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Correlation and Regression Analysis Between HbA1c, Fasting Blood Sugar (FBS), and Random Blood Sugar (RBS) levels in Diabetic and Non-Diabetic patients in ElMarj, Libya

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Abstract:
Diabetes mellitus is a prevalent metabolic disorder requiring reliable diagnostic tools. Hemoglobin A1c (HbA1c), fasting blood sugar (FBS), and random blood sugar (RBS) are commonly used for diagnosis and monitoring. HbA1c offers insight into long-term glycemic control, while FBS and RBS reflect real-time glucose levels. The main aim of this study to evaluate the relationship between HbA1c, FBS, and RBS among individuals attending a private diagnostic laboratory in Elmarj, Libya, and to assess the consistency and strength of these markers. This prospective study included 292 participants from November 2023 to March 2025. HbA1c was measured using fluorescence immunoassay, and FBS/RBS were measured via enzymatic colorimetric methods. Data were analyzed using IBM SPSS Statistics version 26.0. Correlation coefficients and linear regression were applied to assess relationships between variables of the 292 participants, 263 underwent HbA1c and FBS testing, 214 underwent HbA1c and RBS testing, and 187 had all three tests. According to American Diabetes Association criteria, 231 participants (79.1%) were in the diabetic range (HbA1c ≥6.5%). HbA1c showed a moderate positive correlation with FBS ($r = 0.68$) and a stronger correlation with RBS ($r = 0.74$), both statistically significant ($P < .001$). Regression analysis demonstrated consistent positive linear relationships. Concluding that the HbA1c correlates significantly with both FBS and RBS, supporting its utility as a stable marker for long-term glycemic monitoring. The findings reinforce the value of integrating HbA1c with FBS and RBS to enhance diagnostic accuracy in diabetic screening.

Keywords: Hemoglobin A1c, Fasting Blood Sugar, Random Blood Sugar, Diabetes Mellitus, Correlation Analysis.

تحليل الارتباط والانحدار بين مستويات الهيموجلوبين السكري (HbA1c)، وسكر الدم الصائم (FBS)، وسكر الدم العشوائي (RBS) لدى مرضى السكري وغير المصابين بالسكري في المرج، ليبيا.

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الملخص
يُعد داء السكري من الاضطرابات الأيضية الشائعة والتي تتطلب أدوات تشخيصية موثوقة. تُستخدم عادةً قياس الهيموغلوبين السكري (HbA1c)، وسكر الدم الصائم (FBS)، وسكر الدم العشوائي (RBS) للتشخيص والمراقبة. يُقدم الهيموغلوبين السكري رؤية ثاقبة حول نسبة السكر في الدم على المدى الطويل، بينما يعكس سكر الدم الصائم وسكر الدم العشوائي مستويات الجلوكوز في وقت الاختبار. الهدف الرئيسي من هذه الدراسة هو تقييم العلاقة بين الهيموغلوبين السكري (HbA1c)، وسكر الدم الصائم (FBS)، وسكر الدم العشوائي (RBS) لدى الأفراد الذين يراجعون مختبر تشخيصيٍ خاص في المرج، ليبيا، وكذلك تقييم ثبات هذه المؤشرات وقوتها. شملت هذه الدراسة 292 مشاركًا من نوفمبر 2023 إلى مارس 2025. تم قياس الهيموغلوبين السكري (HbA1c) باستخدام قياس المناعية الفلورية (FIA) وتم قياس سكر الدم الصائم، وسكر الدم العشوائي باستخدام

قياس الالون الإنزيمية. تم تحليل البيانات باستخدام برنامج IBM SPSS Statistics الإصدار 26.0. تم تطبيق معاملات الارتباط والانحدار الخطي لتقييم العلاقات بين متغيرات 292 مشاركًا، وقد خضع 263 لاختبار الهيموغلوبين السكري وسكر الدم الصائم، وخضع 214 لاختبار الهيموغلوبين السكري وسكر الدم العشوائي، وأجرى 187 الاختبارات الثلاثة جميعها. ووفقًا لمعايير الجمعية الأمريكية للسكري، كان 231 مشاركًا (79.1٪) في نطاق السكري (HbA1c ≥ 6.5٪). أظهر الهيموغلوبين السكري ارتباطًا إيجابيًا معتدلًا مع سكر الدم الصائم (r = 0.68) وارتباطًا أقوى مع سكر الدم العشوائي (r = 0.74)، وكلاهما ذو دلالة إحصائية (P < .001). أظهر تحليل الانحدار علاقات خطية إيجابية متسقة. وخلص إلى أن الهيموغلوبين السكري يرتبط ارتباطًا كبيرًا بكل من سكر الدم الصائم وسكر الدم العشوائي مما يدعم فائدته كعلامة مستقرة لمراقبة نسبة السكر في الدم على المدى الطويل. وتعزز النتائج قيمة دمج الهيموغلوبين السكري مع سكر الدم الصائم وسكر الدم العشوائي لتعزيز دقة التشخيص في فحص السكري.

الكلمات المفتاحية: داء السكري، الهيموغلوبين السكري (HbA1c)، سكر الدم الصائم (FBS)، سكر الدم العشوائي (RBS)، معامل الارتباط.

Introduction

Diabetes Miletus is one of the most commonly investigate conditions in clinical laboratories, and the most frequently ordered tests include fasting blood sugar (FBS), random blood sugar (RBS) and hemoglobin A_1c (HbA1c). these tests are essential for diagnosis and monitoring diabetes and for controlling blood glucose level to prevent complication of hyperglycemia, such as neuropathy, retinopathy, nephropathy and/or increase risk of cardiovascular, cerebrovascular, and peripheral arteries and cerebrovascular disease. [1]

HbA_1c also named Glycosylated or glycated hemoglobin (the latter being the preferred term), reflects the slow, *non-enzymatic* attachment of glucose to the N-terminal valines of the β-globin chains of the hemoglobin. [2,3] HbA_{1c} was first identified as “unusual” hemoglobin variant in patient with diabetes. Subsequent studies establish a correlation between HbA1c level and blood glucose, confirming its value as a reliable marker for long-term glycemic control [4]. Because red blood cells (RBCs) have lifespan of approximately 120 days, the HbA_1c level reflects the average blood glucose concentration over the preceding two to three months. It’s preferred in clinical setting for long-term monitoring due to its stability and reduced susceptibility to daily fluctuations in glucose levels. However, HbA_1c may be affected by conditions that alter red blood cell turnover, such as hemoglobinopathies and hemolytic anemia, and assay accuracy may vary depending on the testing method used [5]. In contrast, fasting blood sugar (FBS) and random blood sugar (RBS) provide a snapshot of blood glucose at a specific point in time. FBS requires an overnight fast (typically 8 hours), and results can be influenced by factors such as stress or acute illness. RBS, while more convenient, may be affected by recent food intake and therefore is less consistent as a standalone diagnostic tool [6].

For the diagnosis of diabetes, fasting blood glucose (FBG) with a threshold of ≥126 mg/dL is widely used. However, in 2009, an International Expert Committee recommended using HbA1c as an additional diagnostic criterion. According to their guidelines, an HbA1c value of ≥6.5% indicates diabetes, and the diagnosis should be confirmed by repeat testing unless symptoms of hyperglycemia are present alongside a random plasma glucose level ≥200 mg/dL, in which case further testing may not be necessary [7].

The primary aim of this study is to examine the relationship between HbA1c, FBS, and RBS in a general population. Specifically, we aim to determine whether elevated FBS and/or RBS levels consistently correlate with high HbA1c percentages, and conversely, whether normal HbA1c levels reliably indicate normal glucose measurements.

Materials and methods:

This prospective study conducted from November/5/2023 to March/3/2025, and included a total 292 participants. All subjects present in *Plasma Diagnostic Medical Laboratory*, a privately operated facility authorized by the private sector office of the Elmarj health ministry, located in Elmarj city of the eastern part of Libya.

All individuals underwent glycated hemoglobin (HbA_1c), fasting blood sugar (FBS) and/or random blood sugar (RBS) tests were included in the study. Oral consent was obtained from each participant to use their test results for this research. Exclusion criteria included individuals with a known history of hematopoietic diseases, hyperthyroidism, hyperadrenalism, liver or kidney diseases. Sample were collected via venipuncture into two types of tubes:

1. A plain tube without anticoagulant for FBS or RBS analysis.
2. A K_2EDTA tube for HbA1c analysis.

Serum was separated immediately from plain tubes to assay the level of blood sugar (FBS or RBS) using an Enzymatic colorimetric method. Calibration was performed with a standard reagent alongside each test run. fresh whole blood collected in K_2EDTA tube was used for the HbA_1c assay; which using Fluorescence immunoassay (FIA) technique. The cutoff in this study taken based on the recommendation of *International Diabetes Federation* (IDF) and *American Diabetes Association* (ADA) and they are: $HbA_1c \geq 6.5$ %; FBA≥ 126 mg/dL and RBS ≥ 200 mg/dL. In this study descriptive statistics, correlation analysis, and linear regression were conducted using IBM SPSS statistics version 26.0.(IBM corp., Armonk, NY, USA). A p -value < 0.05 was considered statistically significant.

Results:

sample size included in this study was 292 participants (n=292); and the count of cases that underwent HbA1c, FBS and /or RBS tests summarized in table 1.

Table 1. shows the count of cases underwent to tests HbA1c, FBS and /or RBS.

Test	Number of cases
HbA1c + FBS	263 participants
HbA1c + RBS	214 participants
HbA1c + FBS+ RBS	187 participants

According to the age of the participants were ranged in age from 10 to 94 years; and when grouped in 5 years intervals; the most frequent age group was 60-64years, followed by 50-54, 55-69; very few individuals were under 25 or over 85. A histogram (figure 1) illustrates age distribution grouped in 5 years interval.

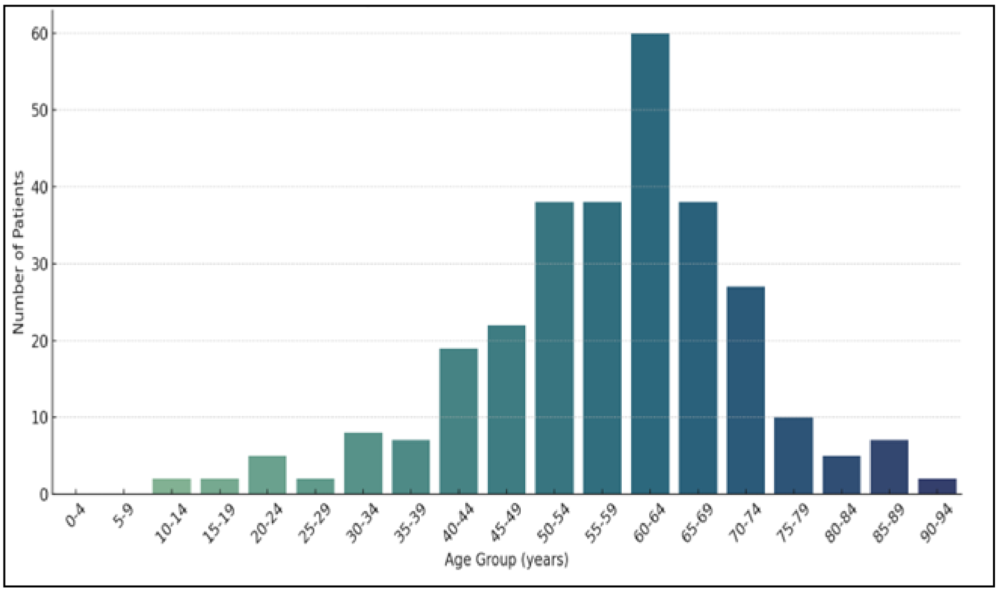

Figure 1. Age distribution grouped in 5 years interval

Regarding sex distribution females were 155 cases Out of 292 participants and represent 53.1 %; while males 137 cases and represent 46.9 %. A pie chart (figure 2) was used to visualize this distribution.

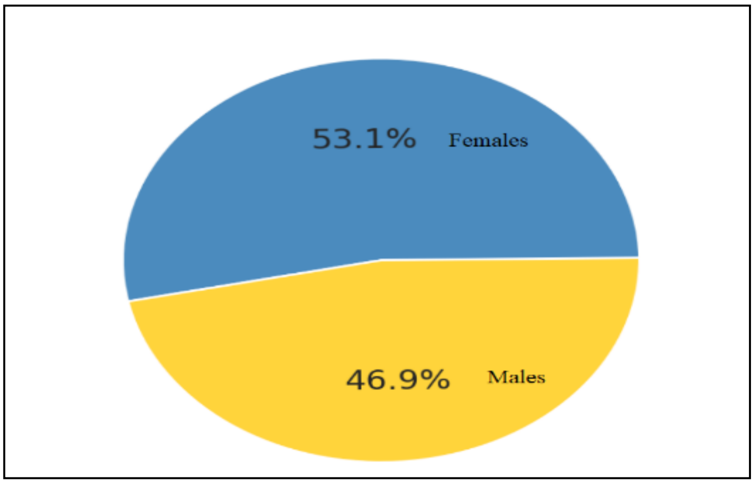

Figure2 . Illustrates the sex distribution in this study.

Based on *American Diabetes Association* (ADA) classification HbA1c level of 292 participants were categorized as below. A bar chart (figure 3) illustrating the results distribution of HBA1c.
Normal (< 5.7 %) count of cases: 29 cases, represent 9.9 %.
Prediabetic (5.7 -6.4 %) count of cases: 32 cases, represent 11.0 %
Diabetic (≥ 6.5) count of cases: 231 cases, represent 79.1 %.

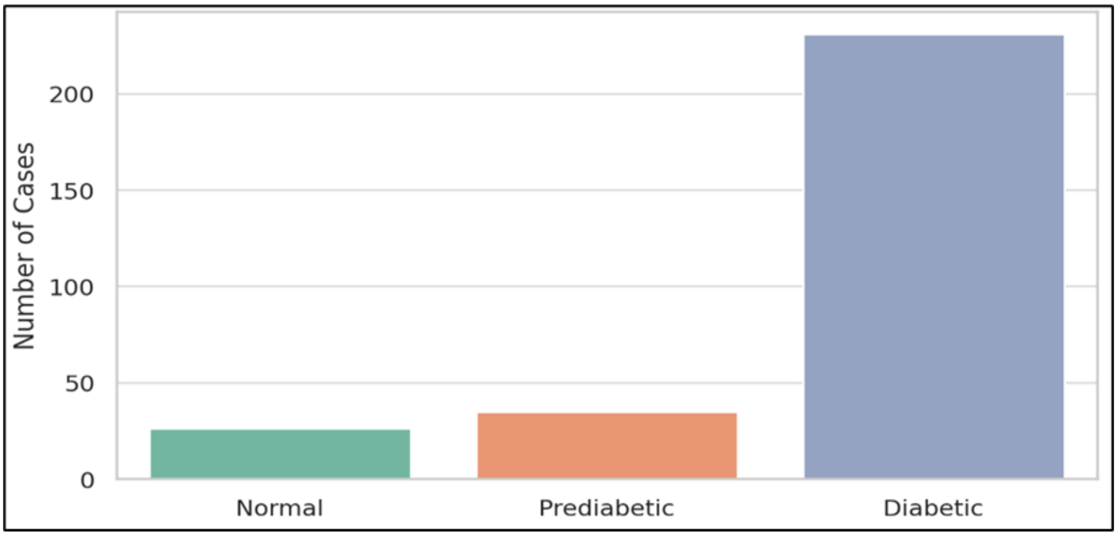

Figure3 . Distribution of the cases according to ADA classification.

Histograms below (figure 4,5 and 6) show the frequencies of HbA1c, FBS and RBS of the cases according to the values of HbA1c in %, FBS and RBS in mg/L respectively. All show reasonable wide distribution with slightly right skewed especially for FBS and RBS; which is common in glucose related data. In Figure 4 which represents the frequency of HbA1c values. The distribution is less skewed than FBS/RBS, reflecting HbA1c's role as a stable, long-term glycemic marker. The peak in the diabetic range (≥6.5%) corroborates the high diabetes prevalence (79.1%) identified in the study.

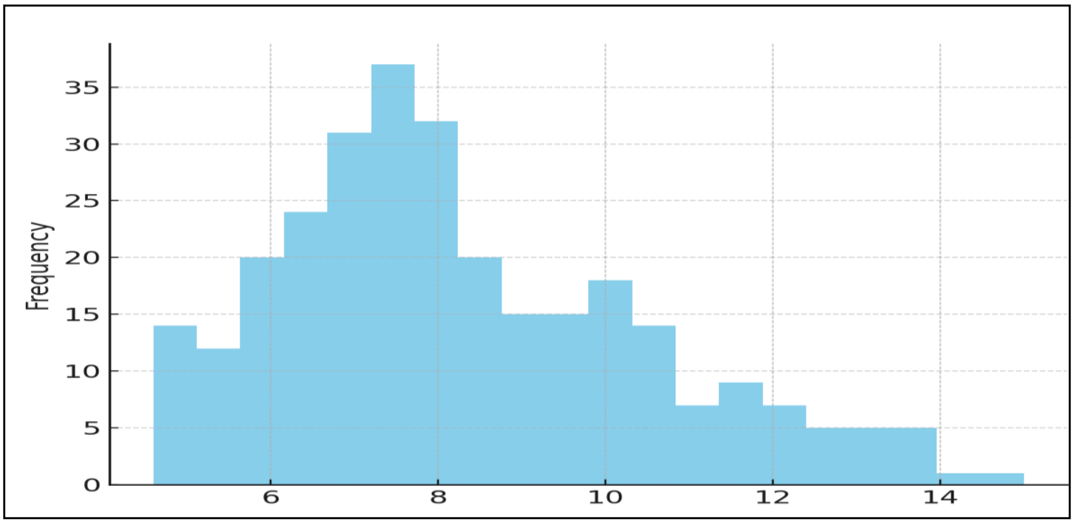

Figure 4. Illustrate the frequency of HbA1c values, which also shows a wide range with mild right skew. This supports the presence of both non-diabetic and diabetic individuals in the sample.

Figure 5 below displays the frequency of cases according to FBS values. The distribution highlights a concentration of FBS values in the hyperglycemic range (≥126 mg/dL), consistent with the high prevalence of diabetes in the study population. This skewness suggests that a substantial proportion of participants had elevated fasting glucose levels.

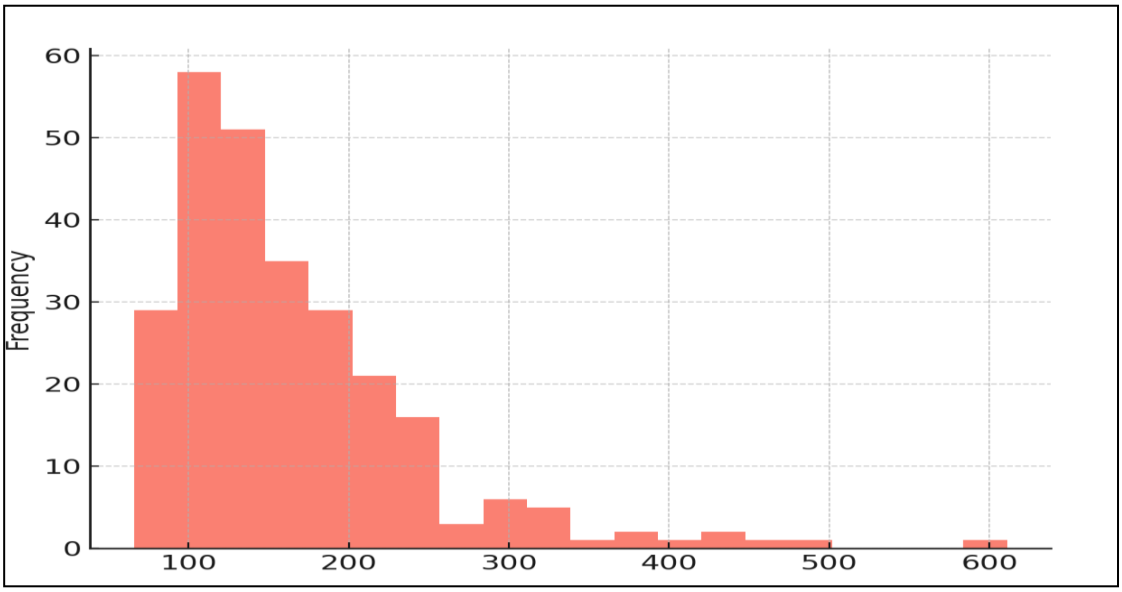

Figure 5. Displays the frequency of Fasting Blood Sugar (FBS) values, which shows a slightly right-skewed pattern

Figure 6 below illustrates the frequency of RBS values. Unlike FBS, RBS exhibits greater variability due to its dependence on recent food intake and metabolic fluctuations. Despite this, the distribution still shows a pronounced right skew, reinforcing the high burden of uncontrolled glycemia in the cohort. The tighter clustering of RBS values around higher glucose concentrations may reflect postprandial hyperglycemia in diabetic individuals.

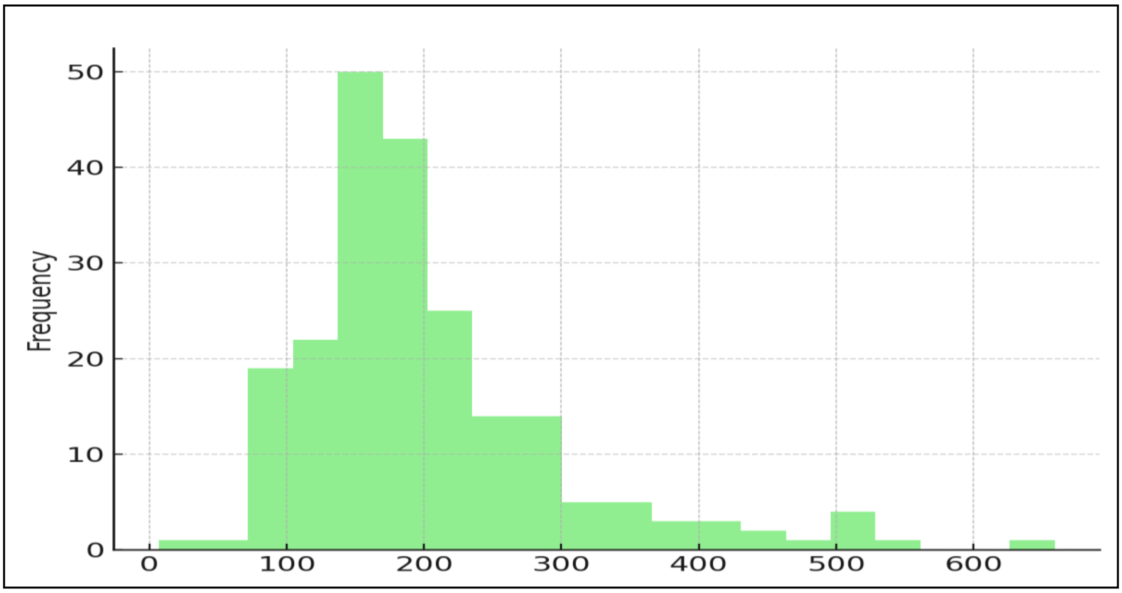

Figure 6. Distribution of Random Blood Sugar (RBS) values. Similar to FBS, it demonstrates right skewness, indicating that a subset of participants had significantly elevated RBS values.

The correlation analysis to evaluate the relationship between variables (HbA1c, FBS and RBS) were as the following:

A. HbA1c versus FBS:

- Linear regression equation is: HbA1c = 0.0191× FBS×5.23
- Pearson Correlation coefficient (r): 0.68
- P-value: extremely small (<1.25-37), including a statistically significant relationship.

B. HbA1c versus FBS:

- Linear regression equation is: HbA1c = 0.0152× FBS×5.23

- Pearson Correlation coefficient (r): 0.74
- P-value: also, extremely small (<8.16-38), a statistically significant relationship.

Scatter plots with linear regression lines in red; each point in the plots represents an individual patient value (figure 7,8). The red regression line in figure 7 indicates a positive linear relation between HbA1c and FBS. A moderate positive correlation was observed (r= 0.68, p< 0.001). in figure 8 the points for RBS versus HbA1c are slightly more tightly clustered around the line than FBS versus HbA1c reflecting slightly stronger correlation (r=0.74, p < 0.001). The key parts of each regression result (coefficients) summarized in table 2.

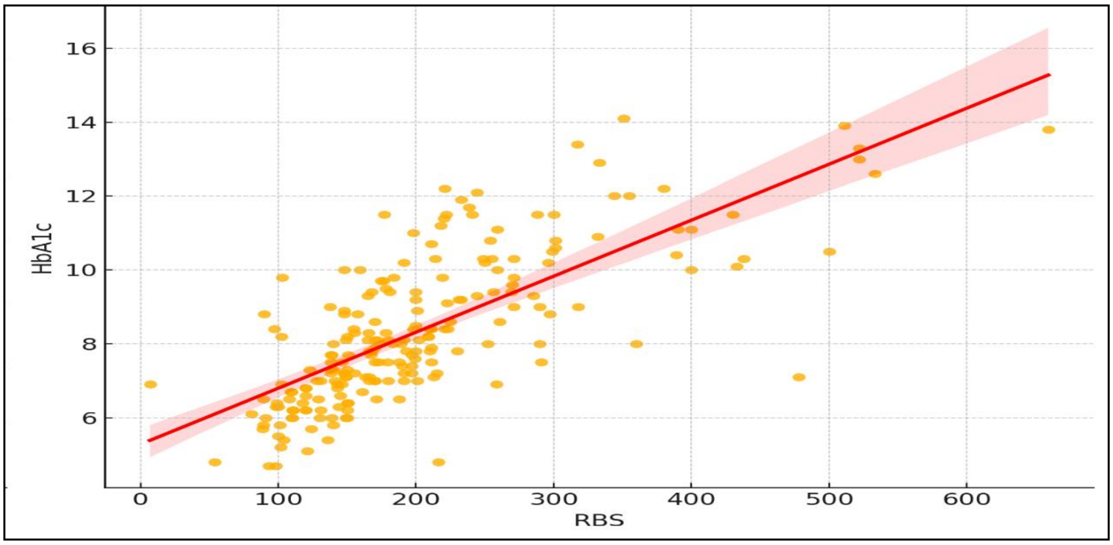

Figure 7. Scattered plot with regression line shows positive regression between HbA1c and FBS.

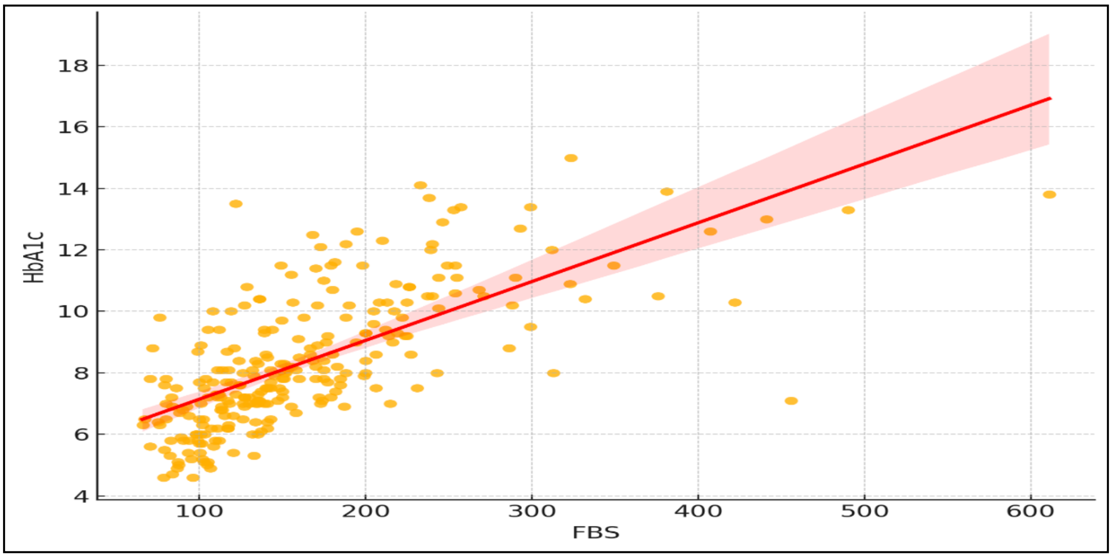

Figure 8. Scattered plot with regression line shows stronger positive regression between HbA1c and RBS.

Table 2. illustrate summary regression result.

Model	Variable	Coefficient	Std. Error	t-value	P-value
HbA1c ~ FBS	Intercept	5.2260	0.045	116.12	<0.001
	FBS	0.0191	0.0013	15.15	<0.001
HbA1c ~ RBS	Intercept	5.2817	0.041	128.45	<0.001
	RBS	0.0152	0.0010	15.84	<0.001

Discussion

This study investigated the relationship between glycated hemoglobin (HbA1c), fasting blood sugar (FBS), and random blood sugar (RBS) levels among 292 individuals attending a diagnostic laboratory in Elmarj, Libya. The findings reveal statistically significant positive correlations between HbA1c and both FBS and RBS, supporting the utility of HbA1c as a reliable long-term indicator of glycemic control. The correlation between HbA1c and FBS was moderate ($r = 0.68$, $p < 0.001$), while the correlation between HbA1c and RBS was slightly stronger ($r = 0.74$, $p < 0.001$). These results are consistent with existing literature indicating that HbA1c correlates with average plasma glucose levels over the preceding two to three months, thereby providing a comprehensive picture of glycemic status, compared to the more variable single-time-point measures of FBS and RBS. Interestingly, the stronger correlation observed between HbA1c and RBS, compared to FBS, may seem counterintuitive since RBS is inherently more variable due to dietary and physiological fluctuations. However, this finding may be influenced by the real-world, uncontrolled nature of sample collection in outpatient settings, where strict fasting prior to FBS measurement may not be fully adhered to, possibly introducing variability. Additionally, a larger sample size for RBS testing (n = 214) compared to complete triad testing (n = 187) may have contributed to greater statistical power in that analysis.

The distribution of HbA1c levels in the study population showed a high prevalence of diabetes, with 79.1% (231 out of 292) of participants classified as diabetic (HbA1c ≥ 6.5%). This high rate may reflect the testing population's characteristics, possibly including individuals with known or suspected diabetes. The implications suggest a significant burden of undiagnosed or poorly controlled diabetes in this community, underscoring the importance of regular screening and public health interventions. While HbA1c remains the gold standard for long-term glycemic monitoring, it is important to recognize limitations. Conditions affecting red blood cell lifespan or hemoglobin variants can alter HbA1c results independently of glucose levels. However, such confounding factors were minimized in this study through exclusion criteria targeting known hematologic and metabolic disorders.

The regression models further reinforce the strength of the association, with significant regression coefficients and low p-values in both HbA1c ~ FBS and HbA1c ~ RBS models. This supports the use of linear predictive modeling in estimating glycemic control across different metrics, though variability in individual glucose levels highlights the need for comprehensive clinical evaluation beyond singular markers.

Despite the strong statistical associations, it is important to consider the clinical implications carefully. While HbA1c provides a valuable overview of long-term glycemic control, its interpretation should always be contextualized with patient history, clinical symptoms, and short-term glycemic markers. FBS and RBS remain essential in acute diagnostic settings, particularly for identifying immediate glycemic excursions or when HbA1c may be unreliable (e.g., in patients with anemia, recent transfusions, or hemoglobinopathies). Additionally, the age distribution and high prevalence of diabetes in the older age groups (particularly 50–64 years) observed in this study highlight a demographic that may benefit most from routine HbA1c screening, lifestyle interventions, and early therapeutic engagement. The near-equal gender distribution further reinforces the wide-reaching nature of glycemic disorders, cutting across both male and female populations.

Conclusion

This study demonstrates a statistically significant and clinically relevant correlation between HbA1c and both FBS and RBS levels among participants in Elmarj, Libya. The findings reinforce the utility of HbA1c as a reliable indicator for long-term glycemic control and support its role in both diagnosis and monitoring of diabetes mellitus. However, FBS and RBS continue to hold diagnostic value, especially when interpreted in conjunction with HbA1c. Broader community screening programs, patient education, and individualized care are recommended to address the high observed rates of hyperglycemia and reduce the burden of diabetes-related complications.

Acknowledgment

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Disclaimer

The article has not been previously presented or published, and is not part of thesis project.

Conflict of interest

There are no financial, personal, or professional conflicts of interest to declare. The study was conducted using routine diagnostic tests paid for by the patients themselves. All data were used after obtaining verbal consent from the participants.

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