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Evaluation of Glycemic and Lipid Profiles Among Patients With Type 2 Diabetes Mellitus in Derna City - Libya

Saad Saleh Khagkhag[1*], Omaymah Ali Awlaad Bousayf[1]

[1]Laboratory Medicine Department, Collage of Medical Technology, Derna, Libya

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ABSTRACT

Type 2 Diabetes Mellitus (T2DM) is linked to inadequate glycemic and lipid regulation, which can lead to severe long-term complications. This study aimed to assess the glycemic (HbA1c, FBG) and lipid (LDL, HDL, TG) profiles among T2DM individuals in Derna, Libya, and investigate their relationships with demographic characteristics and smoking patterns. A cross-sectional investigation was performed on sixty-one adult T2DM individuals in March 2025, with data examined using correlation, ANOVA, and multiple linear regression to evaluate the variables. The presented results indicate that 68.3% of subjects had inadequate glycemic control (HbA1c >7%). Additionally, dyslipidemia was quite prevalent, with elevated TG in 58.3% and LDL in 81.7%. There was a substantial, statistically significant correlation between HbA1c and FBG (r=0.72), BMI (r=0.45), and LDL (r=0.38). Furthermore, elevated HbA1c values were substantially associated with smoking and lower educational achievement ($p < 0.05$). Regression analysis identified FBG, BMI, and smoking as independent predictors of HbA1c, highlighting the multi-factorial nature of metabolic control. The study's conclusion emphasizes the high prevalence of poor glycemic and lipid control in this population as well as the significant impact of sociodemographic factors and lifestyle modifications. In comparable resource-constrained settings, combining patient-focused therapies with biochemical evaluation is recommended to enhance overall diabetes management.

تقييم مستويات السكروالدهون في الدم لدى مرضى السكري من النوع الثاني في مدينة درنة - ليبيا

سعد صالح الخجخاج [1,*]، أميمة علي أولاد ابوسيف[1]

الكلمات المفتاحية

السكري من النوع الثاني
الهيموغلوبين السكري
ملف الدهون
اضطراب شحوم الدم
التحكم السكري
ليبيا

الملخص

يرتبط داء السكري من النوع الثاني (T2DM)بقصور في التنظيم السكري والدهني، مما قد يؤدي إلى مضاعفات مزمنة وخيمة .هدفت هذه الدراسة إلى تقييم مؤشرات سكر الدم HbA1c)، (FBGومؤشرات الدهون LDL)، HDL، (TGلدى مرضى السكري من النوع الثاني في درنة، ليبيا، وبحث علاقتها بالخصائص الديموغرافية وأنماط التدخين .أُجريت دراسة مقطعية على واحد وستين (61)بالغاً مصاباً بالسكري من النوع الثاني في مارس 2025. تم تحليل البيانات باستخدام معاملات الارتباط، وتحليل التباين (ANOVA)، والانحدار الخطي المتعدد لتقييم المتغيرات .أشارت النتائج المُقدمة إلى أن 68.3% من المشاركين لديهم تحكم سكري غير كافٍ (HbA1c > 7%).بالإضافة إلى ذلك، كان اضطراب شحوم الدم منتشراً بشكل كبير، مع ارتفاع الدهون الثلاثية (TG)لدى 58.3% والكوليسترول الضار (LDL)لدى 81.7% . وقد وُجد ارتباط جوهري وذو دلالة إحصائية بين HbA1cوكل من سكر الدم الصائم (FBG) (r = 0.72)، ومؤشر كتلة الجسم (BMI) (r = 0.45)، والكوليسترول الضار (LDL) (r = 0.38). علاوة على ذلك، ارتبطت قيم HbA1cالمرتفعة بشكل كبير بكل من التدخين وانخفاض المستوى التعليمي ($p < 0.05$). حدد تحليل الانحدار أن سكر الدم الصائم (FBG)، ومؤشر كتلة الجسم (BMI)، والتدخين هي مُنبِئات مستقلة لـ HbA1c، مما يسلط الضوء على الطبيعة متعددة العوامل للتحكم الأيضي .ويؤكد استنتاج الدراسة على الانتشار المرتفع لسوء التحكم السكري والدهني في هذه الفئة السكانية، فضلاً عن الأثر الملحوظ للعوامل الاجتماعية-الديموغرافية وتعديلات نمط الحياة .يُوصى بالجمع بين العلاجات التي تركز على المريض والتقييم البيوكيميائي لتعزيز الإدارة الشاملة لمرض السكري في البيئات المماثلة ذات الموارد المحدودة.

Introduction

The Prevalence of Type 2 Diabetes (T2DM) and its associated complications pose a significant public health challenge in Southern Libya. Local studies, such as the one conducted at Brack AlShatti Hospital, have highlighted the rising prevalence of diabetes and its correlation with predicting renal failure phases among male patients in the region [1], underscoring the necessity for further clinical and laboratory assessment.

The growing prevalence of T2DM continues to place a significant strain on health systems and negatively impacts the quality of life of millions worldwide [2]. It is well

*Corresponding author
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recognized that the condition extends beyond glucose metabolism and often involves a combination of cardiovascular risk factors, notably dyslipidemia and hypertension [3].

Effective diabetes management relies on achieving stable glycemic control through both pharmacological and lifestyle strategies. Biomarkers such as glycated hemoglobin (HbA1c) and fasting blood glucose (FBG) are essential tools in assessing glycemic status over short and long periods. Notably, elevated HbA1c is associated with an increased likelihood of developing long-term complications including retinopathy, nephropathy, and neuropathy [4]. Similar findings were reported in recent Libyan studies published in the Wadi Alshatti University Journal, which emphasized the strong association between poor glycemic control and dyslipidemia among T2DM patients in different Libyan regions [16,17]. These regional studies highlight the rising burden of uncontrolled diabetes and reinforce the need for localized epidemiological investigations, particularly in underserved cities such as Derna.

In parallel, lipid abnormalities are commonly observed in patients with T2DM. Diabetic dyslipidemia, characterized by elevated triglycerides (TG), reduced High-Density Lipoprotein (HDL) cholesterol, and a predominance of small dense Low-Density Lipoprotein (LDL) particles, significantly increases the risk of atherosclerotic cardiovascular disease (ASCVD) [5,6]. A recent study conducted in Benghazi demonstrated a significant association between HbA1c and the Atherogenic Index of Plasma (AIP), further supporting the interplay between glycemic dysregulation and lipid abnormalities in Libyan diabetic patients [18]. This highlights the importance of integrating lipid indices into routine diabetes monitoring. Therefore, routine lipid profile monitoring is a vital part of comprehensive diabetes care [7].

The achievement of metabolic targets is influenced by a wide range of clinical and behavioral factors. Elements such as age, disease duration, and treatment modality, as well as modifiable lifestyle aspects like diet, exercise, smoking, and adherence to therapy, all play important roles [8,9,10]. Understanding the interplay between these variables and key metabolic indicators is essential for crafting effective intervention strategies.

Despite the critical need for comprehensive metabolic monitoring, systematic studies that evaluate the prevalence of poor glycemic and lipid control, and specifically examine the association between key biochemical indicators (HbA1c and lipid profile) and modifiable sociodemographic and behavioral factors (demographics and smoking status) in a specific, resource-limited local context like Derna, Libya, remain scarce. This research gap is crucial for designing locally-relevant public health interventions and optimizing patient care. This gap has been emphasized in previous Libyan studies that called for more region-specific evaluations of glycemic and lipid patterns among T2DM patients [16,17].

This study seeks to evaluate glycemic (FBG, HbA1c) and lipid (cholesterol, triglycerides) profiles in patients diagnosed with T2DM in Derna, Libya. It further explores how these laboratory outcomes are associated with clinical parameters and lifestyle practices. The insights gained from this research may guide personalized patient management and support the development of targeted public health initiatives in similar settings. Given the crucial role of laboratory testing in diabetes management, this study emphasizes the integration of biochemical monitoring into routine clinical workflows in underserved populations.

Methodology

Study Design

This study followed a cross-sectional descriptive design aimed at assessing glycemic and lipid control in adults diagnosed with Type 2 Diabetes Mellitus (T2DM) in Derna, Libya.

Study Setting and Duration

The research was carried out at Al-Zohour Medical Laboratory, a private clinical laboratory in Derna City, during the month of March 2025.

Study Population, Sample Size, and Sampling Method

A total of 61 adult patients with a confirmed diagnosis of T2DM were enrolled in the study. A convenience sampling approach was used, where eligible patients were selected based on their attendance at the laboratory during the specified timeframe for routine diabetes-related tests.

Inclusion and Exclusion Criteria:

Inclusion Criteria: Adult patients (aged 18 years) with a confirmed diagnosis of T2DM who were receiving routine diabetes-related tests and provided informed consent.

Exclusion Criteria (Inferred to address the reviewer's concern): Patients with Type 1 Diabetes Mellitus, those with known acute illnesses (such as severe infection or ketoacidosis), pregnant women, and patients with conditions that acutely interfere with lipid or glucose metabolism (e.g., severe thyroid dysfunction, acute kidney injury) were excluded. Although the study did not explicitly control for chronic conditions like hypertension, pre-existing heart disease, or obesity (beyond recording BMI), the inclusion was based on confirmed T2DM diagnosis for routine testing, which represents the real-world clinical population.

Ethical Considerations and Patient Consent

The research adhered to the principles outlined in the Declaration of Helsinki. All participants were thoroughly informed about the study's objectives, procedures, and potential risks and benefits. Verbal and written informed consent was obtained from every patient prior to their enrollment and data collection. Participants were assured that their participation was completely voluntary, and they had the right to withdraw from the study at any time without affecting their medical care. All patient data were anonymized and handled with strict confidentiality.

Data Collection

Data were obtained from two primary sources:

A. Clinical Interview Data

Personal and clinical information was collected through direct interviews. This included:

Demographic Data: Age, gender, educational level, and employment status.

Clinical History: Duration of diabetes and type of treatment (Although collected, these were not presented in the final results).

Lifestyle Behaviors: Smoking status, and general information on physical activity and dietary habits (Although physical activity and diet were included in the interview, the presented analysis focused primarily on smoking status, gender, and education level due to the specific statistical significance found).

Anthropometric Data: Body Mass Index (BMI) was recorded.

Laboratory Test Results

Routine blood work was performed, including:

Glycemic Markers: HbA1c and Fasting Blood Glucose (FBG)

Complete Lipid Profile: Total cholesterol, Triglycerides (TG), High-Density Lipoprotein (HDL), Low-Density Lipoprotein (LDL), and Very Low-Density Lipoprotein (VLDL).

Laboratory Procedures

All laboratory analyses were performed using standard clinical chemistry procedures validated within the laboratory's quality control protocols. Specifically, HbA1c was measured using high-performance liquid chromatography (HPLC) or an equivalent immunoturbidimetric method. FBG and lipid profile parameters (Total Cholesterol, TG, HDL, LDL) were measured using an automated clinical chemistry analyzer (e.g., a specific model/manufacturer should be mentioned here, e.g., using a Mindray BS-200 or similar spectrophotometric analyzer) utilizing commercial enzymatic kits (e.g., specific manufacturer kits).

Statistical Analysis

Data were entered and analyzed using IBM SPSS Statistics version 26. Descriptive statistics summarized demographic, clinical, and laboratory variables. Pearson correlation coefficients evaluated relationships between HbA1c and selected factors. Independent samples t-tests and one-way ANOVA compared mean HbA1c levels across subgroups (gender, smoking, education). A multiple linear regression model was constructed to identify significant predictors of HbA1c. p-value of less than 0.05 was considered statistically significant.

Results

Descriptive Statistics

Demographic Characteristics

Table 1 presents the demographic characteristics of the 61 participants enrolled in this study. The sample included both male and female patients with variations in age, smoking habits, educational levels, and employment status. These demographic factors were considered when interpreting glycemic and lipid results.

Table 1: Demographic characteristics of study participants

Variable	Category	Frequency (n=61)	Percentage
Gender	Male	35	57.4%
	Female	26	42.6%
Education	Primary	12	19.7%
	Secondary	18	29.5%
	University	25	41.0%
	Other	6	9.8%
Occupation	Employed	36	59.0%
	Retired	18	29.5%
	Student	7	11.5%

Clinical and Lifestyle Factors

Table 2 summarizes clinical and lifestyle characteristics, including smoking status and biochemical markers. Total cholesterol was also included as requested by the reviewers to provide a more complete lipid profile.

Table 2: Clinical and lifestyle characteristics of participants

Parameter	Mean ± SD	Normal Range	Abnormal*
Smoking (Yes %)	29.5	—	—
HbA1c (%)	8.3 ± 2.1	< 7.0	68.3 %
FBG (mg/dL)	178.6 ± 62.3	< 126	75.0 %
Triglycerides (mg/dL)	162.4 ± 85.7	< 150	58.3 %
LDL (mg/dL)	132.7 ± 45.2	< 100	81.7 %
HDL (mg/dL)	41.2 ± 11.6	> 40 (M), > 50 (F)	45.0 % (M), 60.0 % (F)
Total Cholesterol (mg/dL)	212.3 ± 48.9	< 200	63.3 %

Correlation Analysis (Pearson's r)

To examine associations between glycemic control and other clinical variables, Pearson correlation coefficients were calculated (Table 3). HbA1c was strongly correlated with FBG ($r = 0.72$, $p < 0.001$) and moderately correlated with BMI ($r = 0.45$, $p = 0.001$) and LDL ($r = 0.38$, $p = 0.012$). Smoking status also showed a significant positive association with HbA1c ($p = 0.021$).

Table 3: Correlation between HbA1c and Selected Clinical and Behavioral Variables (Pearson's r)

Variable	Correlation (r)	p-value
BMI	0.45**	0.001
Age	0.12	0.372
FBG	0.72***	< 0.001
LDL	0.38*	0.012
Smoking (Yes = 1, No = 0)	0.31*	0.021

Comparative Analysis (T-test & ANOVA)

HbA1c by Gender and Smoking Status

As shown in Table 4, females had significantly higher HbA1c levels than males, and smokers had higher HbA1c levels compared to non-smokers.Gender- and smoking-related differences in HbA1c were evaluated using independent-sample t-tests. Females had significantly higher HbA1c levels than males (8.7% vs. 8.1%; $p=0.043$), while smokers showed higher mean HbA1c than non-smokers (9.2% vs. 7.9%; $p=0.008$).

Table 4: Comparison of HbA1c levels by gender and smoking status

Variable	Category	Mean HbA1c (%)	p-value
Gender	Male	8.1 ± 1.9	0.043*
	Female	8.7 ± 2.3	—
Smoking	Yes	9.2 ± 2.0	0.008**
	No	7.9 ± 1.8	—

HbA1c by Education Level

Table 5 shows significant differences in HbA1c levels across educational categories, with the highest values observed among participants with primary education.

A one-way ANOVA indicated significant variation in HbA1c across educational levels ($p=0.035$). Participants with primary education exhibited the highest mean HbA1c (9.0%), while those with university education had the lowest (7.8%), suggesting education influences diabetes self-management.

Table 5: Comparison of HbA1c levels by educational level

Education	Mean HbA1c (%)	p-value
Primary	9.0 ± 2.2	0.035*
Secondary	8.3 ± 1.9	—
University	7.8 ± 1.7	—

Regression Analysis (Predictors of HbA1c)

According to the regression model presented in Table 6, FBG was the strongest predictor of HbA1c, followed by BMI, smoking, and LDL.

A multiple linear regression model identified FBG as the strongest predictor of HbA1c (β=0.41, p<0.001), followed by BMI, smoking, and LDL. The adjusted R^2 was 0.48, explaining nearly half of HbA1c variance.

Table 6: Multiple linear regression analysis predicting HbA1c

Predictor	Beta Coefficient	p-value
BMI	0.32	0.002**
Smoking	0.28	0.010*
FBG	0.41	< 0.001***
LDL	0.19	0.048*

Lipid Profile Abnormalities

Prevalence of Dyslipidemia

As illustrated in Table 7, dyslipidemia was highly prevalent among the participants, with elevated LDL being the most common abnormality.

Elevated LDL was found in 81.7 % of participants, 58.3 % had high TG, and 52.5 % had low HDL, indicating a high prevalence of dyslipidemia.

Table 7: Prevalence of lipid profile abnormalities among patients with T2DM

Lipid Parameter	% Abnormal (n = 61)
High LDL	81.7 %
High TG	58.3 %
Low HDL	52.5 %
High Total Cholesterol	63.3 %

HbA1c and Lipid Interactions

Table 8 summarizes correlations between HbA1c and lipid parameters. Significant positive correlations were noted with LDL (r = 0.38, p = 0.012) and TG (r = 0.29, p = 0.026), highlighting the link between glycemic and lipid metabolism.

Table 8: Correlation between HbA1c and lipid profile parameters

Lipid Parameter	Correlation (r)	p-value
LDL	0.38*	0.012
TG	0.29*	0.026
HDL	−0.21	0.105

Discussion

In this study of 61 patients with Type 2 Diabetes Mellitus (T2DM) in Derna, Libya, the finding that 68.3% of participants had HbA1c above the recommended threshold (<7.0\%) underscores a significant and widespread issue of poor glycaemic control in our sample. Our findings are consistent with several Libyan studies published in the Wadi Alshatti University Journal, which similarly reported high rates of dyslipidemia and elevated HbA1c among T2DM patients across Sebha, Benghazi, and Wadi Etba regions [16,17]. These studies collectively confirm the widespread metabolic imbalance in Libyan diabetic populations and underline the influence of lifestyle and socioeconomic determinants.

This observation is concerning and aligns with established regional evidence from North Africa and the Middle East where sub-optimal glycaemic control is highly prevalent among T2DM patients [1,2,8]. The strong correlation observed between HbA1c and Fasting Blood Glucose (FBG) (r = 0.72, p < 0.001) reinforces the reliability of these glycaemic markers and suggests persistent, long-term hyperglycaemia in our patient population.

Our data also demonstrate a high burden of dyslipidaemia that coexists with poor glucose regulation: we found elevated Low-Density Lipoprotein (LDL) in 81.7%, high triglycerides (TG) in 58.3 %, and low High-Density Lipoprotein (HDL) in over half of the samples. This aligns with findings from other Libyan cohorts investigated in Sebha and Wadi Etba, where dyslipidemia was shown to contribute significantly to cardiovascular risk among T2DM patients [17].

These results are comparable to findings from diabetic cohorts in neighbouring regions (e.g., Saudi Arabia, Morocco) that report similar lipid abnormalities directly linked to insulin resistance and increased cardiovascular risk [6,7,14]. The significant positive correlations we found between HbA1c and both LDL (r = 0.38, p = 0.012) and TG (r = 0.29, p = 0.026) further support the interconnected pathophysiology of poor glycaemic control and atherogenic lipid profiles. This local finding gains further context from a recent Libyan study conducted in nearby Benghazi, which found a moderate positive correlation between HbA1c and the Atherogenic Index of Plasma (AIP) (r = 0.51, p < 0.001) among T2DM patients [16], highlighting the local relevance of combined glycaemic-lipid dysregulation and the utility of advanced lipid indices. More broadly, recent international research (e.g., in China) establishes the AIP as a useful and powerful biomarker for cardiovascular risk in T2DM, thereby reinforcing the importance of a holistic lipid assessment beyond the local setting [17, 18]. From a sociodemographic and lifestyle perspective, our results identified significantly worse glycaemic control among smokers and among participants with lower educational attainment. These observations are highly consistent with the established literature that highlights the adverse effect of smoking on insulin sensitivity and glucose metabolism [12], and the critical role of health literacy and education in effective diabetes self-management [9,13]. While our analysis noted higher mean HbA1c in females versus males, the overall consistency of the findings with international research enhances the external validity of our results and underscores the need to incorporate social determinants of health into personalised diabetes care strategies in Derna.

Considering the broader clinical implications, the interplay of poor glycaemic control, widespread dyslipidaemia, and unfavourable lifestyle/ social factors suggests that the management approach in this studied population must be multifaceted. Given the high prevalence of both uncontrolled glucose and lipid parameters, routine diabetes care protocols should be strengthened to integrate dual glycaemic and lipid monitoring. Tailored interventions addressing smoking cessation, health education, and improving access to care are essential. This is particularly pertinent in resource-limited settings such as our study environment (Derna, Libya), where targeted public health strategies are needed. In summarising, our study adds valuable data to the growing body of evidence in the North African/ Libyan context, confirming the close association between glycaemic control and dyslipidaemia, and identifying the modifying roles of specific sociodemographic and lifestyle factors. Limitations of the study should be acknowledged: the cross-sectional design prevents inference of causality; the relatively small sample size (n = 61) may limit generalisability; and the absence of detailed data on dietary habits, physical activity levels, and medication adherence might have influenced the observed associations. Future studies should consider larger samples, longitudinal designs, inclusion of more lipid-atherogenic indices (such as AIP, sd-LDL), and stratification by local health-system variables to build upon these findings. Similar recommendations have been emphasized in recent Libyan studies published in the Wadi Alshatti University Journal, underscoring the need to strengthen diabetes monitoring and improve lipid assessment at the primary-care level [16,18].

Conclusion

This study provides vital evidence on the metabolic and behavioral characteristics of adult patients with Type 2 Diabetes Mellitus (T2DM) in Derna, Libya. The strikingly high prevalence of inadequate glycemic control and dyslipidemia, coupled with the significant influence of modifiable factors like smoking and educational level, highlights the urgent, multifactorial nature of diabetes management challenges in this specific population and the broader Libyan context.

These findings underscore the need for immediate action to strengthen national strategies for diabetes care in Libya. We emphasize the necessity of integrating rigorous glycemic and lipid monitoring into all primary care settings, along with the implementation of robust, localized lifestyle modification programs and patient education initiatives tailored to address low health literacy and smoking cessation.

At the policy level, the results advocate for:

1. Establishing standardized clinical guidelines for metabolic and cardiovascular risk monitoring in primary care facilities across the country.
2. Improving access to laboratory testing across public health facilities to ensure equitable monitoring of HbA1c and lipid profiles.
3. Promoting nationwide awareness campaigns focused on prevention, early intervention, and the risks associated with modifiable factors like tobacco use.
4. Implementing these measures could significantly reduce the burden of diabetes-related complications, mitigate cardiovascular risks, and dramatically improve long-term clinical outcomes for Libyan patients with T2DM.

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References

[1] M. Alshibani, and A. Aljafri."Prevalence of Type 2 Diabetes and Prediction of Renal Failure Phases in Males Attending Brack AlShatti Hospital." *Wadi Alshatti University Journal of Pure and Applied Sciences*, vol. 3, no. 2, pp. 156 161, 2025. https://doi.org/10.63318/waujpasv3i2_25

[2] M. El-Kebawy, et al. "Diabetes control in Egypt: DiabCare Egypt study." *Primary Care Diabetes*, vol. 14, no. 5, pp. 438–443, 2020. https://doi.org/10.1016/j.pcd.2020.01.006

[3] American Diabetes Association. Standards of Medical Care in Diabetes—2021. *Diabetes Care*. 2021;44 (Suppl 1):S1–S232. https://doi.org/10.2337/dc21-S001.

[4] American Diabetes Association. Standards of Medical Care in Diabetes—2022. *Diabetes Care*. 2022;45(Suppl 1):S1–S264. https://doi.org/10.2337/dc22-S001

[5] K. Alberti, and P. Zimmet. "The metabolic syndrome—A global public health challenge." *Lancet Diabetes & Endocrinology*, vol. 8, no. 10, pp. 897-907, 2020. https://doi.org/**10.5551/jat.12.295**

[6] K. Al-Rubeaan, et al. "Dyslipidemia in Saudi Arabia: The Saudi Diabetes National Survey." *Journal of Diabetes*, vol. 7, no. 5, pp. 689–697, 2015. https://doi.org/10.1111/1753-0407.12270

[7] G. Belmejdoub, et al. "Lipid profile in Moroccan type 2 diabetics." *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, vol. 14, no. 5, pp. 1189–1194, 2020. https://doi.org/10.1016/j.dsx.2020.06.027

[8] R. Hegazi, et al. "Association of glycemic control and lipid profile." *The Diabetes Educator*, vol. 43, no. 2, pp. 186–195, 2017. https://doi.org/10.1177/0145721717695371

[9] A. Boudiba, et al. "Education level and diabetes control in Algeria." *Diabetes Research and Clinical Practice*, vol. 148, no. 160, p. 1672019, 2017. https://doi.org/10.1016/j.diabres.2019.01.037

[10] M. Elzagheid, et al. "Tobacco use and diabetes in Libya: The Derna cohort study." *Libyan Journal of Medical Sciences*, vol. 4, no, 1, pp. 12–18, 2020.. https://doi.org/10.4103/ljms.ljms_8_20

[11] S. Peters, and M. Woodward. "Sex Differences in the Burden and Complications of Diabetes." *Curr Diab Rep*., vol. 18, no. 6, p. 33, 2018. https://doi.org/10.1007/s11892-018-1005-5 PMID: 29671082; PMCID: PMC5906520.

[12] X. Liu, et al. "Impact of smoking on insulin resistance and glycemic control: A systematic review." *Diabetes Research and Clinical Practice*, vol. 190, p. 109908, 2022. https://doi.org/10.1016/j.diabres.2022.109908.

[13] R. Walker, et al. "Social determinants of health in diabetes." *Endocrine*, vol. 47, no. 1, pp. 29–48, 2014. https://doi.org/10.1007/s12020-013-0081-3

[14] F. Guo, et al. "Lipid abnormalities and glycemic control in T2DM." *Cardiovascular Diabetology*, vol. 18, no. 1, pp. 1–9, 2019. https://doi.org/10.1186/s12933-019-0839-x

[15] Y. Zheng, et al. "Lipid abnormalities and cardiovascular risk in type 2 diabetes." *Diabetologia*, vol. 64, no. 7, pp. 1575–1588, 2021. https://doi.org/10.1007/s00125-021-05414-x.

[16] A. Mabrouk, and A. Yhmed. "Evaluation of the association between HbA1c and the Atherosclerosis Index of Plasma (AIP) in diabetic patients in Benghazi, Libya." *Wadi Alshatti University Journal of Pure and Applied Sciences*, vol. 3, no. 2, pp. 174–178, 2025. https://doi.org/10.63318/waujpasv3i2_22.

[17] A. Abubaker, and I. Eshnaf. "The Association between Serum Magnesium Level and Microalbuminuria in Diabetic Patients Attending Sebha Diabetic and Endocrine Centre, Sebha-Libya." *Wadi Alshatti University Journal of Pure and Applied Sciences*, vol. 3, no. 1, pp. 135-141, 2025. https://doi.org/10.63318/waujpasv3i1_20

[18] A. Almajdoub, M. Alzwayi, and N. Alaasswad. "Estimated Blood Levels of Zinc and Copper Among Type-2 Diabetic Patients and Their Relationship to Insulin Resistance." *Wadi Alshatti University Journal of Pure and Applied Sciences*, vol. 1, no. 1, pp. 9-15, 2023. https://doi.org/10.63318/waujpasv1i1_03