

The variation in hematological parameters and their association with HbA1c among Type 2 Diabetes Mellitus Patients

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التغير في المؤشرات الدموية وعلاقتها بالهيموغلوبين السكري (HbA1c) لدى مرضى السكري من النوع الثاني

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المخلص

يُعدّ التغير في المؤشرات الدموية وظهور فقر الدم من الاضطرابات الدموية الشائعة بين مرضى السكري، والتي قد تؤدي إلى تفاقم مضاعفاتهم. ولم تحظ هذه المشكلة بالاهتمام الكافي لدراسة مدى شيوعها وطرق التعامل معها بين مرضى داء السكري (DM). تهدف هذه الدراسة الاسترجاعية إلى تقييم التغير في المؤشرات الدموية وعلاقتها بمستويات الهيموغلوبين السكري (HbA1c) لدى مرضى السكري من النوع الثاني (T2DM) مقارنةً بمجموعة من الأصحاء.

شملت الدراسة 155 مريضاً مصاباً بداء السكري من النوع الثاني ممن يرتادون عيادات السكري، و145 شخصاً سليماً كمجموعة ضابطة. جُمعت عينات الدم من المجموعتين، وتم قياس مستوى HbA1c باستخدام جهاز HLC-7223GX Tosoh Automated Glycohemoglobin Analyzer ، في حين تم تحليل المؤشرات الدموية باستخدام جهاز Sysmex XN-350 الآلي.

أظهرت النتائج وجود فرق معنوي بين متوسط مستوى HbA1c في المجموعتين. كما وُجدت علاقة ارتباط إيجابية بين متوسط عدد كريات الدم الحمراء (RBCs) وكريات الدم البيضاء (WBCs) والصفائح الدموية (Plts) ، إضافةً إلى تركيز الهيموغلوبين (Hb) والهيماتوكريت (Hct) لدى المرضى ومستوى HbA1c ، في حين وُجدت علاقة ارتباط سلبية بين مؤشرات كريات الدم الحمراء (MCV, MCH,

(MCHC) ومستوى HbA1c. لم يُلاحظ أن هذا التغير مرتبط بالجنس، كما لم تُسجل فروق معنوية بين التغيرات ومستوى HbA1c المرتفع. خلصت الدراسة إلى أن مستوى HbA1c والمؤشرات الدموية يمكن أن تكون ذات فائدة سريرية كمؤشرات بديلة من منظور تشخيصي، وربما تكون مفيدة للأشخاص الأكثر عرضة لتطور مضاعفات الأوعية الدقيقة أو الكبيرة.

الكلمات المفتاحية: داء السكري، السكري من النوع الثاني، الهيموغلوبين الغليكوزيلي (HbA1c)، المؤشرات الدموية، فقر الدم.

Abstract:

Variation in the hematological parameters and the onset of anemia are one of the common blood disorders seen in diabetic patients that can exacerbate their complications. This problem has not received sufficient attention to study how common it is and how to treat it among diabetes mellitus (DM) patients. This retrospective study aims to assess the variation of the hematological parameters and their association with HbA1c levels among T2 DM patients in comparison with a healthy control group.

155 patients with T2DM attending diabetes clinics, and 145 healthy subjects were included in this study. Blood samples were collected from both groups. The HbA1c was detected by the HLC-7223GX Tosoh Automated Glycohemoglobin Analyzer, and the hematological parameters were detected by the auto-analyzer Sysmex XN-350 system. The results showed a significant difference between the mean HbA1c level of the two groups, there was a positive correlation between the mean RBCs, WBCs, and Plts count as well as Hb concentration and Hct of the patients and the mean of HbA1c level, while there was a negative correlation between the RBC indices MCV, MCH, and MCHC of the patients and the mean of HbA1c level, the variation was not associated with sex, there was no significant differences between the variation and the HbA1c level increase. We concluded that HbA1c level and hematological parameters had clinical usefulness as surrogate markers for a diagnostic point of view, and possibly a benefit for subjects at increased risk of developing micro / macro vascular complications.

Keywords: Diabetes, Type 2 Diabetes Mellitus, glycated hemoglobin A1c (HbA1c), hematological parameters, anemia.

Introduction:

Diabetes mellitus is a metabolic disorder characterized by high blood glucose levels (chronic hyperglycemia) as a common feature. It is one of the causes of morbidity and mortality, which are not due to the immediate effects of this disorder, but develop as a result of chronic diabetes mellitus. Diabetes mellitus is classified into two types based on insulin dependence. Type 1 diabetes mellitus (T1DM) is also known as insulin-dependent diabetes or juvenile diabetes, resulting from autoimmune damage to insulin-producing beta cells of the pancreas. Whereas non-insulin-dependent diabetes, type 2 diabetes mellitus (T2DM), results from insulin resistance. This is commonly seen in adults. Another type of diabetes, may develop during pregnancy, known as gestational diabetes, which improves or disappears after delivery, but studies showed that 20-50% cases of these can develop type 2 diabetes later in life. Variation of the hematological parameters and anemia is one of the commonest blood disorders in patients with diabetes, raising their complications, particularly in those with nephropathy or

renal failure. It is well known that anemia worsens the severity and impairs the result of peripheral small vessel disease in patients with diabetes. Anemia can lead to stressful complications such as diabetic neuropathy, diabetic nephropathy, and Diabetic retinopathy, and can lead to common and severe effects on kidney, heart, and artery diseases in diabetic patients. The main result of anemia is tissue hypoxia, which is the main cause of diabetes associated organ damage (AlDallal S. M., and Jena N. 2018, Kebede S. A., et al. 2021, and Nasrat M. A., et al. 2018).

There are several factors mentioned as reasons for the earlier onset of anemia in diabetic patients, including systemic inflammation, inhibition of erythropoietin synthesis, damage to the renal interstitium, severe symptomatic autonomic neuropathy causing efferent sympathetic denervation of the kidney, and loss of appropriate erythropoietin, drugs, altered iron metabolism, and hyperglycemia. Patients with diabetic nephropathy usually have a higher degree of anemia than those presenting with other causes of renal failure, and anemia develops earlier in these patients than in those with renal impairment from other causes (Kebede S. A., et al. 2021, Craig KJ, et al. 2005, and Nasrat M. A., et al. 2018). Furthermore, patients with diabetes are two times more likely to be susceptible to anemia than non-diabetic patients. Anemia is identified as a risk factor for cardiovascular and end-stage renal diseases in those patients; also, it has been proven that low hemoglobin (Hb) levels identify diabetic patients at increased risk for hospitalization and premature death (AlDallal S. M., and Jena N. 2018). Several recent studies showed that the occurrence of varied hematological parameters in diabetic patients is often associated with the presence of renal insufficiency. Thus, diabetic patients have a higher prevalence of anemia associated with the level of renal impairment than non-diabetic patients with other causes of renal failure (Dikow R., et al. 2002, Craig K. J., et al. 2005, and El-Achkar T. M., et al. 2004)

Hemoglobin A1c (HbA1c) is a glycated hemoglobin formed by the binding of glucose to the N-terminal Valine of the β -chain of the globulin in the hemoglobin. HbA1c value reflects the average blood glucose levels in the previous 2–3 months; it is a more appropriate test than fasting blood glucose, as it does not require fasting. Thus, HbA1c has been widely used for diagnosing diabetes and monitoring blood glucose levels in patients with diabetes (American Diabetes Association 2018, Peterson K, P., et al. 1998, The Japan Diabetes Society 2013, and World Health Organization 2011). There are many factors, such as structural hemoglobinopathies, thalassemia syndrome, and alterations in the quaternary structure of Hb, that can affect HbA1c levels (Franco R. S. 2009). Additionally, HbA1c levels can be altered by different types of anemia. Anemia can lead to a false increase or decrease in HbA1c levels, depending on the type of anemia. Iron deficiency anemia (IDA) may increase the red blood cell turnover leading to the increase of Hb glycation and decreased HbA1c levels same as sickle cell anemia, some other studies showed that IDA may increase HbA1c levels while non-iron deficiency anemias as hemorrhagic, hemolysis, hemoglobinopathies, red cell disorders, and myelodysplastic disease can lead to increased HbA1c levels (Christy A. L., et al. 2014, Goldstein D. E., et al. 2004, Janice D., et al. 2022, Lacy M. E, et al. 2017, and Solomon A, et al. 2019). Since anemia and abnormalities in hemoglobin can theoretically falsely affect the level of HbA1c, which can negatively affect the diagnosis and monitoring of diabetes, falsely low HbA1c can delay diabetes diagnosis or give the physician the impression that diabetes is well-controlled. On the contrary, a falsely elevated HbA1c can mislabel patients with diabetes and lead to associated psychological stress and improper treatment (Alzahrani B. A., et al. 2023).

A systematic review of 12 studies among people without known diabetes reported that iron deficiency anemia was associated with a false increase in HbA1c (Dikow R., et al. 2002). Non-iron deficiency anemia, such as hemorrhagic, hemolytic anemia, or anemia due to hemoglobinopathies, red cell disorders, and myelodysplastic disease, affects HbA1c values, leading to decreased HbA1c levels, indicating that HbA1c is a very poor marker for diabetic patients with such types of anemia (Adeoye, S., et al. 2014, Aggarwal N., et al. 2013, Janice D., et al. 2022, English E., et al. 2015, Ford E.S., et al. 2011, and Hellman R., 2016). Although some studies reported that HbA1c values increased with decreasing hemoglobin levels (Bae J. C., et al. 2014, Nakagami Junko T., et al. 2017, and Wang D., et al. 2019). It is known that RBC lifespan decreases with hyperglycemia, and a low level of HbA1c has been found to shorten RBC lifespan (Cohen R. M. et al. 2008, and Virtue M. A., et al. 2004). Several studies also show a significant negative correlation between HbA1c and MCV and MCH, as well as a significant positive correlation with RBC count (RBC count increased in patients with higher levels of HbA1c) (Moriya T., et al. 2014, and Rashed E. R., et al. 2020). Anemia is found to be more prevalent in patients with uncontrolled diabetes than in well-controlled diabetes patients (Craig KJ, et al. 2005).

Aim:

As there is a lack of studies about the hematological profile of diabetic patients, this retrospective study was carried out to assess the hematological parameters: red blood cells (RBC) count, white blood cells (WBC) count, and Platelets (Plt) count. hemoglobin (HB) concentration, hematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH). Mean corpuscular hemoglobin concentration (MCHC), and their relationship to HbA1c levels in a cohort of T2DM patients attending Qaser Ahmed Hospital for diabetes treatment and endocrinology in Misurata, and diabetes control clinics in Bani Walid Central Hospital, Aldahra Hospital, and Ayadi Alrahma Clinic in comparison with a healthy control group. in comparison with a healthy group.

Subjects and Methods:

300 cases were included in the study, during the period from January to May 2025, 155 (83 males, 53.55%, 72 females, 46.45%) were **T2DM** patients with a mean age of 57.9 ± 12.8 years. 100 were from Misurata city who attended Qaser Ahmed Hospital for diabetes treatment and endocrinology, and 55 were from Bani Walid city who attended diabetes control clinics in Bani Walid General Hospital, Aldahra Hospital, and Ayadi Alrahma Clinic. In addition to 145 healthy subjects 73 were males (50.34%), 72 were females (49.66%), with a mean age of 47.1 ± 14.9 years, 90 were from Misurata city, and 55 were from Bani Walid city. Blood samples for HbA1c and Complete Blood Count (CBC) were collected in an ethylene diamine tetraacetic acid (EDTA) tube. Laboratory investigations for all cases were done, using HLC-7223GX Tosoh Automated Glycohemoglobin Analyzer for HbA1c, and Complete blood count was done by the auto-analyzer Sysmex XN-350 system.

Statistical Analysis

Data were analyzed using SPSS software (version 23, Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA). The mean and standard deviation were calculated for all parameters. The significance of the mean differences was analyzed using the independent t-test and one-way ANOVA. Categorical data were presented as numbers and percentages and compared using Chi-squared tests. Differences were considered statistically significant when the p -value was <0.05 .

Results

This retrospective study was conducted at Qaser Ahmed Hospital for diabetes treatment and endocrinology in Misurata city, and diabetes control clinics in Bani Walid city at Bani Walid General Hospital, Aldahra Hospital, and Ayadi Alrahma Clinic, a total of 300 participants were included in the study, 155 of them were T2DM patients, 83 (53.55%) were males and 72 (46.45%) were females, while the remain 145 participants were non-diabetic healthy subjects, of which 73 (50.34%) were males and 72 (49.66%) were females. The median duration of disease in the patients was 4.8 years, with most patients (more than 80%) being followed in diabetes control clinics, the majority of them whom are on routine follow-up are with normal renal function tests. Table 1 and Figure 1 illustrate the gender distribution of the participants.

Table 1: The gender distribution of the participants.

	Males	females
patients	83 (53.5%)	72 (46.5%)
controls	73 (50.3%)	72 (49.7%)

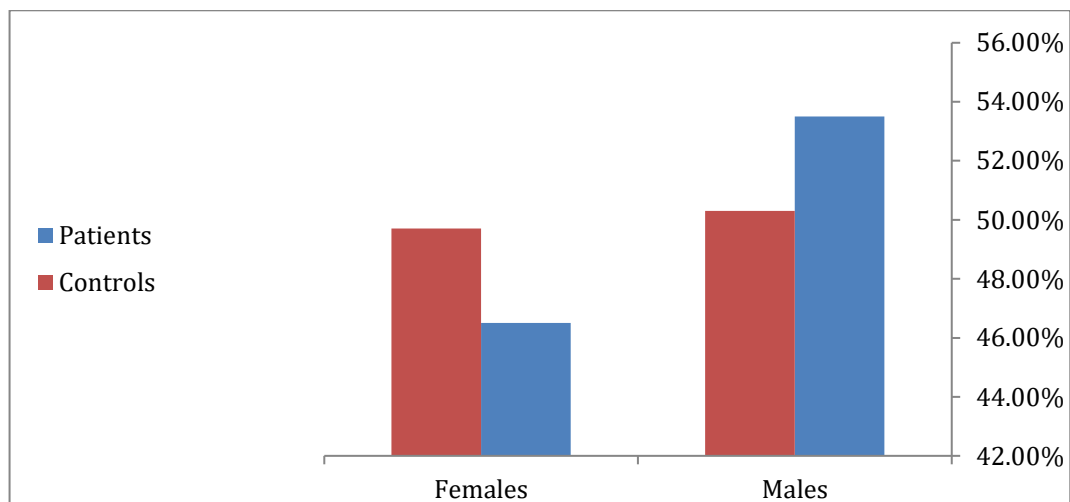
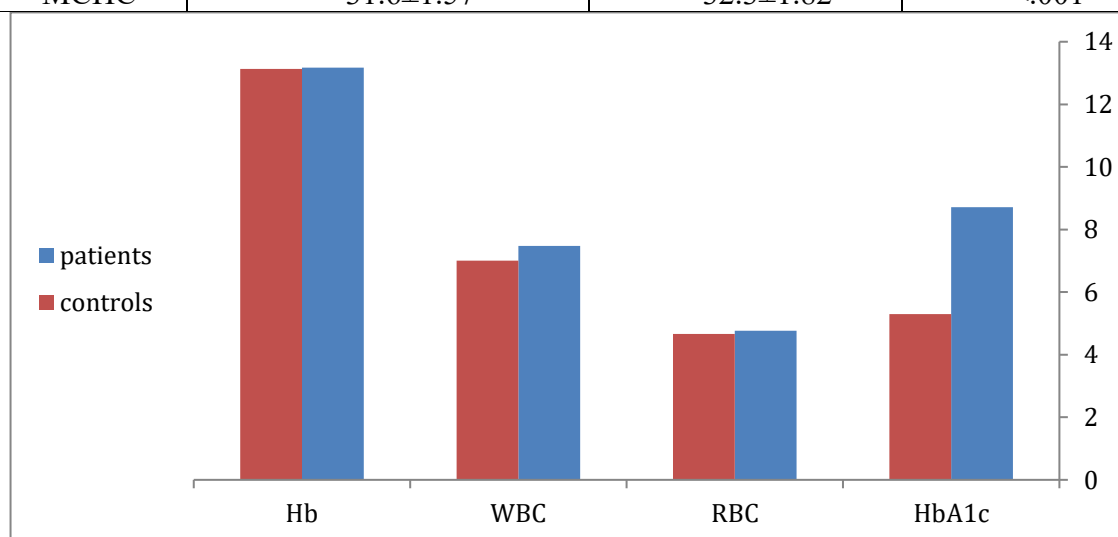
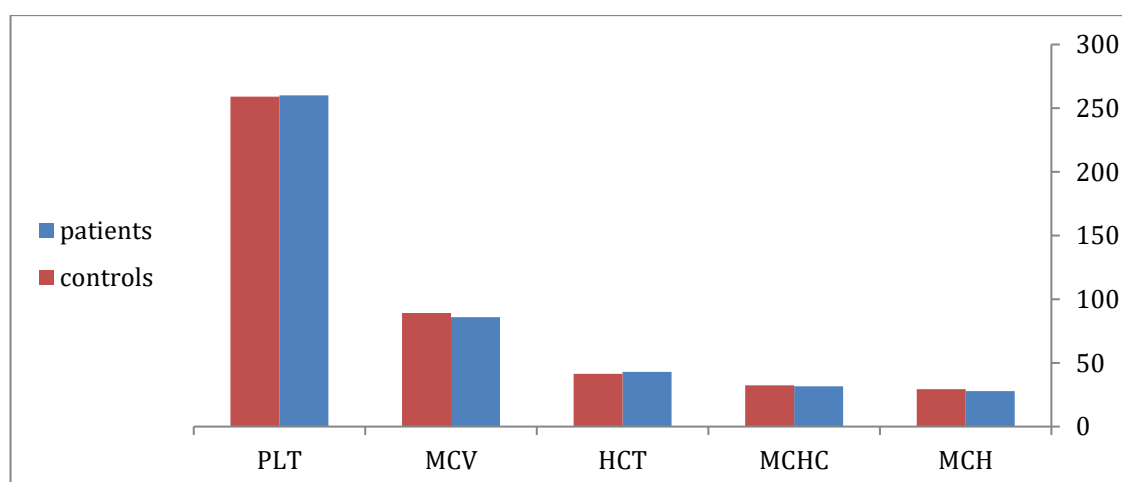


Fig. 1 illustrates the participants' gender distribution.

The results revealed an apparent difference in the mean of *HbA1c* of both groups, for patients it was 8.71 ± 1.79 , and 5.30 ± 0.41 for controls, the statistical analysis shows a significant difference in the results of this parameter ($p < .001$), also there was slight increase in RBCs, WBCs, and PltS count of patients than the control group without significant differences in the results of RBC and PLt count p -value was (0.191, 0.926 respectively), and there was a significant differences in the results of WBC count between the two groups ($p = 0.044$) Hb mean level and mean Hct of patients also were slightly higher compared to the control group without significant differences, p -value was (0.846, 0.110 respectively), RBC indices (MCV, MCH, MCHC) of the patients were lower than the RBC indices of the controls, the statistical analysis shows a significant differences in the results of these indices, p -value was (0.017, $< .001$, $< .001$ respectively). The mean results of *HbA1c* and the hematological parameters are shown in Table 2 and Figures 2 and 3

Table 2: mean results of *HbA1c* and the hematological parameters of patients and controls

	Patients N=155	controls N=145	<i>p</i> -value
<i>HbA1c</i>	8.71±1.79	5.30±0.41	<.001
<i>RBC</i>	4.76±0.61	4.66±0.75	0.191
<i>WBC</i>	7.48±2.01	7.00±2.16	0.044
<i>Plt</i>	260±69.03	259±71.29	0.926
<i>Hb</i>	13.17±1.74	13.13±1.83	0.846
<i>Hct</i>	42.9±10.4	41.3±5.87	0.110
<i>MCV</i>	85.93±13.09	89.10±9.40	0.017
<i>MCH</i>	27.79±2.70	29.31±4.27	<.001
<i>MCHC</i>	31.6±1.57	32.3±1.82	<.001

**Fig 2:** The mean of *HbA1c*, RBC, WBC and Hb of patients and controls**Fig 3:** Mean results of PLT, Hct, MCV, MCH and MCHC of patients and controls.

Sex-based mean results of the HbA1c and the hematological parameters show that the mean of HbA1c level was nearly equal between the males and females within the same group of patients or controls. In contrast, the hematological parameters were varied with sex; the results of male patients showed an increase in the mean of RBC, WBC, and Plt count than the controls without significant differences ($p>0.05$), Hb, and Hct mean results also were higher in male patients than the controls without significant differences ($p>0.05$). In contrast, MCH mean result were lower in male patients than the controls without significant differences ($p>0.05$), the mean results of MCV, and MCHC in patients were lower than controls with significant differences ($p<0.05$), table 3 summarizes the HbA1c, and the hematological parameters mean results of male patient and male controls, figures 4, and 5 illustrates these means.

Table 3: The HbA1c and the hematological parameters mean results of male patients and male controls.

	Male patients (83)	Male controls (73)	p-value
<i>HbA1c</i>	8.70±1.73	5.25±0.36	.000
<i>RBC</i>	5.05±0.52	4.83±0.54	.951
WBC	8.00±2.21	7.08±2.15	.936
Plt	244.027±62.600	238.918±49.140	.085
Hb	14.37±1.19	14.06±1.62	.173
Hct	45.46±9.63	43.59±5.23	.069
MCV	86.28±16.13	91.58±5.53	.004
MCH	28.97±2.14	29.77±2.18	.582
MCHC	31.94±1.55	32.31±1.69	.005

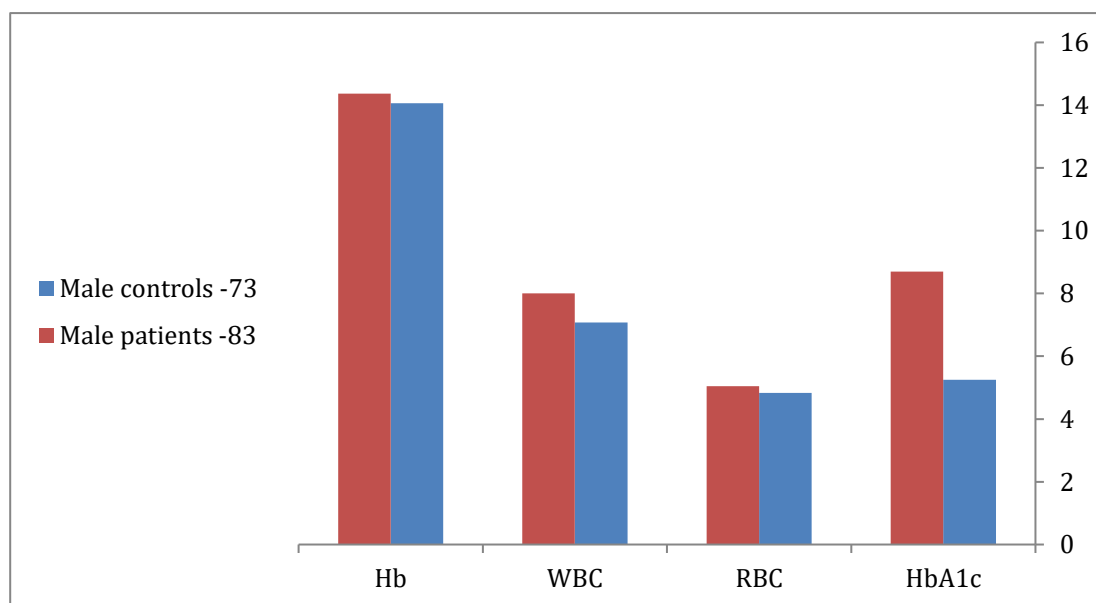


Fig. 4: The mean of *HbA1c*, RBC, WBC, and Hb of male patients and male controls.

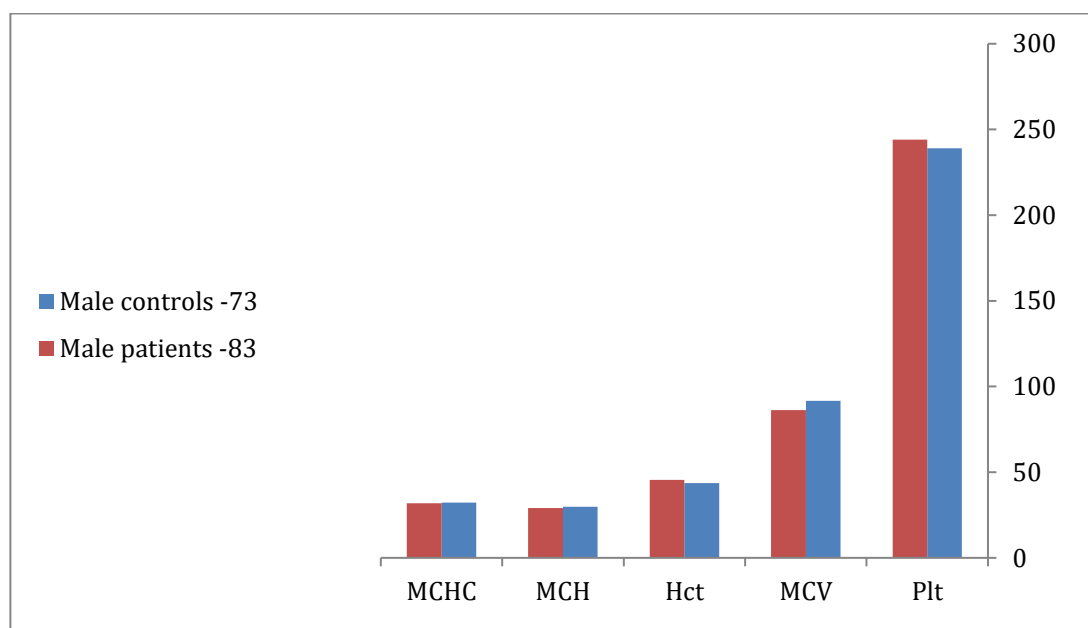


Fig. 5: Mean results of PLt, Hct, MCV, MCH, and MCHC of male patients and male controls

The results of female patients showed nearly an equal mean results of RBC, WBC, and Plt count with the controls without significant differences ($p>0.05$), Hb, Hct, MCV, and MCH mean results were lower in female patients than the controls without significant differences ($p>0.05$), while the MCHC mean result were lower in female patients than the controls with significant differences ($p<0.05$). Table 4 summarizes the HbA1c and the hematological parameters mean results of female patients and female controls, and Figures 6 and 7 illustrate these means.

Table 3: The HbA1c and the hematological parameters mean results of female patients and controls.

	Female patients (72)	Female controls (72)	p-value
<i>HbA1c</i>	8.71±1.84	5.3549±0.46	.000
<i>RBC</i>	4.45±0.56	4.48±0.88	.751
<i>WBC</i>	6.96±1.70	6.91±2.20	.121
<i>Plt</i>	281.681±73.106	281.125±83.370	.772
<i>Hb</i>	11.95±1.38	12.18±1.52	.294
<i>Hct</i>	38.26±4.62	39.13±5.74	.318
<i>MCV</i>	85.28±9.65	86.59±11.63	.463
<i>MCH</i>	26.68±2.78	28.85±5.63	.869
<i>MCHC</i>	31.31±1.55	32.30±1.95	.007

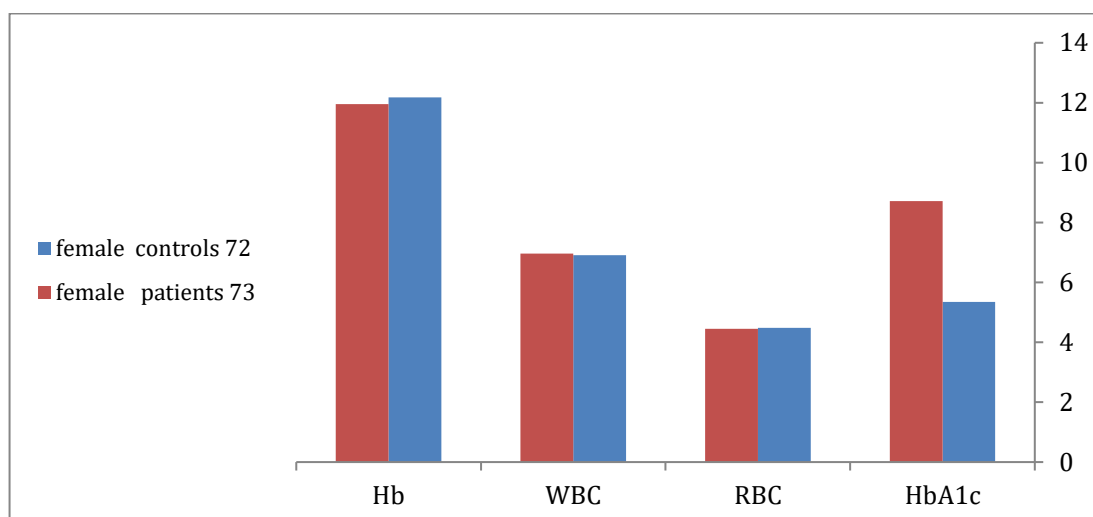


Fig. 6: The mean of *HbA1c*, RBC, WBC, and Hb of female patients and female controls.

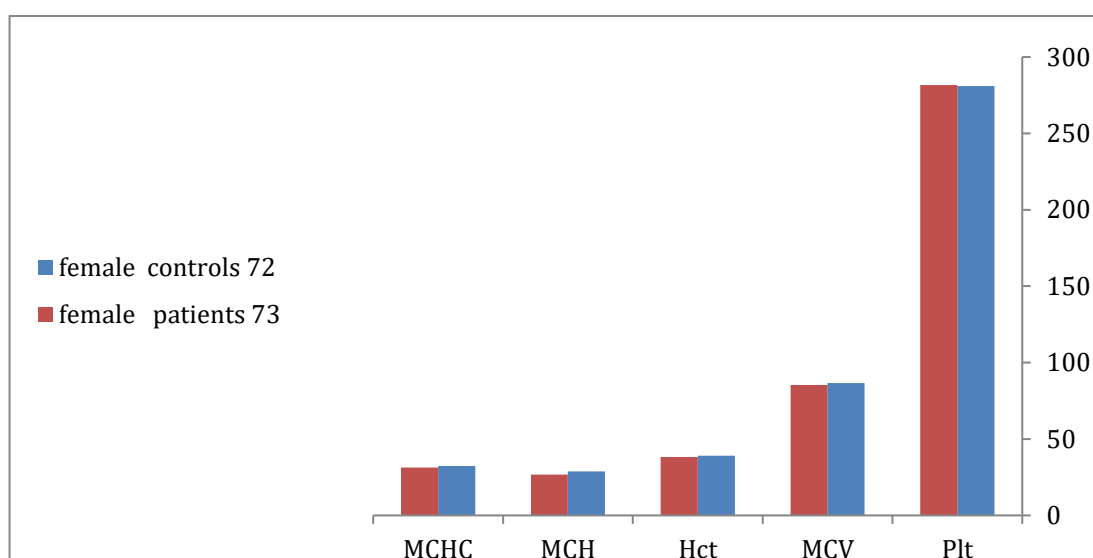
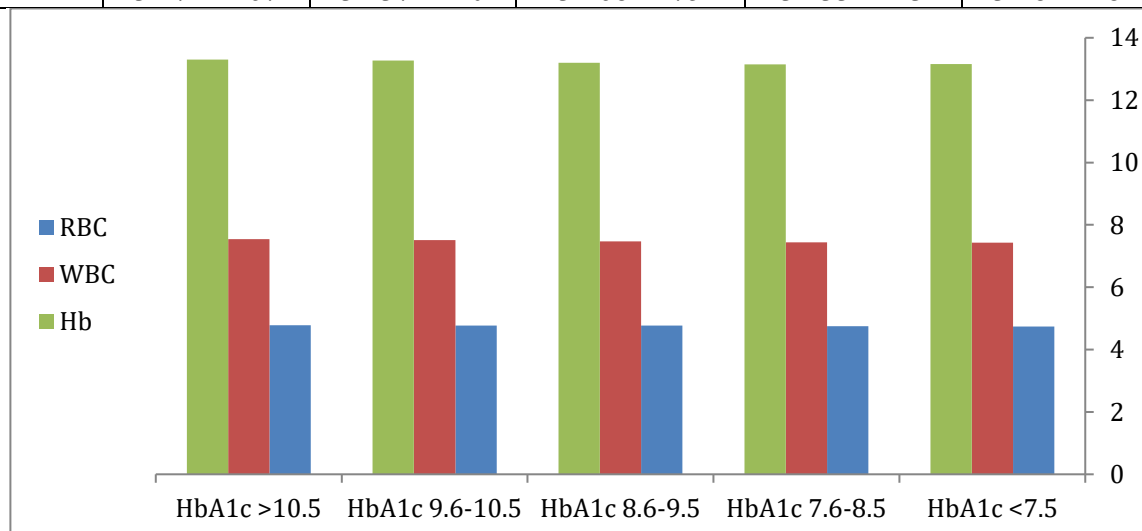
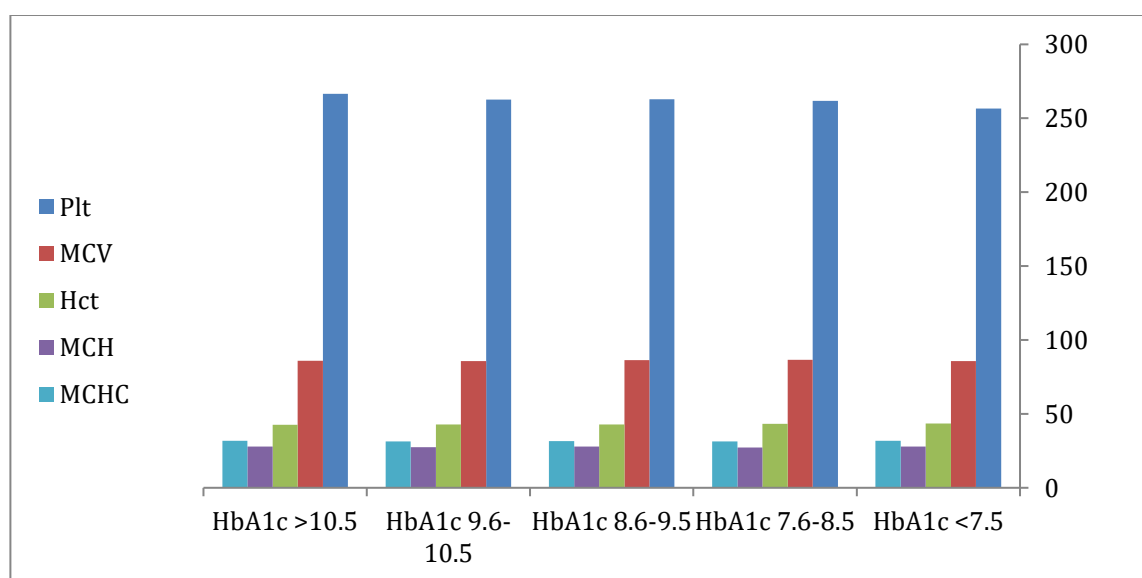


Fig. 7: mean results of PLt, Hct, MCV, MCH, and MCHC of female patients and controls

Mean results of the patients' hematological parameters in association with HbA1c levels show that mean RBC, WBC, Plt count, and Hb concentration slightly increase with the increase of HbA1c level without significant differences ($p>0.05$), while Hct mean results were slightly decreased with the increase in HbA1c level without significant differences ($p>0.05$). The RBC indices MCV, MCH, and MCHC mean results show no correlation with HbA1c levels, and the statistical analysis also shows no significant differences ($p>0.05$). Table 5 summarizes the patients' hematological parameters mean results in association with HbA1c levels. Figures 8 and 9 illustrate these means.

Table 5: The patients' hematological parameters mean results in association with HbA1c levels

	HbA1c ≤ 7.5 (No:44)	HbA1c7.6- 8.5 (No:36)	HbA1c8.6-9.5 (No:22)	HbA1c9.6- 10.5(No:23)	HbA1c >10.5 (No:30)
RBC	4.74 $\pm$ 0.55	4.75 $\pm$ 0.77	4.77 $\pm$ 0.58	4.77 $\pm$ 0.48	4.78 $\pm$ 0.55
WBC	7.43 $\pm$ 2.08	7.44 $\pm$ 1.90	7.47 $\pm$ 1.70	7.51 $\pm$ 1.64	7.54 $\pm$ 2.45
PLt	256.55 $\pm$ 62.23	261.72 $\pm$ 68.81	262.79 $\pm$ 87.76	262.56 $\pm$ 67.45	266.60 $\pm$ 65.37
Hb	13.16 $\pm$ 1.86	13.15 $\pm$ 1.63	13.20 $\pm$ 1.43	13.27 $\pm$ 1.79	13.30 $\pm$ 1.76
Hct	43.42 $\pm$ 13.03	43.21 $\pm$ 5.21	42.92 $\pm$ 13.80	42.75 $\pm$ 5.04	42.55 $\pm$ 6.10
MCV	85.73 $\pm$ 14.15	86.53 $\pm$ 9.62	86.39 $\pm$ 13.64	85.73 $\pm$ 8.58	85.94 $\pm$ 14.90
MCH	27.88 $\pm$ 3.12	27.30 $\pm$ 2.61	27.95 $\pm$ 1.63	27.44 $\pm$ 3.36	27.92 $\pm$ 2.38
MCHC	31.72 $\pm$ 1.67	31.37 $\pm$ 1.20	31.68 $\pm$ 1.75	31.33 $\pm$ 1.13	31.82 $\pm$ 1.84

**Fig. 8:** The mean results of the patients' RBC, WBC, and Hb in association with HbA1c levels.**Fig. 9:** The mean results of the patients' Plt, MCV, Hct, MCH, and MCHC in association with HbA1c levels.

Discussion

Higher HbA1c is the main characteristic of uncontrolled diabetes that, over time, leads to severe damage and affects various body systems. It plays an important role in the clinical diagnosis of diabetes. Previously published studies have investigated and evaluated variations in hematological parameters to be used as predictors of diabetes related complications. However, the CBC test is not routinely considered a clinical biomarker to manage these complications. The results revealed that most of the diabetic patients suffer from multiple complications (Al-Mansoori R., et al. 2023, Altoum, A. E., et al. 2018, Mohamed H., et al. 2021, and Tennyson C., et al. 2013).

WBC is known as a biomarker of chronic inflammation associated with microvascular complications in T2DM. They could be activated by advanced glycation end products, angiotensin II, and oxidative stress related to hyperglycemia (Al-Mansoori R., et al. 2023). Clinically elevated platelet counts are frequently seen in diabetic patients with a long duration of disease; the total number of platelets could negatively influence microvascular circulation in diabetes mellitus and play a part in the progression of arteriosclerotic lesions (Cho N. H., et al. 1992, and Sterner G, et al. 1998).

It is known from previous studies' results that hyperinsulinemia in erythroid progenitors may cause an increase in red blood cell (RBC) and white blood cell (WBC) count (Harjutsalo V., et al. 2008), also insulin increases the Trans capillary movement of albumin, and as a result, the plasma volume decreases and HCT as well as Hb increases (Mehra N. K., et al. 2008). HbA1c has been affected by the hematological parameters variation in both ways positively and negatively according to the type and the cause of variation, some causes such as hemolytic anemia may increase RBC turnover and decrease HbA1c level, while iron deficiency anemia and decrease in ferritin level contributes to an increase in RBC lifespan leading to an increase of HbA1c, therefore RBC lifespan is one of the factors affecting HbA1c level production (Church D, and Simmons D 2014).

Previous studies show a significant negative correlation between HbA1c and MCV and MCH and a significant positive correlation with RBC, WBC, and Plt count, as well as Hb concentration and Hct. In contrast, an inverse correlation between MCV, MCH, MCHC, and HbA1c was observed in many previous studies (Chung F. M., et al. 2005, Rashed E. R., et al. 2020, and Moriya T., 2014). The prevalence of anemia in T2DM patients is low without diabetes-related microvascular complications and hypertension (Kebede S. A., et al. 2021, Craig KJ, et al. 2005, and Nasrat M. A., et al. 2018).

The current study evaluates the relationship between the hematological parameters and HbA1C level in type 2 DM. The results show a positive correlation between RBC, WBC, Plt count, and HbA1c level in type 2 DM patients compared to the control group, as well as Hb concentration and Hct. The results also showed a negative correlation between HbA1c level and MCV, MCH, and MCHC in diabetic patients. Sex-based mean results of the HbA1c and the hematological parameters shows that the mean of HbA1c level was nearly equal between the males and females within the same group patients or controls while the hematological parameters were varied with sex, the CBC reflects physiological variations that exist between males and females due to intrinsic and extrinsic factors these sex differences are normally observed and contributes to lower values in females, (Alsagheer S., and Khaled F. 2025, and Zhu P, et al. 2017), there was no correlation between HbA1c levels and variation in the hematological parameters mean results, no significant differences were detected.

The current study's results were consistent with those of many previous studies. One of these studies was conducted by Rashed ER *et al.* in Tripoli, Libya, assessed the relationship between HbA1c levels and Hb concentration, Hct, RBC count, and RBC indices MCV, MCH, and MCHC. Their results show a significant positive correlation between mean RBC count, Hb concentration, and Hct; also, they show a significant negative correlation between HbA1c and MCV and MCH, while there is no association between MCHC and HbA1c levels (Rashed E. R., et l. 2020). The results of another study done by Jabeen F. *et al.* in Pakistan to assess variations in Hematological parameters induced by HbA1c, show a significant positive correlation between mean HbA1c level and mean RBC, WBC, Plt count, Hb concentration, and Hct, while also, showing a significant positive correlation between mean HbA1c level and mean of MCV, MCH, and MCHC (Jabeen F., et l. 2013). The results of a study conducted by Kaviya N. E, et al. to investigate the differences in hematological parameters between diabetic and non-diabetic individuals in India showed that mean WBC, Plt, and MCV were higher in diabetic patients than in non-diabetic individuals (Kaviya1 N. E., et l. 2020).

The current study results different than the results of the study of Alodhayani A. A. *et al.* which was done in Saudi Arabia to study the relationship between HbA1c levels and CBC parameters in patients with type 2 diabetes mellitus, where was negative correlation of HbA1c levels <10 and WBC count, the count decrease as HbA1c level increased between 6.5-8.5 and positive correlation between HbA1c levels >10 and WBC count, Hb concentration and Hct mean results were positively associated with HbA1c levels between 6.5--10, there mean results increase as the level increase, however there mean results decrease when HbA1c level >10, while there was no significant association between the variation of HbA1c levels and mean results of RBC and Plt count as well as MCV, MCH, and MCHC mean results which had no association with HbA1c levels (Alodhayani A. A., et l. 2022). In a study aimed to assess the effect of DM, including hyperglycemia levels, on the hematological parameters and its association with HbA1C in Saudi Arabia, the results revealed that there was slight increase in the mean of WBC, and Plt count in T2DM patients compared to non-diabetic control group, also there was significant increase in the mean of MCHC, while there was significant decrease in the mean results of RBC count, Hb concentration, Hct, MCV, and MCH (Essawi K., et l. 2023). Jaman *et al.* investigated the association of some hematological parameter variations with glycemic marker HbA1c levels. The results showed a slight increase in mean RBC count and MCHC as HbA1c levels increased; in contrast, there was a decrease in Hct, MCV, and MCH as HbA1c levels increased (Jaman M. S., et l. 2018).

The studies of variation in the hematological parameters in T2DM patients have been reported as a predictive marker reflecting an underlying inflammatory state and associated with cardiovascular complications, as well as diabetic nephropathy that affects the hematopoiesis (Dabbah S., et al. 2010, and Rhodes C.J., et al. 2011), Thus, using CBC as a routine test can help in better management and in monitoring the disease and predicting severity.

Limitation of the study

This is a clinic follow up-based study, the need is to carry out larger multicenter studies to establish the stronger association between hematological parameters variation and HbA1c levels for better diabetes assessment and management.

Conclusion

Poor Glycemic control causes variation in various hematological parameters.. The study indicates the clinical benefit of HbA1c level and hematological parameters as surrogate markers from a diagnostic point of view. Furthermore, hematological parameters are cost-effective and possibly beneficial for subjects at increased risk of developing micro/macrovacular complications and can help in preventive treatment. Good diabetes control, either by diet or hypoglycemic drugs, could be supportive and beneficial in reducing harmful effects in diabetic patients; therefore, CBC is needed as a routine test to be bound with HbA1c level for more accurate diabetes assessment and management.

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Conflict of interest

The authors declare that there is no conflict of interest.

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