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RESEARCH PAPER

Analytical Assesment of Fasting Blood Glucose and Glycated Hemoglobin (HbA1c) for Glycemic Status Classification among Adults Undergoing Routine Laboratory Examination in Duhok, Iraq

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Abstract: The biochemical assessment of glucose metabolism is essential for the early identification of metabolic disorders, particularly prediabetes and diabetes mellitus. Fasting blood glucose (FBS) and glycated hemoglobin (HbA1c) provide complementary biochemical information for evaluating glycemic status through routine clinical chemistry analysis. This study investigated the prevalence of abnormal glycemic status among adults and examined its association with sociodemographic characteristics using complementary analytical methods. A cross-sectional study was conducted involving 600 adults aged ≥18 years undergoing routine laboratory examinations at Dr. Awny Laboratory in Duhok City, Kurdistan Region of Iraq, between September and December 2025. FBS concentrations were determined using a Cobas Pure c303 clinical chemistry analyzer, whereas HbA1c levels were quantified using high-performance liquid chromatography (HPLC). Glycemic status was classified according to the American Diabetes Association criteria, and the data were analyzed using descriptive statistics, binary logistic regression, one-way analysis of variance, and chi-square tests. Of the 600 participants, 434 (72.3%) exhibited normal glycemic status, 127 (21.2%) had prediabetes, and 39 (6.5%) had diabetes mellitus, corresponding to an overall abnormal glycemic prevalence of 27.7%. Mean age increased significantly across the normal, prediabetes, and diabetes groups (25.3 ± 4.8, 37.5 ± 6.2, and 50.1 ± 7.1 years, respectively; $p < 0.001$). Age was independently associated with abnormal glycemic status (adjusted OR = 1.07, 95% CI: 1.06–1.09; $p < 0.001$), whereas gender showed no significant association. These findings demonstrate the practical relevance of automated biochemical glucose determination and HPLC-based HbA1c quantification for the biochemical assessment of glycemic abnormalities in routine laboratory settings. The integration of these analytical approaches provides complementary information for identifying individuals with impaired glucose regulation and highlights the importance of age-stratified biochemical screening for the early detection of metabolic disorders.

Keywords: Fasting Blood Glucose; Glycated Hemoglobin; HPLC; Glycemic Abnormalities; Diabetes Mellitus.

INTRODUCTION

Diabetes mellitus is a heterogeneous group of metabolic disorders characterized by chronic hyperglycemia resulting from impaired insulin secretion, impaired insulin action, or both. Persistent hyperglycemia contributes to microvascular and macrovascular complications involving the retina, kidneys, peripheral nerves, heart, and blood vessels [1,2]. Type 2 diabetes accounts for approximately 90-95% of diabetes cases and commonly develops through the interaction of insulin resistance and progressive beta-cell dysfunction [3].

Prediabetes describes glycemic values above the normal range but below diagnostic thresholds for diabetes. It is clinically important because it

identifies people at increased risk of progression to type 2 diabetes and cardiovascular disease [4]. The American Diabetes Association defines prediabetes as fasting plasma glucose of 100-125 mg/dL and/or HbA1c of 5.7-6.4%, while diabetes-range values are fasting plasma glucose of at least 126 mg/dL and/or HbA1c of at least 6.5% [5]. In asymptomatic individuals, a diabetes diagnosis ordinarily requires confirmatory testing unless two abnormal results are available [5].

Fasting glucose reflects glycemia at a single time point, whereas HbA1c reflects average exposure over approximately two to three months. Because the tests capture different physiological aspects of glucose homeostasis, their results may be discordant, and reliance on one marker may miss a proportion of individuals with abnormal glycemia [6]. HbA1c interpretation nevertheless requires appropriate assay quality and consideration of conditions that alter erythrocyte survival or hemoglobin composition [2].

The Middle East and North Africa carries a substantial and growing diabetes burden [7]. Iraqi studies have reported considerable geographic variation in prediabetes and diabetes prevalence [8,9], but contemporary evidence from Duhok remains limited. The present study therefore aimed to estimate the prevalence of prediabetes and diabetes-range glycemia among adults attending a private diagnostic laboratory in Duhok and to examine the associations of glycemic status with age and sex.

The public-health relevance of dysglycemia extends beyond subsequent conversion to diabetes. Even below the diagnostic threshold, chronic exposure to elevated glucose is associated with adverse cardiometabolic profiles, endothelial dysfunction, and a higher probability of future microvascular and macrovascular disease. Prediabetes is also heterogeneous: some individuals remain stable or return to normoglycemia, whereas others progress rapidly. Identifying people at the screening stage can therefore create an opportunity for risk assessment, weight management, dietary counseling, physical activity, and management of coexisting hypertension or dyslipidemia before irreversible complications develop [4,11].

Laboratory-based screening has particular practical importance in settings where organized population screening is limited. People frequently request biochemical testing for employment, preoperative assessment, nonspecific symptoms, or personal reassurance. These encounters can reveal clinically important abnormalities in people who do not identify themselves as having diabetes. At the same time, laboratory-attendee data require cautious interpretation because access, health awareness, referral patterns, and underlying morbidity may differ from those of the source population. Accordingly, the present investigation was designed as a prevalence study of laboratory attendees rather than a population survey of all Duhok residents.

MATERIALS AND METHODS

Study design and setting

This laboratory-based cross-sectional study was conducted at Awny Laboratory in Duhok, Kurdistan Region of Iraq, from 1 September to 31 December 2025. The report was prepared in accordance with the STROBE recommendations for cross-sectional studies.

Participants and recruitment

Adults aged 18 years or older who attended the laboratory for a routine health screening were approached consecutively during the study period. Participants were eligible when they had fasted for at least 8 h and provided oral informed consent. Pregnant women, individuals with type 1 diabetes or insulin-treated diabetes, and individuals reporting renal, hepatic, thyroid, or malignant disease were excluded. Adults with previously diagnosed type 2 diabetes receiving oral glucose-lowering therapy remained eligible. A structured questionnaire recorded age, sex, medication history, chronic disease history, prior diabetes history, and pregnancy status. The analysis included 600 participants.

Consecutive recruitment was used to reduce selective enrollment by investigators during the defined study period. Nevertheless, because attendance at the laboratory was self-initiated or clinically prompted, the sampling frame did not include adults who did not seek laboratory services. The resulting estimates therefore describe the study attendees and were not age- or sex-standardized to the population of Duhok.

Participant flow

The source records indicate that 600 adults completed both fasting glucose and HbA1c testing and all 600 were included in the final analysis. The total number initially assessed and the exact numbers excluded because of non-fasting status, refusal, or exclusionary medical conditions were not retained in the analysis file. Consequently, a complete screened-to-included flow diagram could

not be reconstructed. The documented flow was: eligible participants (n = 600), completed FPG and HbA1c testing (n = 600), and included in the final analysis (n = 600).

Sample-size calculation

The minimum sample size for estimating a single proportion was calculated using n = Z^2p(1-p)/d^2, with Z = 1.96 for 95% confidence and d = 0.05. Expected prevalences of 20.6% for prediabetes and 13.9% for diabetes yielded minimum sample sizes of approximately 251 and 184, respectively [10]. The final sample of 600 exceeded both requirements and improved the precision of the prevalence estimates.

Specimen collection and laboratory analysis

Venous blood was collected from the antecubital vein under aseptic conditions after a verified fast of at least 8 h. Approximately 4 mL of blood was divided between an EDTA tube for HbA1c measurement and a gel-separator tube for fasting serum glucose. Serum was separated by centrifugation at 4000 rpm for 12 min. Fasting glucose was measured on a Cobas Pure c303 analyzer (Roche Diagnostics, Mannheim, Germany), with daily internal quality-control procedures. HbA1c was measured in fresh EDTA whole blood by high-performance liquid chromatography using the Bio-Rad D-10 Hemoglobin Testing System (Bio-Rad Laboratories, Hercules, CA, USA), an NGSP-certified method traceable to the IFCC reference system. Two levels of quality-control material were analyzed with each batch, and chromatograms were reviewed for suspected hemoglobin variants or analytical interference. Within-run and between-run coefficients of variation and details of participation in an external quality-assessment program were not available for reporting and should be added if retrievable.

The two biomarkers provide complementary information. Fasting glucose is sensitive to short-term physiological variation, including fasting duration, acute stress, recent illness, and specimen handling, whereas HbA1c is comparatively stable across the day but depends on erythrocyte lifespan and Laboratory performance. HbA1c can be misleading in the presence of substantial anemia, hemolysis, recent blood loss or transfusion, and some hemoglobin variants [2,15]. High-performance liquid chromatography was selected because it provides chromatographic separation and is widely used for standardized HbA1c measurement; however, chromatograms and instrument flags must still be reviewed in routine practice when a variant or analytical interference is suspected.

Definition of glycemic status

Normal glycemia was defined as fasting glucose <100 mg/dL and HbA1c <5.7%. Prediabetes was defined as fasting glucose 100-125 mg/dL and/or HbA1c 5.7-6.4%, in the absence of a diabetes-range result. Diabetes-range glycemia was defined as fasting glucose >=126 mg/dL and/or HbA1c >=6.5% [5]. When the two markers fell in different categories, the participant was assigned to the higher category. Prediabetes and diabetes-range groups were combined as 'dysglycemia' for binary regression. The diabetes-range category contained two clinically distinct subgroups: previously diagnosed adults receiving oral therapy and adults whose routine laboratory results entered the diabetes range for the first time. Counts for these subgroups were unavailable; therefore, the reported 6.3% must not be interpreted as the prevalence of newly diagnosed diabetes. A single diabetes-range result in an asymptomatic participant without prior diabetes was treated as a screening finding requiring clinical confirmation.

Ethical considerations

Ethical considerations: The study was conducted at Awny Laboratory using data generated from routine laboratory examinations requested by attendees. Before sample collection, each participant received a brief explanation that their de-identified laboratory results might be used for research purposes and provided oral informed consent. The study protocol was reviewed internally by the laboratory administration to ensure data confidentiality and the exclusion of direct personal identifiers from the analytical dataset. No prospective approval was obtained from an independent institutional ethics committee before the study commenced. Therefore, an independent retrospective ethics determination or formal waiver should be obtained from an appropriate institutional ethics committee before manuscript submission. Once available, this statement should be updated to include the name of the committee, the approval or waiver number, and the date of the decision.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA). Continuous variables are reported as mean +/- standard deviation and categorical variables as number and percentage. Prevalence estimates are accompanied by 95% Wilson confidence intervals. Continuous variables were compared across the

three glycemic groups by one-way analysis of variance. Categorical distributions were compared using the chi-square test. Binary logistic regression was used to estimate the independent associations of age and sex with dysglycemia; results are reported as adjusted odds ratios (aORs) with 95% CIs. All tests were two-sided, and $p < 0.05$ was considered statistically significant.

The principal outcome was overall dysglycemia, defined as prediabetes plus diabetes-range glycemia. Prevalence CIs were emphasized because they communicate the precision of the estimates more directly than p values. The regression model was deliberately limited to age and sex because these were the consistently available candidate predictors. No causal interpretation was assigned to regression coefficients because exposure and outcome information were collected at the same encounter.

RESULTS AND DISCUSSION

Participant characteristics and glycemic status

Among 600 participants, 435 (72.5%) had normal glycemia, 127 (21.2%) had prediabetes, and 38 (6.3%) had diabetes-range glycemia. The combined prevalence of dysglycemia was 27.5% (165/600; Table 1). Mean age rose progressively from 25.3 years in the normal group to 37.5 years in the prediabetes group and 50.1 years in the diabetes-range group ($p < 0.001$). Mean HbA1c and fasting glucose values also differed across categories, as expected from the classification criteria (Table 2).

The 38 participants in the diabetes-range category included both previously diagnosed individuals receiving oral therapy and participants newly identified during routine screening. Because subgroup counts were unavailable, separate estimates for known and newly detected diabetes could not be calculated.

Table 1. Prevalence of glycemic categories among study participants (n = 600).

Glycemic category	n	Prevalence (%)	95% CI (%)
Normal glycemia	435	72.5	68.8-75.9
Prediabetes	127	21.2	18.1-24.6
Diabetes-range glycemia	38	6.3	4.6-8.6
Overall dysglycemia	165	27.5	24.1-31.2

CI, confidence interval. Wilson 95% confidence intervals are reported.

Table 2. Characteristics of participants across glycemic categories (n = 600).

Variable	Normal (n=435)	Prediabetes (n=127)	Diabetes-range (n=38)
Age (years)	25.3 +/- 4.8	37.5 +/- 6.2	50.1 +/- 7.1
HbA1c (%)	5.2 +/- 0.3	5.9 +/- 0.2	7.1 +/- 0.4
Fasting glucose (mg/dL)	88.5 +/- 8.1	112.3 +/- 9.7	142.7 +/- 12.5

Values are mean +/- standard deviation. Overall ANOVA $p < 0.001$ for each variable.

Age and sex distributions

Within the 165 participants with dysglycemia, the proportion with diabetes-range glycemia tended to increase with age, from 16.7% among those aged 25-34 years to 37.5% among those aged 65 years or older. The distribution between prediabetes and diabetes-range categories across age groups did not reach statistical significance in this restricted dysglycemic subgroup ($p = 0.080$; Table 3). The stronger age association became evident when all participants, including those with normal glycemia, were considered in the regression analysis.

Table 3. Age distribution among participants with dysglycemia (n = 165).

Age group	Prediabetes, n (%)	Diabetes-range, n (%)
25-34	5 (83.3)	1 (16.7)
35-44	23 (88.5)	3 (11.5)
45-54	36 (75.0)	12 (25.0)
55-64	38 (84.4)	7 (15.6)
>=65	25 (62.5)	15 (37.5)
Total	127	38

Percentages are calculated within each age group. Chi-square $p = 0.080$.

Of the 341 male participants, 252 (73.9%) had normal glycemia, 72 (21.1%) had prediabetes, and 17 (5.0%) had diabetes-range glycemia. Among 259

females, the corresponding counts were 183 (70.7%), 55 (21.2%), and 21 (8.1%). The overall distribution did not differ significantly by sex (chi-square p = 0.289; Figure 1).

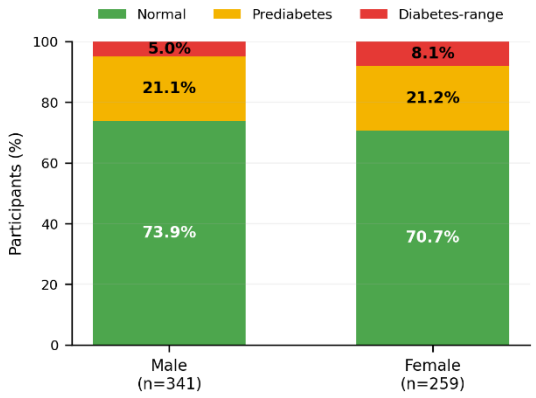


Figure 1. Distribution of glycemic status by sex among study participants (n = 600).

Factors associated with dysglycemia

In binary logistic regression, age was independently associated with dysglycemia. Each one-year increase in age was associated with approximately 7% greater odds of having prediabetes or diabetes-range glycemia (aOR, 1.07; 95% CI, 1.06-1.09; p < 0.001). Male sex was not independently associated with dysglycemia (aOR, 1.00; 95% CI, 0.67-1.49; p = 0.991; Table 4).

Table 4. Multivariable factors associated with dysglycemia (n = 600).

Variable	aOR	95% CI	p value
Age (per year)	1.07	1.06-1.09	<0.001
Male sex (vs female)	1.00	0.67-1.49	0.991

aOR, adjusted odds ratio; CI, confidence interval. The model included age and sex.

Interpretation and comparison with previous studies

The principal finding was that more than one in four adults attending the laboratory had dysglycemia. The prediabetes estimate of 21.2% was higher than the 17.0% reported among apparently healthy adults in Baghdad [8], while the diabetes-range estimate of 6.3% was lower than the 11.5% reported in a systematic community sample from Mosul in 2025 [9]. Because the diabetes-range group combined previously diagnosed oral-therapy cases with newly detected cases, this percentage represents diabetes-range glycemia in the study sample and not incidence or prevalence of newly diagnosed diabetes. Differences in participant selection, age structure, setting, prior diagnosis, and diagnostic criteria can materially influence prevalence estimates. In particular, the present convenience sample of laboratory attendees should not be interpreted as representative of the entire adult population of Duhok.

The strong association between advancing age and dysglycemia is biologically and epidemiologically plausible. Aging is accompanied by progressive beta-cell dysfunction, changes in body composition, reduced physical activity, and increasing insulin resistance. The Baghdad and Mosul studies likewise reported higher abnormal glycemia at older ages [8,9]. The current regression estimate suggests a cumulative effect: although the per-year odds ratio appears modest, the difference becomes clinically meaningful across decades.

Sex was not independently associated with dysglycemia. Prediabetes proportions were nearly identical in males and females, while diabetes-range glycemia was numerically more frequent among females. The absence of statistical significance may reflect limited numbers in the diabetes-range subgroup and the lack of adjustment for adiposity, pregnancy history, physical activity, and socioeconomic factors. Therefore, the result should not be interpreted as evidence that sex-related risk differences are absent in the wider population.

Using both fasting glucose and HbA1c is a practical strength because the markers capture different aspects of glycemic exposure. Large pooled analyses have shown substantial discordance between the two tests and have demonstrated that prevalence varies according to the biomarker used [6]. However, the present dataset did not report the full FPG-by-HbA1c cross-classification; future work should quantify agreement, test-specific detection, and the proportion of cases identified by only one marker.

The findings have a practical local implication. Adults undergoing routine laboratory testing, particularly at older ages, represent an opportunity for early recognition and referral. Nevertheless, screening results should lead to clinical assessment rather than automatic labeling. Confirmatory testing is especially important for asymptomatic participants with a single diabetes-range result [5].

The observed 27.5% prevalence of overall dysglycemia indicates that abnormal glycemia was not confined to a small high-risk subgroup within the laboratory population. Prediabetes accounted for most abnormal results, outnumbering diabetes-range glycemia by more than three to one. This

distribution is consistent with the natural history of type 2 diabetes, in which a larger intermediate-risk population precedes the smaller group that crosses diagnostic thresholds at a particular point in time. From a prevention perspective, the prediabetes group may offer the greatest opportunity for lifestyle-based risk reduction, although the intensity of follow-up should be individualized according to age, adiposity, family history, cardiovascular risk, and the degree of glycemic elevation.

The difference between the mean ages of the three categories was substantial. Several mechanisms may contribute to this pattern. With advancing age, pancreatic beta cells may become less able to compensate for insulin resistance; skeletal muscle mass and activity may decline; visceral adiposity may increase; and cumulative exposure to obesogenic environments and diabetogenic medications may rise. Age is therefore unlikely to act as an isolated biological cause. Instead, it functions partly as a marker of accumulated metabolic and behavioral exposures. Because these accompanying factors were not measured comprehensively, the age coefficient should be viewed as an overall association rather than a mechanistically specific effect.

The use of an 'either-test-positive' rule increases sensitivity for identifying abnormal glycemia, but it also affects comparability with studies requiring concordant tests or using only one marker. In population datasets, HbA1c- and fasting-glucose-based categories overlap incompletely [6,16]. HbA1c may identify sustained moderate hyperglycemia when fasting glucose remains below a threshold, while fasting glucose may identify hepatic insulin resistance or short-term fasting hyperglycemia before HbA1c becomes abnormal. For a stronger future analysis, the raw dataset should be presented as a 3 x 3 cross-classification of the two tests, followed by percentage agreement and Cohen's kappa. Such analysis would show whether the added value of combined testing in Duhok is clinically meaningful rather than merely assumed.

Comparisons with studies from Baghdad, Mosul, Pakistan, Saudi Arabia, and Nigeria should be interpreted in light of methodological heterogeneity [8,9,12-14]. Population-based probability samples generally provide stronger prevalence inference than clinic- or laboratory-based samples. Studies also differ in fasting verification, age eligibility, exclusion of known diabetes, use of HbA1c versus glucose, confirmatory testing, rural representation, and the prevalence of obesity. Consequently, a higher or lower percentage does not necessarily indicate a true geographic difference in disease burden. Harmonized multicenter protocols are needed before reliable within-Iraq regional comparisons can be made.

Strengths and limitations

Strengths include the sample of 600 adults, concurrent assessment of fasting glucose and HbA1c, and use of standardized automated laboratory platforms. Several limitations require consideration. First, this was a single-center laboratory-attendee sample rather than a probability sample of Duhok residents, limiting generalizability. Second, the cross-sectional design cannot establish temporal or causal relationships. Third, the regression model included only age and sex; important factors such as body mass index, waist circumference, family history, blood pressure, physical activity, smoking, and socioeconomic status were unavailable for the present analysis. Fourth, one-time diabetes-range results were not confirmed on a separate day. Fifth, conditions that may influence HbA1c, including anemia, altered erythrocyte turnover, recent transfusion, and hemoglobin variants, were not systematically reported. Finally, the absence of a cross-tabulation of fasting glucose and HbA1c prevented formal assessment of concordance between the two markers.

Additional sources of uncertainty include possible misclassification of self-reported fasting status and the inability to quantify separately previously diagnosed oral-therapy cases and newly detected diabetes-range cases. The original form did not capture body mass index, waist circumference, blood pressure, lipid profile, family history, or lifestyle factors. Information on anemia, hemoglobin disorders, and recent transfusion was also unavailable, although these conditions can affect HbA1c interpretation. The very small number of diabetes-range observations within some age strata reduced the stability of subgroup comparisons. Furthermore, the study did not measure two-hour glucose after an oral glucose tolerance test, which can detect impaired glucose tolerance that is missed by fasting glucose and HbA1c. These limitations may have caused either underestimation or overestimation, depending on the direction and frequency of each source of misclassification.

Public-health and clinical implications

The results support development of a structured pathway for abnormal results discovered during routine laboratory visits. Such a pathway could include verification of prior diagnosis and medication

use, repeat or confirmatory testing when required, measurement of blood pressure and anthropometric indices, assessment of cardiovascular risk, and referral to primary care. Individuals with prediabetes may benefit from practical counseling on weight, diet, and physical activity, while those with diabetes-range results require timely clinical confirmation and evaluation. Laboratories should communicate clearly that a screening result is not always equivalent to a final diagnosis.

At the health-system level, the study demonstrates the feasibility of generating local surveillance information from routinely accessible laboratory platforms. However, surveillance based solely on private laboratories may systematically underrepresent adults with financial, geographic, or cultural barriers to testing. Collaboration among public hospitals, primary-care centers, academic institutions, and private laboratories would yield a more inclusive evidence base for Duhok and the wider Kurdistan Region.

Pathophysiological interpretation of the findings

The progressive increase in mean age across the glycemic categories can be understood within the pathophysiology of type 2 diabetes. In the early stages of insulin resistance, pancreatic beta cells increase insulin secretion sufficiently to preserve near-normal glucose concentrations. Over time, susceptible individuals lose this compensatory capacity. Fasting glucose then begins to rise as hepatic glucose production becomes less effectively suppressed, while postprandial glucose may increase because of impaired first-phase insulin secretion and reduced peripheral glucose disposal. HbA1c integrates these repeated fasting and postprandial disturbances over several weeks. The separation of the mean values observed in this study is therefore compatible with a continuum of deteriorating glucose regulation rather than three biologically isolated states.

Age may also interact with sarcopenia, visceral adiposity, chronic low-grade inflammation, sleep disturbance, and reduced physical activity. Skeletal muscle is a major site of insulin-mediated glucose uptake; consequently, loss of muscle mass and function can contribute to impaired glucose disposal. At the same time, accumulation of visceral fat promotes release of free fatty acids and inflammatory mediators that interfere with insulin signaling. These mechanisms were not measured directly in the present study, but they provide plausible hypotheses for future investigation. Including waist circumference, body composition, inflammatory biomarkers, and physical-activity measurements would help distinguish chronological aging from the modifiable exposures that accompany it.

Prediabetes should not be regarded as a uniform or inevitably progressive condition. Risk varies according to the number of abnormal tests, proximity to the diabetes threshold, body weight, family history, gestational diabetes history, and cardiometabolic comorbidity. A participant with mild isolated HbA1c elevation may have a different risk trajectory from a participant with both elevated fasting glucose and HbA1c near the diabetes range. This reinforces the importance of retaining the continuous test values and the pattern of biomarker agreement rather than relying exclusively on a single categorical label.

Interpretation and follow-up of laboratory findings

The clinical response to screening should be proportionate to the result and the participant's broader risk profile. Normal results do not eliminate future risk, particularly in people with obesity, a strong family history, prior gestational diabetes, hypertension, dyslipidemia, or exposure to diabetogenic medicines. Prediabetes-range findings warrant risk-factor assessment and planned retesting, while a diabetes-range result in an asymptomatic person should generally be confirmed. When fasting glucose and HbA1c are markedly discordant, clinicians should examine preanalytical conditions, adherence to fasting, medication use, recent illness, anemia, renal function, blood loss, transfusion history, and possible hemoglobin variants before assigning a diagnosis [2,5,15].

Table 5. Proposed interpretation and follow-up pathway for glycemic screening results.

Screening pattern	Interpretation	Suggested next step
Both tests normal	No current biochemical evidence of dysglycemia	Reassess according to age and risk factors; reinforce healthy lifestyle
Prediabetes range on either test	Increased future diabetes and cardiovascular risk	Assess BMI, waist, blood pressure, lipids, family history, and lifestyle; plan repeat testing

Screening pattern	Interpretation	Suggested next step
Diabetes range on one test	Possible diabetes; not automatically confirmed in an asymptomatic person	Repeat the abnormal test or obtain a second diagnostic test promptly and arrange clinical review
Diabetes range on both tests	Two abnormal results support diagnosis when analytically valid	Clinical evaluation, complication-risk assessment, education, and treatment planning
Marked FPG-HbA1c discordance	Possible biological, preanalytical, or analytical explanation	Review fasting status, acute illness, anemia, erythrocyte turnover, transfusion, renal disease, and hemoglobin variants

FPG, fasting plasma glucose; BMI, body mass index. The pathway summarizes diagnostic and confirmatory principles in the ADA Standards of Care [5] and does not replace individualized clinical judgment.

Relevance to Duhok and the Kurdistan Region

Local evidence is important because diabetes risk and access to prevention are shaped by social and health-system context. Duhok city serves urban residents as well as people from surrounding districts, displaced communities, and families with differing access to continuous primary care. Dietary transition, reduced occupational activity, sedentary transport, psychosocial stress, and uneven opportunities for preventive care may all influence metabolic risk. The present study cannot quantify these influences, yet its findings show that routine laboratory encounters can identify a substantial group requiring further assessment. This is particularly relevant when individuals use private laboratories without a regular primary-care provider who can integrate laboratory results with longitudinal clinical information.

A regional strategy should avoid limiting attention to individuals who already have symptoms. Type 2 diabetes can remain clinically silent while vascular injury develops, and prediabetes is commonly unrecognized. Community education could emphasize that testing is most useful when linked to follow-up, not when results are interpreted in isolation. Clear referral arrangements between laboratories, family physicians, internists, dietitians, and public health services would reduce the risk that an abnormal value is documented but never acted upon. Educational material should be culturally and linguistically appropriate and should explain the distinction between screening, confirmation, and long-term monitoring.

Laboratory quality and reporting considerations

The validity of any prevalence estimate depends on analytical quality. Laboratories contributing to future surveillance should document reagent lots, calibration traceability, internal quality-control performance, instrument maintenance, and participation in external quality assessment. For glucose, delays in separating cells from serum or plasma can lower measured concentrations through ongoing glycolysis. For HbA1c, laboratories should use methods standardized to recognized reference systems and should establish procedures for chromatogram review and reporting of suspected variants. Recording these details would make results more reproducible and allow readers to judge whether differences between studies reflect biology or laboratory practice.

Reports delivered to participants should use consistent terminology and reference limits. Values in the diabetes range should be accompanied by a concise interpretive note when confirmation is required, and critical or highly elevated results should trigger timely communication according to laboratory policy. A future electronic registry could capture de-identified age, sex, test values, prior diagnosis, and follow-up status across participating sites. With appropriate governance and ethics oversight, such a system could monitor temporal trends, identify underserved groups, and evaluate whether screen-detected participants successfully reach clinical care.

Priorities for future research

A subsequent study should employ multicenter probability or stratified sampling and prespecify age and sex strata. Core measurements should include body mass index, waist circumference, blood pressure, lipid profile, family history, smoking, physical activity, dietary indicators, socioeconomic variables, medication exposure, and prior diabetes status. The protocol should record potential HbA1c interferences and incorporate confirmatory testing for diabetes-range results. Analytically, investigators should report test concordance, age- and sex-standardized prevalence, multivariable risk models, model calibration and discrimination, and sensitivity analyses using alternative diagnostic rules. Follow-up of participants with prediabetes would allow estimation of regression to normal glycemia, persistence, and progression to diabetes, thereby converting a cross-sectional prevalence

study into a clinically more informative longitudinal program.

CONCLUSION

Dysglycemia affected 27.5% of adults attending a private diagnostic laboratory in Duhok, including 21.2% with prediabetes and 6.3% with diabetes-range glycemia. The latter category combined known oral-therapy cases and newly detected cases and therefore should not be interpreted as newly diagnosed diabetes prevalence. Prediabetes constituted the majority of abnormal results, emphasizing a potentially important window for preventive assessment. Advancing age, but not sex, was independently associated with dysglycemia. The concurrent use of fasting glucose and HbA1c provided broad screening coverage, although test-specific detection, percentage agreement, and Cohen's kappa could not be calculated because individual cross-sectional data were unavailable. These findings support age-sensitive case finding, confirmatory testing where appropriate, and clear referral pathways for adults with abnormal results. Because participants were recruited from one private laboratory, the estimates should not be generalized to all Duhok residents. Population-based multi-center studies incorporating anthropometric, behavioral, socioeconomic, and clinical risk factors are needed to define the regional burden, evaluate biomarker agreement, and develop locally appropriate screening and prevention strategies.

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DECLARATIONS

Author contributions: Conceptualization, Zhiyar Nizar Saeed; Methodology, Zhiyar Nizar Saeed and Pasar Nizar Saeed; Investigation, Zhiyar Nizar Saeed; Laboratory Analysis, Pasar Nizar Saeed; Data Curation, Zana Sabri Qasim; Formal Statistical Analysis, Zhiyar Nizar Saeed; Writing - Original Draft, Zhiyar Nizar Saeed; Writing - Review and Editing, Darya Salih Hussein and Zana Sabri Qasim; Supervision, Pasar Nizar Saeed. All authors reviewed and approved the final manuscript.

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Conflict of interest: The authors declare that they have no conflicts of interest.

Data availability: The de-identified data supporting the findings of this study are available from the corresponding author upon reasonable request.

Informed consent: Oral informed consent was obtained from all participants before sample collection and use of de-identified results for research.

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