**Open Access Library Journal**
2026, Volume 13, e15730
ISSN Online: 2333-9721
ISSN Print: 2333-9705

# Abnormally Long QTC Interval and Associated Factors among Individuals Attending Diabetic Clinic at Lira Regional Referral Hospital in Northern Uganda: A Cross-Sectional Study

**Jimmy Odongo Ogwal[1], Victor Muyambi[2*], Cleophus Mugumya[3], Kenneth Kwenya[1], Naome Aryem[1], Edward Ojuka[1], Rebecca Awili[4], Samuel Okello[1], Jolly Joe Enyang[1], Abel Obeny[1], Edmand Kabaterine[2], Caleb Angulu[1]**

[1]Faculty of Medicine, Lira University, Lira, Uganda
[2]Department of Nursing, Faculty of Health Sciences, Bishop Stuart University, Mbarara, Uganda
[3]Faculty of Health Sciences, Victoria University, Kampala, Uganda
[4]Faculty of Nursing and Midwifery, Lira University, Lira, Uganda
Email: *muyambivictor@gmail.com

**How to cite this paper:** Ogwal, J.O., Muyambi, V., Mugumya, C., Kwenya, K., Aryem, N., Ojuka, E., Awili, R., Okello, S., Enyang, J.J., Obeny, A., Kabaterine, E. and Angulu, C. (2026) Abnormally Long QTC Interval and Associated Factors among Individuals Attending Diabetic Clinic at Lira Regional Referral Hospital in Northern Uganda: A Cross-Sectional Study. *Open Access Library Journal*, **13**: e15730.
https://doi.org/10.4236/oalib.1115730

**Received:** July 2, 2026
**Accepted:** August 23, 2026
**Published:** August 26, 2026



## Abstract

**Background:** Heart rate-corrected QT (QTc) interval prolongation is associated with increased risk of cardiovascular events and mortality among individuals with diabetes mellitus (DM). However, limited data exist on the epidemiology of abnormally long QTc among people with DM in northern Uganda. **Objectives:** We determined the prevalence and factors associated with abnormally long QTc intervals among individuals attending the diabetic clinic at Lira Regional Referral Hospital (LRRH) in northern Uganda. **Methods:** We conducted a cross-sectional study among individuals attending the diabetic clinic at LRRH from July to December 2025. Twelve-lead electrocardiogram recordings were performed on all participants. We collected clinical and laboratory data related to diabetes disease status and treatment. QTc was calculated using Bazett's formula for heart rates 60 - 100 beats/minute and Fredericia's formula for extremes, then categorized using standardized sex-adjusted thresholds. Borderline and prolonged categories were combined as "abnormally long QTc" for analysis. Modified Poisson regression with robust variance was used to identify factors associated with abnormally long QTc intervals. **Results:** We recruited 338 participants with a mean age of 52.4 years (SD ± 10.2) and a mean HbA1c of 9.2% (SD ± 2.8); 63.0% were female. The prevalence of abnormally long QTc interval was 22.5% (76/338, 95% CI: 18.3% - 27.3%). In multivariate analysis, factors independently associated with a higher prevalence of abnormally long QTc included elevated mean arterial pressure (aPR = 1.16, 95% CI:

1.05 - 1.28, p = 0.002) and use of furosemide-containing antihypertensive regimens (aPR = 1.32, 95% CI: 1.11 - 1.57, p = 0.002). Protective factors included adequate physical activity (≥150 minutes/week) (aPR = 0.85, 95% CI: 0.77 - 0.94, p = 0.002) and use of oral hypoglycemic agents alone (aPR = 0.62, 95% CI: 0.55 - 0.70, p < 0.001) or combined with injectable agents (aPR = 0.57, 95% CI: 0.50 - 0.66, p < 0.001) compared to injectable-only regimens. **Conclusions:** Approximately one in five individuals with diabetes in routine care at LRRH has an abnormally long QTc interval, representing a substantial burden of potential arrhythmic risk. Elevated mean arterial pressure, furosemide use, insulin-only therapy, and physical inactivity were independently associated with abnormally long QTc. These findings support routine ECG screening in diabetic clinics and careful consideration of antihypertensive and hypoglycemic agent selection in this population.

## Subject Areas

Diabetes & Endocrinology

## Keywords

QT Interval, Prevalence, Diabetes Mellitus, QTc Prolongation, Uganda, Cardiovascular Risk

## 1. Introduction

The morbidity and mortality burden of diabetes mellitus is escalating rapidly in low-income countries, with approximately five percent of deaths among adults aged 20 - 60 years in Africa now attributable to diabetes [1]. Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality in individuals with diabetes, yet it often goes unrecognized until advanced stages [2].

A major risk factor for CVD events and mortality in people with diabetes is abnormalities of cardiac rhythm, particularly prolongation of the heart rate-corrected QT (QTc) interval. Prolonged QTc interval in diabetic individuals is associated with increased risk of stroke, ischemic heart disease, and sudden cardiac death [3] [4]. A recent systematic review confirmed that QTc prolongation is a consistent predictor of cardiovascular mortality in diabetic populations [5]. Consequently, QTc interval measurement on electrocardiography (ECG) represents a potentially valuable tool for identifying diabetic patients at high risk for cardiovascular events [6]-[8].

The prevalence of abnormally long QTc interval among individuals with diabetes varies widely across studies, with higher estimates reported in type 2 diabetes (15% - 67%) compared to type 1 diabetes (8%) [9]-[11]. However, there is a paucity of data on its prevalence and correlates in sub-Saharan Africa, home to an estimated 25 million people with diabetes [1]. A previous study from southwestern Uganda reported a prevalence of abnormally long QTc of 29.8% among dia-

betic patients in ambulatory care [12], but no data exist from northern Uganda, where healthcare access and socioeconomic challenges may differ substantially.

Understanding the burden and determinants of abnormally long QTc intervals in this setting is critical for developing targeted screening and prevention strategies. We therefore sought to determine the prevalence of QTc interval abnormalities and associated factors among patients with diabetes attending the diabetic clinic at Lira Regional Referral Hospital (LRRH) in northern Uganda.

## 2. Methods

### 2.1. Study Design and Setting

We conducted a cross-sectional study among patients with diabetes attending the outpatient diabetic clinic at Lira Regional Referral Hospital from July to December 2025. LRRH is located in Adyel Division, Lira City, approximately one kilometer from Lira town center, serving a population of about two million people primarily from the Lango sub-region. The diabetic clinic manages an average of 150 patients per month, providing essential diabetes care and education.

### 2.2. Study Population and Eligibility Criteria

We included diabetic patients aged 18 to 65 years attending the clinic during the study period. Diabetes was defined as fasting capillary glucose ≥ 7.0 mmol/L or current treatment for diabetes mellitus. We excluded individuals with acute febrile illnesses in the preceding 48 hours, those with reported or documented electrolyte abnormalities within the preceding month (including potassium < 3.5 mmol/L or >5.5 mmol/L, magnesium < 0.7 mmol/L or >1.1 mmol/L, or calcium < 2.1 mmol/L or >2.8 mmol/L), those with other endocrine disorders (e.g., thyroid hormone disorders), and those actively taking medications known to affect cardiac rhythm or QTc interval (antiarrhythmic drugs classes I and III, antidepressants, or digitalis) in the prior 24 hours. We also excluded individuals with self-reported or documented history of cardiac disease (heart failure, ischemic heart disease), renal disease, or hepatic disease.

### 2.3. Sample Size and Sampling

Sample size was calculated using the Kish-Leslie formula for cross-sectional studies [13]. Using a prevalence of abnormally long QTc of 29.8% from a previous Ugandan study [12], a 5% margin of error, and a 95% confidence interval, we calculated a minimum sample of 322 participants. After accounting for a 10% non-response rate, we targeted 358 participants. Consecutive sampling was employed until the sample size was attained.

### 2.4. Data Collection Procedures

We collected socio-demographic and clinical characteristics using a structured interviewer-administered questionnaire, including data on alcohol use, smoking, physical activity, and diabetes treatment history. Diabetes type was determined

from the patients' medical records.

#### 2.4.1. Anthropometric Measurements

Weight was measured to the nearest 0.1 kg using a calibrated Seca weighing scale (Seca 762, GmbH & Co. KG, Hamburg, Germany) with participants wearing light clothing and no shoes. Height was measured to the nearest 0.1 cm using a stadiometer with participants standing upright. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared and categorized according to WHO standards: underweight (<18.5), normal (18.5 - 24.9), overweight (25.0 - 29.9), and obese (≥30.0). Waist circumference was measured at the umbilical level using inelastic tape to the nearest 0.1 cm at the end of normal expiration.

#### 2.4.2. Blood Pressure Measurement

Blood pressure was recorded in a sitting position using an automatic sphygmomanometer (Omron HEM 705 LP, Omron Healthcare, Inc., Bannockburn, IL, USA). Mean arterial pressure (MAP) was calculated as diastolic blood pressure plus one-third of pulse pressure.

#### 2.4.3. Laboratory Measurements

Blood was collected for glycosylated hemoglobin (HbA1c) measurement (Cobas Integra 400, Roche Diagnostics, Basel, Switzerland). Random blood sugar measurements were obtained using a Freestyle Glucometer (Abbott Diabetes Care Inc., Maidenhead, UK).

#### 2.4.4. Physical Activity Assessment

Physical activity was assessed by asking participants about total weekly time engaged in physical activities (including walking, running, swimming, and ball games). Adequate physical activity was defined as ≥150 minutes per week according to WHO recommendations [14].

### 2.5. Measurement and Classification of QTc Interval

We performed 12-lead ECG recordings on all study participants using a portable ECG machine (Edan Instruments, Inc., Hessen, Germany). Participants rested in a supine position for 5 minutes before recordings. The QT interval was measured from the beginning of the QRS complex to the end of the T wave, where it crosses the isoelectric line. When a U wave was present, we measured the QT interval to the bottom of the angle between the T and U waves. QT was taken as the mean of QT from five consecutive cycles in lead V5.

We calculated the QTc interval using Bazett's formula ($QTc = QT/RR^{1/2}$) for heart rates between 60 and 100 beats/minute and Fredericia's formula ($QTc = QT/RR^{1/3}$) for heart rates < 60 or >100 beats/minute, as Bazett's formula tends to over-correct at high heart rates and under-correct at low heart rates [15]. We classified the QTc interval as normal (<430 ms in males, <450 ms in females), borderline (430 - 450 ms in males, 450 - 470 ms in females), or prolonged (>450 ms in males, >470 ms in females) according to established criteria [15]. For analysis,

borderline and prolonged categories were combined as "abnormally long QTc" to increase statistical power, consistent with previous studies [12] [16].

### 2.6. Statistical Analysis

Data were double-entered into Excel and exported to STATA version 17 (Stata Corp, College Station, Texas, USA) for cleaning and analysis. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, and categorical variables as frequencies and percentages.

The prevalence of abnormally long QTc interval was calculated as the proportion of participants meeting sex-specific criteria for borderline or prolonged QTc (*i.e.*, QTc ≥ 430 ms in males or ≥450 ms in females), with 95% confidence intervals using the exact binomial method.

For factors associated with abnormally long QTc, we first compared characteristics between participants with normal and abnormally long QTc using chi-square tests for categorical variables and t-tests or Wilcoxon rank-sum tests for continuous variables. Modified Poisson regression with robust variance was used to estimate prevalence ratios (PR) and 95% confidence intervals [17]. Variables with $p < 0.2$ in bivariate analysis were entered into multivariable models using stepwise backward elimination with entry and removal probabilities of 0.05 and 0.1, respectively. Given the clinical overlap between mean arterial pressure, hypertension history, and antihypertensive regimen, we assessed collinearity using variance inflation factors (VIF) and found no evidence of multicollinearity (VIF < 2.0 for all variables). We retained MAP as a continuous measure of blood pressure control and included hypertension history and antihypertensive regimen as separate variables to capture both disease status and treatment effects. Age and diabetes duration were forced into the model a priori based on clinical relevance. Statistical significance was set at $p < 0.05$.

### 2.7. Ethical Considerations

Ethical approval was obtained from the Lira University Research Ethics Committee (approval number: LUREC-2025-404). Administrative permission was granted by the hospital director of LRRH and the person in charge of the diabetic clinic. This study adhered to the Declaration of Helsinki. All participants provided written informed consent before enrollment. Participants who could not write provided consent with a thumbprint. Each participant received an incentive of 10,000 Ugandan shillings for transport reimbursement, and those requiring further evaluation were referred to appropriate care.

## 3. Results

### 3.1. Participant Characteristics

Of 480 individuals attending the diabetic clinic during the study period, 120 were not recruited (94 did not meet inclusion criteria [age > 65 years, n = 48; age < 18 years, n = 12; acute febrile illness, n = 15; active medications affecting QTc, n =

19], and 26 declined participation). Of the 360 recruited, 10 (2.8%) did not return their questionnaires. Of the 350 questionnaires returned, 12 (3.4%) were excluded due to incomplete or inappropriate completion, leaving 338 participants for analysis (response rate: 93.9%).

Baseline characteristics are summarized in Table 1. The mean age was 52.4 years (SD ± 10.2), and 63.0% (213/338) were female. The majority had type 2 diabetes (315/338, 93.2%), with 6.8% (23/338) having type 1 diabetes. Mean HbA1c was 9.2% (SD ± 2.8), and mean duration of diabetes was 6.2 years (SD ± 5.7). The majority of participants (70.7%, 239/338) had a history of hypertension.

Table 1. Baseline characteristics of participants by QTc status.

| Variable | Category | Total (N = 338) | Normal QTc (n = 262) | Abnormally Long QTc (n = 76) | p-Value |
|---|---|---|---|---|---|
| **Age** | Below 60 years | 156 (46.2%) | 133 (85.3%) | 23 (14.7%) | 0.002* |
| | ≥60 years | 182 (53.8%) | 129 (70.9%) | 53 (29.1%) | |
| **Sex** | Female | 213 (63.0%) | 169 (79.3%) | 44 (20.7%) | 0.293 |
| | Male | 125 (37.0%) | 93 (74.4%) | 32 (25.6%) | |
| **BMI** | Normal | 176 (52.1%) | 148 (84.1%) | 28 (15.9%) | 0.008* |
| | Overweight | 95 (28.1%) | 69 (72.6%) | 26 (27.4%) | |
| | Obese | 67 (19.8%) | 45 (67.2%) | 22 (32.8%) | |
| **Systolic BP** | Normal | 116 (34.3%) | 99 (85.3%) | 17 (14.7%) | 0.013* |
| | High | 222 (65.7%) | 163 (73.4%) | 59 (26.6%) | |
| **Diastolic BP** | Normal | 286 (84.6%) | 221 (77.3%) | 65 (22.7%) | 0.803 |
| | High | 52 (15.4%) | 41 (78.8%) | 11 (21.2%) | |
| **MAP** | Normal | 185 (54.7%) | 155 (83.8%) | 30 (16.2%) | 0.002* |
| | High | 153 (45.3%) | 107 (69.9%) | 46 (30.1%) | |
| **Heart Rate** | Low | 18 (5.3%) | 17 (94.4%) | 1 (5.6%) | 0.159 |
| | Normal | 292 (86.4%) | 222 (76.0%) | 70 (24.0%) | |
| | High | 28 (8.3%) | 23 (82.1%) | 5 (17.9%) | |
| **Diabetes Duration** | <8 years | 163 (48.2%) | 127 (77.9%) | 36 (22.1%) | 0.856 |
| | ≥8 years | 175 (51.8%) | 135 (77.1%) | 40 (22.9%) | |
| **RBS** | Normal | 188 (55.6%) | 139 (73.9%) | 49 (26.1%) | 0.078 |
| | High | 150 (44.4%) | 123 (82.0%) | 27 (18.0%) | |
| **History of Hypertension** | No | 99 (29.3%) | 95 (96.0%) | 4 (4.0%) | <0.001* |
| | Yes | 239 (70.7%) | 167 (69.9%) | 72 (30.1%) | |
| **Smoking History** | No | 314 (92.9%) | 239 (76.1%) | 75 (23.9%) | 0.062 |
| | Yes | 24 (7.1%) | 23 (95.8%) | 1 (4.2%) | |
| **PA** | <150 min/week | 62 (18.3%) | 35 (56.5%) | 27 (43.5%) | <0.001* |
| | ≥150 min/week | 276 (81.7%) | 227 (82.2%) | 49 (17.8%) | |

Note: *BMI: body mass index; BP: blood pressure; MAP: mean arterial pressure; RBS: random blood sugar; PA: physical activity; Data presented as n (%) unless otherwise specified; $p < 0.05$; *Abnormally long QTc includes borderline and prolonged categories combined.

### 3.2. Prevalence of Abnormally Long QTc Interval

Out of the 338 participants analyzed, 76 had abnormally long QTc intervals, giving a prevalence of 22.5% (95% CI: 18.3% - 27.3%) as shown in Figure 1.

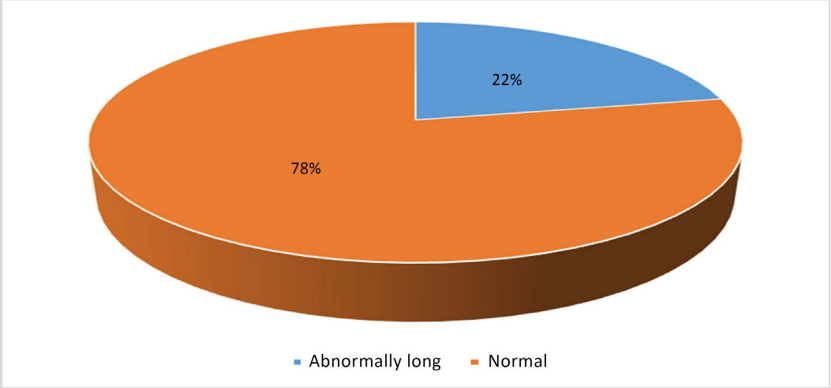


Figure 1. Prevalence of abnormally long QTc interval among study participants.

### 3.3. Factors Associated with Abnormally Long QTc Interval

In multivariable analysis, the factors independently associated with a higher prevalence of abnormally long QTc were elevated MAP (aPR = 1.16, 95% CI: 1.05 - 1.28, p = 0.002) and use of furosemide-containing antihypertensive regimens (calcium channel blocker + loop diuretic) (aPR = 1.32, 95% CI: 1.11 - 1.57, p = 0.002) (Table 2). Adequate physical activity (≥150 minutes/week) remained protective (aPR = 0.85, 95% CI: 0.77 - 0.94, p = 0.002). Compared to injectable-only antidiabetic regimens, use of oral agents alone (aPR = 0.62, 95% CI: 0.55 - 0.70, p < 0.001) and combined oral and injectable regimens (aPR = 0.57, 95% CI: 0.50 - 0.66, p < 0.001) were associated with lower prevalence of abnormally long QTc.

Table 2. Multivariate analysis of factors associated with abnormally long QTc interval.

| Variable | Category | aPR (95% CI) | p-Value |
|---|---|---|---|
| **Mean Arterial Pressure** | High vs. Normal | 1.16 (1.05 - 1.28) | 0.002 |
| **Antihypertensive Regimen** | ACE inhibitor (ref) | 1.00 | |
| | Ca channel blocker + ACE inhibitor | 1.04 (0.93 - 1.17) | 0.442 |
| | Ca channel blocker + thiazide (furosemide) | 1.32 (1.11 - 1.57) | 0.002 |
| | Ca channel blocker alone | 1.14 (1.00 - 1.30) | 0.047 |
| **Antidiabetic Regimen** | Injectable only (ref) | 1.00 | |
| | Oral only | 0.62 (0.55 - 0.70) | <0.001 |
| | Combined oral and injectable | 0.57 (0.50 - 0.66) | <0.001 |
| **Physical Activity** | ≥150 vs. <150 min/week | 0.85 (0.77 - 0.94) | 0.002 |

Note: aPR: adjusted prevalence ratio; CI: confidence interval; ref: reference category.

## 4. Discussion

We found a high prevalence of abnormally long QTc interval (22.5%) among individuals with diabetes attending the diabetic clinic at LRRH in northern Uganda, with elevated mean arterial pressure, furosemide use, insulin-only therapy, and physical inactivity identified as key modifiable correlates.

### 4.1. Prevalence of Abnormally Long QTc Interval

The prevalence of abnormally long QTc interval (22.5%, 95% CI: 18.3% - 27.3%) observed in our study is comparable to findings from other African settings. A study from Tanzania reported a prevalence of 32% among type 2 diabetic patients at Kilimanjaro Christian Medical Center [18], while research from southwestern Uganda found a prevalence of 29.8% [12]. Our estimate is slightly lower but within the range reported from international studies (15% - 67%) [9]-[11]. A recent systematic review of QTc prolongation in diabetes mellitus reported pooled prevalence estimates ranging from 17% - 35% across various populations, with our findings falling within this range [5].

The prevalence we observed is substantially higher than that reported in the general population in Uganda (11.7%) [19], reinforcing that diabetes itself confers increased risk for QTc prolongation. This phenomenon is hypothesized to result from persistent hyperglycemia, which increases intracellular calcium, promotes free radical production, alters cardiac sympathovagal balance, and diminishes nitric oxide production [20]. Low nitric oxide levels impair primary active transport mechanisms in cardiomyocytes, prolonging myocardial repolarization [21].

Our prevalence is lower than that reported from India (42% among patients with cardiovascular autonomic neuropathy) [22], likely because our study population represented the full spectrum of diabetic patients rather than those with established complications. This suggests that our findings may be generalizable to routine diabetic care populations in similar resource-limited settings.

### 4.2. Factors Associated with Abnormally Long QTc Interval

#### 4.2.1. Mean Arterial Pressure

The independent association between elevated MAP and abnormally long QTc (aPR = 1.16, p = 0.002) aligns with previous studies demonstrating that blood pressure influences cardiac repolarization [23]-[26]. Chronic pressure overload from hypertension leads to left ventricular hypertrophy, which is associated with downregulation of potassium channels responsible for phase 3 repolarization [27]. Additionally, hypertension-induced myocardial fibrosis disrupts electrical coupling between myocytes, creating heterogeneous repolarization that prolongs the QT interval [28]. In diabetic patients, this effect may be amplified by concomitant autonomic neuropathy and microvascular damage.

#### 4.2.2. Antihypertensive Medications

The finding that furosemide-containing regimens (calcium channel blocker +

loop diuretic) were associated with a higher prevalence of abnormally long QTc (aPR = 1.32, p = 0.002) is clinically significant. Loop diuretics like furosemide can cause excessive urinary loss of potassium and magnesium, electrolytes critical for normal cardiac repolarization [29]. Hypokalemia reduces the driving force for potassium efflux during phase 3 of the action potential, while hypomagnesemia impairs sodium-potassium ATPase function and exacerbates potassium wasting [30] [31]. However, it is important to note that we did not measure serum electrolytes concurrently with ECG recordings. The observed association may be partially explained by the underlying disease severity or other unmeasured confounders, and our findings should be interpreted as hypothesis-generating rather than causal. Nevertheless, our findings suggest that when furosemide use is unavoidable in diabetic patients, regular monitoring of serum electrolytes with prompt replacement may be prudent.

#### 4.2.3. Antidiabetic Medications

Patients requiring injectable antidiabetic agents (primarily insulin) had a significantly higher prevalence of abnormally long QTc compared to those on oral agents alone (aPR = 0.62 for oral-only vs. injectable-only, $p < 0.001$). The association between insulin-only therapy and QTc prolongation likely reflects that insulin-treated patients have more advanced disease, longer diabetes duration, poorer glycemic control, and potentially greater end-organ damage, all of which are independent risk factors for QTc prolongation [32]. While insulin-induced hypoglycemia can acutely prolong the QT interval through catecholamine-mediated hypokalemia [33], we cannot disentangle the medication effect from the underlying disease severity in this cross-sectional design. Therefore, the observed association should be interpreted as a marker of higher-risk patients rather than a direct pharmacological effect of insulin itself. Patients on combination therapy (oral + injectable) also had a lower prevalence than injectable-only patients (aPR = 0.57), possibly because combination therapy allows lower insulin doses, reducing hypoglycemia risk while maintaining glycemic control.

#### 4.2.4. Physical Activity

Adequate physical activity (≥150 minutes/week) was independently protective against QTc prolongation (aPR = 0.85, p = 0.002). Regular exercise improves autonomic balance by increasing vagal tone and reducing sympathetic drive, stabilizing myocardial repolarization [34]. Physical activity also improves glycemic control, reduces oxidative stress, and promotes favorable cardiac remodeling, all of which may preserve normal ion channel function [35].

### 4.3. Clinical and Public Health Implications

Our findings have several practical implications for diabetes care in resource-limited settings. First, the high prevalence of abnormally long QTc (22.5%) supports routine ECG screening for diabetic patients, particularly those with multiple risk factors. ECG is relatively low-cost and feasible in district-level hospitals in Uganda.

Second, stringent blood pressure control should be prioritized, as elevated MAP was a strong independent correlate of QTc prolongation. Third, when diuretic therapy is necessary, potassium-sparing agents may be preferred over loop diuretics, or close electrolyte monitoring should be implemented. Fourth, physical activity should be promoted not only for glycemic control but specifically for cardiac electrical stability. Finally, patients requiring insulin therapy warrant closer ECG monitoring, with careful attention to avoiding hypoglycemic episodes.

### 4.4. Limitations

Several limitations should be acknowledged. The cross-sectional design precludes causal inference; we can identify associations but not determine directionality. Medication use, diabetes duration, and hypoglycemic history were based on patient records and self-report, introducing potential information bias. QTc interval was measured at a single time point, not accounting for day-to-day variability due to fluctuations in glucose, electrolytes, or autonomic function. We did not measure serum electrolytes concurrently with ECG recordings, which limits our ability to definitively attribute the furosemide-QTc association to electrolyte disturbances. We excluded patients with known cardiac, renal, or hepatic disease, which may have underestimated the true prevalence in the broader diabetic population. Diabetes type was not included as a covariate in the final model due to limited power for subgroup analysis, though we have acknowledged this as an unmeasured confounder. Finally, the single-center design may limit generalizability to other regions.

## 5. Conclusion

Approximately one in five individuals with diabetes attending the diabetic clinic at LRRH in northern Uganda has an abnormally long QTc interval, representing a substantial burden of potential arrhythmic risk. Elevated mean arterial pressure, furosemide-containing antihypertensive regimens, insulin-only therapy, and physical inactivity were independently associated with abnormally long QTc. These findings support the integration of routine ECG screening into diabetic care in Uganda and highlight the importance of careful antihypertensive selection, hypoglycemic agent optimization, and promotion of physical activity to mitigate cardiovascular risk in this vulnerable population.

## Funding

This research was supported by Lira University Research and Innovation Fund. The funder had no role in study design, data collection, analysis, interpretation, or manuscript preparation.

## Availability of Data and Materials

The datasets generated and analyzed during this study are available from the corresponding author on reasonable request.

## Ethics Approval and Consent to Participate

Ethical approval was obtained from the Lira University Research Ethics Committee (approval number: LUREC-2025-404). Administrative permission was granted by Lira Regional Referral Hospital. This study adhered to the Declaration of Helsinki. All participants provided written informed consent before enrollment.

## Acknowledgements

We thank the study participants for their valuable time and cooperation. We are grateful to the staff and management of Lira Regional Referral Hospital, particularly the diabetic clinic team, for their support during data collection. We acknowledge the Department of Physiology, Faculty of Medicine, and the office of the Directorate of Graduate and Research Training of Lira University for support.

## Author Contributions

JOO, NA, AO, CA, JJE, and RA conceived the study. JOO, EO, VM, and SO designed the study protocol. JOO, ED, CM, and KK supervised data collection. JOO and RA performed statistical analysis. JOO and VM drafted the manuscript. All authors reviewed, edited, and approved the final manuscript. JOO is the guarantor of this work.

## Conflicts of Interest

The authors declare no competing interests.

## References

[1] World Health Organization (2016) Global Report on Diabetes. World Health Organization.

[2] Schernthaner, G., Lotan, C., Baltadzhieva-Trendafilova, E., Ceponis, J., Clodi, M., Ducena, K., *et al.* (2018) Unrecognised Cardiovascular Disease in Type 2 Diabetes: Is It Time to Act Earlier? *Cardiovascular Diabetology*, **17**, Article No. 145. https://doi.org/10.1186/s12933-018-0788-7

[3] Cardoso, C.R.L., Salles, G.F. and Deccache, W. (2003) QTc Interval Prolongation Is a Predictor of Future Strokes in Patients with Type 2 Diabetes Mellitus. *Stroke*, **34**, 2187-2194. https://doi.org/10.1161/01.str.0000085084.15144.66

[4] Veglio, M., Sivieri, R., Chinaglia, A., Scaglione, L. and Cavallo-Perin, P. (2000) QT Interval Prolongation and Mortality in Type 1 Diabetic Patients: A 5-Year Cohort Prospective Study. *Diabetes Care*, **23**, 1381-1383. https://doi.org/10.2337/diacare.23.9.1381

[5] Cox, A.J., Azeem, A., Yeboah, J., Soliman, E.Z., Aggarwal, S.R., Bertoni, A.G., *et al.* (2014) Heart Rate-Corrected QT Interval Is an Independent Predictor of All-Cause and Cardiovascular Mortality in Individuals with Type 2 Diabetes: The Diabetes Heart Study. *Diabetes Care*, **37**, 1454-1461. https://doi.org/10.2337/dc13-1257

[6] Okin, P.M., Devereux, R.B., Lee, E.T., Galloway, J.M. and Howard, B.V. (2004) Electrocardiographic Repolarization Complexity and Abnormality Predict All-Cause and Cardiovascular Mortality in Diabetes. *Diabetes*, **53**, 434-440. https://doi.org/10.2337/diabetes.53.2.434

[7] Rossing, P., Breum, L., Major-Pedersen, A., Sato, A., Winding, H., Pietersen, A., *et al.* (2001) Prolonged QTc Interval Predicts Mortality in Patients with Type 1 Diabetes Mellitus. *Diabetic Medicine*, **18**, 199-205. https://doi.org/10.1046/j.1464-5491.2001.00446.x

[8] Salles, G.F., Bloch, K.V. and Cardoso, C.R.L. (2004) Mortality and Predictors of Mortality in a Cohort of Brazilian Type 2 Diabetic Patients. *Diabetes Care*, **27**, 1299-1305. https://doi.org/10.2337/diacare.27.6.1299

[9] Li, X., Ren, H., Xu, Z., Liu, Y., Yang, X. and Liu, J. (2012) Prevalence and Risk Factors of Prolonged QTc Interval among Chinese Patients with Type 2 Diabetes. *Experimental Diabetes Research*, **2012**, 1-6. https://doi.org/10.1155/2012/234084

[10] Veglio, M., Bruno, G., Borra, M., Macchia, G., Bargero, G., D'errico, N., *et al.* (2002) Prevalence of Increased QT Interval Duration and Dispersion in Type 2 Diabetic Patients and Its Relationship with Coronary Heart Disease: A Population-Based Cohort. *Journal of Internal Medicine*, **251**, 317-324. https://doi.org/10.1046/j.1365-2796.2002.00955.x

[11] Yang, X., Su, J., Zhang, X., Zhao, L., Xu, F., Wang, X., *et al.* (2017) The Relationship between Insulin Sensitivity and Heart Rate-Corrected QT Interval in Patients with Type 2 Diabetes. *Diabetology & Metabolic Syndrome*, **9**, Article No. 69. https://doi.org/10.1186/s13098-017-0268-3

[12] Migisha, R., Agaba, D.C., Katamba, G., Miranda, S.L., Muyingo, A. and Siedner, M.J. (2021) High Prevalence of Prolonged QTc Interval among Individuals in Ambulatory Diabetic Care in Southwestern Uganda. *International Journal of Diabetes in Developing Countries*, **41**, 614-620. https://doi.org/10.1007/s13410-021-00944-6

[13] Kish, L. (1965) Sampling Organizations and Groups of Unequal Sizes. *American Sociological Review*, **30**, 564-572. https://doi.org/10.2307/2091346

[14] World Health Organization (2010) Global Recommendations on Physical Activity for Health. World Health Organization.

[15] Goldenberg, I., Moss, A.J. and Zareba, W. (2006) QT Interval: How to Measure It and What Is "Normal". *Journal of Cardiovascular Electrophysiology*, **17**, 333-336. https://doi.org/10.1111/j.1540-8167.2006.00408.x

[16] Vandenberk, B., Vandael, E., Robyns, T., Vandenberghe, J., Garweg, C., Foulon, V., *et al.* (2016) Which QT Correction Formulae to Use for QT Monitoring? *Journal of the American Heart Association*, **5**, e003264. https://doi.org/10.1161/jaha.116.003264

[17] Zou, G. (2004) A Modified Poisson Regression Approach to Prospective Studies with Binary Data. *American Journal of Epidemiology*, **159**, 702-706. https://doi.org/10.1093/aje/kwh090

[18] Ruhangisa, F.G., Chamba, N.G., Kilonzo, K.G., *et al.* (2022) Prevalence of Prolonged QTc Interval and Associated Factors among Type Two Diabetic Patients at Kilimanjaro Christian Medical Centre, in North? Eastern Tanzania. *Journal of Diabetic Complications & Medicine*, **7**, 1-9.

[19] Magodoro, I.M., Albano, A.J., Muthalaly, R., Koplan, B., North, C.M., Vořechovská, D., *et al.* (2019) Population Prevalence and Correlates of Prolonged QT Interval: Cross-Sectional, Population-Based Study from Rural Uganda. *Global Heart*, **14**, 17-25. https://doi.org/10.1016/j.gheart.2018.11.002

[20] Tesfamariam, B. and Cohen, R.A. (1992) Free Radicals Mediate Endothelial Cell Dysfunction Caused by Elevated Glucose. *American Journal of Physiology-Heart and Circulatory Physiology*, **263**, H321-H326. https://doi.org/10.1152/ajpheart.1992.263.2.h321

[21] Fiorentini, A., Perciaccante, A., Valente, R., Paris, A., Serra, P. and Tubani, L. (2010)

The Correlation among QTc Interval, Hyperglycaemia and the Impaired Autonomic Activity. *Autonomic Neuroscience*, **154**, 94-98. https://doi.org/10.1016/j.autneu.2009.11.006

[22] Pillai, J.N. and Madhavan, S. (2015) Cardiac Autonomic Neuropathy and QTc Interval in Type 2 Diabetes. *Heart India*, **3**, 8-11. https://doi.org/10.4103/2321-449X.153279

[23] Satpathy, S., Satpathy, S. and Nayak, P. (2018) Correlation of Blood Pressure and QT Interval. *National Journal of Physiology, Pharmacy and Pharmacology*, **8**, 207-210. https://doi.org/10.5455/njppp.2018.8.0934414092017

[24] Sun, G., Zhou, Y., Ye, N., Wu, S. and Sun, Y. (2019) Independent Influence of Blood Pressure on QTc Interval: Results from a General Chinese Population. *BioMed Research International*, **2019**, 1-8. https://doi.org/10.1155/2019/1656123

[25] Peng, S., Yu, Y., Hao, K., Xing, H., Li, D., Chen, C., *et al.* (2006) Heart Rate-Corrected QT Interval Duration Is Significantly Associated with Blood Pressure in Chinese Hypertensives. *Journal of Electrocardiology*, **39**, 206-210. https://doi.org/10.1016/j.jelectrocard.2005.08.007

[26] Matsumura, K., Takata, Y., Ansai, T., Awano, S., Takehara, T., Fujii, K., *et al.* (2004) Association of QT Interval with Blood Pressure in 80-Year-Old Subjects. *Hypertension Research*, **27**, 387-391. https://doi.org/10.1291/hypres.27.387

[27] Oikarinen, L., Nieminen, M.S., Toivonen, L., Viitasalo, M., Wachtell, K., Papademetriou, V., *et al.* (2003) Relation of QT Interval and QT Dispersion to Regression of Echocardiographic and Electrocardiographic Left Ventricular Hypertrophy in Hypertensive Patients: The Losartan Intervention for Endpoint Reduction (LIFE) Study. *American Heart Journal*, **145**, 919-925. https://doi.org/10.1016/s0002-8703(02)94785-x

[28] Kahan, T. and Bergfeldt, L. (2005) Left Ventricular Hypertrophy in Hypertension: Its Arrhythmogenic Potential. *Heart*, **91**, 250-256.

[29] Whalen, K. (2019) Pharmacology. 7th Edition, Wolters Kluwer.

[30] Roden, D.M. (2016) Predicting Drug-Induced QT Prolongation and Torsades de Pointes. *The Journal of Physiology*, **594**, 2459-2468.

[31] Tisdale, J.E. (2016) Drug-Induced QT Interval Prolongation and Torsades de Pointes. *Canadian Pharmacists Journal*, **149**, 139-152.

[32] Aburisheh, K., AlKheraiji, M.F., Alwalan, S.I., Isnani, A.C., Rafiullah, M., Mujammami, M. and Alfadda, A.A. (2023) Prevalence of QT Prolongation and Its Risk Factors in Patients with Type 2 Diabetes. *BMC Endocrine Disorders*, **23**, Article No. 50. https://doi.org/10.1186/s12902-022-01235-9

[33] Frier, B.M. (2014) Hypoglycaemia in Diabetes Mellitus: Epidemiology and Clinical Implications. *Nature Reviews Endocrinology*, **10**, 711-722.

[34] Mirahmadizadeh, A., Farjam, M., Sharafi, M., Fatemian, H., Kazemi, M., Geraylow, K.R., *et al.* (2021) The Relationship between Demographic Features, Anthropometric Parameters, Sleep Duration, and Physical Activity with ECG Parameters in Fasa Persian Cohort Study. *BMC Cardiovascular Disorders*, **21**, Article No. 585. https://doi.org/10.1186/s12872-021-02394-8

[35] Colberg, S.R., Sigal, R.J., Yardley, J.E., Riddell, M.C., Dunstan, D.W., Dempsey, P.C., *et al.* (2016) Physical Activity/Exercise and Diabetes: A Position Statement of the American Diabetes Association. *Diabetes Care*, **39**, 2065-2079. https://doi.org/10.2337/dc16-1728