Scientific Journal for Publishing in Health Research and Technology

Volume 2, Issue 3, 2026, Pages: 101-112

Journal homepage: https://sjphrt.com.ly/index.php/sjphrt/en/index

Sex and Seasonal Variation in Blood Glucose Among Trauma Patients: A Retrospective Laboratory Study from Benghazi, Libya

Abdelmuhsen M. Abusneina [1] *, Raja A. Aljibali [2], Soad M. Elwirfli [3]

[1] Department of Molecular Diagnostics, Faculty of Biomedical Sciences, University of Benghazi, Benghazi, Libya

[2,3] Department of Forensic Sciences, Faculty of Biomedical Sciences, University of Benghazi, Benghazi, Libya

التباين في مستوى سكر الدم تبعًا للجنس وفصول السنة لدى مرضى الإصابات: دراسة مخبرية استرجاعية من بنغازي، ليبيا

عبد المحسن محمد أبوسنينة [1] *، رجاء عبد الله الجبالي[2]، سعاد محمد الورفلي[3]

[1] قسم التشخيص الجزيئي، كلية العلوم الطبية الحيوية، جامعة بنغازي، بنغازي، ليبيا

[3،2] قسم علوم الطب الشرعي، كلية العلوم الطبية الحيوية، جامعة بنغازي، بنغازي، ليبيا

*Corresponding author: abdelmuhsen.abusneina@uob.edu.ly

Received: May 14, 2026	Accepted: July 20, 2026	Published: August 09, 2026

Abstract:

Blood glucose concentration varies with biological sex and time of year, yet population-level data from North Africa are scarce. Often, evidence derives from laboratory records where sampling methods are poorly described. This study examined sex and seasonal variations in blood glucose within a Libyan hospital population. A retrospective, cross-sectional analysis was conducted on 4,939 blood glucose measurements recorded during 2018 at Al-Jala Hospital for Surgery and Accidents, Benghazi. The study utilized available covariates, specifically sex and month of collection. Analyses included descriptive statistics, Welch-corrected t-tests, one-way and two-way analysis of variance, Games-Howell post-hoc comparisons, and effect size calculations. The mean blood glucose was 125.60 mg/dL (SD 65.90; range 24–719). Levels were significantly higher in female than male patients (129.51 vs. 123.42 mg/dL; mean difference 6.09, 95% CI 2.07–10.11; $p = .003$). Seasonal variation was observed ($F(3, 4935) = 4.55$, $p = .003$) with no significant interaction ($p = .673$). Effect sizes were small (partial eta-squared of 0.0016 for sex and 0.0023 for season; Cohen's d of 0.093). Post-hoc tests revealed significant differences only between winter and spring, and winter and autumn. The marked monthly variation in record volume (range 67–754) suggests that the seasonal pattern reflects differences in sampling frequency rather than physiological fluctuations. These findings underscore the limitations of interpreting retrospective laboratory data without accounting for ascertainment bias.

Keywords: blood glucose; seasonal variation; sex differences; trauma; retrospective study; clinical laboratory; ascertainment bias; Libya.

الملخص

يتباين تركيز الجلوكوز في الدم تبعًا للجنس البيولوجي والتوقيت خلال السنة، غير أن البيانات السكانية من شمال أفريقيا نادرة، وكثيرًا ما تُستمد الأدلة المتاحة من سجلات مخبرية نادرًا ما يُوصف فيها أسلوب أخذ العينات. هدفت هذه الدراسة إلى فحص التباين في سكر الدم تبعًا للجنس وفصول السنة لدى مجموعة من مرضى أحد المستشفيات الليبية. أُجري تحليل استرجاعي مقطعي على 4,939 قياسًا لسكر الدم سُجّلت خلال عام 2018 في مستشفى الجلاء للجراحة والحوادث ببنغازي، معتمدًا على متغيرات الجنس وشهر أخذ العينة. شملت التحليلات الإحصاء الوصفي، واختبار (t) بتصحيح ويلش، وتحليل التباين الأحادي والثنائي، ومقارنات "جيمس-هاول" البعدية، وحجوم الأثر. بلغ متوسط سكر الدم 125.60 ملغم/دل (الانحراف المعياري 65.90؛ المدى 24 إلى 719). كانت القيم أعلى لدى الإناث منها لدى الذكور (129.51 مقابل 123.42 ملغم/دل؛ فرق المتوسطين 6.09، فاصل ثقة 95% من 2.07 إلى 10.11؛ p = .003)، وتباين السكر عبر الفصول (F(3, 4935) = 4.55؛ p = .003) دون تفاعل دال بين العاملين (p = .673). كان الأثران صغيرين، إذ بلغ مربع إيتا الجزئي 0.0016 للجنس و0.0023 للفصل، وبلغ معامل كوهين (d) نحو 0.093. لم تظهر فروق دالة إحصائيًا بعد التصحيح سوى بين الشتاء والربيع وبين الشتاء والخريف. يُرجح التباين الواضح في عدد السجلات الشهرية (تراوح بين 67 و754) أن النمط الفصلي يعكس تباينًا في وتيرة أخذ العينات بدلًا من التقلبات الفسيولوجية. تؤكد هذه النتائج محدودية تفسير البيانات المخبرية الاسترجاعية دون مراعاة تحيّز الاختيار.

الكلمات المفتاحية: سكر الدم، التباين الفصلي، الفروق بين الجنسين، الإصابات، دراسة استرجاعية، المختبر السريري، تحيّز الاختيار، ليبيا.

1. Introduction

Blood glucose concentration is not a static physiological parameter. It is influenced by a range of temporal and demographic factors beyond diet and disease, and both biological sex and time of year have been implicated repeatedly. Furthermore, integrating sustainable practices in pharmacological research is becoming essential, as highlighted by recent efforts to advance green pharmacy and utilize biodegradable systems to mitigate pharmaceutical pollution. (Salem, 2025).

Seasonal variation in glucose has been documented since the early 1980s. In a Southern California community study of 4,541 adults, fasting plasma glucose peaked in winter and reached its lowest point in spring, correlating with sunshine exposure and ambient temperature across two years of follow-up (Suarez & Barrett-Connor, 1982). Similar winter elevations were reported in a United Kingdom occupational cohort (Jarrett et al., 1984) and in a Greek primary-care sample of patients with type 2 diabetes followed over five years, in which fasting glucose and glycated hemoglobin both peaked in colder months (Gikas et al., 2009). Working with three years of laboratory data from over 3,000 patients with diabetes, Kershenbaum et al. (2011) confirmed that population-average glucose is higher in winter than summer and that this reflects a general seasonal tendency rather than isolated high readings in a subgroup. A nationwide Chinese study of approximately 1.4 million adults found that seasonal fluctuation in fasting glucose persisted after adjustment for age and sex and varied with latitude (Zhang et al., 2021), The environmental basis is less certain: in two European population-based cohorts of middle-aged adults, greater bright-sunlight exposure was associated with lower insulin resistance, whereas outdoor temperature showed no independent association once sunlight was accounted for (Noordam et al., 2019). The direction of the effect is not settled. A Dutch population-based cohort found a summer peak among middle-aged adults but a winter peak

among elderly adults (Cepeda et al., 2018). A Swedish study of pregnancy glucose tolerance reported summer-peak post-load values and a corresponding summer peak in gestational diabetes diagnoses (Katsarou et al., 2016), while a Swedish cohort of elderly men found that winter reductions in insulin sensitivity were offset by increased secretion, leaving fasting glucose largely unchanged (Berglund et al., 2012). Seasonal effects have since been confirmed at the individual level using wearable sensors, with poorer control in colder months (Belsare et al., 2023).

Sex differences are similarly established and similarly contested. In fasting cohorts, men typically show higher fasting glucose than women while women show higher post-load values, a divergence attributed partly to body size and glucose distribution volume (Færch et al., 2010). Sex differences in insulin sensitivity, body composition, and hormonal regulation are well characterized (Tramunt et al., 2020), and genome-wide analysis of random glucose in 476,326 individuals has identified sex-dimorphic genetic effects (Meta-Analysis of Glucose and Insulin-Related Traits Consortium, 2023).

Much of the recent evidence in both literatures comes from retrospective laboratory records rather than purpose-built cohorts. Laboratory records are not a random sample of a population; they are the residue of clinical decisions about whom to test. Agniel et al. (2018) examined 272 laboratory test types across 669,452 patients and found that the presence of a test order, independent of the result, carried substantial predictive information about survival. When the decision to test varies with the exposure of interest, any association with the result is confounded at source. This concern is recognized in the electronic health record literature (Farmer et al., 2018) and has motivated a dedicated reporting standard for research using routinely collected data (Benchimol et al., 2015).

Population-level glucose data from North Africa remain scarce, and Libya is largely absent from this literature, despite recent efforts to document regional epidemiological and clinical laboratory profiles (Ben Hsin et al., 2025). The objectives of this study were to describe sex and seasonal variation in blood glucose across a full calendar year in a Libyan hospital laboratory population, to quantify the magnitude of any variation observed, and to characterize the distribution of measurements across the year.

2. Materials and Methods

2.1 Study design, setting, and data source

This was a retrospective, cross-sectional analysis of blood glucose results recorded during routine clinical care at Al-Jala Hospital for Surgery and Accidents, Benghazi, Libya, a 465-bed trauma and accident hospital comprising twelve surgical departments and receiving emergency and ambulance cases referred from across eastern and southern Libya. Results were extracted from clinical files covering a continuous twelve-month period in 2018 and de-identified at the point of extraction. The sample comprises a mixture of inpatient, emergency, and outpatient testing; the proportions are not documented and cannot be reconstructed. Fasting status was not recorded, so measurements reflect a mixture of fasting and non-fasting states and are treated throughout as random glucose.

2.2 Study population and variables

The dataset comprised 4,939 blood glucose measurements with complete sex and date information. No measurements were excluded on the basis of glucose value. No information was available on age, prior diagnosis of diabetes, medication, or indication for testing. The dependent variable was blood glucose concentration (mg/dL). Independent variables were sex and season. Seasons were defined meteorologically: winter (December, January, February), spring (March, April, May), summer (June, July, August), and autumn (September, October, November).

2.3 Statistical analysis

Descriptive statistics were computed overall and by sex and season. Sex differences were tested by an independent-samples t-test; because Levene's test indicated unequal variances, the Welch-corrected result is reported. Seasonal differences were tested by one-way and Welch's analysis of variance with Games-Howell post-hoc comparisons, and sex and season were then entered together in a two-way analysis of variance using Type III sums of squares. Effect sizes are reported as partial eta-squared and Cohen's d, and the monthly distribution of records was tabulated directly. Significance was set at $\alpha = 0.05$. Reporting follows the STROBE statement (von Elm et al., 2007) and its RECORD extension for routinely collected health data (Benchimol et al., 2015).

2.4 Ethical considerations

Data were extracted from clinical records and de-identified at the point of extraction; the analyzed dataset contained no identifying information, and individual consent was not required as the analysis was retrospective and used anonymized data arising from routine clinical care.

3. Results

3.1 Sample characteristics

The 4,939 measurements comprised 3,171 from male patients (64.2%) and 1,768 from female patients (35.8%). Mean blood glucose was 125.60 mg/dL (SD 65.90), ranging from 24 to 719 mg/dL (Table 1). The distribution was strongly right-skewed: the standard deviation was 52.5% of the mean, and the maximum lay approximately nine standard deviations above it. Variance was distributed unevenly across groups. The standard deviation among female patients (73.08) exceeded that among males (61.43), and the spring standard deviation (77.66) exceeded the winter value (56.04) by almost 40%.

Table (1) Blood glucose concentration (mg/dL) by sex and by season.

Group	n	Mean	SD	Minimum	Maximum
All measurements	4,939	125.60	65.90	24	719
Male	3,171	123.42	61.43	24	719
Female	1,768	129.51	73.08	29	719
Spring	926	130.43	77.66	28	719
Summer	1,873	124.93	64.47	28	719
Autumn	1,217	127.48	64.94	24	503
Winter	923	119.67	56.04	42	475

3.2 Sex differences

Levene's test indicated unequal variances between sexes ($F = 42.08$, $p < .001$). The Welch-corrected test showed mean glucose was significantly higher in female than male patients (mean difference 6.09 mg/dL, 95% CI 2.07 to 10.11; $t(3160.1) = 2.97$, $p = .003$). Cohen's d was 0.093 (Figure 1).

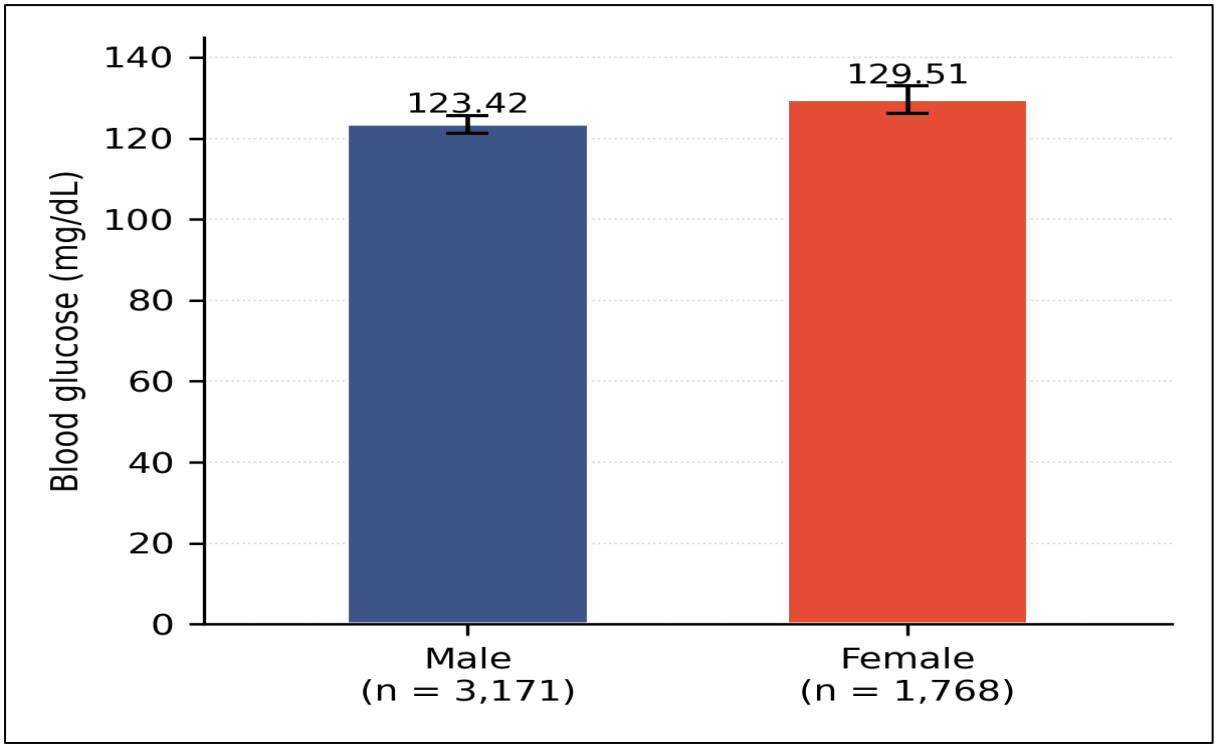

Figure (1) Mean blood glucose concentration by sex. Bars show group means; error bars show 95% confidence intervals.

3.3 Seasonal differences

Mean glucose ranged from 130.43 mg/dL in spring to 119.67 mg/dL in winter (Figure 2). One-way analysis of variance was significant, $F(3, 4935) = 4.55$, $p = .003$; Welch's analysis of variance, appropriate given the unequal seasonal variances, gave $F(3, 2369.9) = 4.88$, $p = .002$. Games-Howell post-hoc comparisons identified two significant contrasts: winter was lower than spring ($p = .004$) and lower than autumn ($p = .015$). The remaining four comparisons, including winter against summer, were not significant (Table 2).

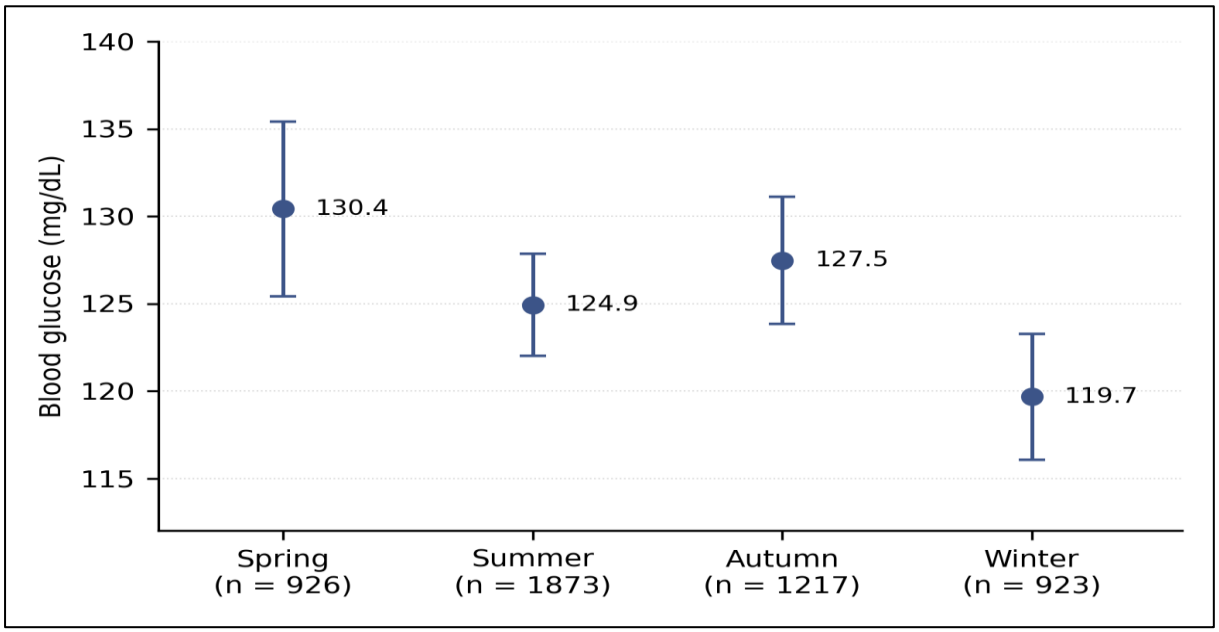

Figure (2) Mean blood glucose concentration by meteorological season (n = 4,939). Points show group means; error bars show 95% confidence intervals.

Table (2) Pairwise seasonal comparisons of mean blood glucose, Games-Howell procedure.

Comparison	Mean difference (mg/dL)	95% CI	p
Spring vs. Summer	5.50	−0.29, 11.29	.245
Spring vs. Autumn	2.95	−3.24, 9.14	.761
Spring vs. Winter	10.76	4.59, 16.93	.004
Summer vs. Autumn	−2.55	−7.22, 2.12	.685
Summer vs. Winter	5.26	0.61, 9.91	.119
Autumn vs. Winter	7.81	2.67, 12.95	.015

3.4 Combined model and effect magnitude

With sex and season entered together, both main effects were significant and the interaction was not (Table 3). The full model explained 0.52% of the variance in blood glucose ($R^2 = .005$, adjusted $R^2 = .004$). Partial eta-squared was 0.0016 for sex, 0.0023 for season, and 0.0003 for the interaction (Figure 3). The absence of an interaction indicates that the seasonal pattern did not differ between sexes.

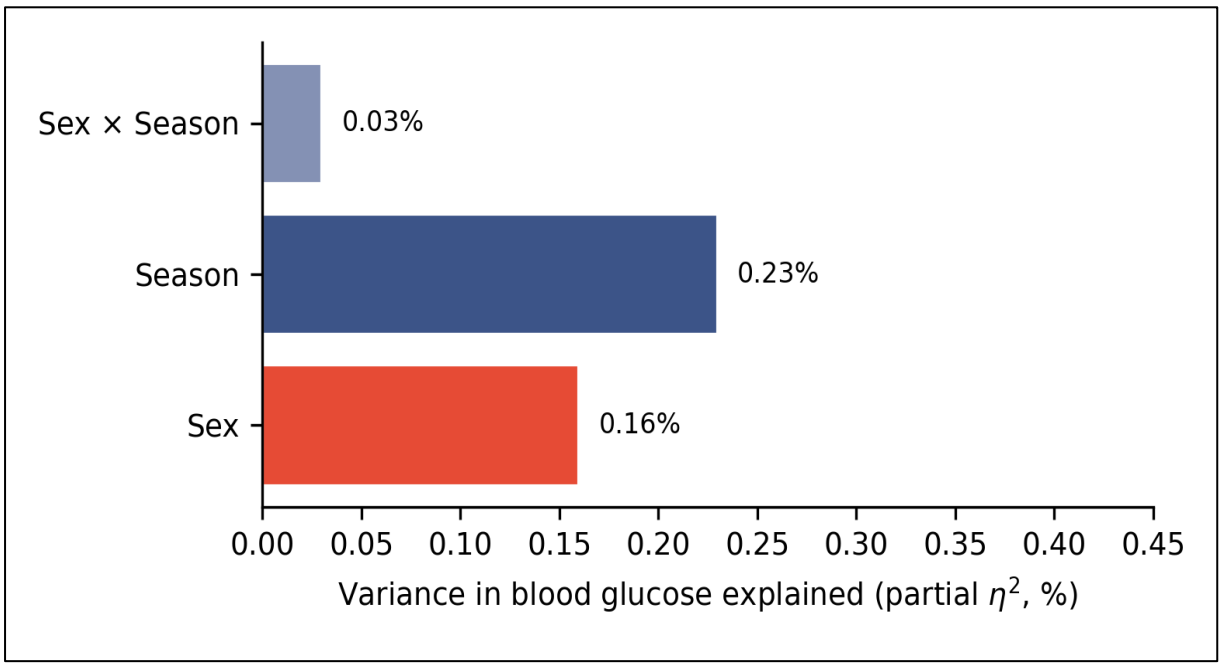

Figure (3) Proportion of variance in blood glucose explained by each model term (partial eta-squared, expressed as a percentage). All three terms account for well under one percent.

Table (3) Two-factor analysis of variance for blood glucose concentration, with effect sizes (Type III sums of squares).

Source	Type III SS	df	Mean square	F	p	Partial η²
Sex	33,768.64	1	33,768.64	7.81	.005	0.0016
Season	49,442.62	3	16,480.87	3.81	.010	0.0023
Sex × Season	6,667.02	3	2,222.34	0.51	.673	0.0003
Error	21,330,031.09	4,931	4,325.70	—	—	—
Corrected total	21,441,227.78	4,938	—	—	—	—

3.5 Distribution of measurements across the year

Measurements were not distributed evenly across the twelve months (Figure 4, Table 4). Uniform sampling would place 412 records in each month. Observed counts ranged from 67 in January to 754 in July, a ratio of 11.3 to 1. January and March together contributed 136 of 4,939 measurements. Each season was consequently dominated by a single month: winter was 65.0% December, spring 71.5% May, autumn 59.3% September, and summer 40.3% July (Figure 5).

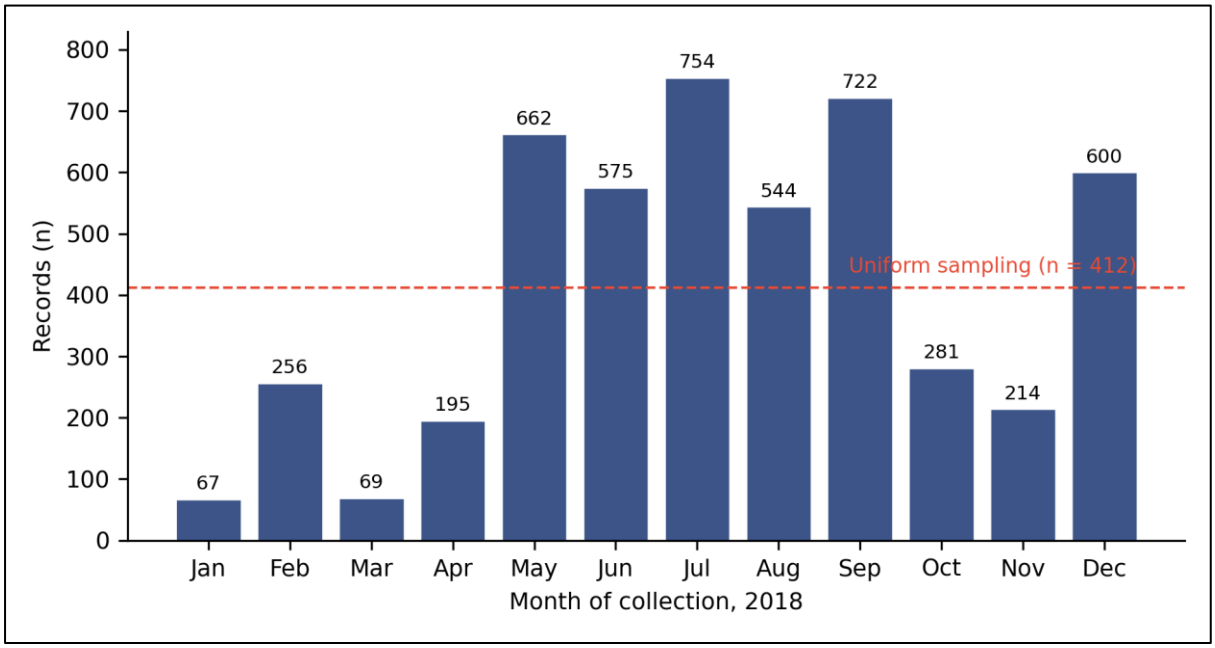

Figure (4) Number of blood glucose measurements by calendar month, 2018 (n = 4,939). The dashed line indicates the count expected under uniform sampling across twelve months (n = 412).

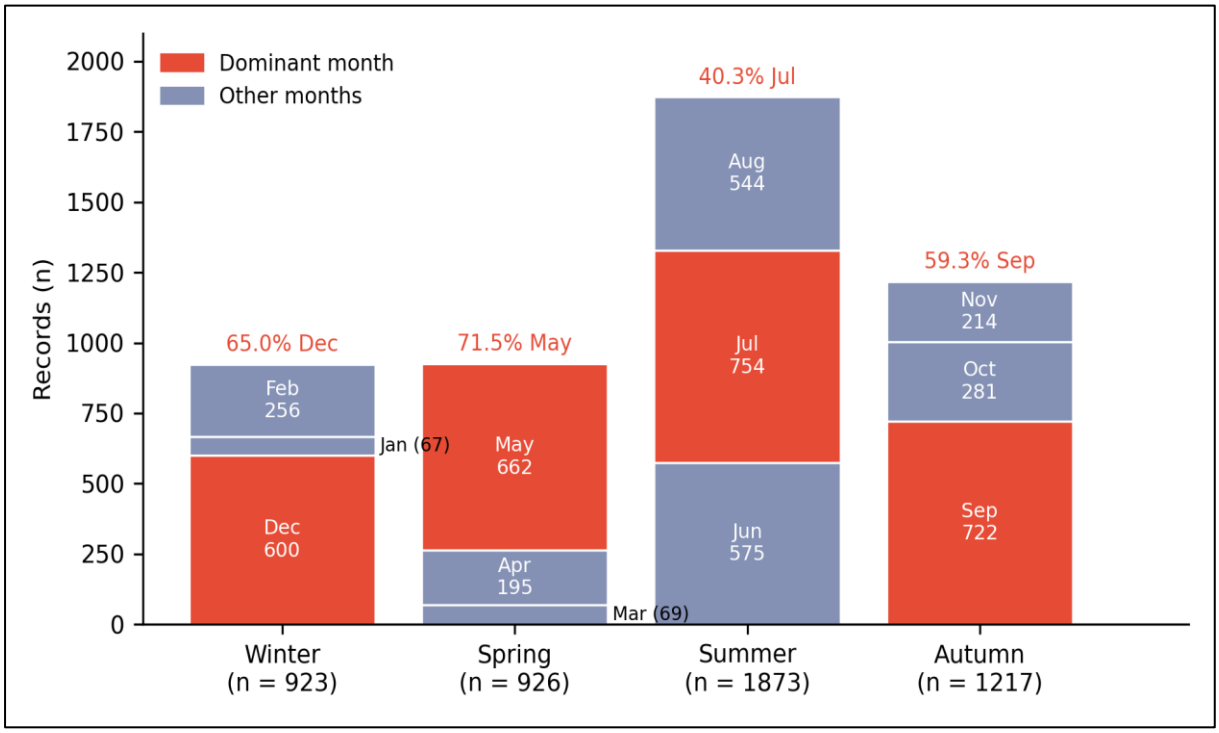

Figure (5) Composition of each meteorological season by contributing month (n = 4,939).

Stacked bars show the number of measurements contributed by each month; the dominant month in each season is highlighted. No season draws evenly on its three constituent months.

Table (4) Distribution of blood glucose measurements by month and resulting composition of each season.

Month	n	% of total	Season	Season n	Dominant month	Share of the season
January	67	1.4	Winter	923	December	65.0%
February	256	5.2				
December	600	12.1				
March	69	1.4	Spring	926	May	71.5%
April	195	3.9				
May	662	13.4				
June	575	11.6	Summer	1,873	July	40.3%
July	754	15.3				
August	544	11.0				
September	722	14.6	Autumn	1,217	September	59.3%
October	281	5.7				
November	214	4.3				

4. Discussion

In this retrospective analysis of 4,939 blood glucose measurements from a Libyan trauma and accident hospital, mean glucose was significantly higher in female than in male patients and differed significantly across the four meteorological seasons, with the lowest values in winter. The two factors acted independently, as the interaction term was not significant. Both effects were small: together with the interaction, they accounted for approximately 0.5% of the variance in blood glucose, and half of the pairwise seasonal contrasts did not survive correction for multiple comparisons.

The seasonal direction observed here, a winter trough, is consistent with some reports and at variance with others. Winter elevations have been described in a Southern Californian community sample (Suarez & Barrett-Connor, 1982), a United Kingdom occupational cohort (Jarrett et al., 1984), Greek primary care (Gikas et al., 2009), an Israeli diabetes laboratory dataset (Kershenbaum et al., 2011), and a nationwide Chinese population (Zhang et al., 2021). Conversely, summer peaks have been reported among middle-aged adults in the Rotterdam Study (Cepeda et al., 2018) and in a Swedish pregnancy cohort (Katsarou et al., 2016), and a Swedish study of elderly men found fasting glucose largely unchanged across seasons because reduced winter insulin sensitivity was offset by increased secretion (Berglund et al., 2012). Cepeda et al. (2018) reported opposite directions in middle-aged and elderly participants within a single cohort, attributing the summer peak in younger adults to lifestyle and the winter peak in older adults to ambient temperature and impaired thermoregulation. The present dataset contains no age information, and the direction observed here cannot therefore be placed within that framework.

The sex difference observed, with higher values in female patients, differs from the pattern usually reported for fasting glucose, in which men show higher values (Færch et al., 2010; Zhang et al., 2021). Random rather than fasting measurements were analyzed here, and Færch et al. (2010) noted that women show higher post-load glucose than men, so a mixed fasting and non-fasting sample may plausibly reproduce a pattern closer to the post-load one. Sex-dimorphic genetic effects on random glucose have also been described (Meta-Analysis of

Glucose and Insulin-Related Traits Consortium, 2023). These explanations remain speculative in the absence of age, fasting status, and diagnostic information.

Two features of the present dataset bear on how these findings should be read. The first is the nature of the population. The records originate from a surgical and accident hospital, and the male preponderance of 64.2% is consistent with the demographic profile of injury. Acute injury, burns, surgery, and critical illness raise blood glucose through catecholamine and cortisol release, hepatic gluconeogenesis, and peripheral insulin resistance, a response that occurs in patients without any prior diagnosis of diabetes (Dungan et al., 2009). Admission hyperglycemia in trauma is common, is graded with injury severity, and is independently associated with mortality, infectious complications, and prolonged stay (Laird et al., 2004; Sung et al., 2005). The observed mean of 125.60 mg/dL, maximum of 719 mg/dL, and coefficient of variation of 52.5% are compatible with this picture, and admission glucose in such a population may reflect physiological stress and injury severity in addition to glycemic regulation. Differences in injury mechanism and severity between male and female patients, and variation across the year in the mix of patients presenting, could each contribute to the differences reported here. Neither possibility can be examined with the variables available.

The second feature is the distribution of measurements across the year. Testing volume varied by a factor of 11.3 between the busiest and quietest months, and each season drew most of its records from a single month, so that the winter mean approximates that of December and the spring mean that of May. The seasonal contrasts that survived correction therefore compare a small number of months within a single year rather than seasons in the general sense. Variation of this magnitude in testing volume is a property of the ordering process rather than of ambient conditions, and factors that alter whether a test is ordered also alter which patients enter the dataset. Agniel et al. (2018) demonstrated the scale of this effect across 272 test types in 669,452 patients, showing that the presence of a laboratory order predicted survival even when the result was discarded. Kershenbaum et al. (2011) addressed the analogous question directly by examining whether an observed population-level seasonal signal reflected a general tendency or the behavior of a subgroup.

Effect magnitude warrants separate comment. Within-subject biological variation in glucose is of the order of 5% to 7% (Sacks et al., 2023), so at the observed mean, a single individual measured repeatedly under identical conditions would be expected to vary by approximately 6 to 9 mg/dL. The sex difference of 6.09 mg/dL falls within that interval, and the full seasonal span of 10.8 mg/dL is smaller than one-fifth of the pooled standard deviation. With a sample of this size, statistical significance is readily attained by differences that carry no clinical implication.

Analytical and pre-analytical factors could not be characterized. Glucose in uncentrifuged whole blood declines through continuing glycolysis at approximately 5% to 7% per hour, at a rate that increases with ambient temperature (Hedayati et al., 2020; Sacks et al., 2023), and the effect is measurable in routine practice, where point-of-care and central laboratory glucose diverge in proportion to specimen turnaround time (Schroeder et al., 2016). In Benghazi, where summer temperatures considerably exceed winter, this would predict lower measured glucose in summer, whereas the observed minimum occurred in winter; sample degradation is therefore unlikely to account for the seasonal pattern, although it may have attenuated it. Whether point-of-care glucometer readings contributed to the dataset could not be established. Capillary point-of-care measurement in critically ill patients carries greater error relative to reference methods than laboratory assays do (Slater-MacLean et al., 2008), and an emergency and trauma setting is where such measurements are most likely to be made.

4.1 Limitations

Several limitations follow from the nature of the data source. Age was not recorded, which removes both the strongest determinant of blood glucose and a documented modifier of the

seasonal pattern itself (Cepeda et al., 2018). Prior diagnosis of diabetes, medication, and indication for testing were likewise unrecorded, so patients with established disease could not be identified or analyzed separately. Fasting status was unknown. Patient identifiers were not retained, so repeat testing could not be excluded and the independence assumption underlying the analyses cannot be verified; because more severely injured patients are tested more frequently and have higher glucose (Laird et al., 2004). No range checking was applied, and the observed minimum of 24 mg/dL and maximum of 719 mg/dL are both clinically possible and indistinguishable from transcription error in unverified records. The proportions of inpatient, emergency, and outpatient testing are undocumented. Finally, the data derive from a single institution in a single year and are not representative of the Libyan population or of Libyan clinical laboratories generally.

5. Conclusion

Blood glucose in this Libyan trauma hospital population was significantly higher in female than male patients and varied significantly across seasons, with the lowest values in winter and no interaction between the two factors. Both effects were negligible in magnitude, together explaining approximately half a percent of the variance in glucose, and half of the seasonal contrasts did not survive correction for multiple comparisons. Measurements were distributed very unevenly across the year, so that each season was dominated by a single month, and the population was one in which admission glucose reflects physiological stress in addition to glycemic regulation. The differences observed are therefore best regarded as descriptive of this dataset rather than as evidence of glucose physiology.

These findings contribute the first description of sex and seasonal variation in blood glucose from a Libyan hospital laboratory population and provide a reference point for a region largely absent from this literature. They also carry a practical message for laboratory-based research and for the clinical services that generate such data. Reporting the distribution of measurements across the study period, and reporting effect sizes alongside p-values, costs nothing and allows readers to judge how far an observed association reflects the biology of the patients rather than the circumstances under which they were tested. As laboratory information systems become more widely established in Libyan hospitals, recording age, fasting status, indication for testing, and a stable patient identifier would allow the questions raised here to be answered properly, and would convert routine clinical data into a resource capable of supporting population health research.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

References

[1] Agniel, D., Kohane, I. S., & Weber, G. M. (2018). Biases in electronic health record data due to processes within the healthcare system: Retrospective observational study. BMJ, 361, k1479. https://doi.org/10.1136/bmj.k1479

[2] Belsare, P., Bartolome, A., Stanger, C., & Prioleau, T. (2023). Understanding temporal changes and seasonal variations in glycemic trends using wearable data. Science Advances, 9(38), eadg2132. https://doi.org/10.1126/sciadv.adg2132

[3] Ben Hsin, M. A. M., Emsaed, H. A. M., Abujarida, A. R., Sauf, M. A., Soof, S. A., & Salem, M. O. A. (2025). A Study on the Isolation and Identification of Bacteria in Patients with Urinary Tract Infections in Libyan Laboratories. Afro-Asian Journal of Scientific Research (AAJSR), 1(4), 1-10.

[4] Benchimol, E. I., Smeeth, L., Guttmann, A., Harron, K., Moher, D., Petersen, I., Sørensen, H. T., von Elm, E., & Langan, S. M. (2015). The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLOS Medicine, 12(10), e1001885. https://doi.org/10.1371/journal.pmed.1001885

[5] Berglund, L., Berne, C., Svärdsudd, K., Garmo, H., Melhus, H., & Zethelius, B. (2012). Seasonal variations of insulin sensitivity from a euglycemic insulin clamp in elderly men. Upsala Journal of Medical Sciences, 117(1), 35–40. https://doi.org/10.3109/03009734.2011.628422
[6] Cepeda, M., Muka, T., Ikram, M. A., Franco, O. H., & Schoufour, J. D. (2018). Seasonality of insulin resistance, glucose, and insulin among middle-aged and elderly population: The Rotterdam Study. The Journal of Clinical Endocrinology & Metabolism, 103(3), 946–955. https://doi.org/10.1210/jc.2017-01921
[7] Dungan, K. M., Braithwaite, S. S., & Preiser, J. C. (2009). Stress hyperglycaemia. The Lancet, 373(9677), 1798–1807. https://doi.org/10.1016/S0140-6736(09)60553-5
[8] Færch, K., Borch-Johnsen, K., Vaag, A., Jørgensen, T., & Witte, D. R. (2010). Sex differences in glucose levels: A consequence of physiology or methodological convenience? The Inter99 study. Diabetologia, 53(5), 858–865. https://doi.org/10.1007/s00125-010-1673-4
[9] Farmer, R., Mathur, R., Bhaskaran, K., Eastwood, S. V., Chaturvedi, N., & Smeeth, L. (2018). Promises and pitfalls of electronic health record analysis. Diabetologia, 61(6), 1241–1248. https://doi.org/10.1007/s00125-017-4518-6
[10] Gikas, A., Sotiropoulos, A., Pastromas, V., Papazafiropoulou, A., Apostolou, O., & Pappas, S. (2009). Seasonal variation in fasting glucose and HbA1c in patients with type 2 diabetes. Primary Care Diabetes, 3(2), 111–114. https://doi.org/10.1016/j.pcd.2009.05.004
[11] Hedayati, M., Razavi, S. A., Boroomand, S., & Kheradmand Kia, S. (2020). The impact of pre-analytical variations on biochemical analytes stability: A systematic review. Journal of Clinical Laboratory Analysis, 34(12), e23551. https://doi.org/10.1002/jcla.23551
[12] Jarrett, R. J., Murrells, T. J., Shipley, M. J., & Hall, T. (1984). Screening blood glucose values: Effects of season and time of day. Diabetologia, 27(6), 574–577. https://doi.org/10.1007/BF00276972
[13] Katsarou, A., Claesson, R., Ignell, C., Shaat, N., & Berntorp, K. (2016). Seasonal pattern in the diagnosis of gestational diabetes mellitus in Southern Sweden. Journal of Diabetes Research, 2016, 8905474. https://doi.org/10.1155/2016/8905474
[14] Kershenbaum, A., Kershenbaum, A., Tarabeia, J., Stein, N., Lavi, I., & Rennert, G. (2011). Unraveling seasonality in population averages: An examination of seasonal variation in glucose levels in diabetes patients using a large population-based data set. Chronobiology International, 28(4), 352–360. https://doi.org/10.3109/07420528.2011.560315
[15] Laird, A. M., Miller, P. R., Kilgo, P. D., Meredith, J. W., & Chang, M. C. (2004). Relationship of early hyperglycemia to mortality in trauma patients. The Journal of Trauma, 56(5), 1058–1062. https://doi.org/10.1097/01.ta.0000123267.39011.9f
[16] Meta-Analysis of Glucose and Insulin-Related Traits Consortium. (2023). GWAS of random glucose in 476,326 individuals provide insights into diabetes pathophysiology, complications and treatment stratification. Nature Genetics, 55(9), 1448–1461. https://doi.org/10.1038/s41588-023-01462-3
[17] Noordam, R., Ramkisoensing, A., Loh, N. Y., Neville, M. J., Rosendaal, F. R., Willems van Dijk, K., van Heemst, D., Karpe, F., Christodoulides, C., & Kooijman, S. (2019). Associations of outdoor temperature, bright sunlight, and cardiometabolic traits in two European population-based cohorts. The Journal of Clinical Endocrinology & Metabolism, 104(7), 2903–2910. https://doi.org/10.1210/jc.2018-02532
[18] Sacks, D. B., Arnold, M., Bakris, G. L., Bruns, D. E., Horvath, A. R., Lernmark, Å., Metzger, B. E., Nathan, D. M., & Kirkman, M. S. (2023). Guidelines and recommendations for laboratory analysis in the diagnosis and management of diabetes mellitus. Clinical Chemistry, 69(8), 808–868. https://doi.org/10.1093/clinchem/hvad080

[19] Salem, M. O. A. (2025). Advancing Green Pharmacy through Biodegradable Drug Delivery Systems for Reducing Pharmaceutical Pollution and Enhancing Therapeutic Outcomes. Al-Mutawassit Journal for Basic and Applied Sciences, 35-43. https://www.mutawassitpub.com/index.php/mjbas/article/view/6

[20] Schroeder, L. F., Giacherio, D., Gianchandani, R., Engoren, M., & Shah, N. H. (2016). Postmarket surveillance of point-of-care glucose meters through analysis of electronic medical records. Clinical Chemistry, 62(5), 716–724. https://doi.org/10.1373/clinchem.2015.251827

[21] Slater-MacLean, L., Cembrowski, G., Chin, D., Shalapay, C., Binette, T., Hegadoren, K., & Newburn-Cook, C. (2008). Accuracy of glycemic measurements in the critically ill. Diabetes Technology & Therapeutics, 10(3), 169–177. https://doi.org/10.1089/dia.2008.0263

[22] Suarez, L., & Barrett-Connor, E. (1982). Seasonal variation in fasting plasma glucose levels in man. Diabetologia, 22(4), 250–253. https://doi.org/10.1007/BF00281300

[23] Sung, J., Bochicchio, G. V., Joshi, M., Bochicchio, K., Tracy, K., & Scalea, T. M. (2005). Admission hyperglycemia is predictive of outcome in critically ill trauma patients. The Journal of Trauma, 59(1), 80–83. https://doi.org/10.1097/01.ta.0000171452.96585.84

[24] Tramunt, B., Smati, S., Grandgeorge, N., Lenfant, F., Arnal, J. F., Montagner, A., & Gourdy, P. (2020). Sex differences in metabolic regulation and diabetes susceptibility. Diabetologia, 63(3), 453–461. https://doi.org/10.1007/s00125-019-05040-3

[25] von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gøtzsche, P. C., & Vandenbroucke, J. P. (2007). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: Guidelines for reporting observational studies. The Lancet, 370(9596), 1453–1457. https://doi.org/10.1016/S0140-6736(07)61602-X

[26] Zhang, Y., Tong, M., Wang, B., Shi, Z., Wang, P., Li, L., Ning, Y., & Lu, T. (2021). Geographic, gender, and seasonal variation of diabetes: A nationwide study with 1.4 million participants. The Journal of Clinical Endocrinology & Metabolism, 106(12), e4981–e4992. https://doi.org/10.1210/clinem/dgab543

