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Measuring certain immunological and hematological factors in patients with type 2 diabetes

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Abstract
Type 2 Diabetes Mellitus (T2DM) entails a multifaceted global health crisis involving metabolic and immunological system disruptions. This cross-sectional study examines the relationship between blood pressure, Self-Monitoring of Blood Glucose, dietary compliance, and the effect of these variables on the immunological and hematological parameters of 124 participants aged 30-85 (97 T2DM patients and 27 healthy controls) of both genders from Sinjar General Hospital. The study utilized a laboratory and questionnaire-based approach to assess blood glucose levels, inflammatory markers (IL-1, IL-17A, IL-37) using the ELISA technique, and blood parameters using a CBC analyzer. Our study showed that patients with abnormal blood pressure had a higher value of exhausted immune cells, represented by a lower value of anti-inflammatory cytokines. In addition, the participants who practiced Self-Monitoring of Blood Glucose and maintained a healthy diet showed better blood glucose levels. On the other hand, IL-1 and IL-17A levels reflected the sustained pro-inflammatory activation and showed the existence of a glycemic control and disease duration deficiency. On the other hand, IL-37 had a lower level in patients with renal failure. In patients with uncontrolled hyperglycemia, the hematological changes were more prominent, supporting the interactions between metabolic, inflammatory, and immune changes in T2DM. This study encourages the reduction of multiplism to simplify a T2DM patient's care and optimize the clinical outcome of T2DM by focusing on the control of cardiovascular risks, Self-Monitoring of Blood Glucose, and dietary compliance.

Keywords: T2DM, blood pressure, SMBG, dietary compliance, IL-1, IL-17A, IL-37

Introduction

Type 2 Diabetes Mellitus (T2DM) is a disease that affects adults and is responsible for more than 90% of cases of diabetes mellitus. It is considered a serious public health concern. It is responsible for the deaths of 3.8 million adults annually. T2DM is one of the most common chronic diseases in the world. It affects 537 million adults and is projected to reach 783 million by 2045 (Sun *et al*., 2022). It is characterized by the overabundance of glucose in the bloodstream (hyperglycemia) due to the inability of the body to secrete enough insulin to stimulate uptake. This is due to the resistance to insulin and gradual dysfunction of the insulin secreting beta cells (β cells) (Mahmood *et al*., 2013) [18]. T2DM has a number of other effects that compound the derangements of metabolism, such as other states of viscera (abdominal) fat accumulation and insulin resistance. This also has another role, where T2DM has been considered primarily an inflammatory disorder (Młynarska *et al*., 2025). There is a low but chronic presence of inflammation that appears to be a causative factor in T2DM and the complications that come from the disease due to the obstruction of the micro and macro vasculature (Pellegrini *et al*., 2024) [26].

The range of pathophysiological aspects involved in T2DM and its complications extends far beyond glucose metabolism, encompassing the interconnected immune dysregulation, various hematological changes, and differing aspects of cardiovascular disease. Of all the comorbidities, hypertension is the most common as it is seen in about 60% of cases and significantly speeds the development of both cardiovascular and microvascular complications (Liu *et al*., 2024, Wang *et al*., 2025) [15, 37]. There is a synergistic effect of the combined conditions, and in fact, patients with T2DM and hypertension have been shown to have a 72% increased risk of all-cause mortality and a 57% increased risk of a cardiovascular event as compared to patients with T2DM and normal blood pressure. This is due to a combination of pathophysiological processes that include, but are not limited to, the combination of endothelial dysfunction, increased activity of the renin-angiotensin-aldosterone system, and increased overall inflammation (Liu *et al*., 2025) [17]. A wider range of infections is associated with diabetes mellitus, and the relationship between the general predisposition to infections and the level of glycemic control in that population have been studied extensively (AL-Allaff and Al-Shahery 2012) [1].

To manage Type 2 Diabetes Mellitus (T2DM), a multi-faceted approach that incorporates self-management strategies as well as pharmacological treatment is necessary. Self Monitoring Blood Glucose (SMBG) has become a necessary tool for patients managing their own diabetes. SMBG permits patients to see the effects that exercise, nutrition, and medication have on their blood sugar, allowing for therapeutic decisions to be made (Puzhakkal *et al*., 2025) [33]. Dietary compliance is another major therapeutic tool for managing diabetes. The degree of compliance to a diet has direct influence on diabetes control and prediction of outcomes (Mohammed *et al*., 2020) [23]. A lesser studied aspect of diabetes management is self-control. Even though compliance for the two previously mentioned behavioral factors is low, self-control is the most neglected domain. Adherence to dietary guidelines is documented to only 37%, with 63% of participants demonstrating poor dietary adherence, a sense of neglect for self-management practices (PDAQ) (Alebachew *et al*., 2023) [5].

Understanding T2DM has deepened the study of glycemic control and both the immune and blood components individually. Chronic hyperglycemia creates a background of red blood cells, white blood cells, and platelets (and their corresponding functions) to be modified. It creates a background of white blood cell and inflammatory cytokines to be modified with pro-inflammatory signals of IL-1, IL-6, IL-17, and TNF-α (Bambo *et al*., 2024) [11]. The most studied and documented of the altered inflammatory signal activity is IL-37. It has been studied and documented as the signal that is attempting to control the chronic inflammatory situation of the altered (metabolic) background (Majnarić *et al*., 2022) [19]. It is imperative to study the immune and blood components that have been altered, in order to understand the nature of T2DM and how to treat it more accurately.

This study enrolled 124 participants and took place at Sinjar General Hospital from September to December 2025. This study aims to determine the relationships between self-monitoring, dietary compliance, self-reporting blood pressure and the immunological (IL-1, IL-17A, IL-37) and blood parameters. This study attempts to provide empirical data to design integrated diabetes care protocols. Improving the patients' quality of care is the primary objective of this study.

Materials and Methods

Study area: Clinical samples were collected from patients coming to Sinjar hospital in Sinjar district – Mosul governorate. For the period between (1-9-2025 to 30-12-2025) [29]. The required tests and practical experiments were carried out in the laboratories of the department of biology at the college of science-university of Mosul, and advanced immunology laboratories in the mentioned hospital.

Study Cases: This cross-sectional study included 124 participants; 97 (78.23%) were patients with T2DM, and 27 (21.77%) were apparently healthy controls as illustrated in Figure (1). included 78 (62.9%) females and 46 (37.1 %) males, with ages ranging from 35-85 years. the study was conducted with the formal consent of all participants.

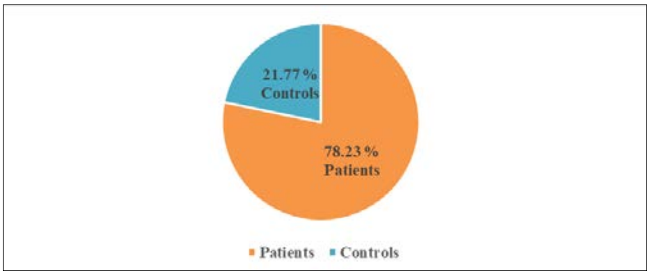

Fig 1: Patients and Controls distribution of the study population (n = 124).

Data Collection

Patient demographic and clinical data were documented using a structured questionnaire that included information on age, sex, body mass index (BMI), disease duration, family history of diabetes, physical activity status, dietary compliance, and self-monitoring of blood glucose practices. Blood pressure measurements were obtained and categorized as normal or abnormal. Blood samples were collected for the measurement of fasting blood sugar (FBS), random blood sugar (RBS), and complete blood count parameters using a Sysmex XN-350 automated hematology analyzer. Immunological markers (IL-1, IL-17A, IL-37) were quantified using sandwich ELISA techniques.

Blood and serum collection

A 5 mL of venous blood was collected from all participants (both control and patient groups) using sterile medical syringes. The collected blood was distributed into two tubes. The first tube is EDTA tube contains an anticoagulant in which 1 ml of blood was placed then gently inverted several times to ensure proper mixing with the anticoagulant for direct Complete Blood Count(CBC). The remaining portion 4 ml of the blood sample was placed into second tube which is gel tube without anticoagulant, used for serum separation. The samples were centrifuged at 5000 rpm for 10 minutes to obtain the serum. After centrifugation, the serum was placed into small sterile Eppendorf tubes and stored at (−20°C) until the required laboratory assays were performed.

Complete blood count (CBC) examination

The Sysmex XN-350 used to measure the Red blood cells parameters, Hemoglobin concentration and total white blood cell count in peripheral blood, the assay also determined the total leukocytes count and the differential count for each leukocyte subtype (lymphocytes, monocytes, neutrophils, eosinophils, and basophils) was determined.

Principle: Blood samples were collected and transferred into EDTA tubes, where they were gently mixed. The machine was then powered on, and the patient's information including name, age, and the required test was entered through the electronic control panel. The EDTA tube containing venous blood was placed beneath the device's designated needle holder, and a specific volume of blood was automatically aspirated for analysis. The required measurement parameters were displayed on the screen, and then printed report was subsequently generated manually. the complete blood count was subsequently performed using Japanese -made Sysmex XN-350 analyzer

Immunological examination: Serum levels of IL-1, IL-17A, and IL-37 were measured using ELISA kits according to the manufacturer's instructions. All samples were analyzed in duplicate. Optical density was read at 450 nm, and concentrations were calculated using a four-parameter logistic standard curve generated from recombinant standards.

Principle: This ELISA kit is based on the Sandwich-ELISA technique for the quantitative determination of IL-1, IL-17A, and IL-37 in serum samples. The microplate wells supplied with the kit are pre-coated with monoclonal antibodies specific to each target cytokine. Standards and samples are added to the designated wells, allowing the respective cytokine to bind to the immobilized capture antibody. After incubation, an HRP-conjugated detection antibody specific to the target cytokine is added, forming an antigen–antibody–enzyme sandwich complex.

Following washing steps to remove unbound materials, TMB substrate solution is introduced into the wells, resulting in the development of a blue color. The reaction is terminated by adding the stop solution, causing the color to change from blue to yellow. The optical density (OD) is measured at 450 nm using a microplate reader. The absorbance intensity is directly proportional to the concentration of the cytokine in the sample, and quantification is achieved by comparing sample OD values with the standard curve. (Albadrani and Altobje 2024) [4]

Ethical considerations

Before initiating the study, ethical approval was obtained from the Nineveh health department/research and development division, preceded by an official request approved by the scientific council at the faculty of science/University of Mosul. The study adhered to the requirements of public ethics stipulated internationally and by the Helsinki convention. Prior to enrollment, the participants signed the permission form to participate, provided that all their information was completely confidential and only for scientific research. The tests mentioned in this study were provided free to the participants.

Statistical Analysis

Data were analyzed using completely randomized design (CRD) with t-tests for comparisons between two groups and Duncan's Multiple Range Test (DMRT) for comparisons among three or more groups. Pearson's correlation analysis was used to determine statistical associations between parameters. Statistical significance was considered at $p < 0.01$ and $p < 0.05$ levels.

Results and Discussion

The Relationships between Blood Pressure and Type 2 Diabetes Mellitus

Hypertension represents the most common comorbidity among patients with T2DM, with studies demonstrating that approximately 59.9% of T2DM patients are affected by concurrent hypertension (Akalu *et al*., 2020). The 2025 [3, 36] AHA/ACC guidelines maintain a diagnostic and treatment threshold of 130/80 mmHg for hypertension in adults, including those with diabetes, emphasizing the importance of early and intensive blood pressure control to reduce cardiovascular and renal risk (Santulli *et al*., 2025) [33]. This co-occurrence is not coincidental but rather reflects shared pathophysiological mechanisms including insulin resistance, chronic inflammation, endothelial dysfunction, and activation of the sympathetic nervous system and renin-angiotensin-aldosterone system (Mancusi *et al*., 2020) [21].

In our study, we classified 70 T2DM patients into two groups based on blood pressure status: 19 patients with normal blood pressure and 51 patients with abnormal blood pressure. Our findings revealed several important associations between hypertension and immunological parameters in diabetic patients.

The results presented in Table (1) demonstrated clear variations in some of glycemic and immunological parameters among the studied groups according to blood pressure status.

FBS mean value in the normal blood pressure group was 166 mg/dL, which was significantly higher than that of the control group (90 mg/dL), while the abnormal blood pressure group exhibited an even higher mean value of 187 mg/dL which was also significantly higher than that of the control group, although a difference in mean values was observed between the patients groups, this difference did not reach statistical significance and this may be due to small sample size. This finding may also be attributed to suboptimal treatment adherence, limited therapeutic awareness, lifestyle-related factors, as well as the small sample size, which may have influenced the observed differences among patients with concurrent diabetes and abnormal blood pressure. Previous longitudinal research has demonstrated that elevated fasting glucose levels are an independent risk predictor for the development of hypertension, supporting the association between higher fasting blood glucose and abnormal blood pressure in diabetic populations and this findings are corroborate with our findings (Liu *et al*., 2021) [16].

RBS mean value in the normal blood pressure and abnormal blood group were 259,256mg/dL respectively, and higher than that of the control group (102 mg/dL), with a significant difference while both blood pressure groups exhibited a comparable values without a significant difference, this difference did not reach statistical significance and this may be due to small sample size.

With respect to IL-1 levels, the normal blood pressure group showed a mean concentration of 26.33 pg/mL, which was higher than that observed in the abnormal blood pressure group (21.07 pg/mL), while the control group demonstrated an intermediate mean value of 23.47 pg/mL. The difference between patients groups and healthy control was statistically significant. While IL-37, an anti-inflammatory cytokine, showed a clear declining trend across the groups. The highest mean level was observed in the normal blood pressure group (13.58 pg/mL), followed by the abnormal blood pressure group (11.73 pg/mL), while the control group showed the lowest mean value (10.98 pg/mL). These differences were statistically significant.

This pattern of IL-1 and IL-37 levels may be attributed to differences in disease severity related to diabetes duration and cumulative metabolic burden. Elevated levels in patients with normal blood pressure may reflect a more active and balanced immune response, whereas reduced levels in patients with abnormal blood pressure may result from chronic inflammation–induced cytokine exhaustion and immune dysregulation. Additionally, the small sample size may have influenced the observed differences.

Hypertension commonly coexists with T2DM and shares overlapping pathophysiological pathways of inflammation and endothelial dysfunction (Verma *et al*., 2025) [36].

We observed from table (1) that both interleukin-1 and interleukin-37 were elevated in diabetic patients with normal blood pressure, while they were low in diabetic patients with abnormal blood pressure. This indicates that high blood pressure inversely affected the production of these cytokines, suggesting an interaction between high blood pressure and diabetes in terms of their impact on cytokines. However, our findings are consistent with a previous report by (Al-Shukaili *et al*. 2013) [7] they observed that T2DM patients with hypertension actually had lower levels of certain inflammatory mediators such as IL-1 than those without hypertension. As shown in table (1) No significant differences were observed in the remaining parameters, including lymphocytes, granulocytes, RBC, hemoglobin and IL-17Alevels, as their values were largely comparable across the groups and did not reach statistical significance.

The relationship between hypertension and T2DM extends beyond simple comorbidity to represent a synergistic interaction that accelerates end-organ damage. Over 25% of T2DM patients with hypertension or even "high-normal" blood pressure show signs of cardiac injury, as evidenced by elevated N-terminal proBNP levels (Landolfo *et al*., 2024A) [13] This underscores the importance of comprehensive cardiovascular risk assessment and aggressive blood pressure management in all diabetic patients, regardless of apparent blood pressure severity.

Table 1: Hematological, biochemical, and immunological parameters according to blood pressure category in T2DM patients and Control group.

The case	Variable	FBS	RBS	WBC	LYM	GRAN	RBC	HGB	IL-1	IL-17A	IL-37
	Normal Range	≤100 mg/dl	<140 mg/dl	3.54-9.06 $\times 10^9$/L	0.71-4.53 $\times 10^9$/L	1.42-7.06 $\times 10^9$/L	M:4.30-5.60 F:4-5.20 $\times 10^{12}$/L	M:13.30-16.20 F:12-15.80 $\times 10^{12}$/L	6.3-38.9 pg/ml	4.8-31.7 pg/ml	9.4-13.2 pg/ml
Normal Blood Pressure	Mean	166 a	259 a	7.75 a	2.51 a	4.69 a	4.63 ab	13.07 a	26.33 a	19.45a	13.58 a
	N. Sample	19	19	19	19	19	19	19	18	17	18
	S.D	45.1	62.98	1.90	0.76	1.45	0.49	1.68	6.79	7.77	2.69
Abnormal Blood Pressure	Mean	187 a	256 a	6.88 ab	2.29 a	4.14a	5.03 a	13.65a	21.07 b	18.15 a	11.73b
	N. Sample	51	51	51	51	51	51	51	48	47	50
	S.D	77.05	91.94	2.02	0.75	1.49	1.10	2.76	7.56	7.12	1.36
Controls group	Mean	90 b	102 b	5.93 b	2.64a	4.19 a	4.48 b	13.77 a	23.47 ab	19.57 a	10.98b
	N. Sample	21	21	21	21	21	21	21	18	19	19
	S.D	10.21	12.50	1.71	0.98	1.43	0.50	1.52	8.72	8.71	1.014

The Impact of Self-Monitoring of Blood Glucose on Diabetes Management

Self-monitoring of blood glucose (SMBG) represents a fundamental component of diabetes self-management, enabling patients to evaluate their individual responses to therapy and assess whether glycemic goals are being achieved. (ADA 2025) [33] Emphasize that glucose monitoring allows people with diabetes to evaluate their individual responses to therapy and make informed decisions regarding nutrition, physical activity, and medication adjustments.

Our study investigated the relationship between SMBG practices and glycemic control among T2DM patients. We categorized patients into those under “regular monitoring” (n=19) and those “without regular monitoring” (n=51).

Our findings demonstrated that patients who regularly monitored their blood glucose had significantly lower glycemic markers compared to those who did not monitor regularly. Specifically, the regular monitoring group had a mean fasting blood sugar of 149 mg/dL compared to 193 mg/dL in the non-monitoring group, and a mean random blood sugar of 205 mg/dL compared to 276 mg/dL in the non-monitoring group.

These findings are consistent with recent literature demonstrating that effective SMBG leads to good glycemic control, which reduces the risk of acute and chronic complications, including diabetic ketoacidosis and both macrovascular and microvascular damage (Makkar *et al* ., 2025) [20]. Frequent self-monitoring of blood glucose is associated with better glycemic control and has been shown to improve outcomes in diabetes management (Sun *et al*.,2024) [8]. We examined patients who regularly self-monitor their glucose versus those who do not, along with controls (**Table 2**). Consistent with expectations, patients under regular monitoring showed a significantly elevated mean FBS level 149 mg/dl compared with the control group 90 mg/dl, while remaining significantly lower than patients without regular monitoring, who exhibited the highest mean FBS value 193 mg/dl. A similar pattern was observed for RBS, where regularly monitored patients had a mean value of 205 mg/dl, which was significantly lower than that of non-monitored patients 276 mg/dl but higher than controls 102 mg/dl with a significant difference among all three groups. These findings indicate that regular self-monitoring of blood glucose is associated with better glycemic control, although values may still remain above the normal range in diabetic patients. Patients who check their blood sugars frequently are more likely to adjust their diet, medications, or seek medical advice proactively, resulting in better control. Our findings align with evidence that frequent self-monitoring of blood glucose has been shown to improve glycemic control by enabling timely dietary and therapeutic adjustments, resulting in lower fasting glucose levels and improved HbA1c (ADA 2024 , Shah *et al*.,2025) [30].

Mean WBC count was higher in patients under regular monitoring (7.44 $\times 10^9$/L) compared with the control group (5.93 $\times 10^9$/L), with a statistically significant difference. This elevation may reflect chronic low-grade inflammation associated with persistent hyperglycemia and insulin resistance in type 2 diabetes mellitus. While RBC counts were significantly higher in regularly monitored patients 5.02 $\times 10^{12}$/L compared with controls 4.47 $\times 10^{12}$/L, suggesting possible metabolic and rheological adaptations related to glycemic status. These findings suggest that hematological alterations in type 2 diabetes are primarily inflammatory in nature and are better reflected by leukocyte activation rather than changes in erythrocyte parameters. Previous study (Kheradmand *et al*., 2021) [12] have demonstrated a significant difference in WBC count between DM patients and healthy controls this finding are agreement with the result of present study.

Regarding cytokines, IL-37 levels demonstrated a distinct pattern. Patients without regular monitoring exhibited the highest mean IL-37 level 12.31 pg/mL, followed by patients under regular monitoring (11.98 pg/mL), while the control group showed the lowest level (10.97 pg/mL), with a statistically significant difference. This finding may reflect a compensatory anti-inflammatory response that increases with poorer glycemic control. And we didn’t a find a study similar with our study.

As shown in table (2) No notable differences were observed among the remaining variables Lymphocyte and granulocytes, HGB, IL-1, IL – 17A counts as their values were largely comparable and no statistically significant differences were detected.

(ADA 2025) Standard s recommend that people with diabetes should be provided with blood glucose monitoring devices as indicated by their circumstances, preferences, and treatment. For patients on insulin therapy, the recommendations include checking blood glucose when fasting, before and after meals and snacks, at bedtime, in the middle of the night, and before, during, and after exercise. Safety checks must be performed whenever hypoglycemia or hyperglycemia is suspected, after treating lows until normoglycemic, and before performing critical tasks like driving.

Recent study had also highlighted the evolution of glucose monitoring technology, with continuous glucose monitoring (CGM) systems offering significant advantages over traditional SMBG. A study published in 2024 found that CGM use was associated with a significantly greater reduction in HbA1c (-0.62%, $p < 0.01$) compared with matched controls at 3 months (Shields *et al*., 2024) [32].

These findings underscore the importance of patient education and healthcare provider engagement in promoting SMBG. Healthcare providers should not only recommend SMBG but also provide specific guidance on monitoring frequency, target glucose ranges, and appropriate responses to out-of-range values. Additionally, addressing barriers such as the cost of glucometers and test strips, fear of pain during finger-prick procedures, and lack of knowledge about the benefits of monitoring is essential for improving SMBG practices.

Table 2: Glycemic, Hematological, and Immunological Parameters according to study group.

The case	Variable	FBS	RBS	WBC	LYM	GRAN	RBC	HGB	IL-1	IL-17A	IL-37
	Normal Range	≤100 mg/dl	<140 mg/dl	3.54-9.06 $\times10^9$/L	0.71-4.53 $\times10^9$/L	1.42-7.06 $\times10^9$/L	M:4.30-5.60 F:4-5.20 $\times10^{12}$/L	M:13.30-16.20 F:12-15.80 $\times10^{12}$/L	6.3-38.9 pg/ml	4.8-31.7 pg/ml	9.4-13.2 pg/ml
Patients Under Regular Monitoring	Mean	149 b	205 b	7.44 a	2.37 a	4.58 a	5.02a	13.56 a	23.030 a	19.560a	11.98 ab
	N. Sample	19	19	19	19	19	19	19	19	18	19
	S.D	35.70	45.58	2.35	0.88	1.71	0.84	2.04	9.10	9.19	1.59
Patients Without Regular Monitoring	Mean	193 a	276 a	6.91 ab	2.34 a	4.18 a	4.88 ab	13.47 a	22.29 a	18.07 a	12.31 a
	N. Sample	51	51	51	51	51	51	51	47	46	49
	S.D	76.05	88.02	1.88	0.71	1.39	1.04	2.69	7.13	6.42	2.11
Control group	Mean	90 c	102 c	5.93 b	2.64 a	4.19 a	4.47 b	13.76 a	23.47 a	19.56 a	10.97 b
	N. Sample	21	21	21	21	21	21	21	18	19	19
	S.D	10.21	12.50	1.71	0.98	1.43	0.50	1.52	8.72	8.71	1.01

The Role of Dietary Compliance in Diabetes Management

Dietary management represents a cornerstone of T2DM care, with adherence to dietary recommendations significantly influencing glycemic control, complication prevention, and quality of life. Despite its importance, studies indicate that dietary compliance remains a significant challenge for many patients. A 2024 study from Ethiopia found that overall adherence to dietary recommendations among type 2 diabetic patients was 62.8% (Atinafu *et al*., 2025), while a 2025 [10] study from China reported that 46.1% of patients had poor dietary compliance (Tang *et al*., 2025) [35].

Our study examined the relationship between dietary compliance and glycemic control by categorizing patients into those who adhered to dietary recommendations (n=48) and those who did not (n=22). As presented in table (3) FBS and RBS means of the follow-up group were 170 , 240 mg/dl respectively and the non-follow group 205 , 291 respectively differed significantly from the control group 90 , 102 respectively indicating clear glycemic elevation in both diabetic groups. Moreover, the difference between the follow and non-follow groups confirms a significant effect of dietary adherence on glucose control. These differences are biologically plausible because regular follow-up and dietary adherence typically improve glucose control through better medication compliance, structured lifestyle changes, and earlier correction of hyperglycemia.

Recent lifestyle/diet literature supports that higher adherence to nutrition education and dietary interventions is associated with better glycemic outcomes in T2DM. This interpretation is consistent with recent evidence demonstrating that higher adherence to nutrition education and dietary interventions is associated with improved glycemic outcomes in patients with type 2 diabetes mellitus, thereby supporting the current findings (ADA, 2024 , Strydom., *et al*. 2025) [26, 33].

Evidence indicates that dietary changes alone may not play a decisive role in preventing type 2 diabetes unless accompanied by weight loss and lifestyle modifications, particularly physical activity and this finding partially inconsistent with our finding (Salvado *et al* .,2011).

For WBC, diet-following patients showed a mean of 7.21 $\times10^9$ /L, significantly higher than the controls 5.93 $\times10^9$ /L, while the non-follow group 6.92 $\times10^9$ /L demonstrated partial significance, falling between the two groups. Even when values remain within reference ranges, a higher WBC in diabetes is often interpreted as a marker of meta-inflammation/low-grade systemic inflammation driven by chronic hyperglycemia, oxidative stress, and endothelial activation. The study conducted by Shaw *et al* ,2025[31] are consistent with recent studies reporting that the presence of higher WBC in diabetics compared with controls is consistent with modern work describing diabetes-related meta-inflammation and inflammatory cytokine involvement in metabolic disease.

While for RBC mean of diet-following diabetic patients was 4.78$\times10^{12}$/L demonstrated partial significance with control group mean 4.47 $\times10^{12}$/L and non-diet-following diabetic patients 5.22 $\times10^{12}$/L show a significant difference with both groups. This may be due to hemoconcentration (dehydration related to higher glucose/ osmotic diuresis), altered blood rheology in insulin resistance, or metabolic stress effects on erythrocyte turnover (Le Devehat *et al*., 2004) [14].and this findings aligns with findings present study. A previous study (Al-Allaff and Mohmad, 2021) [28] reported that the ketogenic diet significantly increased total white blood cell (WBC) count without affecting neutrophil and lymphocyte counts. Similarly, our results showed a significant rise in total WBCs with no significant changes in neutrophils or lymphocytes, which is consistent with the findings of present study.

As shown in table (3) IL-37 showed that both diabetic groups 12.15 pg/ml for follow, 12.38 for non-follow were higher than controls 10.97 pg/ml indicating a significant difference. Suggesting a possible compensatory anti-inflammatory response in chronic metabolic stress.

Recent study indicates that adherence to specific dietary patterns can influence circulating levels of inflammatory cytokines in individuals with type 2 diabetes, highlighting the potential role of diet in modulating immune and inflammatory pathways involved in disease progression (Motamedi *et al*., 2022) [24].

No notable differences were observed among the remaining variables Lymphocyte and granulocytes, HGB, IL-1 , IL – 17A as their values were largely comparable and no statistically significant differences were detected as showed in table (3).

These findings align with recent research identifying the factors that influence dietary compliance. A 2025[29] study identified family history of diabetes, duration of disease, presence of comorbidities, and receipt of diabetic nutrition education as significant factors associated with dietary adherence (Atinafu *et al* .,2025) [33],. Patients who had a family history of diabetes were 1.58 times more likely to adhere, possibly due to increased awareness and shared knowledge within the household. Patients who were diagnosed with T2DM for more than 5 years were 1.46 times more likely to adhere compared to those diagnosed for A shorter period, likely due to increased exposure to healthcare professionals and repeated education. Patients who received diabetic nutrition education were 1.14 times more likely to adhere, highlighting the importance of structured education programs (Atinafu *et al*., 2025) [10].

The study found that older patients generally demonstrate better compliance, possibly because older individuals have more personal time for health education post-retirement. Female patient's exhibit higher levels of dietary compliance compared to males, attributed to women being more communicative, receptive to medical guidance, and having fewer social activities that interfere with dietary management. Higher educational attainment is directly proportional to better compliance, as patients with more education have a more accurate understanding and acceptance of dietary treatment plans. Economic status also plays a crucial role, with higher-income groups having better access to medical resources and more likely to develop healthy dietary habits.

Table 3: Glycemic, Hematological, and Immunological Parameters according to study group.

The case	Variable	FBS	RBS	WBC	LYM	GRAN	RBC	HGB	IL-1	IL-17A	IL-37
	Normal Range	≤100 mg/dl	<140 mg/dl	3.54-9.06 $\times10^9$/L	0.71-4.53 $\times10^9$/L	1.42-7.06 $\times10^9$/L	M:4.30-5.60 F:4-5.20 $\times10^{12}$/L	M:13.30-16.20 F:12-15.80 $\times10^{12}$/L	6.3-38.9 pg/ml	4.8-31.7 pg/ml	9.4-13.2 pg/ml
Follow diabetic patients	Mean	170 b	240 b	7.21 a	2.39 a	4.31 a	4.78 ab	13.26 a	22.37 a	18.15 a	12.15 a
	N. Sample	48	48	48	48	48	48	48	46	46	48
	S.D	54.60	69.85	1.94	0.75	1.42	.675	1.93	5.96	6.99	1.65
Without Follow diabetic patients	Mean	205 a	291 a	6.92 ab	2.27 a	4.24 a	5.22a	14 a	22.81 a	19.36 a	12.38 a
	N. Sample	22	22	22	22	22	22	22	20	18	20
	S.D	92.50	103.88	2.18	0.77	1.65	1.42	3.47	10.84	8.04	2.63
Control group	Mean	90 c	102 c	5.93 b	2.64 a	4.19 a	4.47b	13.77 a	23.47 a	19.57a	10.98 b
	N. Sample	21	21	21	21	21	21	21	18	19	19
	S.D	10.21	12.50	1.71	0.98	1.43	0.50	1.52	8.72	8.71	1.014

Conclusion

This cross-sectional study conducted at Sinjar General Hospital provides important insights into the relationships between blood pressure, self-monitoring of blood glucose, dietary compliance, and their effects on immunological and hematological parameters in patients with T2DM. Our findings demonstrate that hypertension is associated with altered cytokine profiles, potentially indicating immune exhaustion in patients with concurrent T2DM and hypertension. Furthermore, regular self-monitoring of blood glucose and dietary compliance were significantly associated with improved glycemic control.

The study highlights the importance of integrated management strategies that address cardiovascular risk factors, promote patient self-monitoring behaviors, and enhance dietary adherence. Healthcare providers should emphasize the importance of blood pressure control, provide education and support for SMBG, and offer tailored dietary counseling to address the specific barriers faced by each patient. Future research with larger sample sizes and longitudinal designs is needed to further elucidate the complex interactions between these factors and their long-term impact on diabetes outcomes.

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