	0.326
PDW	-0.001	0.994	-0.035	0.610	0.042	0.532	0.017	0.799	-0.038	0.576
MPV	-0.031	0.653	-0.056	0.411	0.035	0.609	-0.012	0.855	-0.062	0.367

*: Significant correlation at *P<0.05*; **: Significant correlation at *P<0.01*

4.10. Correlation between health problems, period of DM, family history, and BMI with haematological parameters in diabetic patients.

The health problems were a significant (*P*<0.05) (r = 0.137) positive correlation with Hct value (Table .10).

The family history was a significantly positive correlated with Hb concentration and MCH at (*P<0.*05) (r = 0.139 & 0.144, respectively), while, a negative correlation with platelets count and RDW at (*P<0.05*) (r = -0.132 & -0.148, respectively) (Table .10).

The body mass index was a positive correlated significantly with RDW at (*P<0.0*1), and with platelets count and at (*P<0.05*) (r =0.177 & 0.151, respectively), but, a negatively correlated with MCHC at (*P < 0.01*) (r = -0.195) (Table .10).

Table. 10: Correlation between health problems, period of DM, family history, and BMI with haematological parameters in diabetic patients.

	Health Problems		**Period of DM**		**Family History**		**BMI**	
	Correlation Coefficient	***P-Value***	**Correlation Coefficient**	***P-Value***	**Correlation Coefficient**	***P-Value***	**Correlation Coefficient**	***P-Value***
RBCs	0.124	0.066	-0.097	0.152	0.048	0.483	-0.017	0.798
Hb	0.126	0.062	-0.077	0.256	0.139*	0.040	-0.083	0.223
HCT	0.137*	0.042	-0.099	0.145	0.119	0.079	-0.013	0.847
MCV	-0.005	0.943	0.021	0.755	0.108	0.110	0.029	0.670
MCH	0.041	0.546	0.016	0.817	0.144*	0.033	-0.078	0.248
MCHC	-0.004	0.958	0.019	0.782	0.119	0.078	-0.195**	0.004
WBCs	-0.022	0.742	0.096	0.158	-0.095	0.162	0.125	0.064
LYM %	-0.036	0.593	0.027	0.694	0.025	0.712	-0.012	0.858
NEUT %	0.080	0.239	-0.055	0.418	-0.053	0.433	0.041	0.541
PLT	-0.108	0.111	0.048	0.477	-0.132*	0.050	0.151*	0.025
RDW	-0.100	0.138	0.031	0.653	-0.148*	0.028	0.177**	0.009
PDW	-0.079	0.241	0.063	0.351	-0.034	0.612	0.005	0.943
MPV	-0.026	0.703	0.032	0.643	-0.077	0.256	0.125	0.064

*: Significant correlation at *P<0.05*; **: Significant correlation at *P<0.01*

5. Discussion

Diabetes mellitus is a combination of heterogeneous disorders commonly presenting with episodes of hyperglycemia and glucose intolerance, as a result of lack of insulin, defective insulin action, or both (Sicree et al., 2006).

The current study showed that a significantly (*P<0.01*) increased in fasting blood sugar and HbA1c in diabetic patients compared to the healthy individuals. These results are run parallel to the results obtained by Azab *et al.,* 2020 who reported that diabetic patients had a significant (*P<0.01*) increase in fasting blood sugar and HbA1c when compared with controls. Also, Satti *et al.,* 2017 reported that levels of glucose, hemoglobin A1c (HbA1c) were increased among uncontrolled T2DM in Sudan.

Patients with type 2 diabetes have an increased prevalence of dyslipidemia, which contributes to their high risk of cardiovascular diseases (Shaik *et al.,* 2022).

The current study showed that serum levels of total cholesterol, triglycerides, LDL, V LDL, and LDL/HDL ratio were significantly (*P<0.01*) increased and HDL concentration was a significant *P<0.01*) decreased in diabetic patients compared with the healthy individuals. These results are similar to the results of Azab *et al.,* 2020 who recorded that the diabetic patients had a significant (*P<0.01*) increase in serum total cholesterol and LDL as compared with the controls. Also, Alam *et al.,*2015 reported that 33% of diabetic patients had abnormal serum cholesterol levels. For this reason, if diabetes subjects are long-time suffering from hyperlipidemia then cardiovascular risk factors and macrovascular complications increase to an alarming level. On the other hand, Azab *et al.,* 2020 reported that there were a non-significant changes recorded in serum triglycerides and VLDL-C concentrations in diabetic patients when compared to the controls.

The function of the pancreatic β-cells may also be compromised after long-term exposure to free fatty acids, leading to increased predisposition to T2DM. Increased hepatic free fatty acids contribute to the increased hepatic synthesis of triglycerides, which in turn results in elevated concentrations of very LDL particles. As a consequence, the characteristic hypertriglyceridemia and possible fatty liver emerge, a common finding in patients with insulin resistance. Afterward, various lipases contribute to the remodeling of VLDL-C to small, dense LDL-C particles. Also, cholesteryl ester transfer protein (CETP) exchanges TG from VLDL to cholesterol found in HDL-C and LDL-C, leading to cholesterol-rich atherogenic VLDL-C particles. HDL particles that undergo these modifications are cleared more readily by the kidney, resulting in lower HDL-C levels. The more TG-rich LDL particles undergo metabolism by lipases, again resulting in small, dense LDL-C particles that exhibit increased atherogenicity (Kalofoutis *et al.,* 2007, Azab *et al.,* 2020).

A similar correlation has been reported by several other studies (Sacks, 2007 and Ozder, 2014, Hussain *et al.,* 2017, Satti *et al.,* 2017, Alzahrani *et al.,* 2019) that found a positive relationship between HbA1c and high triglycerides levels, in agreement with the present study. Alzahrani *et al.,* 2019 found that a significant serum blood glucose concentration and increased HbA1c. correlation between HbA1c with triglycerides in T2DM patients. This finding indicates that HbA1c is a direct indicator of increased TG and indirectly helps in assessing the risk for macro- and microvascular problems (Hussain *et al.,* 2017 , Naqvi *et al.,* 2017, Alzahrani *et al.,* 2019).

On the other hand, a study reported no correlation between HbA1c and triglycerides (Sarkar and Meshram, 2017). Alzahrani *et al.,* 2019 found that a non significant correlation between HbA1c with BMI, triglycerides, HDL-C, and LDL-C in T2DM patients. In addition, Shaik *et al.,* 2022 reported that HbA1c has a significant correlation with triglyceride, total cholesterol, LDL-*C*, and VLDL-*C* among the lipid profile.

The present study found no relationship between HbA1c and TC or LDL-C. Our results are consistent with another study also reporting no significant relationship between these parameters (Sarkar and Meshram, 2017). However, these results are inconsistent with the results of numerous other studies that have stated a significant relationship between HbA1c and TC and LDL-C (Deshmukh *et al*., 2015, Hussain *et al.,* 2017, Kundu *et al*., 2017).

The present results show a statistically non-significant negative link between HbA1c and HDL-C. This is in agreement with the results from a few other studies (1,9) but is inconsistent with several studies that reported a notable.. negative relationship between HbA1c and HDL-C (Deshmukh *et al*., 2015, Samdani *et al*., 2017, Sarkar and Meshram, 2017). Hussain *et al.,* 2017 reported that HbA1c could be a predictor of TC,TG, and LDL-C. HbA1c, which is among the tests used in the diagnosis and monitoring of diabetic patients, provides information about the amount of glucose in the blood over the last three months. It is the basic marker for determining long-term glucose levels in diabetic patients (Baker *et al.,*1984, American Diabetes Association , 2003, Sacks *et al.,* 2011), which is consistent with Sacks, 2007 and Alboueishi *et al.,* 2021 were recorded that a significant positive correlation between HbA1c and FBS. Also, a previous studies in Libya (Aghil *et al.,* 2017), Saudi Arabia (Alouffi *et al.,* 2017), Afghanistan (Hussain *et al.,* 2017), and Iran (Arab *et al.,* 2018), were showed that a highly significant direct correlation between FBS and HbA1c. Metcalf *et al* , 2017 reported that HbA1c may be useful as a diagnostic test for diabetes such.

Alboueishi *et al.,* 2021 mentioned that HbA1c had a significant direct relationship with total cholesterol (r = 0.223, p = 0.000), triglycerides, and LDL (r = 0.104, p =0.67) (r = 0.240, p =0.000) but not with HDL (r = 0.88, p = 0.123). In a study by Arab *et al.,* 2018, HbA1c had a significant positive correlation with total cholesterol, triglycerides, and LDL and HDL levels. These results suggest that the relationship between HbA1c level and serum lipids of patients with type 2 diabetes may be a suitable predictor of CVD in these patients (Naeem *et al.,* 2015). In Oman, Al-Alawi, 2014 reported a correlation between improved dyslipidemia and HbA1c Control. As Hyperlipidemia has been associated with the development of CVD, dyslipidemia is likely to be but one of many reasons for the accelerated macro vascular disease in diabetic patients. Nonetheless, treatment of lipid abnormalities has the potential to reduce cardiovascular events more than 50%, to rates that are seen in countries with lower Cholesterol and less atherosclerotic burden. This leads to the expectation that treatment of elevated lipid levels will allow patients with diabetes to lead longer healthier lives (Goldberg, 2001).

Hussain *et al.,* 2017 reported that the mean values of FBS, TG,TC, LDL-C, and HDL-C were higher in T2DM patients than the reference normal range (NCEP ATPIII guidelines). Moreover, both lipid profile and DM have been shown to be important predictors of metabolic disorders (Goldberg, 2001)**.** Early detection and treatment of dyslipidemia associated with DM may be one-step to reducing the CVD risk (Khaw *et al.,* 2004, Tabish, 2007).

Since hematocrit has a direct relation with red blood cell, if red blood cell volume and life span are affected hematocrit level will also be affected. Anemia and glycosylation increased red cell turnover that has a direct effect on hematocrit and HbA1c consecutively (Buch *et al.* 2017). The study of Biresaw, 2021 showed that Hct has a significant correlated with HbA1c (r=0.15, P<0.05). The finding is in line with studies by Wu *et al.* 2018 and Abass *et al.* 2017.

Biresaw, 2021 recorded that MCV had a significant and weak positive correlation (r=0.189, p<0.01) with HbA1C. similar results showed that a positive correlation between MCV and HbA1C (r=0.07, P<0.053) (Farooqui.*et al.,* 2019) and (r =0.95, P<0.256) (Abass *et al.* 2017).

The result of the study of Biresaw, 2021 reported that RBCs count, Hct value, and MPV showed a weak positive correlation with fasting blood sugar. likewise, studies from Ethiopia by Biadgo *et al.,* 2016 and Saudi Arabia by Farooqui. et al., 2019 showed a positive correlation of FBS with RBCs count, Hct value, and Hb content among diabetic patients.

The result was similar to findings from Biresaw, 2021 who found that a weak positive correlation between FBS and Hct value (r=0.112, P<0.01) and Biadgo *et al.,* 2016 obtained that a significant weak positive correlation between FBS with RBC count, Hct value, and Hb in diabetic patients. Also, Farooqui. *et al.*, 2019 found that a significant correlation between FBS and Hct value (r=0.23, p< 0.001).

Biresaw, 2021 reported that MPV is a parameter used to assess platelet size, and it is a potential biomarker of platelet reactivity, which showed a positive correlation with FBS (r=0.134, p<0.01). These biomarker of platelet reactivity play a critical role in the pathophysiology of the thrombotic events leading to diabetic complications it has been shown that larger platelets are more reactive than smaller ones.

Biresaw, 2021 mentioned that PDW can directly measure the variability in platelet size, and its high values suggest increased production of larger platelets. Also, Vinik *et al.,* 2001 recorded that the MPV and PDW were significantly (p<0.05) increased in the diabetic patients compared to the control.

Asmamaw *et al.*, 2021 reported that there was a significant mean difference between good and poor glycemic controlled T2 DM patients in RBCs count, Hb concentration, MCV, MCH, and red cell distribution width, respectively. RBCs count was inversely correlated (r=-0.280, p=0.002) with HbA1c while MCV (r=0.267, p=0.003), MCH (r=0.231, p=0.010), and red cell distribution width (r= 0.496, p=0.000) were positively correlated with level of HbA1c. Chaudhari, 2017 recorded that a significant decrease in Hb, Hct, MCV, MCH, MCHC and increased RDW and HbA1c concentration in type II diabetic patients compared with the controls. Silva *et al*., 2016 found that a significant negative correlation between HbA1c with Hb, Hct, and MCV in diabetic patients. Hardikar *et al*., 2012 recorded that a negative association between HbA1c with Hb, MCV, MCH, and MCHC in diabetic patients.

Biadgo *et al.,* 2016 recorded a significant increase in WBCs, neutrophil, and lymphocyte counts, RDW, PDW, and MPV in diabetic patients compared with the controls. Anthropometric measurements significantly correlated with WBCS and platelet indices.

Al Salhen and Mahmoud, 2017 studied the haematological parameters among 103 type 2 diabetic patients (79 males + 24 females) at El-Beida Hospital, El-Beida City, Libya, and 39 healthy subjects (29 males and 10 females). The results showed a significant decrease in RBCs count, hemoglobin content, Hct value, and MCV in diabetic patients as compared to the controls. On the other hand, MCHC, MCH, WBC, lymphocytes, and neutrophils counts were increased in diabetic patients as compared to the controls. No differences were found between platelets counts in the diabetic patients and the controls.

Xiangyu *et al.,* 2017 found that the median of RBCS count, Hb, Hct, MCV, MCH, and MCHC were decreased and WBCs count was increased in diabetic patients compared to non-diabetic individuals. in a cross-sectional analysis of the routine health examination data from 20128 participants with complete baseline data in Yinzhou District 2013. The PDW and PLT were not significantly different between diabetic group and non-diabetic group, (16% vs. 16%, P=0.88, and $194x10^9$/L vs. $196x10^9$/L, P=0.05 respectively) The MPV was significantly higher in diabetic group (9.3fl vs. 9.2fl, *P<0.05*). MPV was an independent risk factor of diabetes mellitus.

Adane *et al.,* 2020 carried out a comparative cross-sectional study on 164 DM patients and 82 controls at the chronic illness clinic of University of Gondar Hospital from January to April 2020. Data were collected using a pretested structured questionnaire. 5 ml of venous blood was collected by vacutainer blood collection technique, RBC parameters were determined by using Sysmex KX21N analyzers. The results showed a significant decrease in the mean RBCs count, hemoglobin concentration, Hct, and MCV and a significant increased in MCHC in DM patients when compared with the controls. A negative correlations were observed between BMI and Hb concentration (r= −0.242, P=0.029), MCH (r= −0.250, P=0.024), and MCHC (r= −0.209, P=0.007) in diabetic patients. On the other hand, a positive correlation was observed between MCV and diastolic blood pressure (r= 0.176, P=0.024) in diabetic patients. Therefore, this study suggested that RBC parameters abnormalities should be evaluated and treated periodically in DM patients for better prognosis and quality of life.

The Bivariate correlation of HbA1c with hematocrit (r=0.15, P=0.01), imply cell quantity (r=0.189, P=0.01), imply corpuscular hemoglobin(r=0.147, P=0.01and pink cell distribution width (r= 0.156, P= 0.01) revealed tremendous and vulnerable high quality correlation. The relationship of FBS with a few hematological parameters showed positive correlation. A Pearson's correlation analysis revealed a susceptible superb correlation of pink blood mobile (r=0.147, p=0.01), Hemoglobin (r=0.133, P=0.01), HCT (r=0.112, P=0.05) and imply platelet extent (r=zero.134, P=0.01) with fasting blood sugar (Biresaw, 2021).

6. Conclusion

It can be concluded that the results showed diabetic patients had hyperglycemia, increased of HbA1C, dyslipidemia, and disturbance in haematological parameters. Diabetic patients are advised to periodically check blood sugar levels, HA1C, lipid profile, and hematological parameters. Further studies are needed to confirm these results in a large sample in other regions.

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